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The History of the Medical Department of the United States Navy in World War II

Volume I

U.S. Marine Corps

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DEPARTMENT OF THE NAVY
Headquarters United States Marine Corps
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FOREWORD

1. PURPOSE

Fleet Marine Force Reference Publication (FMFRP) 12-12, *The History of the Medical Department of the United States Navy in World War II*, Volume I, is published to ensure the retention and dissemination of useful information which is not intended to become doctrine or to be published in Fleet Marine Force manuals. FMFRP's in the 12 Series are a special category of publications: reprints of historical works which were published commercially and are no longer in print.

2. SCOPE

This reference publication was published by the United States Government Printing Office in 1953. As a narrative and pictorial history it provides invaluable insight as to the medical care provided to the naval service in World War II. Discussions of the medical services in Pacific campaigns, in the various combat organizations, and on the many types of medical fields of endeavor give a complete understanding of the vast effort expended in medical services during World War II. This volume is invaluable to medical personnel and to those who support medical personnel involved in the provision of medical care to the contemporary Marine or sailor.

3. CERTIFICATION

Reviewed and approved this date.

BY DIRECTION OF THE COMMANDANT OF THE MARINE CORPS

M. P. SULLIVAN
Major General, U.S. Marine Corps
Deputy Commander for Warfighting
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DISTRIBUTION:

Franklin Delano Roosevelt, President of the United States, 1933 to 1945.

Ross T McIntire, Vice Admiral (MC) USN (Retired), Surgeon General, United States Navy, 1938 to 1946.

Foreword

The achievements of military medicine in World War II were numerous and remarkable, and the results equally remarkable. Out of every 100 wounded men 98 recovered, in contrast with the experience in World War I, when only about 90 recovered out of every 100 wounded men. In earlier wars, one-half or more of all wounded men died as a result of their injuries. The World War II recovery rate for some injuries was striking; as an example, deaths from wounds of the head, chest, and abdomen were about 65 percent lower than in World War I

The chief reason why so many more lives were saved in World War II was the high standard of professional skill and training of the physician, dentist, nurse, and corpsman. Further, skilled medical personnel were assigned to ships, planes, and amphibious forces in all parts of the world, and vast quantities of medical supplies—drugs, serums, plasma, whole blood, beds, bedding, and hospital equipment and appliances—were provided for every operating force no matter where located.

Although the war officially began for the United States on 7 December 1941, the conflagration in Europe in the fall of 1939 was a portent and preparations were then made to meet the approaching national danger. These included a vast expansion of the Navy and its Medical Department. At the beginning of the war the Medical Department of the Navy consisted of less than 13,000 persons; in 1945, at the peak of expansion, it included 169,225 men and women. To obtain the medical facilities and supplies necessary for this expansion was a task of great magnitude.

Many new hospitals were built, and suitable buildings and grounds were acquired and converted to special hospitals. Overseas, the mobile hospital was an innovation that proved of immense value. Hospital transports were of great importance in the campaigns in the Central and Western Pacific. Hospital ships were an invaluable asset, not only in furnishing hospitalization for personnel in fleet and amphibious forces, but also in acting as floating medical warehouses for the distribution of medical supplies, serums, plasma, and whole blood. The use of some types of landing craft as hospitals and for the collection of casualties during amphibious landings was also a most important development.

The procurement of drugs, vaccines, serums, surgical dressings and instruments, and hospital equipment and appliances of every type was a vast undertaking which was well done, but the prompt and efficient distribution of these supplies to the Navy in every part of the world was the really great achievement.

The prevention of disease was as important as the care of the sick and wounded; personnel were vaccinated against such diseases as smallpox, typhoid fever, typhus fever, tetanus, yellow fever, and cholera. This resulted in the saving of countless lives and prevented the disastrous effects of epidemic disease in the combat forces. The measures instituted for the prevention of malaria, typhus fever, and other diseases were guides to the success of many campaigns.

Dental officers and dental personnel played an important part in the war. They gave first aid to the wounded and rendered the finest dental care. Mobile dental units were built to care for personnel attached to isolated stations where regular dental service could not be maintained. A program of prosthetic dentistry was developed which saved valuable manpower for the Navy. Working with the plastic surgeon, the dental officers devised prosthetic facilities for oral, facial, and eye wounds that facilitated the repair of these serious and disfiguring injuries and hastened the rehabilitation of the injured or blinded man.

This war emphasized the great importance of the specialities of aviation medicine, submarine medicine, and amphibious medicine. The latter was so completely organized that medical assistance was brought to the wounded men on the beachhead or in the field at the very earliest moment; never before had it been possible to bring first aid to men on the field of battle so early.

The Hospital Corps of the Navy played a great and heroic part in this as in every other war since its establishment in 1898. Everywhere they were conspicuous for their courage and devotion to duty. The lives of many men were saved by their fearlessness and by the skillful care they rendered.

The splendid work done by the Navy Nurse Corps in World War I was repeated in World War II. In hospitals at advance bases and in hospital ships and hospitals all over the world they carried out their mission tirelessly and efficiently. Their effect on morale, and the comfort and assistance they rendered to the sick was invaluable. The Women Appointed for Volunteer Emergency Service, newly organized in World War II, rendered the finest assistance to the Medical Department in the special fields allied to medicine.

Developments in medicine and surgery and their application to military medical problems made necessary a program of continuous research. The newly established Naval Medical Research Institute at Bethesda, Md., formed the center of this work in the field of naval military medicine. Here, as well as at other naval medical activities, workers in the sciences allied to medicine, the physiologist, psychologist, physicist, chemist, bacteriologist, botanist, and entomologist (added to the family of the Medical Department during World War II), carried on research problems, and their work contributed to the prevention of disease, the relief of suffering, and the saving of lives.

As the wartime Surgeon General of the Navy, I am proud to have directed the Medical Department in its great tasks. I also had the honor to serve as White House physician. This made my work greater, for frequently I was away from Washington on the various long journeys made by President Roosevelt to attend conferences or inspect military forces in the field. These travels, however, gave me a great advantage, for they enabled me to visit almost all theaters of war and to observe the needs and problems of the medical activities in the field.

The great responsibilities imposed upon the Medical Department of the Navy by the war were discharged so efficiently because of the skill, the courage, and the unswerving devotion to duty of all members of the Medical Department, from the hospital apprentice to the personnel of the office of the Surgeon General. Their magnificent achievements in medicine during World War II were unprecedented and were symbolized by President Roosevelt at the dedication ceremonies of the National Naval Medical Center where he said: "Let the hospital stand for all men to see through all the years as a monument to our determination to work and to fight until the time comes when the human race shall have that true health in body and spirit which can be realized only in a climate of equity and faith."

ROSS T McINTIRE
Vice Admiral (MC) USN (Retired)[1]

[1] Surgeon General, U. S. Navy, 1938-46, and Physician to the White House, 1938-45.

Preface

Early in World War II, President Roosevelt directed the "preserving for those who come after us an accurate and objective account of our present experience," and on 23 March 1942 a "Committee on Records of World War II" was designated to activate such a program. In the Navy, Surgeon General McIntire ordered the medical departments of all ships and stations to include in their Annual Sanitary Report an account of their experiences in administrative matters as well as in clinical and preventive medicine. These reports covered the period from 7 December 1941 to 31 August 1945.

In 1943 an Administrative History Section was designated in the Administrative Division of the Bureau. This group assembled a Historical Data Series from the Annual Sanitary Reports and, under the general rules prescribed by the Director of Naval History, compiled the "U.S. Navy Medical Department Administrative History 1941–1945."

The data for chapters I and II were obtained from the sources mentioned. The remaining chapters were written, individually or in collaboration, by 37 naval officers, each recording the accomplishments of the Medical Department of the Navy in the field with which, by virtue of wartime experience, he was peculiarly familiar. The Aviation Branch of the Research Division of the Bureau compiled the section of Chapter X on Naval Aviation Medical Research.

The original work of assembling and editing this material was accomplished by Capt. Louis H. Roddis (MC) USN (Retired), who acted as editor until 30 June 1950. At that time Capt. Joseph L. Schwartz (MC) USN took over the task and completed a major part of it before his retirement on 7 August 1951.

This history is not an exhaustive report, but merely highlights the successful manner in which the 169,225 officers and men of the Medical Department coped with unprecedented problems in clinical and preventive medicine and in medical administration during the war. New hospital facilities were required to fit a new type of warfare, and the transportable, self-contained hospital was devised. New types of vehicles for medical care and transportation of patients were needed, and the jeep ambulance, the amphibious surgical unit, the hospital-type LST, and the ambulance plane were developed. Penicillin, whole blood, and plasma were made available in every battle zone. When necessary, blood was flown directly from the United States to the combat area. During the battle of Iwo Jima, whole blood was dropped by parachute to medical units in action in the field 48 hours after the plane had taken off from San Francisco. For the first time in military history, teams of epidemiologists accompanied assault forces, and field sanitation, hygiene, and preventive medicine were immediately instituted. These teams were a vital factor in lowering the morbidity and mortality rates in combat troops.

Officers of the Medical, Dental, Nurse, and Hospital Corps, specialists in fields allied to medicine, WAVES, and Hospital Corpsmen brought to the patient the best in clinical medicine. By their ability, resourcefulness, and devotion, they achieved results never before attained in military medicine. Volume I of The History of the Medical Department of the U. S. Navy in World War II is a partial record of their accomplishments and a testimony to their capable performance.

Bennett F. Avery

BENNETT F. AVERY
Captain (MC) USN, Editor

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Illustrations

FIGURE

The photograph in figure 3 is by courtesy of the Fairchild Air Photos Co. The remainder are official photographs of the U.S. Coast Guard, U.S. Marine Corps, U.S. Navy, U.S. Army, and U.S. Air Force.

Tables

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Chapter I

Facilities of the Medical Department of the Navy

Joseph L. Schwartz, *Captain (MC) USN (Retired)*

Continental and Extracontinental Hospitals

Long before the attack on Pearl Harbor, the 75 officers, 32 enlisted men, and 225 civilians who manned the 11[1] divisions of the Bureau of Medicine and Surgery under the direction of the Surgeon General, Rear Admiral Ross T McIntire (MC) USN, were busily engaged with plans and problems involved in processing personnel, expanding physical and material facilities, and stockpiling supplies for the Medical Department of the Navy to meet the needs of war, should it involve the United States. The war already sweeping over Europe had brought forth in 1940 the declaration by President Roosevelt of a Limited National Emergency, and reserve medical department personnel who volunteered for service were therefore ordered to active duty. The expansion of personnel that took place is portrayed in table 1.

TABLE 1.—*Increase in Medical Department personnel on active duty, 1939–1945.*

	30 June 1939	30 June 1941	1945
Medical Corps officers	841	1,957	14,191
Dental Corps officers	255	511	7,012
Nurse Corps officers	439	524	10,968
Hospital Corps officers		195	3,429
Hospital Corps	4,267	10,547	132,500
WAVES			1,125

The naval hospitals and hospital ships in commission in 1941 are listed in table 2. For the continental hospitals, the comparative census of patients is given for 1941 and 1945, indicating the great increase in demand for hospital beds after 7 December 1941.

TABLE 2.—*Hospitals and hospital ships in commission in 1941*

	Patient census	
	1941	VJ-day
U. S. Naval Hospital, Annapolis, Md. (fig. 1)	83	284
U. S. Naval Hospital, Bremerton, Wash. (fig. 2)	299	871
U. S. Naval Hospital, Brooklyn, N. Y. (fig. 3)	589	1,125
U. S. Naval Hospital, Charleston, S. C. (fig. 4)	124	697
U. S. Naval Hospital, Chelsea, Mass. (fig. 5)	495	2,701
U. S. Naval Hospital, Corona, Calif. (fig. 6)		3,611
U. S. Naval Hospital, Corpus Christi, Tex. (fig. 7)	206	1,115
U. S. Naval Hospital, Great Lakes, Ill. (fig. 8)	350	7,532
U. S. Naval Hospital, Jacksonville, Fla. (fig. 9)	209	1,825
U. S. Naval Hospital, Mare Island, Calif. (fig. 10)	676	2,281
U. S. Naval Hospital, Newport, R. I. (fig. 11)	245	1,305
U. S. Naval Hospital, Parris Island, S. C. (fig. 12)	214	651
U. S. Naval Hospital, Pensacola, Fla. (fig. 13)	227	1,073
U. S. Naval Hospital, Philadelphia, Pa. (fig. 14)	643	3,316
U. S. Naval Hospital, Portsmouth, Va. (fig. 15)	1,199	3,103
U. S. Naval Hospital, Portsmouth, N. H. (fig. 16)	124	390
U. S. Naval Hospital, Quantico, Va. (fig. 17)	118	451
U. S. Naval Hospital, San Diego, Calif. (fig. 18)	1,360	[1] 8,069
U. S. Naval Hospital, Washington, D. C. (fig. 19)	210	[2]
U. S. Naval Hospital, Pearl Harbor, T. H.		
U. S. Naval Hospital, Canacao, P. I.		
U. S. Naval Hospital, Guam, M. I.		
U. S. Naval Mobile Hospital No. 1, Guantanamo Bay, Cuba		
U. S. S. *Relief* (fig. 20)		
U. S. S. *Solace* (fig. 21)		

[1] Maximum patient census, 12,068, January 1945.
[2] Decommissioned 1942.

After the flames of war spread over Pearl Harbor, the construction of new hospitals was expedited and the bed capacity of existing hospitals was expanded by adding H-type frame ward buildings and by decreasing the normal peacetime 8-foot interval between beds to 6 feet. That the need for additional hospital facilities was great is indicated by the following as shown in figure 22: In June 1939 the total patient census in naval hospitals was 4,124; in June 1941 it was 7,723; the average census of patients for the year 1942 was 13,274; in 1943 it was 39,723; in 1944 it was 70,576; and in 1945 it was 90,635.

[1] Bureau Divisions:

Physical Qualifications and Medical Records, Personnel, Dentistry, Aviation, Medicine, Planning, Research, Inspections, Publications, Materiel and Finance, and Administration.

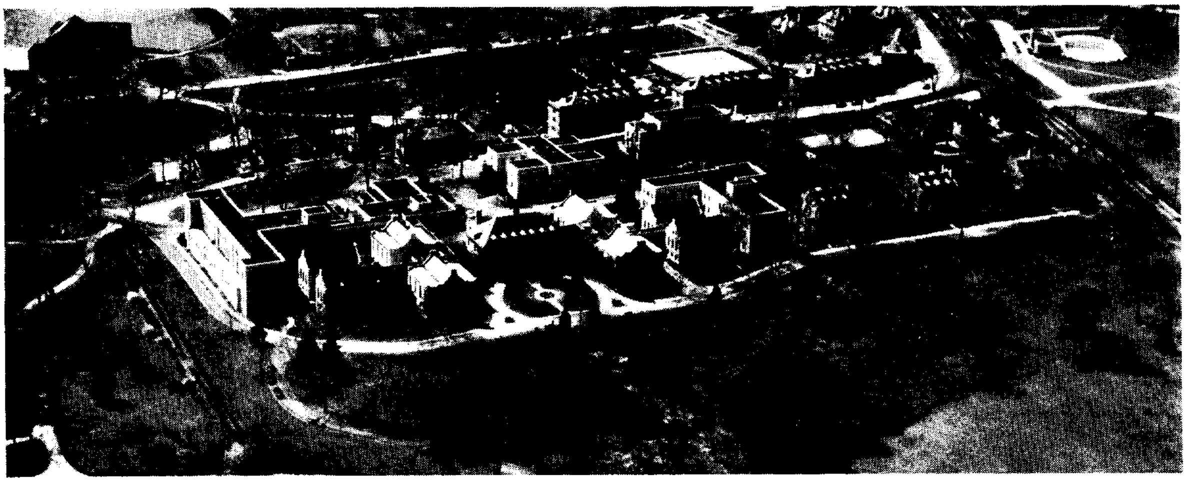
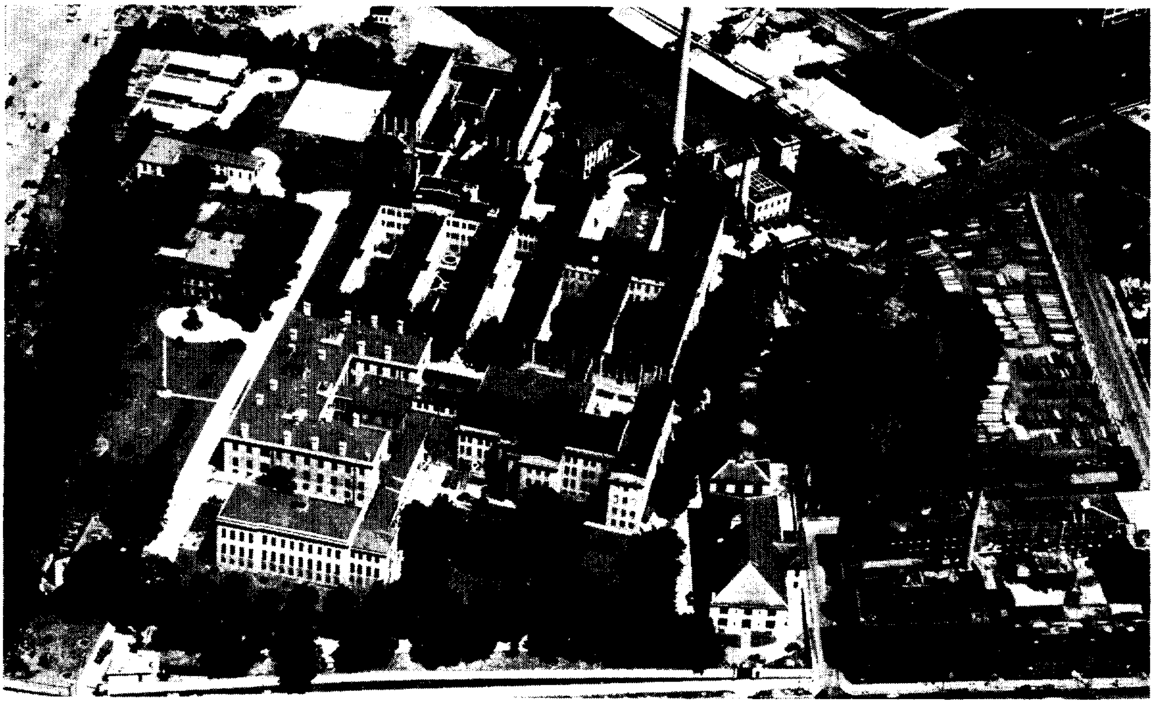


FIGURE 1.—U. S. Naval Hospital, Annapolis, Md.

FIGURE 2.—U. S. Naval Hospital, Bremerton, Wash.



—*Courtesy of Fairchild Air Photos Co.*

FIGURE 3.—U. S. Naval Hospital, Brooklyn, N.Y.

FIGURE 4.—U. S. Naval Hospital, Charleston, S.C.

FIGURE 5.—U. S. Naval Hospital, Chelsea, Mass.

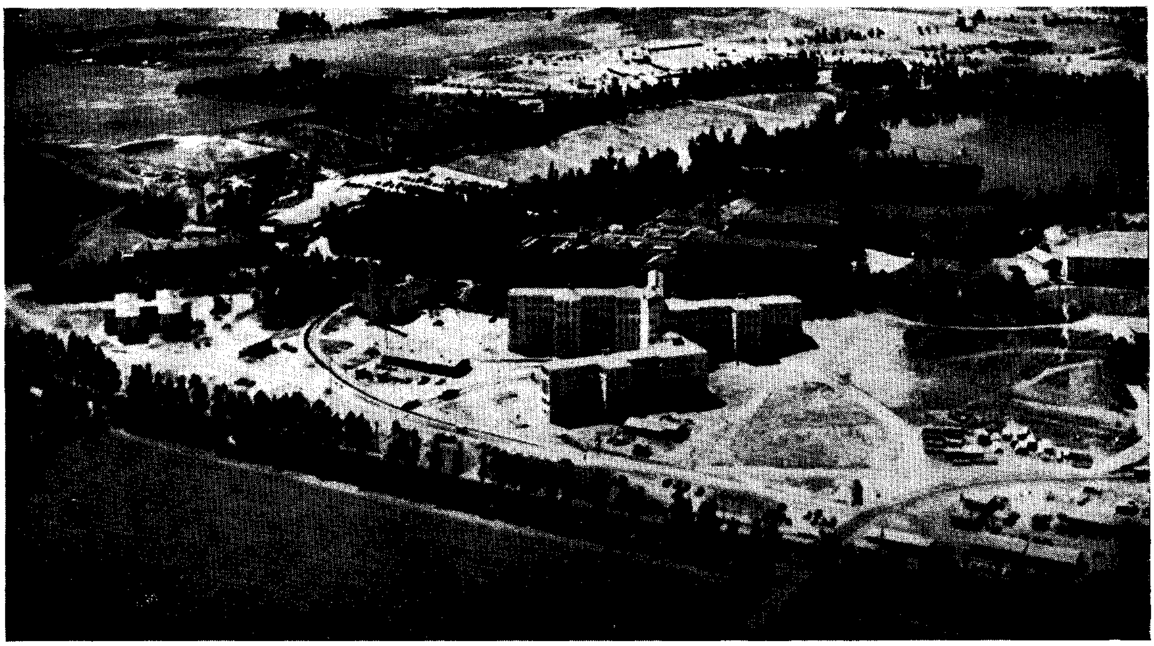


FIGURE 6.—U. S. Naval Hospital, Corona, Calif.

FIGURE 7.—U. S. Naval Hospital, Corpus Christi, Tex.

FIGURE 8.—U. S. Naval Hospital, Great Lakes, Ill.

FIGURE 9.—U. S. Naval Hospital, Jacksonville, Fla.

FIGURE 10.—U. S. Naval Hospital, Mare Island, Calif.

FIGURE 11.—U. S. Naval Hospital, Newport, R.I.

FIGURE 12.—U. S. Naval Hospital, Parris Island, S.C.

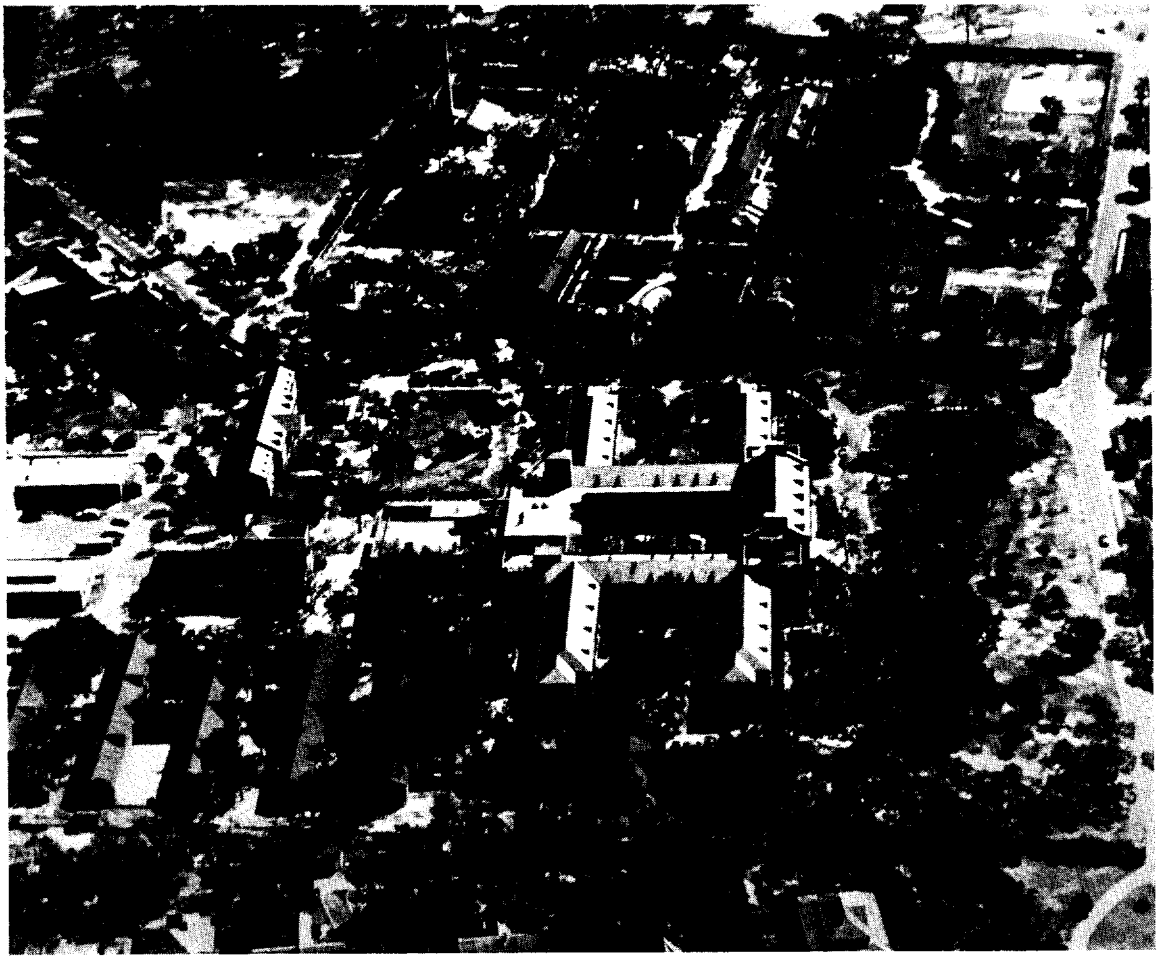


FIGURE 13.—U. S. Naval Hospital, Pensacola, Fla.

FIGURE 14.—U. S. Naval Hospital, Philadelphia, Pa.

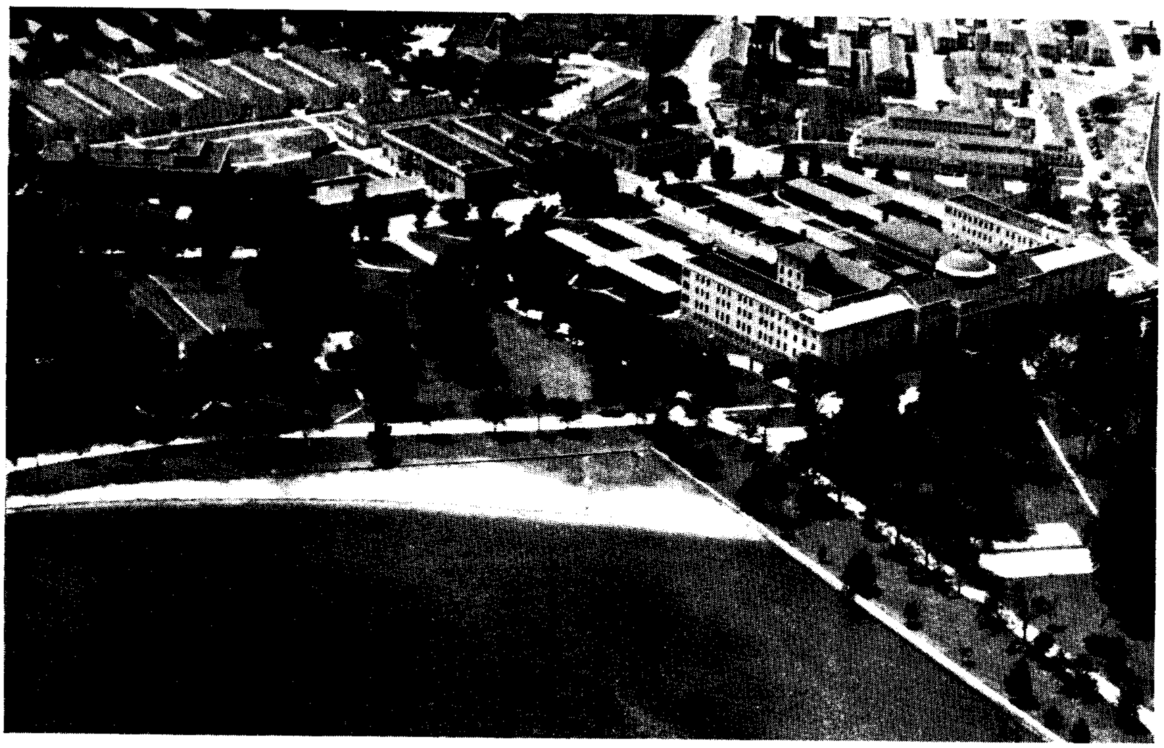


FIGURE 15.—U. S. Naval Hospital, Portsmouth, Va.

FIGURE 16.—U. S. Naval Hospital, Portsmouth, N.H.

FIGURE 17.—U. S. Naval Hospital, Quantico, Va.

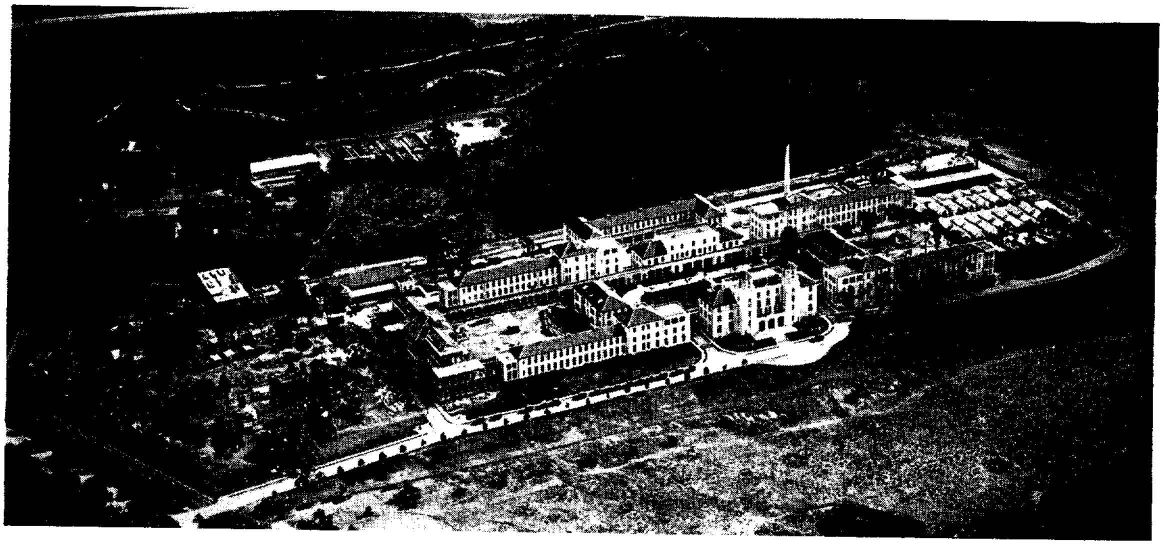


FIGURE 18.—U. S. Naval Hospital, San Diego, Calif.

FIGURE 19.—U. S. Naval Hospital, Washington, D.C.

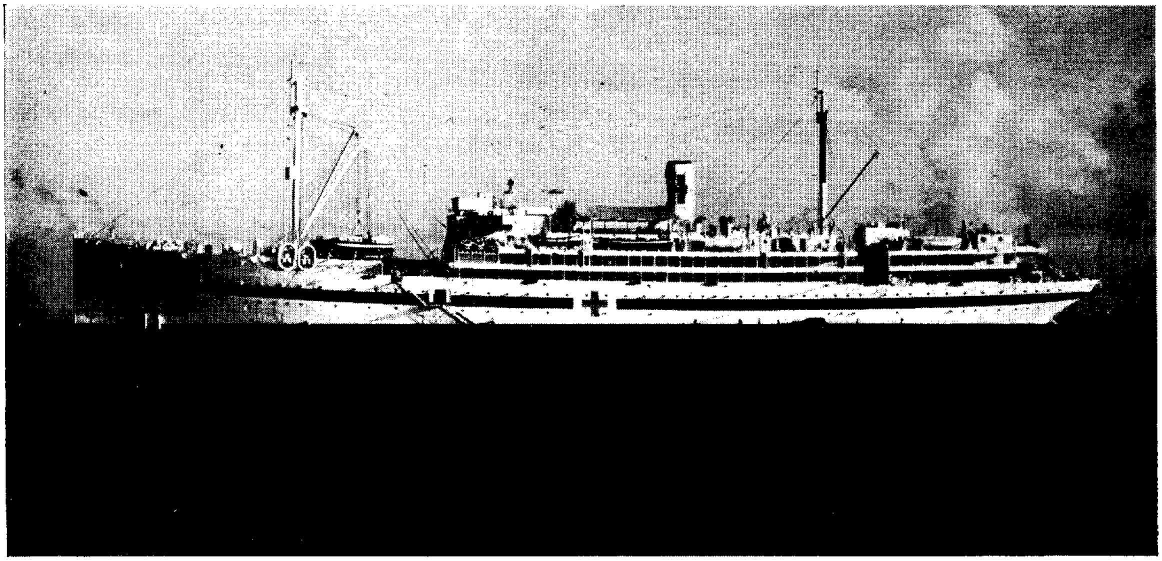


FIGURE 20.—U.S.S. *Relief*

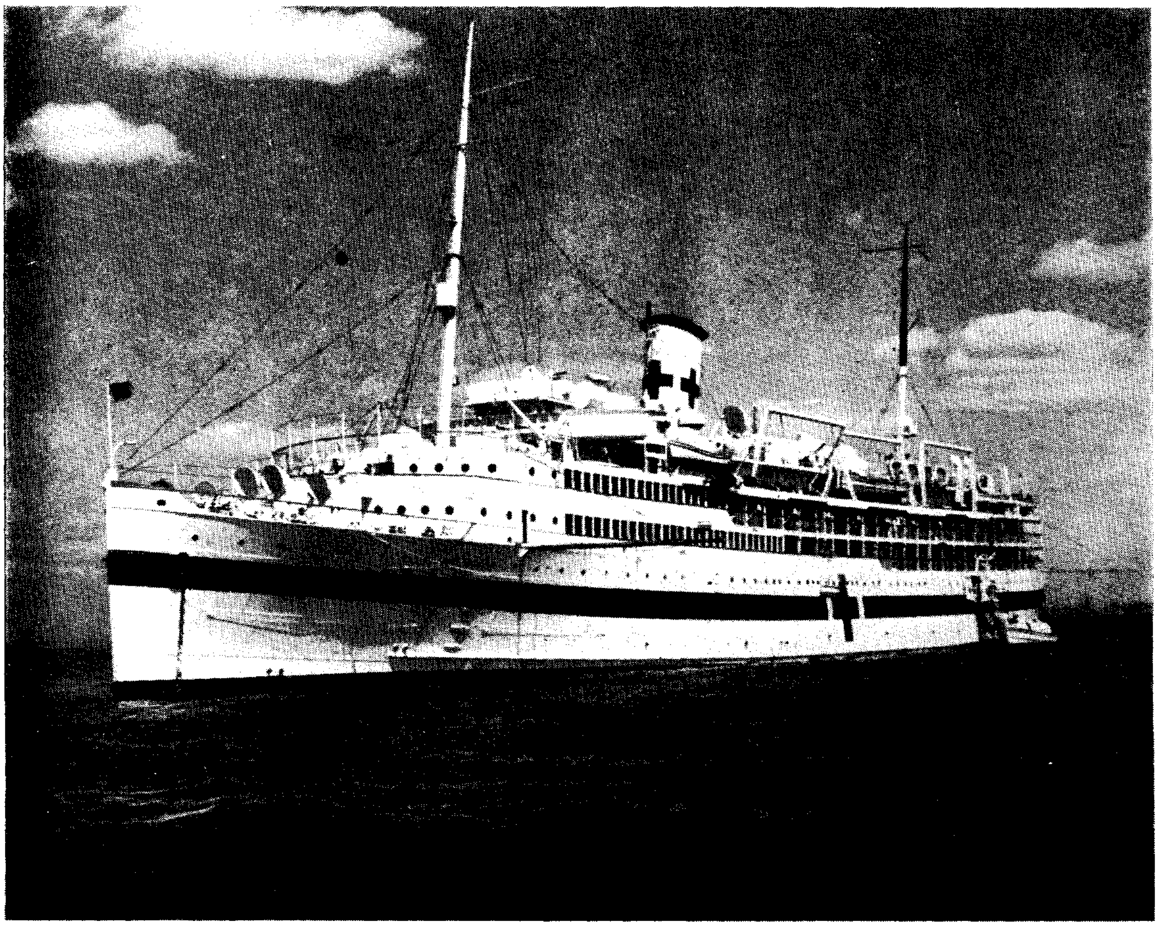


FIGURE 21.—U.S.S. *Solace*

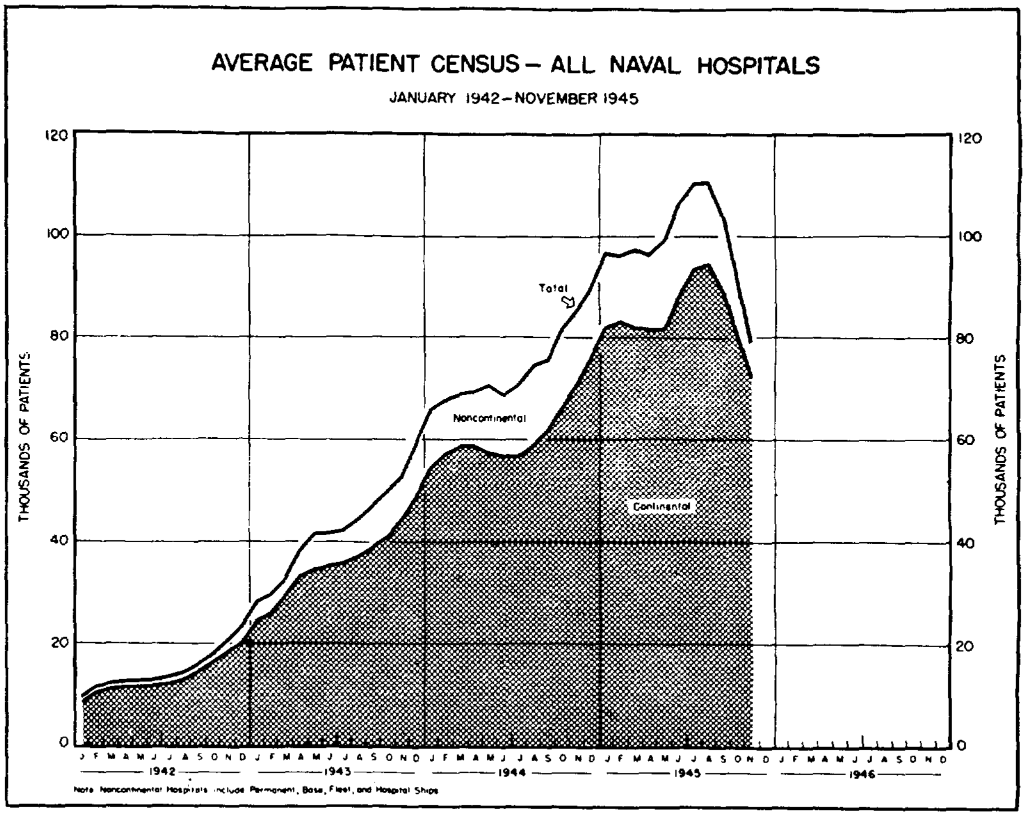


FIGURE 22.—Average patient census, all naval hospitals.

In 1942 alone, nine continental and two extracontinental hospitals were commissioned (table 3):

TABLE 3.—*Hospitals commissioned in 1942*

	Patient census V-J Day
U.S. Naval Hospital, Bethesda, Md.[1] (fig. 23)	2,426
U.S. Naval Hospital, San Francisco (Treasure Island), Calif. (fig. 24)	1,276
U.S. Naval Hospital, Oakland, Calif. (fig. 25)	5,400
U.S. Naval Hospital, Seattle, Wash. (fig. 26)	3,031
U.S. Naval Hospital, Key West, Fla. (fig. 27)	2,609
U.S. Naval Hospital, Charleston, S.C.	697
U.S. Naval Hospital, Long Beach, Calif. (fig. 28)	2,281
U.S. Naval Hospital, Norfolk, Va. (fig. 29)	1,652
U.S. Naval Hospital, Norman, Okla. (fig. 30)	1,811
U.S. Naval Hospital, Balboa, C.Z.	192
U.S. Naval Hospital, Coco Solo, C.Z.	236

[1] This was a subordinate command of the National Naval Medical Center commissioned 5 February 1942, and replaced the U. S. Naval Hospital, Washington, D. C., originally commissioned October 1906.
Also included in the National Naval Medical Center were the following activities:
U. S. Naval Medical School (originally established 1822).
U. S. Naval Dental School (originally established 1923).
U. S. Naval Medical Research Institute (established 1942).
U. S. Naval School of Hospital Administration (reorganized and established 1945).
U. S. Hospital Corps School (Women's Reserve) (commissioned 1944; decommissioned 1946).
The cornerstone for the Center was laid by President Roosevelt on 11 November 1940. Rear Admiral Charles M. Oman (MC) USN was the first commanding officer of the Center.

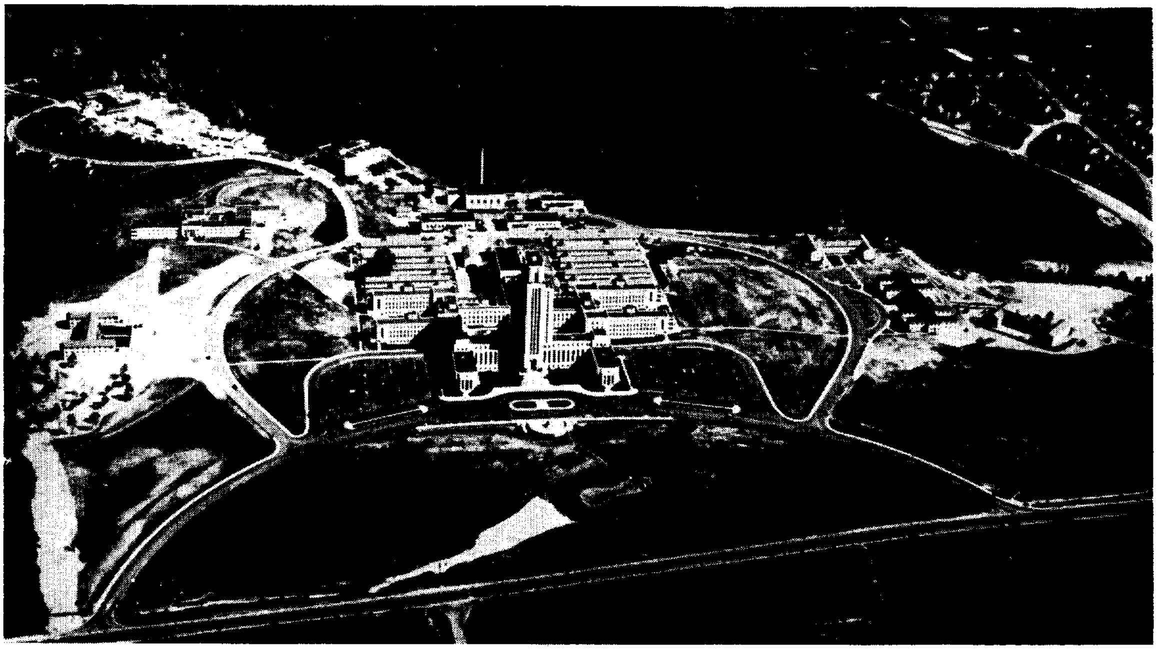


FIGURE 23.—U. S. Naval Hospital, Bethesda, Md.

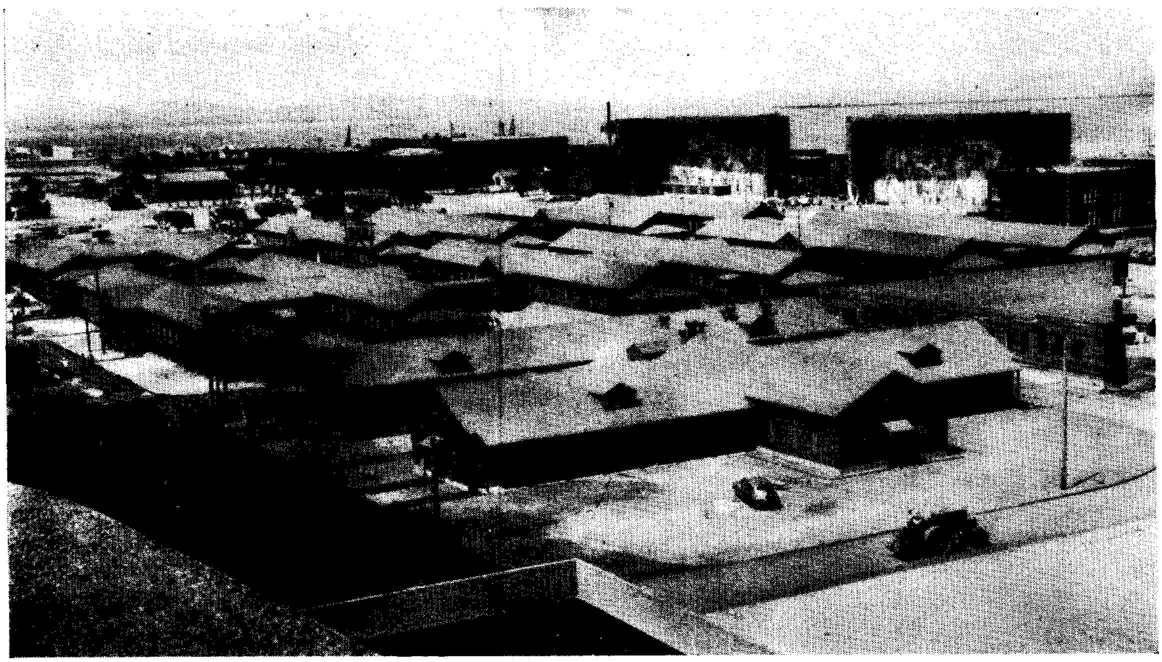


FIGURE 24.—U. S. Naval Hospital, San Francisco (Treasure Island), Calif.

FIGURE 25.—U. S. Naval Hospital, Oakland, Calif.

FIGURE 26.—U. S. Naval Hospital, Seattle, Wash.

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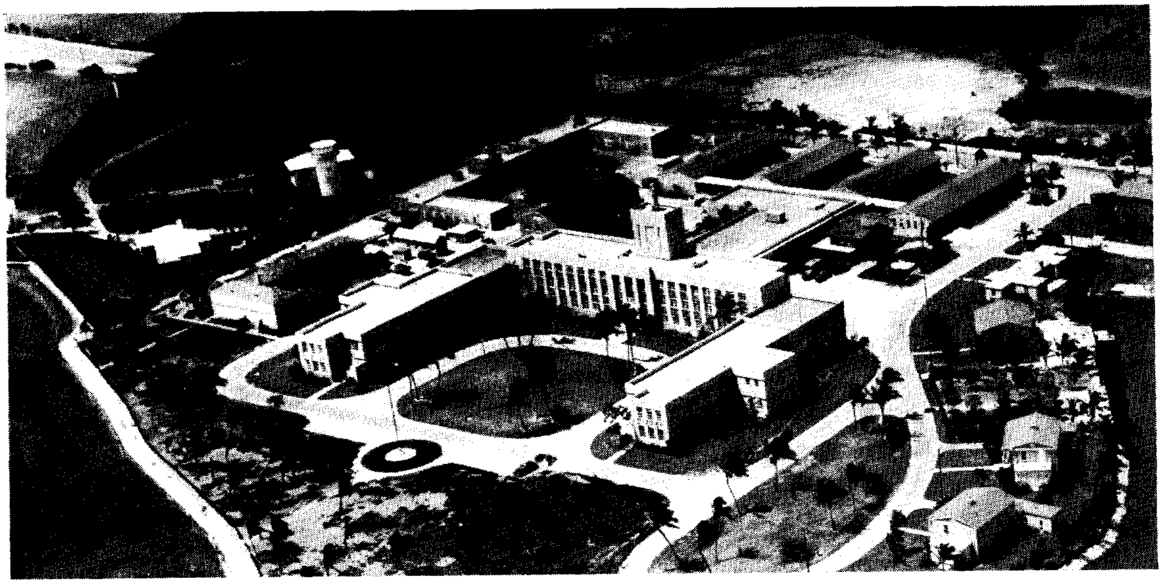

FIGURE 27.—U. S. Naval Hospital, Key West, Fla.

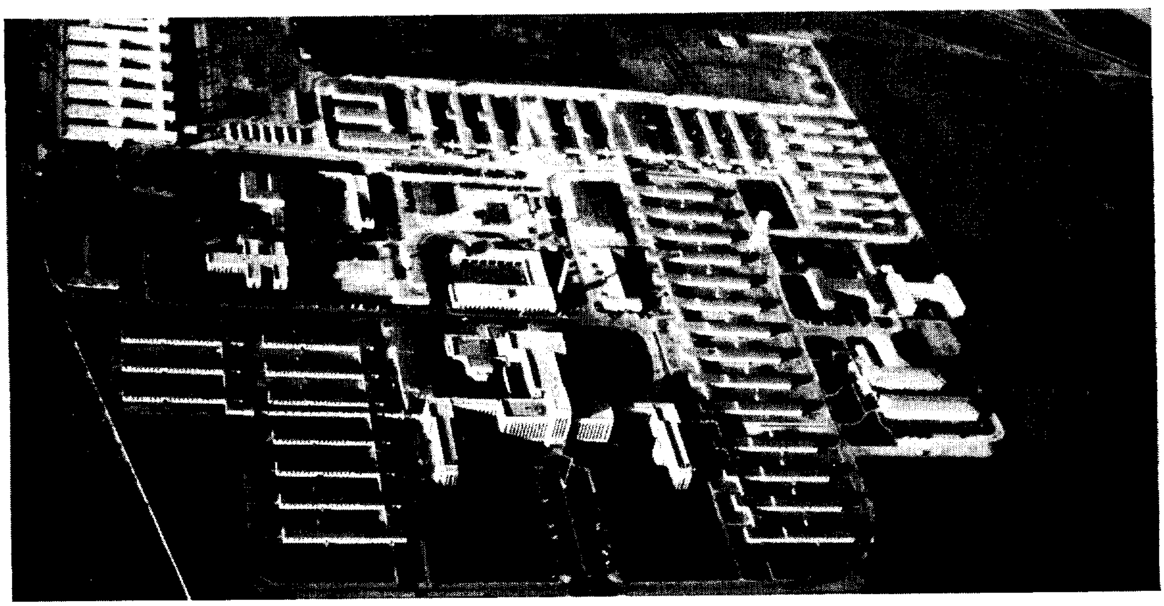

FIGURE 28.—U. S. Naval Hospital, Long Beach, Calif.

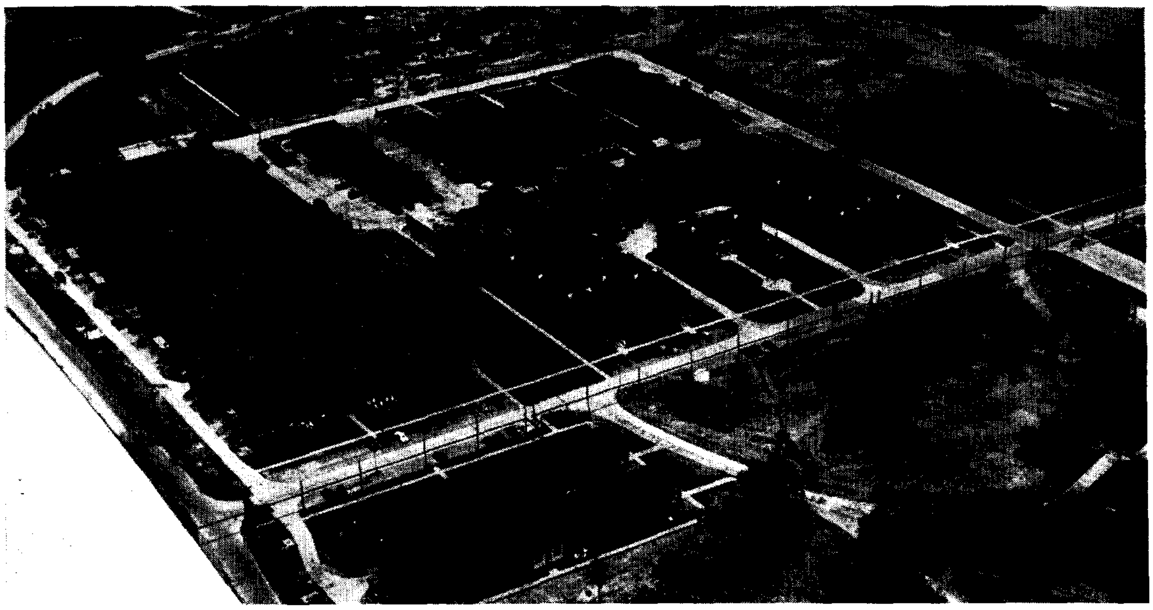

FIGURE 29.—U. S. Naval Hospital, Norfolk, Va.

Development of Mobile and Base Hospitals[2]

In 1939, when world war appeared imminent, the Bureau of Medicine and Surgery realized the need for some type of prefabricated hospital that would be completely self-sustaining and yet transportable and of such construction that it could be set up without the employment of skilled mechanics. As a result U.S. Naval Mobile Hospital No. 1, which is more fully described in chapter III, was designed and constructed. This was a 500-bed, completely equipped, transportable type, general hospital with self-contained power, water, commissary, laundry, and repair facilities. It was first set up at Guantanamo Bay, Cuba, in November 1940, where it served local and fleet units (fig. 31). After its experimental phase in Cuba, its portability was tested by being torn down, shipped to Bermuda, and set up there (fig. 32). The experience in erecting this type of hospital paved the way for better mobile and base hospital construction. Although it was observed that these hospitals did not possess a high degree of mobility, nevertheless they could be moved and set up in any area with a minimum of time, expense, and labor. They contained the following facilities: (*a*) water purification and softening plant; (*b*) storage spaces for supplies; (*c*) laundry; (*d*) galley; (*e*) automotive and ambulance equipment; (*f*) fire-fighting equipment; (*g*) light and power supplies; (*h*) refrigeration facilities; and (*i*) x-ray, dental, laboratory, and other equipment and facilities of a general hospital.

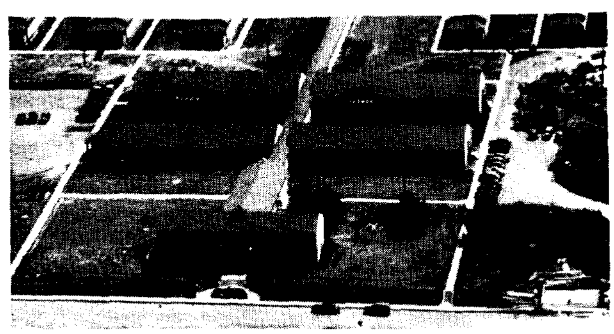

FIGURE 30.—U. S. Naval Hospital, Norman, Okla.

[2] In August 1943 the designation Mobile Hospital was changed to Fleet Hospital; new serial numbers were assigned by adding 100 to the old number, except for Mobile Hospitals 1 and 2, which became Fleet Hospitals 1 and 2 respectively.

The supplies, equipment, and buildings for all mobile and base hospitals were procured by the Medical Supply Depot, Brooklyn, N.Y., and each hospital was commissioned there. During the period of assembling and packing the hospital supplies and equipment, the hospital staff assembled at the Depot, where they were indoctrinated in the methods of hospital construction and outfitting and were advised regarding the methods of identification of the packed and crated equipment.

Upon reaching their destination the staff of the hospital immediately set up temporary quarters, and when the material for the hospital arrived the hospital corpsmen under the direction and with the physical assistance of the Medical Corps, Dental Corps, and Hospital Corps officers began the job of unloading and sorting the equipment and supplies and erecting the prefabricated components of the hospital—the quonset, Iceland, and similar huts. This was no small task; some of the hospitals had as many as 300 buildings, including huts[3] and sheds.

At first some of the hospitals experienced difficulty in obtaining sufficient medical supplies; in particular there was a great shortage of quinine and atabrine. Many administrative difficulties presented themselves. There was some confusion regarding the procedures for requisitioning supplies, often the allotment status was unknown and instructions regarding accounting procedures were not received,

[3] The floor space of the quonset hut was 16 by 36 feet and of the Iceland hut 24 by 36 feet.

FIGURE 31.—Mobile Hospital No. 1 at Guantanamo Bay, Cuba.

FIGURE 32.—Mobile Hospital No. 1 at Bermuda.

and some hospitals were uncertain how to obtain items not listed in the supply catalogue.

The size of the mobile and base hospitals varied from 200 to 2,500 beds. In the majority of the hospitals, the number of medical officers attached ranged from 40 to 54, of dental officers from 1 to 4, of Hospital Corps officers from 1 to 5, and of hospital corpsmen from 235 to 500. Usually about 80 enlisted men with non-medical ratings were attached to the hospital. There were no civilian employees, and until the early part of 1944 none of the hospitals had Navy nurses.

Plans for the construction of mobile and base hospitals having been perfected following the experiences with the U.S. Naval Mobile Hospital No. 1 in Guantanamo and Bermuda, similar but improved versions (fig. 33) were erected in the battle zones all over the world. The first of these, U.S. Naval Mobile Hospital No. 2, was disembarked at Pearl Harbor on 26 November 1941, just 12 days before the attack by the Japanese. By the end of 1942 8 mobile and base hospitals of 500 beds each had been assembled, shipped, and erected in battle zones.

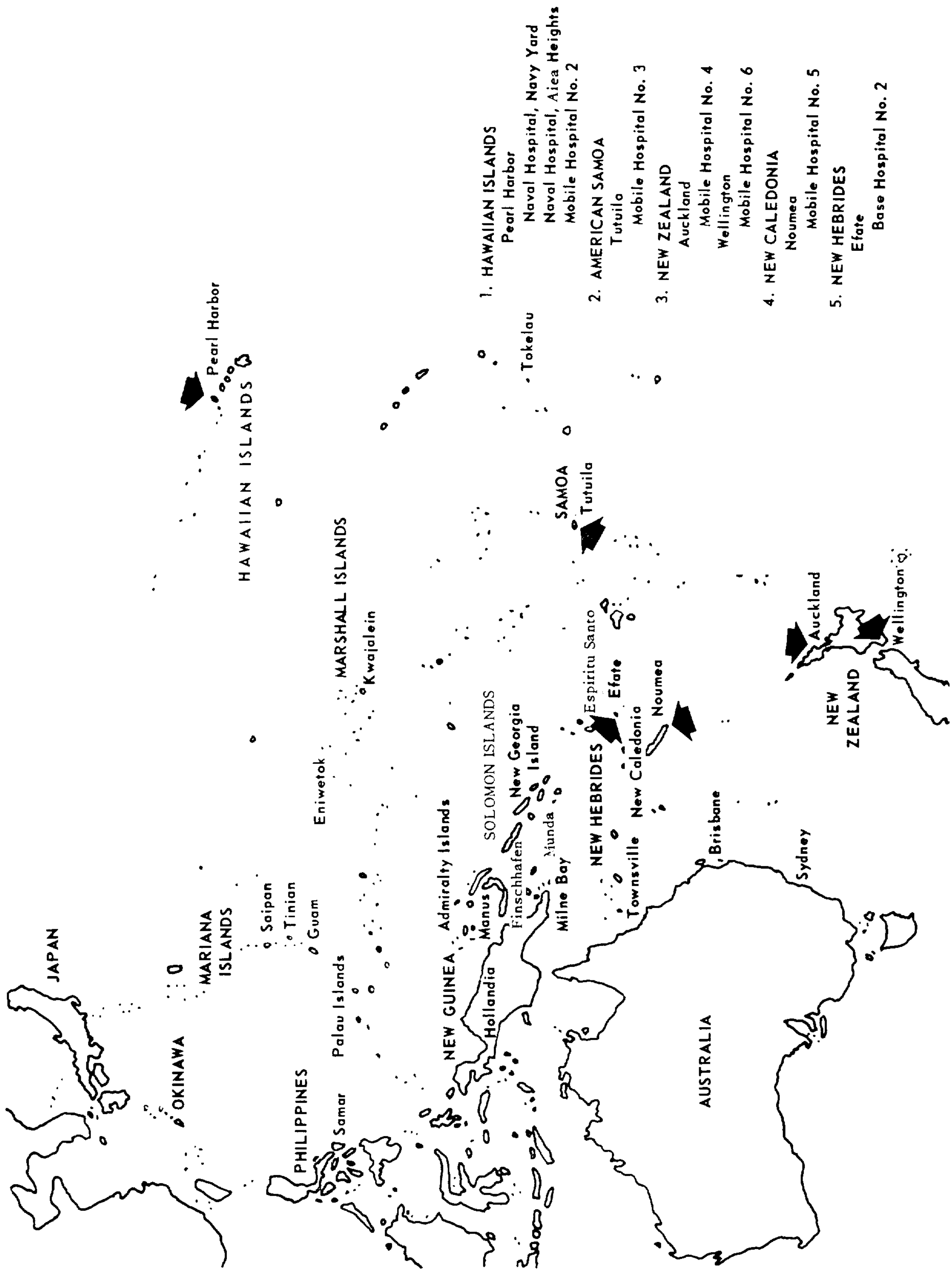

FIGURE 33.—U.S. Naval Hospitals in the Pacific in 1942.

FIGURE 34.—Mobile Hospital No. 8 at Guadalcanal.

Two base hospitals and five mobile hospitals were commissioned in 1942 (table 4).

TABLE 4.—*Mobile and base hospitals commissioned in 1942*

Base hospitals:
- U.S. Naval Base Hospital No. 1, Londonderry, North Ireland
- U.S. Naval Base Hospital No. 2, Efate Island, New Hebrides [1]

Mobile hospitals:
- U.S. Naval Mobile Hospital No. 2, Pearl Harbor (commissioned Aug 1941)
- U.S. Naval Mobile Hospital No. 3, Tutuila, Samoa; Guam [2]
- U.S. Naval Mobile Hospital No. 5, Noumea, New Caledonia [3]
- U.S. Naval Mobile Hospital No. 7, Noumea, New Caledonia
- U.S. Naval Mobile Hospital No. 8, Guadalcanal, Solomon Islands (fig. 34) [4]

The U.S. Naval Fleet Hospital No. 103, Guam, and the U.S. Naval Convalescent Hospital, Harriman, N.Y. (fig. 35), were also commissioned in 1942.

[1] Base Hospital No. 2, Efate, New Hebrides, arrived at Villa, 4 May 1942. It was the first base hospital established in the Southwest Pacific. During the period 4 May 1942 to 31 December 1942 this hospital admitted 2,949 patients with malaria. Casualties from Guadalcanal were admitted to Base Hospital No. 2, usually within 36 hours after they were injured. Most of the patients were brought by air to an airfield 6 miles from the hospital. A quonset hut for the reception of patients was placed near the landing strip of the airfield and a medical officer supervised the transfer of patients from airplane to ambulance. In 1944 this hospital was moved to Noumea and in July 1945 to Subic Bay.

[2] Mobile Hospital No. 3, in American Samoa, was one of the hospitals established in the Pacific in 1942 that did not receive a large number of battle casualties. In Samoa, filariasis was a major problem. Up to 1 January 1944, this hospital evacuated 2,904 patients with filariasis to the United States.

[3] Mobile Hospital No. 5, later Fleet Hospital No. 105, arrived in Noumea in September 1942 and received its first patients on 22 April 1943. During the period from September 1942 to December 1945, 23,866 patients were admitted. The maximum patient census was 2,100.

[4] Mobile Hospital No. 8, arrived on Guadalcanal in April 1943. It was commissioned August 1943 and designated as Fleet Hospital No. 108 in 1944. By December 1944 this hospital had treated 39,395 patients. During 1943, 2,208 patients were admitted for some form of psychoneurosis.

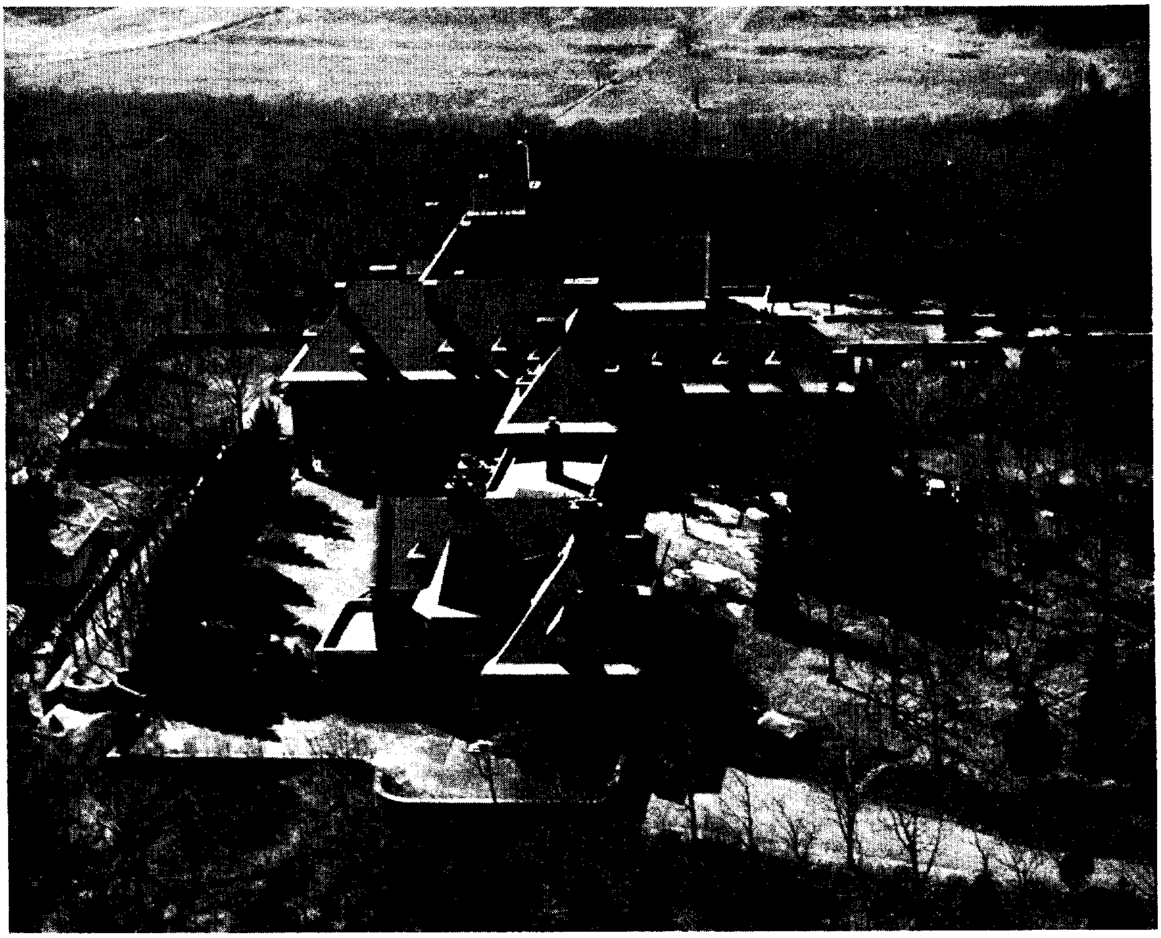

FIGURE 35.—U. S. Naval Convalescent Hospital, Harriman, N.Y.

In February 1943 the bed capacity of previously constructed mobile hospitals was expanded to 1,000 beds, and in June all base hospitals were equipped for 1,000-bed capacity. In addition numerous new hospitals were commissioned in 1943 (table 5):

TABLE 5.—*Hospitals commissioned in 1943*

	Patient census V-J Day
Continental hospitals:	
U.S. Naval Hospital, Farragut, Idaho (fig. 36)	2,489
U.S. Naval Hospital, Bainbridge, Md. (fig. 37)	1,979
U.S. Naval Hospital, St. Albans, N.Y. (fig. 38)	4,642
U.S. Naval Hospital, Sampson, N.Y. (fig. 39)	2,119
U.S. Naval Hospital, Memphis, Tenn. (fig. 40)	1,321
U.S. Naval Hospital, New Orleans, La. (fig. 41)	1,212
U.S. Naval Hospital, Camp Lejeune, New River, N.C. (fig. 42)	1,730
U.S. Naval Hospital, Oceanside, Calif. (fig. 43)	1,534
U.S. Naval Hospital, Shoemaker, Calif. (fig. 44)	3,031
Extracontinental hospitals:	
U.S. Naval Hospital, Aiea Heights, T.H.	----
U.S. Naval Hospital, San Juan, P.R.	----
U.S. Naval Hospital, Trinidad, B.W.I.	----
Base hospitals:	
U.S. Naval Base Hospital No. 3, Espiritu Santo, New Hebrides	----
U.S. Naval Base Hospital No. 4, Wellington, New Zealand; Okinawa (fig. 45)	----
U.S. Naval Base Hospital No. 5, Casablanca, French Morocco	
U.S. Naval Base Hospital No. 6, Espiritu Santo, New Hebrides	----
U.S. Naval Base Hospital No. 7, Tulagi, Solomon Islands	----
U.S. Naval Base Hospital No. 8, Pearl Harbor, T.H.	----
U.S. Naval Base Hospital No. 9, Oran, Algeria	----
U.S. Naval Base Hospital No. 10, Sydney, Australia	----
U.S. Naval Base Hospital No. 11, Munda, New Georgia	----
U.S. Naval Base Hospital No. 13, Milne Bay, New Guinea	----
Mobile hospitals:	
U.S. Naval Mobile Hospital No. 4, Auckland, New Zealand	----
U.S. Naval Mobile Hospital No. 6, Wellington, New Zealand	----
U.S. Naval Mobile Hospital No. 9, Brisbane, Australia	----
U.S. Naval Mobile Hospital No. 10, Russell Islands, Solomon Islands	----
U.S. Naval Mobile Hospital No. 11, Guam, Mariana Islands	----
U.S. Naval Mobile Hospital No. 12, New Caledonia (Noumea)[1]	----
Convalescent hospitals:	
U.S. Naval Special Hospital, Santa Cruz, Calif.	891
U.S. Naval Special Hospital, Asheville, N.C.	367
U.S. Naval Special Hospital, Yosemite, Calif. (fig. 46)	709
U.S. Naval Special Hospital, Sun Valley, Idaho	978
U.S. Naval Special Hospital, Glenwood Springs, Colo. (fig. 47)	526

[1] Mobile Hospital No. 12 was commissioned in September 1943 and decommissioned in November 1945. By receipt and transfer, about 1,400 officers and men served with this unit, but it never operated as a hospital and never admitted a patient. This hospital arrived at Noumea in May 1944; from there it was shipped to Guadalcanal, Espiritu Santo, Eniwetok, and finally Okinawa. It was never erected.

FIGURE 36.—U. S. Naval Hospital, Farragut, Idaho.

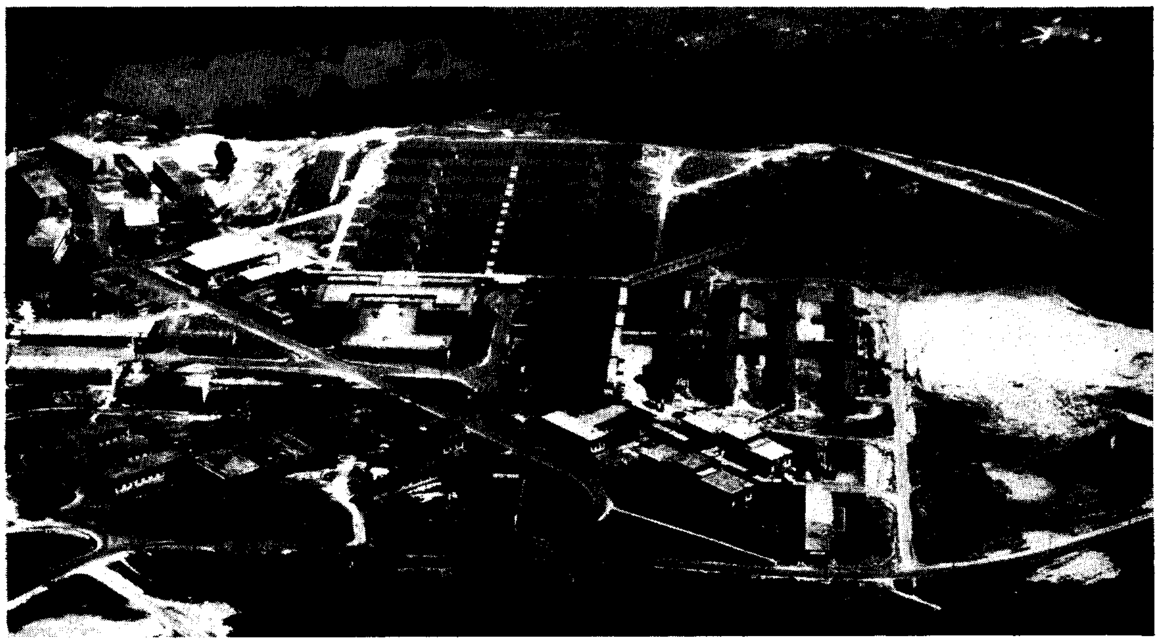

FIGURE 37.—U. S. Naval Hospital, Bainbridge, Md.

FIGURE 38.—U. S. Naval Hospital, St. Albans, N.Y.

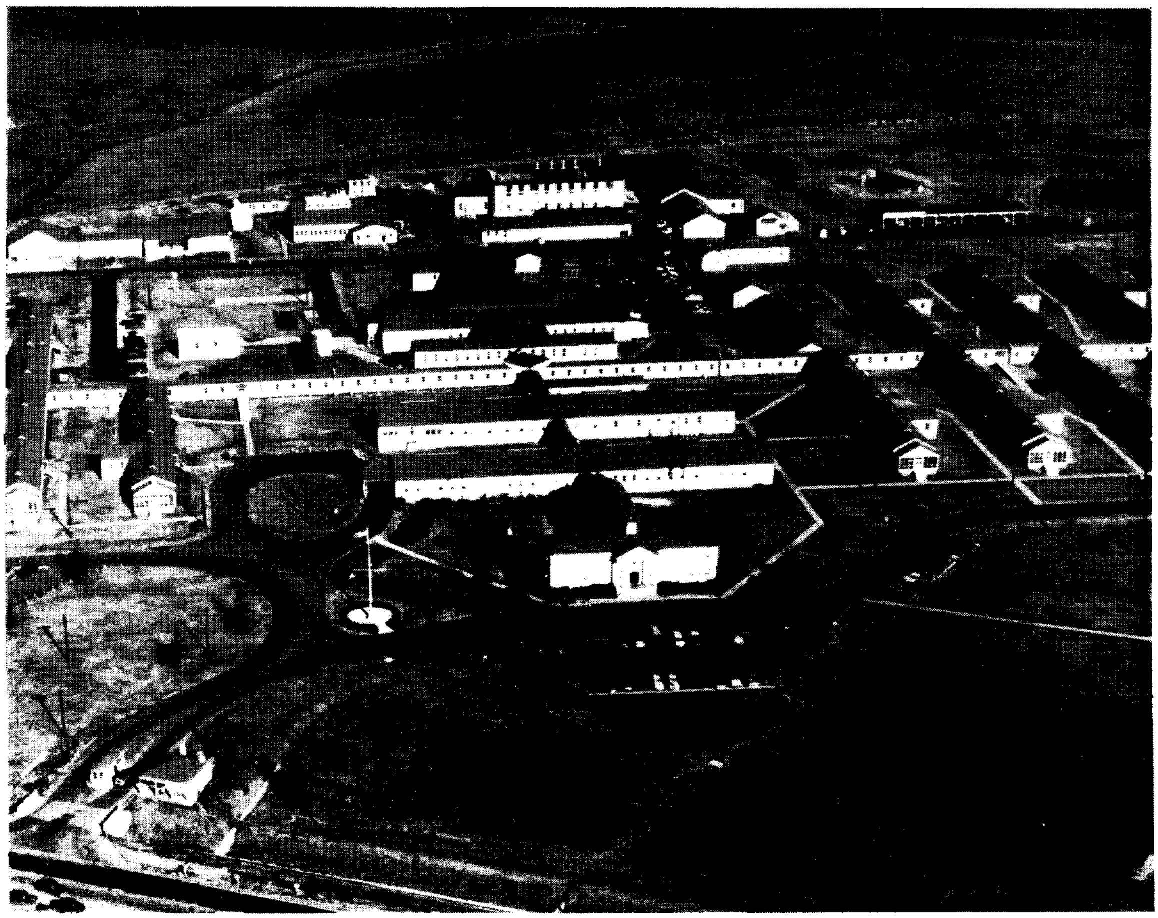

FIGURE 39.—U. S. Naval Hospital, Memphis, Tenn.

FIGURE 40.—U. S. Naval Hospital, Sampson, N.Y.

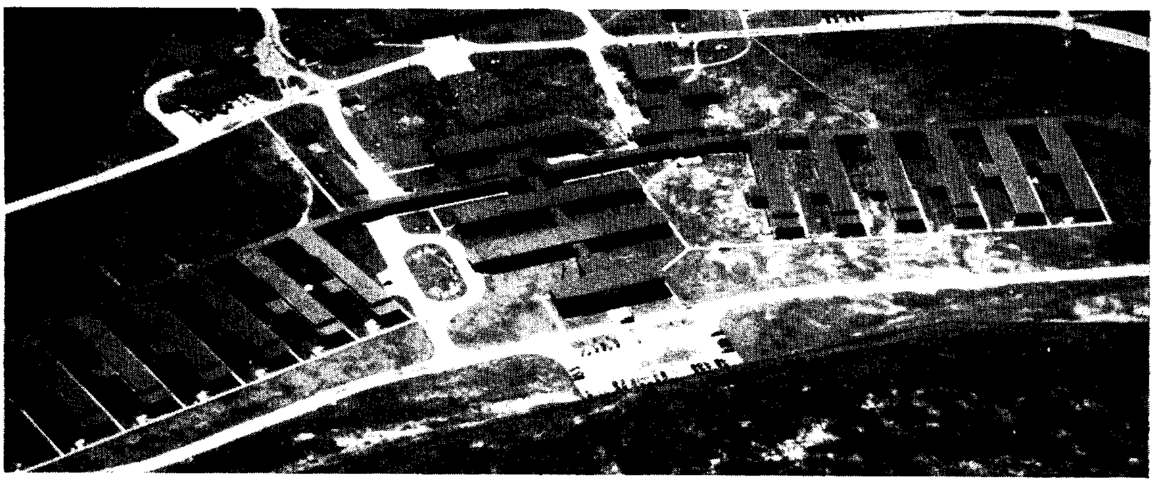

FIGURE 41.—U. S. Naval Hospital, New Orleans, La.

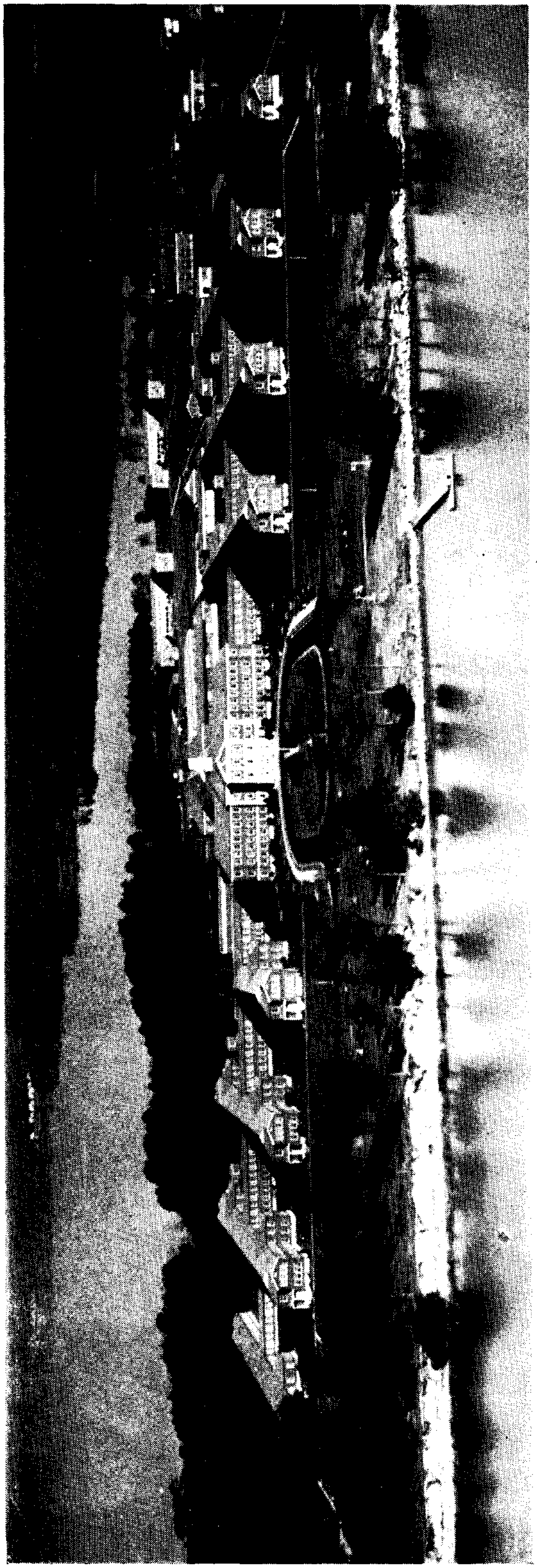

FIGURE 42.—U. S. Naval Hospital, Camp Lejeune, New River, N.C.

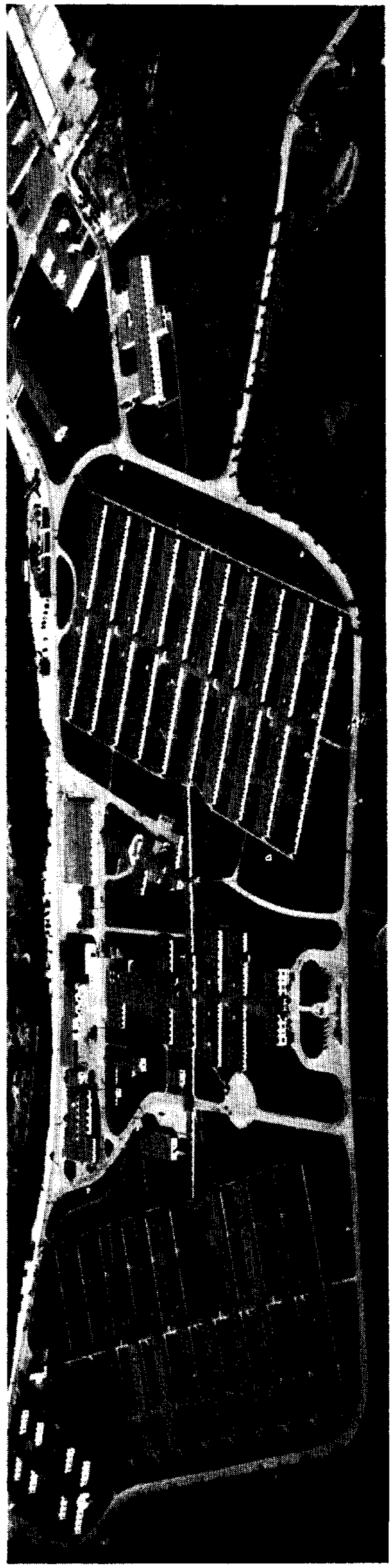

FIGURE 43.—U. S. Naval Hospital, Santa Margarita Ranch, Oceanside, Calif.

FIGURE 44.—U. S. Naval Hospital, Shoemaker, Calif.

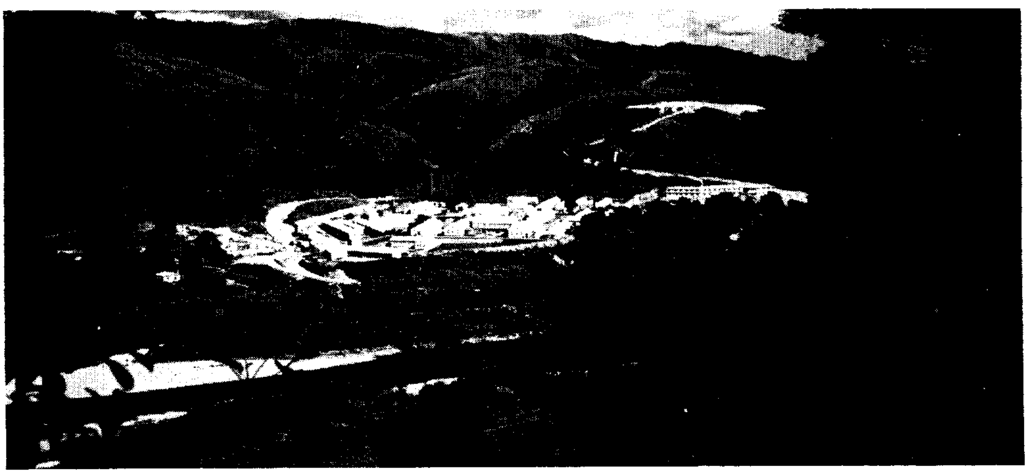

FIGURE 45.—U. S. Naval Base Hospital No. 4, Wellington, New Zealand

FIGURE 46.—U. S. Naval Convalescent Hospital, Yosemite, Calif.

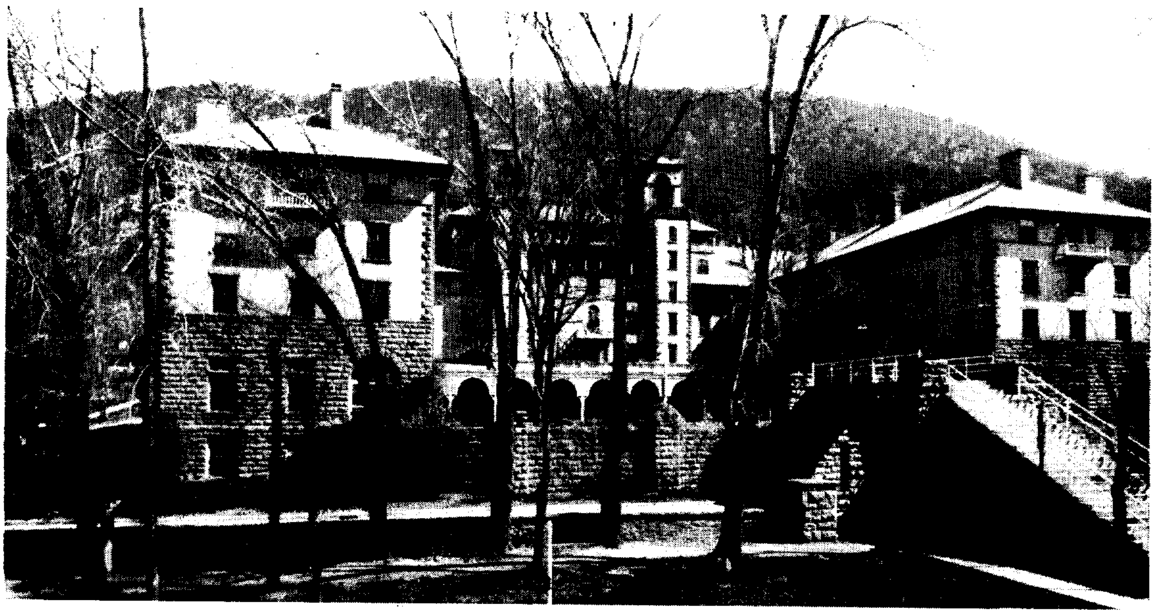

FIGURE 47.—U. S. Naval Convalescent Hospital, Glenwood Springs, Colo.

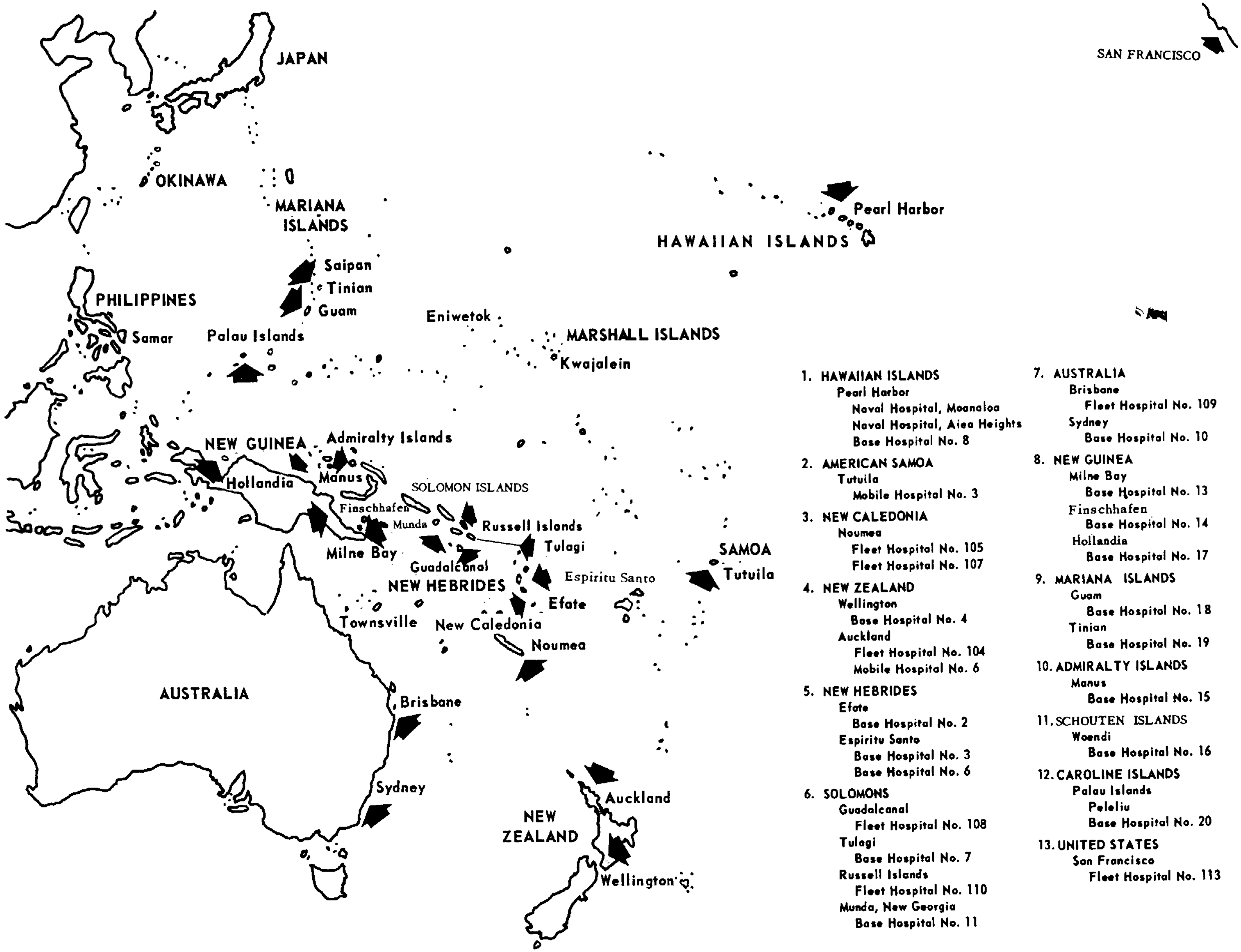

FIGURE 48.—Mobile and base hospitals in the Pacific in 1944.

Figure 48 shows the location of mobile and base hospitals in the Pacific during 1944. In that year the hospital facilities listed in table 6 were commissioned.

TABLE 6.—*Hospitals and hospital ships commissioned in 1944*

	Patient census V–J Day
Continental hospitals:	
U.S. Naval Hospital, San Leandro, Calif. (fig. 49)	1,373
U.S. Naval Hospital, Fort Eustice, Va. (fig. 50)	1,339
U.S. Naval Hospital, Astoria, Oreg.	414
Base hospitals:	
U.S. Naval Base Hospital No. 12, Netley, Hants, England	----
U.S. Naval Base Hospital No. 14, Finschhafen, New Guinea; Cavite, P.I.	----
U.S. Naval Base Hospital No. 15, Manus Island, Admiralty Islands	----
U.S. Naval Base Hospital No. 16, Woendi, Schouten Islands	----
U.S. Naval Base Hospital No. 17, Hollandia, New Guinea	----
U.S. Naval Base Hospital No. 18, Guam, Mariana Islands	----
U.S. Naval Base Hospital No. 19, Tinian Island, Mariana Islands	----
U.S. Naval Base Hospital No. 20, Peleliu, Palau Islands	----
Fleet hospitals:	
U.S. Naval Fleet Hospital No. 113, San Francisco, Calif.	----
U.S. Naval Fleet Hospital No. 114, Samar, P.I. [1]	----
Hospital ships:	
U.S.S. *Bountiful*	----
U.S.S. *Refuge*	----
U.S.S. *Samaritan* (fig. 51)	----
Convalescent hospitals:	
U.S. Naval Special Hospital, Arrowhead Springs, Calif.	692
U.S. Naval Special Hospital, Banning, Calif.	831
U.S. Naval Special Hospital, Beaumont, Calif.	240
U.S. Naval Special Hospital, Sea Gate, N.Y.	685
U.S. Naval Special Hospital, Springfield, Mass.	424

[1] Fleet Hospital No. 114, a 1,000-bed unit, arrived at Samar, March 1945, and was expanded to 3,000 beds by incorporating Fleet Hospital No. 109. The hospital was operating on 2 July 1945 and 5,684 patients were admitted during the 2 months of July and August. This hospital had a strikingly high incidence of admissions for ureteral calculus, 117 admissions in 2 months. The widespread use of sulfonamides may have been a factor in this.

In 1945 the hospital facilities shown in table 7 were commissioned:

TABLE 7.—*Hospitals and hospital ships commissioned in 1945*

	Patient census V–J Day
Continental hospitals:	
U.S. Naval Hospital, Dublin, Ga. (fig. 52)	889
U.S. Naval Hospital, Corvallis, Oreg. (fig. 53)	1,573
Base hospitals:	
U.S. Naval Base Hospital No. 21, Kwajalein Island, Marshall Islands	----
Fleet hospitals:	
U.S. Naval Fleet Hospital No. 115, Guam, Mariana Islands	----
U.S. Naval Fleet Hospital No. 116, Brooklyn, N.Y.; San Pedro, Calif.	----
Hospital ships:	
U.S.S. *Benevolence*	----
U.S.S. *Consolation* (fig. 54)	----
U.S.S. *Haven* (fig. 55)	----
U.S.S. *Repose*	----
U.S.S. *Rescue* (fig. 56)	----
U.S.S. *Sanctuary*	----
U.S.S. *Tranquillity* (fig. 57)	----
Military government hospitals:	
U.S. Naval Military Government Hospital, Saipan, Mariana Islands	----
U.S. Naval Military Government Hospital, Guam, Mariana Islands	----
U.S. Naval Military Government Hospital, Tinian, Mariana Islands	----
Special augmented hospitals:	
Special Augmented Hospital No. 3, Okinawa, Ryukyu Islands	----
Special Augmented Hospital No. 4, Okinawa, Ryukyu Islands	----
Special Augmented Hospital No. 6, Okinawa, Ryukyu Islands	----
Special Augmented Hospital No. 7, Okinawa, Ryukyu Islands	----
Special Augmented Hospital No. 8, Okinawa, Ryukyu Islands	----
Convalescent hospitals:	
U.S. Naval Special Hospital, Asbury Park, N.J.	551
U.S. Naval Special Hospital, Palm Beach, Fla.	1,540
U.S. Naval Special Hospital, Camp White, Oreg.	----
U.S. Naval Special Hospital, Camp Wallace, Tex.	----

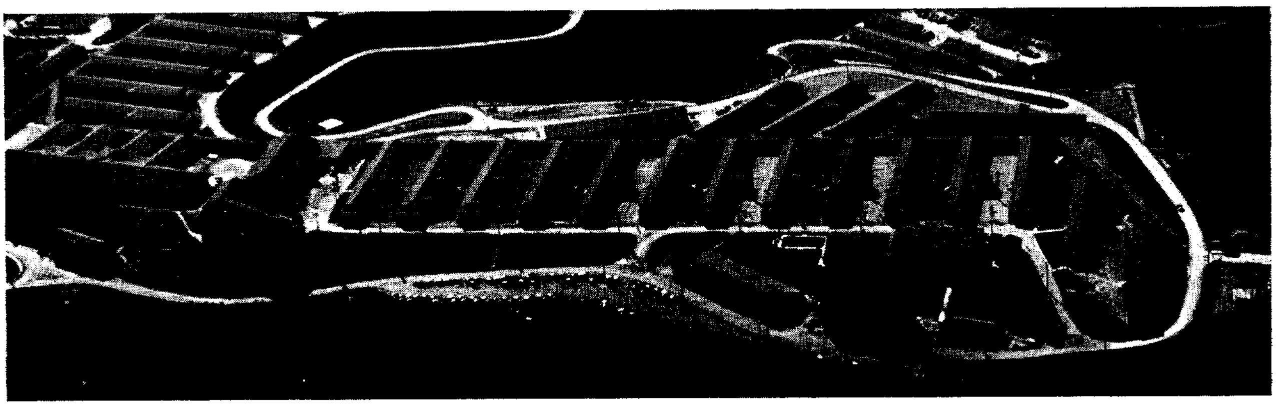

FIGURE 49.—U. S. Naval Hospital, San Leandro, Calif.

FIGURE 50.—U. S. Naval Hospital, Fort Eustice, Va.

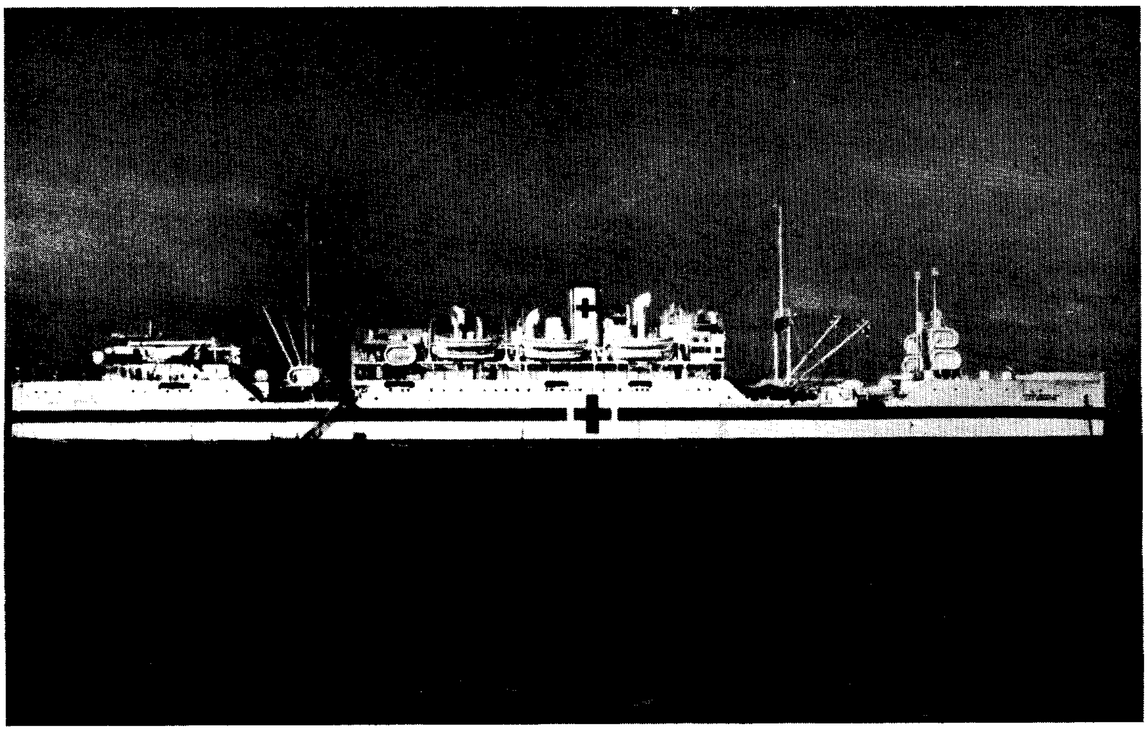

FIGURE 51.—U.S.S. *Samaritan*

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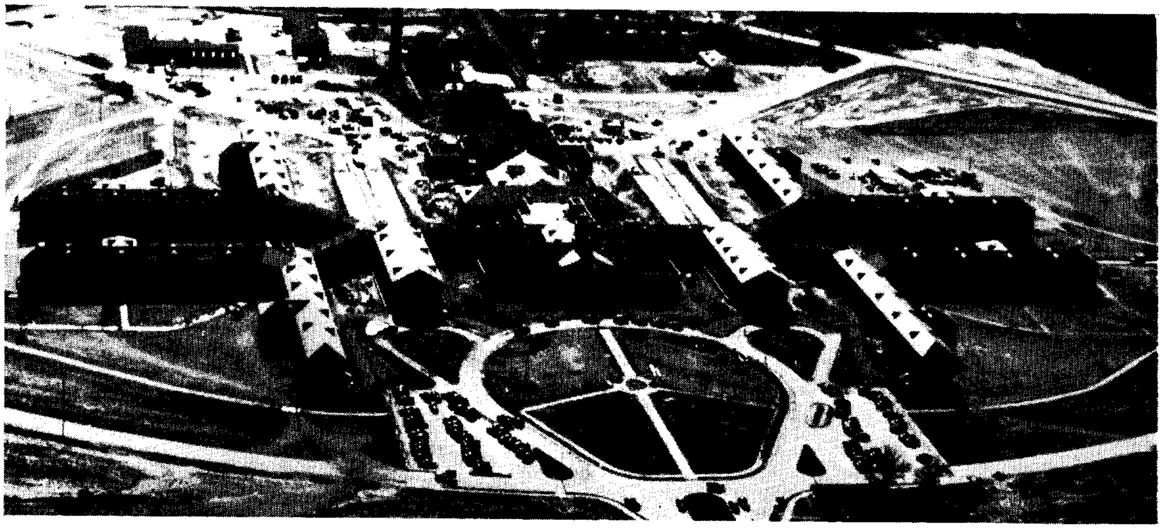

FIGURE 52.—U. S. Naval Hospital, Dublin, Ga.

FIGURE 53.—U. S. Naval Hospital, Corvallis, Oreg.

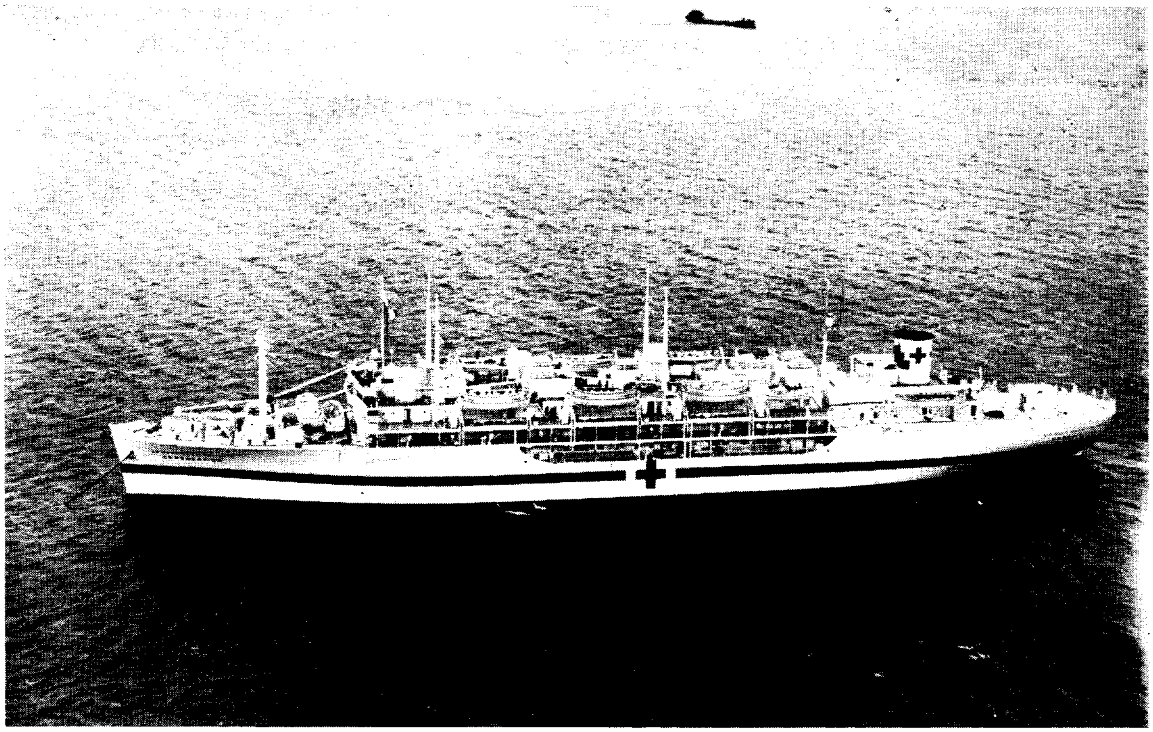

FIGURE 54.—U.S.S. *Consolation.*

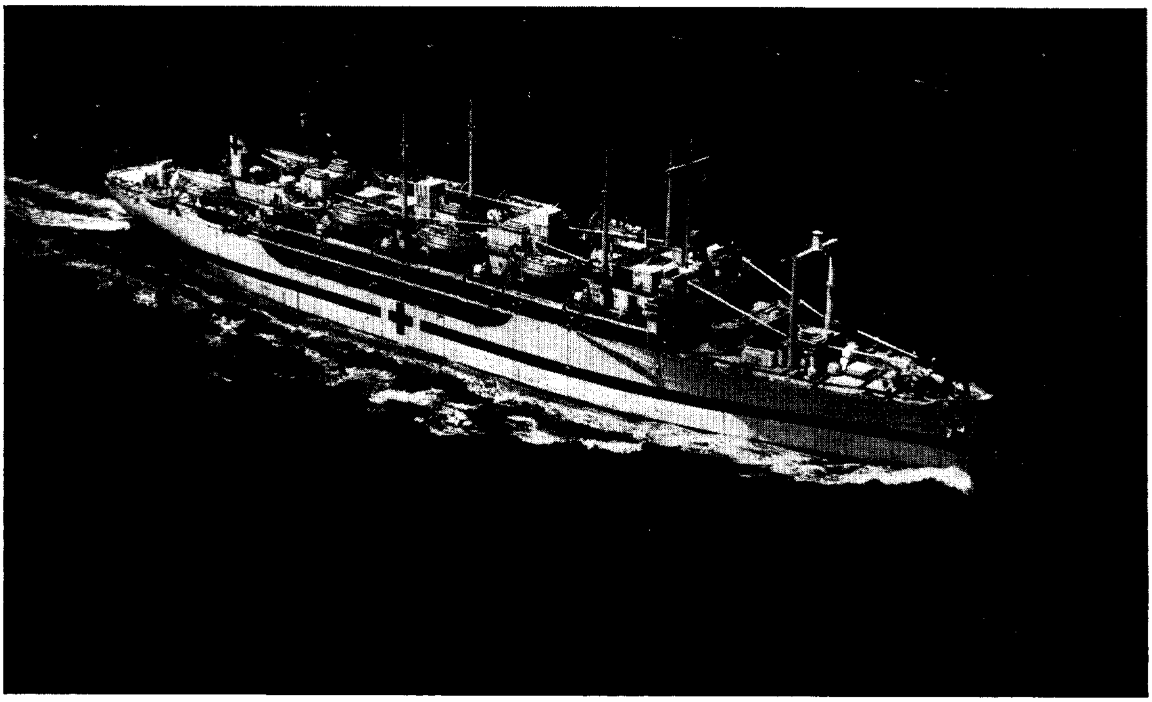

FIGURE 55.—U.S.S. *Haven.*

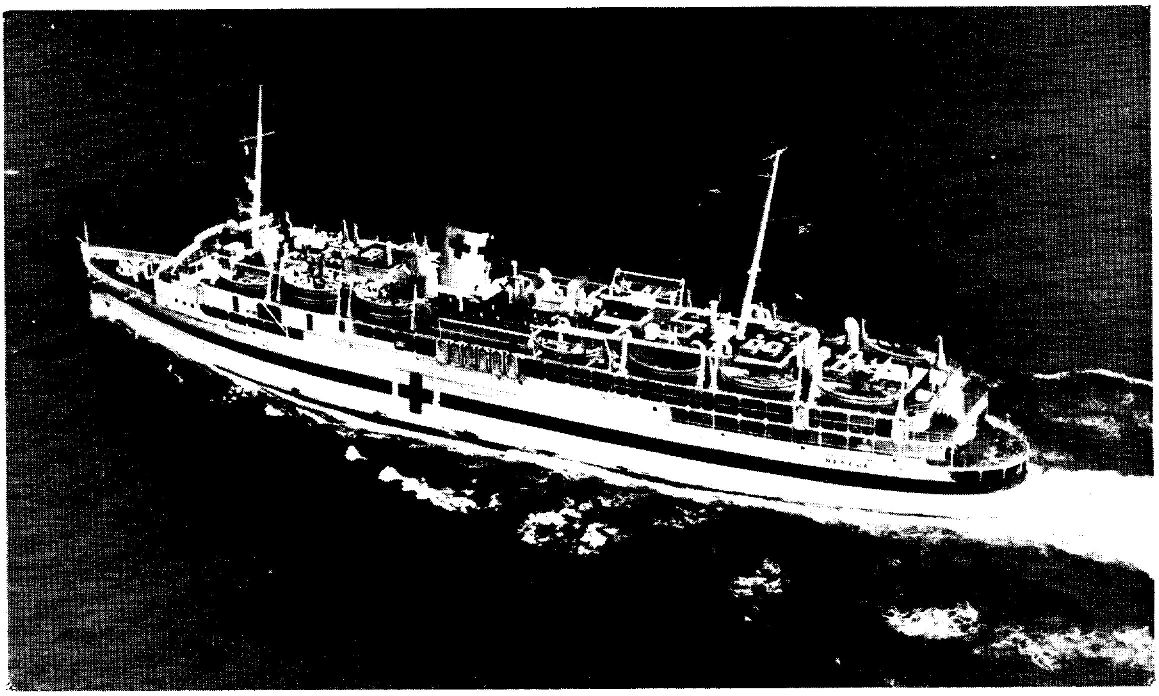

FIGURE 56.—U.S.S. *Rescue.*

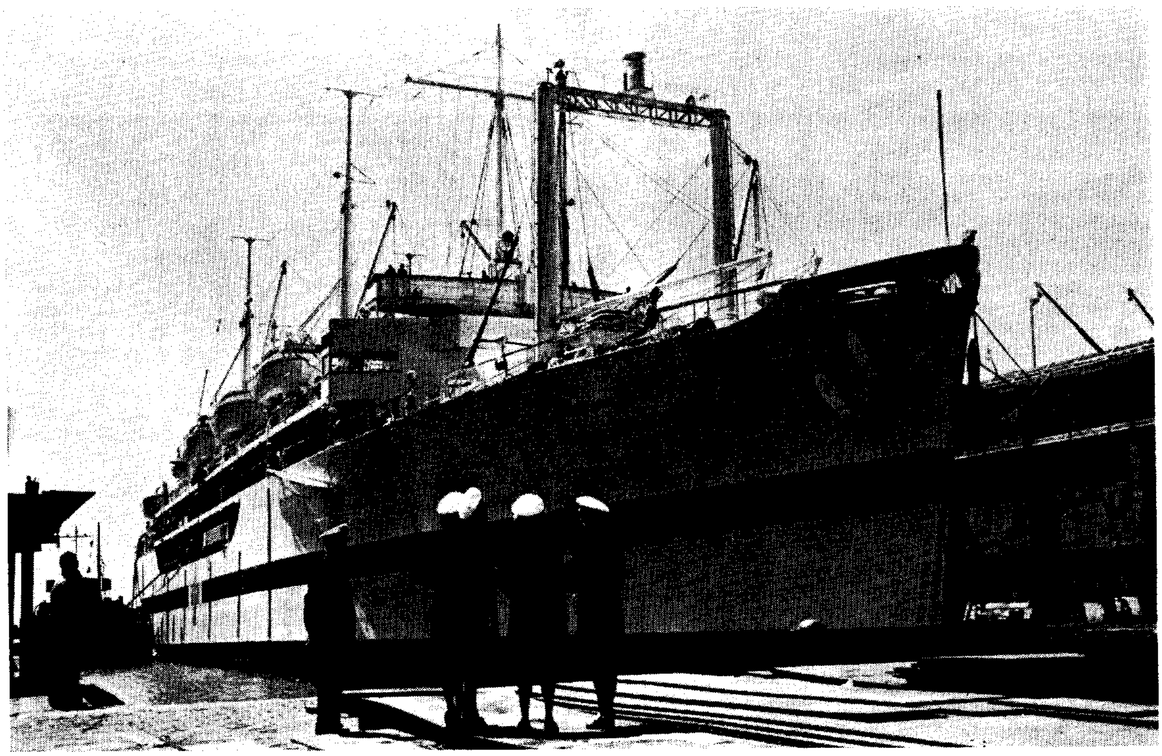

FIGURE 57.—U.S.S. *Tranquillity.* The first of six 15,000-ton hospital ships of the *Haven* class to be converted from a Maritime Commission C–4 hull. These vessels were completely air conditioned and the medical facilities were equal to those of a large modern hospital.

At the end of the war there were in commission 42 naval hospitals and 12 naval convalescent hospitals in the continental United States. Overseas there were 6 permanent hospitals, 36 mobile, base, or fleet hospitals (figs. 58, 59, 60), 12 hospital ships, 3 hospital transports, and 3 military government hospitals. Logistic support was furnished by 32 medical supply facilities, depots, warehouses, and supply barges (table 8).

TABLE 8.—*Medical supply facilities, all types*

Medical supply depots:
- Brooklyn, N.Y.
- Oakland, Calif.
- Pearl Harbor, T.H.
- Guam, Mariana Islands (Annex at Saipan)

Medical supply storehouses and storage facilities in the United States:
- Newport, R.I.
- Charleston, S.C.
- Seattle, Wash.
- San Pedro, Calif.
- San Diego, Calif.
- Naval Supply Depot, Mechanicsburg, Pa.
- Naval Supply Depot, Spokane, Wash.
- Naval Supply Depot, Clearfield, Utah.

Medical supply storehouses overseas:
- Balboa, C.Z.
- Londonderry, North Ireland
- Exeter, England
- Sydney, Australia
- Auckland, New Zealand
- No. 1, Subic Bay, Philippine Islands
- No. 3, Kodiak, Alaska
- No. 4, Samar, Philippine Islands
- No. 7, San Juan, P.R.
- No. 9, Casablanca, French Morocco
- No. 10, Recife, Brazil
- No. 11, Espiritu Santo, New Hebrides
- No. 13, Saipan, Mariana Islands
- Supply Facility Fleet Hospital 105, New Caledonia

Supply barges:
- U.S.S. *Silica*
- U.S.S. *Lignite*
- U.S.S. *Mare*
- YF 787
- YF 738
- YF 739
- YF 740
- YF 754

DEFICIENCIES IN MOBILE AND BASE HOSPITALS

Mobile and base hospitals successfully treated thousands of patients during the war, but they never attained the degree of mobility desired for combat areas. The deficiencies of the mobile (fleet) and base hospitals in combat areas were noted in the Seventh Fleet report for 1944:

> Although fleet and base hospitals as presently planned are excellent as to comfort for patients and working conditions for Medical Department personnel, they possess distinct disadvantages. They are bulky and require considerable shipping space to transport, time and effort to establish, and even more effort to dismantle, refit, and move forward. In a fast moving type of warfare over the vast distances typified in the operations in the Southwest Pacific, hospitals have not been capable of receiving casualties until the assault beaches moved far ahead. With the consistent shortage of AH's, APH's, and APA's in the Seventh Fleet, it was necessary in many areas to resort to hospitalizing

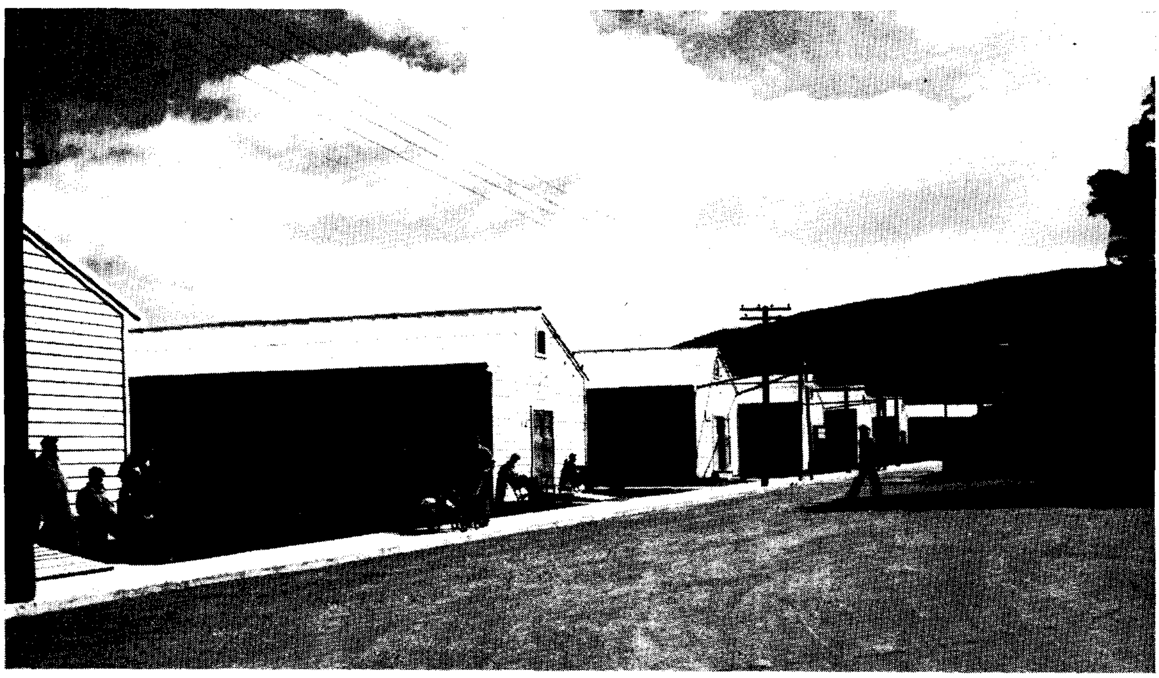

FIGURE 58.—Main ward buildings, Base Hospital No. 4, Wellington, New Zealand.

FIGURE 59.—One of the wards, Base Hospital No. 4.

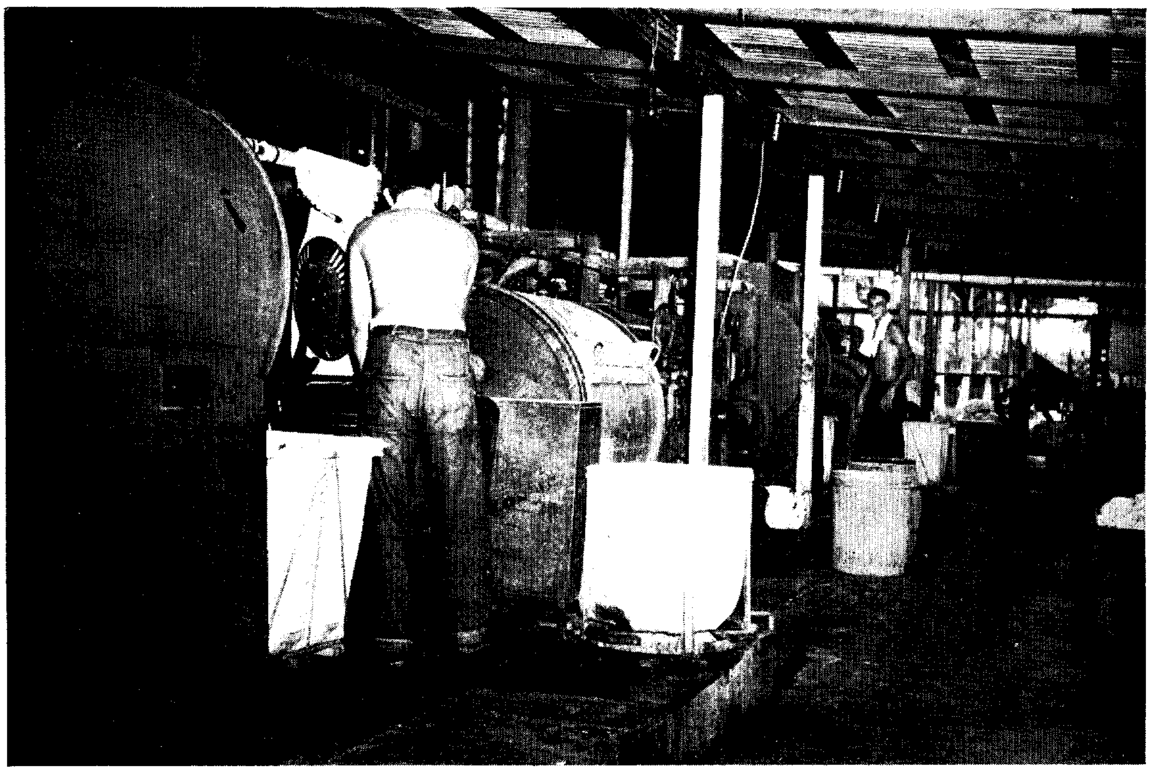

FIGURE 60.—Laundry. Base Hospital No. 6, Espiritu Santo, New Hebrides.

naval patients in Army hospitals. The latter were easily transported and quickly erected, and while they did not afford many of the refinements of the less mobile naval hospitals, they offered excellent early care to casualties at a time when the need was urgent. Canvas-housed, truly mobile hospitals are a paramount need in amphibious warfare, both for Army and Navy support.

Special Augmented Hospitals

In 1945, in the closing months of the war, a new type hospital, the Special Augmented Hospital, was used for the first time on Okinawa. In composition and function it was intermediate between a Marine Corps field hospital and the fleet base hospitals that had been used throughout the war in the Pacific. These special augmented hospitals were designed to bring hospital services and specialized care to personnel in the combat area.

Plans were made by the Bureau of Medicine and Surgery for 8 of these new hospitals. Four were to have a bed capacity of 200 each and 4 to have a bed capacity of 400 each. Of the number planned, 5 left the United States for Okinawa.

Personnel for the special augmented hospitals were assembled at San Bruno, Calif., in the late summer of 1944. There they were given comprehensive physical conditioning which included hiking and camping expeditions under conditions that approximated those in the field of combat. The men lived in tents, ate from mess kits, practiced field sanitation, and were instructed in infiltration tactics, the use of the rifle, tent construction and maintenance, and chemical warfare. Special groups received instruction in tropical diseases at Treasure Island, Calif. General duty corpsmen were given refresher courses and some men were detailed to Navy hospitals for training in the specialties, such as laboratory and x-ray.

Special Augmented Hospital No. 6 was commissioned on 7 March 1945, and 3 days later Special Augmented Hospital Nos. 3, 4, 7, and 8 were commissioned. Special Augmented Hospital No. 6, the first to sail, arrived at Okinawa on 4 May 1945, and received its first patients on 17 June 1945. Special Augmented Hospitals Nos. 4, 7, and 8 arrived on 14 July 1945. Of the five special augmented hospitals to arrive in Okinawa, only Nos. 3 and 6 actually received patients before the surrender of Japan. The others received their first patients in September, and continued to care for them for several months after the war.

Regarding the function of the "Augmented" Hospital, the following comments were made:

> Although the exact place of the augmented hospital was never made clear, nevertheless, certain comments can be made. If it was intended that this type of hospital should be in operation during the active campaign for the island, then its equipment and construction contained too much of a semipermanent or permanent character, so that it could not be erected quickly. On the other hand, if it was intended that this hospital should come into operation after the termination of hostilities, as was the case, then its construction was too temporary in character to afford desired comfort and efficiency.
>
> Not knowing what were the planned expectations for such a hospital, it was difficult to judge its effectiveness. Probably the most effective function of this hospital was the ability to keep beds available for the demand for admissions which was placed upon it; however, because evacuation had to be made so frequently, prolonged treatment, elective surgery, and complete diagnostic procedures had to be curtailed.

Medical Facilities; European, Atlantic, & African Theaters

Two base hospitals were established in the United Kingdom. The 300-bed Naval Base Hospital No. 1 at Londonderry, Ireland, was commissioned in February 1942 and provided hospitalization and outpatient service for personnel of the Allied Services as well as of the U.S. Navy. Naval Base Hospital No. 12 was set up in the Royal Victoria Military Hospital at Netley, Hants, Southampton, which was turned over to the Navy on 28 February 1944.

A fuller account of its development as a 1,000-bed hospital and of its outstanding achievements is given in chapter III.

Naval Base Hospital No. 12 was established primarily for the treatment of casualties during the invasion of Europe. The first D-day casualties were received on 9 June 1944 and in the following 4 months a total of 7,877 patients (including 4,226 war casualties) were admitted. There were only 18 deaths during this period, 11 of these the result of wounds incurred in action against the enemy. The mortality rate of combat casualties was only 0.26 percent.

Prior to the establishment of this hospital, all U.S. Navy patients requiring return from the European area to the United States for further treatment or disposition were evacuated through the U.S. Naval Dispensary at Roseneath, Scotland. Evacuations through the Base Hospital proved more satisfactory because of its proximity to the southern ports where there were fewer travel difficulties. After it was decommissioned on 30 September 1944, U.S. Naval Advanced Amphibious Base, Plymouth, Devon, and U.S. Naval Base No. 2, Roseneath, Scotland, were designated as evacuation centers for the southern and northern areas respectively.

At Camp Knox, Reykjavik area, the headquarters of the Naval Operating Base, Iceland, a dispensary was already functioning in July 1942. It had 21 huts and contained 109 beds. During 1942, approximately 75 percent of the patients were from ships operating in Iceland waters. This dispensary was centrally located, well staffed, and equipped to meet hospital needs of Navy personnel stationed in Iceland or in ships operating in Icelandic waters. Auxiliary dispensaries were established at the Tank Farm and at Falcon Comperea at Hoalford, as well as at the Fleet Air Base, Reykjavik.

Dispensary facilities in the United Kingdom were located at the activities listed in table 9, and other dispensaries were established at Saltash, Appledore, Falmouth, Fowey, Salcombe, Dartmouth, Teignmouth, Penarth and Milford Haven, St. Mawes, Poole, Portland-Weymouth, Southampton, Deptford, Exeter, and Calstock. On 15 June 1944 a dispensary of 50 beds was set up in Blackheath, London, to care for convalescent and overflow patients from the main dispensary and to serve as a dressing station for bomb casualties. During the 5-month period prior to D–day, the number of available beds in England for reception of casualties had reached 3,500.

TABLE 9.—*Dispensaries in the United Kingdom*

	Bed capacity	Date commissioned
USN Base, Roseneath, Scotland	325	Aug. 24, 1942
USNAATB, Appledore, Devon	61	July 29, 1943
USNAATSB, St. Mawes, Cornwall	34	Sept. 7, 1943
USNAAB, Falmouth, Cornwall	220	Oct. 11, 1943
USNAATSB, Fowey, Cornwall	93	Oct. 25, 1943
USNAAB, Plymouth, Devon	500	Nov. 6, 1943
USNAATSB, Salcombe, Devon	117	Nov. 25, 1943
USNAATSB, Teignmouth, Devon	87	Dec. 1, 1943
USNAAB, Dartmouth, Devon	356	Dec. 24, 1943
USNAAB, Milford Haven, Wales	800	Jan. 12, 1944
USNAAMSB, Penarth, Wales	50	Jan. 12, 1944
USNASB, Exeter, Devon	46	Feb. 3, 1944
USNAAMB, Deptford, London	10	Apr. 10, 1944
USNAAB, Portland-Weymouth, Dorset	123	May 1, 1944
USNAAB, Poole, Dorset	24	May 11, 1944
USNAAB, Southampton, Netley, Hants	10	May 11, 1944

The hospital and dispensary facilities established in the European, Atlantic, and North African theaters are shown in figures 61, 62, and 63.

TABLE 10.—*Hospitals and dispensaries in the Atlantic Theater*

	Bed capacity
Canal Zone:	
Balboa:	
Naval hospital	350
Dispensary (naval station)	8
Marine sick bay (annex to naval station)	14
Sick bay, naval ammunition depot	4
Coco Solo:	
Naval hospital	464
Dispensary (naval station)	30
Dispensary (Cristobal Annex to naval station)	4
Dispensary, naval air station	90
Farfan: Sick bay (radio station)	5
Tobago Island: Dispensary (naval station)	20
Galapagos Island: Dispensary (naval base)	15
Puerto Castilla, Honduras: Dispensary (naval base)	14
Corinto, Nicaragua: Dispensary (naval base)	16
Barranquilla: Dispensary (naval base)	4
Netherlands West Indies: Curacao (naval camp)	25
Virgin Islands: St. Thomas naval station	10
Brazil:	
Caravellas, dispensary	10
Maceió, dispensary	11
Rio de Janeiro, Dispensary (naval operating facility)	8
Santa Cruz, Dispensary	15
British West Indies:	
Antigua (N.A.A.F.)	2
Great Exuma (N.A.A.F.)	4
Trinidad:	
Hospital	290
NAS dispensary	66
Cuba:	
Guantanamo Bay:	
Naval station	220
Naval air station	16
Marine Corps Base	8
Puerto Rico:	
Roosevelt Roads (naval station)	7
San Juan:	
Naval hospital	200
Naval air station	39

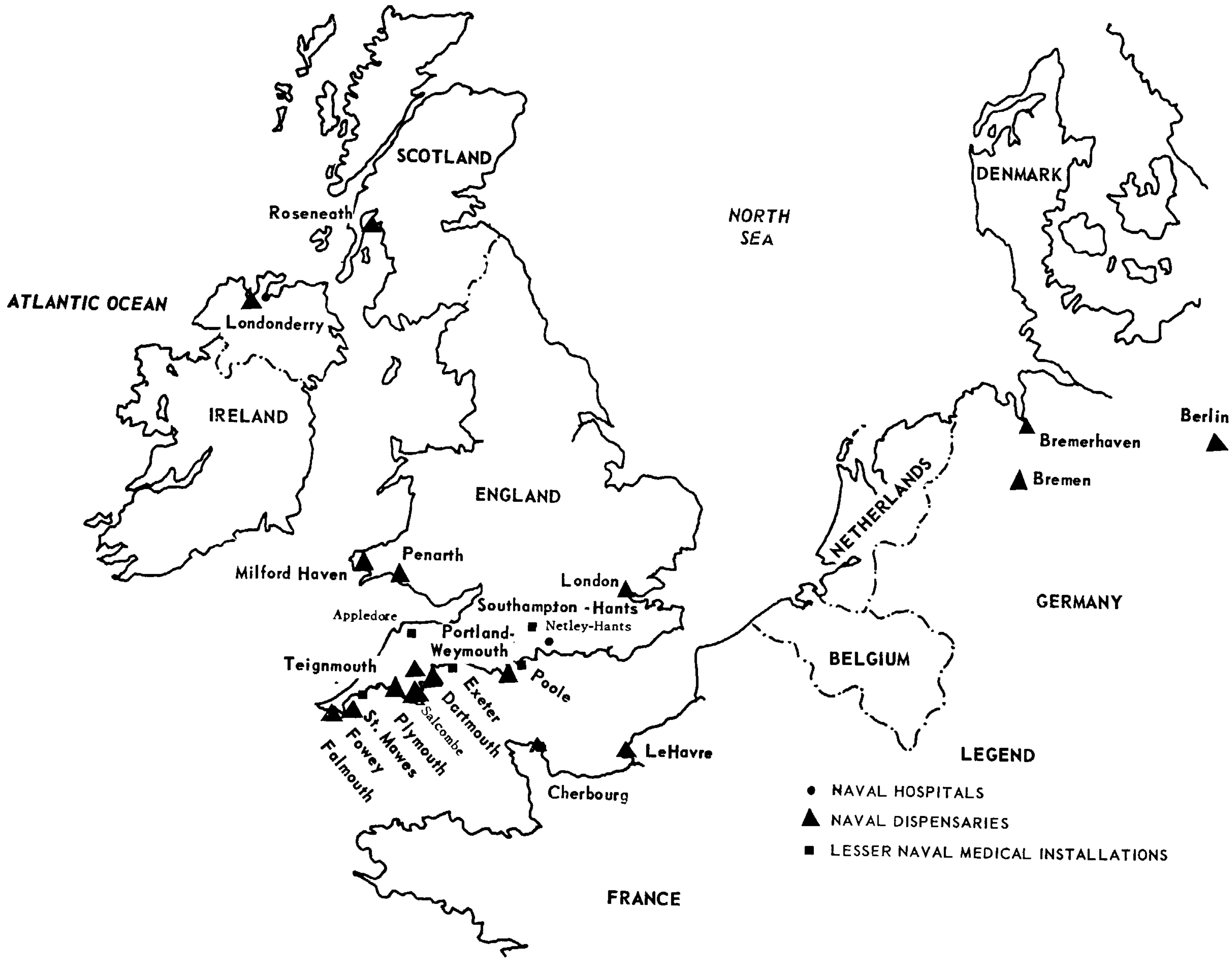

FIGURE 61.—Naval hospitals and dispensaries in the European Theater.

FIGURE 62.—Naval hospitals and dispensaries in the North and South Atlantic Theaters.

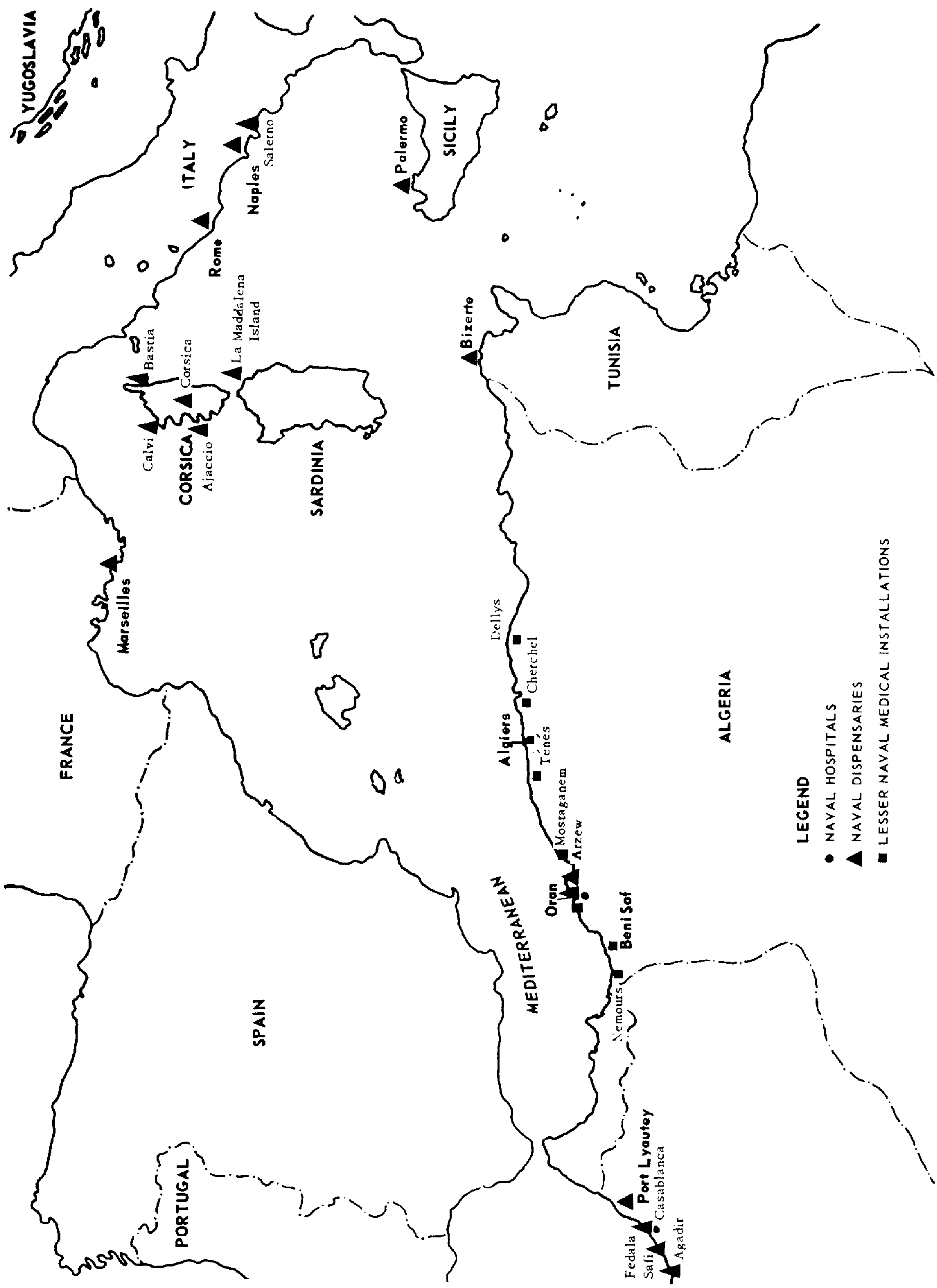

FIGURE 63.—Naval hospitals and dispensaries in North Africa.

As the forces moved into North Africa, dispensaries were established there. Two days after the landing operation had started, on 10 November 1942, naval medical personnel set up a small sickbay in a camel barn on the dock of Fédala. Later, dispensaries were set up at Oran, Port Lyautey, Arzew, Bizerte, and Casablanca. Because of the importance of Casablanca as a port of entry and as an evacuation center, the dispensary there later became U.S. Naval Base Hospital No. 5. Dispensaries were established at Fédala, Safi, and Agadir in French Morocco, and sickbays of varying sizes were set up at Mers-el-Kebir, Algiers, Nemours, Beni Saf, Mostaganem, Ténès, Cherchel, and Dellys in Algeria. By summer of 1943 it was obvious that a naval hospital was required for personnel in the Northwest African waters, and to meet this need U.S. Naval Base Hospital No. 9 was disembarked at Oran on 3 September 1943. With the assistance of construction battalions, this 500-bed, completely equipped hospital was ready to receive patients 2 months after construction began.

In Sicily a 50-bed dispensary was established at Palermo and smaller units were set up on the south coast of the island. In September 1943, all U.S. Navy activities in Sicily were consolidated at the Naval Operating Base, Palermo, where a dispensary of 160 beds was established. Later in 1944, 25-bed dispensaries were established at Calvi, Bastia, Ajaccio, Corsica, and at La Maddalena Island, Sardinia (table 11). The largest and most important dispensary in Italy was at Naples, but Salerno and Rome each had a small dispensary.

Dispensaries were set up on the French invasion beaches, Omaha and Utah, on 12 July 1943. Later, after the ports became available, dispensaries were established at Cherbourg, Le Havre, Chateau de La Prunay, Louvecinnes, and Seine-et-Oise. The most important medical installation in southern France was the dispensary at Marseilles, established after the Normandy invasion. On the heels of the Allied crossing of the Rhine, 50-bed dispensaries were established at Frankfort and Berlin, Germany.

TABLE 11.—*Medical Department facilities in the African Theater, 1 January 1945*

Activity	Bed capacity
Algeria:	
Arzew, Dispensary U. S. Naval Station	98
Oran, Base Hospital No. 9	500
Oran, Dispensary, U. S. Naval Station	44
French Morocco:	
Agadir, Sick Bay, FAW 15, Detachment No. 1	68
Casablanca, Base Hospital No. 5	96
Port Lyautey, Dispensary (NAS)	130
Tunisia: Bizerte Dispensary, AATB	68
Corsica: Dispensary, Ajaccio	25
Sicily:	
Palermo Dispensary, NOB Sick Bay (port area)	155
Dispensary, Palermo	100
Italy:	
Naples Dispensary, USN Detachment	140
Rome, Dispensary (SENALUSLO)	4
Sardinia:	
La Maddalena Is. PT Base No. 12	10
Dispensary, La Maddalena Island	25

Submarine Medicine[4]

Prior to World War II there were about 8 medical officers in the Navy who were qualified in submarine medicine and therefore particularly interested in the sanitary and hygienic aspects and the safety problems of life in a submarine. They had been trained primarily in deep-sea diving and were familiar with the construction and operation of a submarine, the problems of submarine escape and salvage, the use of the rescue "bell" and the submarine escape "lung," and the operation of the training tank. With the advent of war a great many more officers trained in submarine medicine were immediately required and the facilities of both the Deep Sea Diving School, Washington, D.C., and the Submarine Base, New London, Conn., were activated. For the first 2 years of the war these medical officers, like their predecessors, were trained primarily in deep-

[4] Adapted from the BuMed publication "The History of Submarine Medicine in World War II" by Capt. C. W. Shilling (MC) USN and Mrs. J. W. Kohl.

sea diving, and so were not prepared to cope with all the medical aspects of submarine duty. When the inadequacy in training became apparent, the course was lengthened by 3 weeks, and beginning June 1943 the training included "tank instruction and escape, inspection and instruction trips on submarines, dark adaptation instruction, and similar matters," as well as "demonstration of diving equipment, lectures, and demonstrations and . . . . participation in the submarine personnel and sound listening personnel selection system."

A deterrant to efficient submarine medicine in the early part of the war was the necessity of at times assigning to a submarine base, submarine tender, or submarine squadron, a senior medical officer who was not trained or qualified in submarine medicine. In March 1944, when qualification[5] in submarine medicine became a prerequisite for such assignments, a broad program of submarine medicine was activated. Distribution of medical supplies was then reorganized and a careful check was made of the physical condition of submarine personnel before going on patrol or immediately upon return. Pharmacist's mates attached to submarines were indoctrinated in special phases of submarine medicine, a pool of graduates of the "School of Pharmacist's Mates entering the Submarine Service" was established, and a system of refresher training for those in the pool was inaugurated.

When the V-boats were commissioned in 1924, medical department personnel were not assigned to the submarines. With improvement in submarine design, long cruises became routine and there arose the need for Hospital Corps personnel aboard. The assignment of hospital corpsmen was a success, for a good pharmacist's mate proved to be one of the most valuable members of the crew, not only because of his specialized knowledge but also because of his influence on the morale of the crew. How well they performed is a matter of record—the superb manner in which they carried out their assignments during World War II is attested to by the commendations and awards they received.

[5] To give recognition to submarine medicine, those medical officers qualified in submarine medicine were authorized to wear the distinctive insignia in 1943.

Early in the war, Hospital Corps personnel assigned to submarines were obtained from the forces afloat or ashore and were given a course of indoctrination in submarine operation at the Submarine School, New London, Conn., prior to assignment to duty in submarines. As the war progressed it became apparent that not all Hospital Corps personnel assigned to submarines had been adequately trained. In June 1943 a School for Pharmacist's Mates entering Submarine Service was established; there the 6 weeks' course included didactic and practical instruction in first aid and minor surgery, hygiene and sanitation, materia medica, toxicology, anesthesia, laboratory procedures, pharmacy, chemistry, and indoctrination in the environmental factors of life in a submarine. After March 1945 only men who were graduates of the Hospital Corps School were assigned to the "School for Pharmacist's Mates entering the Submarine Service." Graduates of this school were invaluable, for they not only provided care for the sick and injured in a highly efficient manner but also performed general operational duties such as sonar operator, radar operator, lookout, and librarian.

SUBMARINE PATROL EXAMINATIONS

Prepatrol examinations of all personnel were conducted to make certain that no man who was physically or emotionally below par was permitted to go on patrol. Such men were transferred to a rest camp. Elaborate facilities for rest and recreation were established at the Royal Hawaiian Hotel as well as on Midway, Majuro, Guam, Saipan, Manus, and Milne Bay. Immediately after return from patrol another complete physical examination, including roentgenograms of the chest, was done by qualified submarine medical officers. A complete dental examination was also made and the needed dental repairs recorded. Results of both the physical and dental examinations were entered upon cards, which were filed aboard the ship and formed a continuous history of the physical condition of each man. Upon transfer to another submarine force activity, the history card was transferred to the receiving unit. If transferred out of the submarine service, the card was filed at SubBase, Pearl Harbor. The pharmacist's mate in each submarine was required to make appropriate entries on the history card while on patrol. Thus the medical problems and health conditions occurring on patrol were reported to the Force medical officer by recording and forwarding to him a summary of the data on the history cards.

Although the standard Health Record provided a continuous history, it failed to serve the purpose of these cards in that only serious conditions warranting admittance to the sick list were entered in the health record, and at each re-enlistment the history sheets were removed and sent to the Bureau. The cards thus filled a void.

SUBMARINE MEDICAL FACILITIES AND SUPPLIES

Facilities for medical care of submarine personnel during World War II (figs. 64, 65), were similar to those in small craft, but many

FIGURE 64.—Minor surgery aboard a submarine.

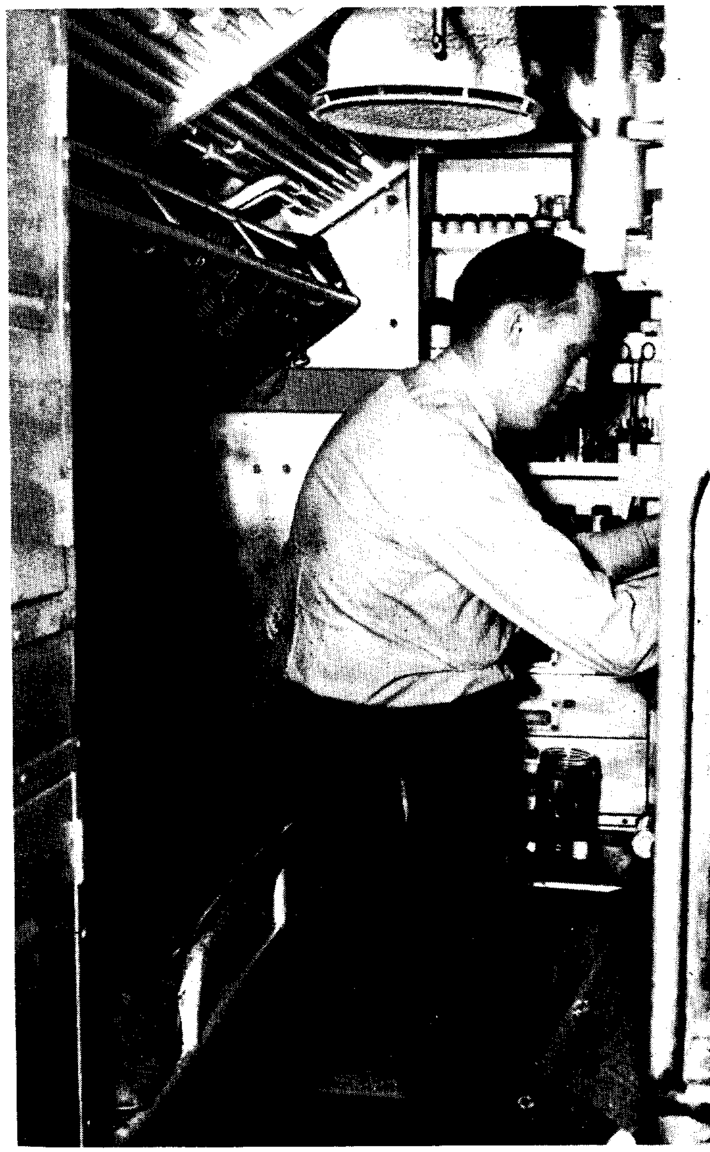

FIGURE 65.—Medical locker in a submarine.

problems of medical supply required solution. As an example there was need for a complete and exhaustive study of the medical supplies and equipment allowance for submarines. Replenishment of supplies for submarines should have been accomplished either from a submarine tender or a submarine base and not from a medical supply depot, because the smallest amount such an activity ordinarily issued was too large for a submarine where storage space was an acute problem. In the newer type submarines, such as the guppy-snorkel, the storage problem was even more critical.

The pharmacist's mate in a submarine needed a handbook which outlined medical and surgical diagnosis and care, and described the pharmacologic action and indication for use of each medical item in stock. The handbook which was available during the war did not in any sense meet the requirements, and it was necessary to mimeograph and distribute to submarine pharmacist's mates all types of instruction for medical care as the occasion arose.

AIR-SEA RESCUE OPERATIONS

Submarines rescued 549 survivors, in air-sea rescue operations. The part played by the pharmacist's mates in this undertaking was very important, for 48 percent of the rescued aviators required medical care because of serious injury. The following excerpts from patrol reports indicate how well the pharmacist's mate cared for his patients:

One man received a severe laceration of the forearm which required seven stitches. Two men were injured by misfire of the 20-mm. gun; in one it was deemed necessary to amputate two toes of the right foot. Due to a shortage of surgical instruments, a pair of sterilized side cutters were used to cut portions of the shattered bone. Because the "phalanges—were completely shattered, they were not sutured but left open to allow free drainage. A generous amount of sulfanilamide powder was used. The other man was wounded in the shoulder but no lead or foreign body could be located. This man was back to duty in three days.

The medical department, in the person of the Chief Pharmacist's Mate, did a particularly capable job in handling the Jap prisoner of war recovered after his plane was shot down. Though suffering from shock, second degree burns of the face and hands, and several other serious wounds from gunshot and the crash, he was brought around very well and will probably recover.

An injured German prisoner was treated for a dislocated left knee, broken right collar bone, badly lacerated mouth and nose, and three missing teeth. Recovery was satisfactory except that he succeeded in misaligning his clavicle after it was lined up properly.

The price of sinking one sampan, damaging one, and learning the use they are put to (as submarine traps) was three men wounded. One man received two .25 caliber hits in the left side, one bullet ranging upward, fracturing the rib and puncturing the left lung, the other bullet lodging in the diaphragm. A second man received five hits in the right shoulder; the third was struck in the right hip by a piece of flying metal. In view of the nature of the wounds, left the area 24 hours early, setting course for Midway at best speed. The Chief Pharmacist's Mate............ is particularly commended for his quick and efficient action in caring for these three wounded shipmates. By his proficient skill and painstaking efforts he prevented complications and enabled return of his patients to the facilities of a hospital, well on the road to recovery. He has been recommended for promotion and the Bronze Star Medal.

One man suffered a compound fracture of his right ring finger and a simple fracture of his index finger when a storeroom hatch cover fell on his fingers. The boat was dived to a hundred feet to furnish a stable platform for sewing up the fingers and setting the bones. While the finger tips are still stiff one month after the accident, they are healed nicely and PhM1c............ is to be commended for his efficiency and skill.

The ...., on her second patrol, established an all time record for the recovery of friendly aviators, when in five rescues she picked up a total of 30 men. The first man, recovered on 25 May 1945, had severe lacerations and second degree burns. Five days later 5 more men were recovered, all in good condition, 18 minutes after their plane had crashed. On 29 May, 16 men were rescued, 2 of whom were seriously injured; 1 had severe head and body injuries, the second had a possible fracture of the back and skull. One man of this group died.

SURGICAL CARE ON WARTIME OPERATING SUBMARINES

Injuries aboard combat submarines were commonly sustained by personnel on the bridge, particularly during the lightninglike maneuvers necessary to clear the bridge in the relatively few seconds that elapsed between the time the diving signal was given and the submarine submerged. Crushed fingers, broken ribs, dislocations, bruished shoulders, and lacerations of various degrees resulted from the sudden exodus of men from the bridge through a

24-inch hatch and down the slippery and precipitous ladder into the conning tower.

APPENDICITIS ABOARD COMBAT SUBMARINES

Probably no other single disease caused more anxiety to submarine personnel than appendicitis. Because medical officers were not carried on submarines, it became important to formulate and promulgate a policy governing the treatment of appendicitis. All pharmacist's mates in the submarine service and those in the "School for Pharmacist's Mates entering Submarine Service" were impressed with the fact that in untrained hands the diagnosis of appendicitis is difficult and that gastrointestinal disturbances and constipation which are common in personnel in submarines add to the difficuly in diagnosis. The order, "Never resort to surgery," and "Never give a cathartic to a patient suspected of having appendicitis," was put into effect toward the end of the first year of the war, and a conservative method of treatment was outlined.

INCIDENCE AND MORTALITY RATES OF APPENDICITIS

The diagnosis of acute appendicitis was made 78 times in 1943 (8.9 cases per thousand) and 124 times in 1944 (9.2 cases per thousand), in personnel attached to submarines. Pharmacist's mates made the diagnosis of appendicitis (acute, chronic, or diagnosis undetermined and admitted for observation) on 116 war patrols in 127 instances during the entire war. On 8 patrols more than 1 man was admitted with this condition. In 16 instances one case of appendicitis was reported from the same submarine on 2 successive patrols, presumably by the same pharmacist's mate. In 34 instances the patient was sufficiently ill to warrant transfer for treatment. Twelve men in whom the diagnosis of appendicitis was made during the patrol are known to have had surgical treatment upon arrival in port.

Throughout the war in the submarine force, not one death from appendicitis was reported. Commanding officers were so impressed with the performance of pharmacist's mates in handling these emergencies that in 22 instances they were especially commended.

APPENDECTOMIES PERFORMED ABOARD SUBMARINES ON WAR PATROLS

Regardless of the order not to perform appendectomy on personnel in submarines this operation was found necessary on several occasions. An appendectomy was done by a pharmacist's mate aboard the U.S.S. *Seadragon,* on 11 September 1942. Subsequent to the operation, which lasted about 3 hours, the patient was ill for 14 days. Higher authority observed in connection with this operation:

> The incident . . . is believed to be the first of its kind in submarine history. While this case had a happy ending, it is pointed out that this particular pharmacist's mate had had considerable experience in assisting at surgical operations . . . it is hoped that his success will not encourage others to take . . . risks.

In another instance, on board the U.S.S. *Grayback,* in December 1942, the patient had been ill for about 48 hours before he was operated on. At the operation, which lasted about 1½ hours, the appendix was found to be ruptured. Sulfanilamide powder was instilled, drainage was instituted (an elastic rubber band), and the abdomen was closed. Ether, administered by a submarine escape lung mouthpiece, was used as an anesthetic. Spoons were flattened for use as retractors, and long nose pliers from the engine room were also employed. The first assistant was a motor machinist's mate, first class.

In the third instance an operation for appendicitis was performed aboard the U.S.S. *Silversides* on 22 December 1942. The patient had been ill for about 12 hours prior to the operation, which was performed on the wardroom table, with the submarine submerged at 100 feet. The effectiveness of the spinal anesthesia having worn off, "Ether was administered, following the directions on the can. This anesthetized the operating staff as well as the patient. One hour after completion (the operation lasted about 4 hours) we tangled with a destroyer. The patient was convalescing the following morning to the tune of torpedo firing, two depth charge attacks, two 'crash dives' and an aerial bombing which knocked him out of his bunk. The conduct of the patient . . . was exemplary throughout the operation and the period following."

Comments made by the commanding officer of one submarine concerning the operation performed aboard his ship are pertinent.

> It is recommended that all men who have a history or indications of chronic appendicitis not be sent out on patrol until their appendix has been removed. This also applies to any other ailment which may require an emergency operation at some future date.

DISEASES OF PERSONNEL IN SUBMARINES

No health problems entirely peculiar to the submarine service existed. As in all other branches of the military forces, the most common ailments were acute infections of the upper respiratory tract, injuries, and diseases of the gastrointestinal system.

INFECTIONS OF THE RESPIRATORY TRACT

A high incidence of "colds" was commonly experienced during the first 3 weeks of a cruise, even in tropical waters. Protective clothing was inadequate for patrols in northern operational areas, particularly in the winter when the interior of the ship was cold and damp, and "colds" commonly occurred during the passage from warm to cool operational areas. The most practical prophylaxis was afforded by optimal atmospheric and living conditions while on patrol and carefully supervised recuperation at rest centers. The effectiveness of germicidal lamps aboard submarines warranted investigation. A battery of such lamps was installed in one submarine, but the ship's loss prevented adequate evaluation.

Acute upper respiratory diseases such as catarrhal fever, sore throat, and tonsillitis were reported on over 400 patrols. On 211 patrols they accounted for 1,068 man-days lost. Upon occasion the incidence of these diseases aboard submarines on war patrols assumed such proportions as to interfere with the operation of the ship. At times as many as 70 percent of the crew were affected.

TUBERCULOSIS

Prolonged residence in submarines where sunlight was absent and outside ventilation was limited to parts of each day was considered conducive to activation of quiescent tuberculosis and to droplet spread of the disease. Roentgenograms of the chests of submarine personnel were therefore taken periodically. It was found, however, that the incidence of tuberculosis in submarine crews, ranging from 0.41 to 0.43 percent, was the same as that in the crews of surface craft, but was higher than the 0.32 percent incidence in the fleet as a whole.

GASTROINTESTINAL DISEASES

Diseases of the digestive system accounted for 24.1 admissions per thousand. The four most common conditions noted on war patrols were acute gastroenteritis, chronic constipation, acute appendicitis, and "diagnosis undetermined (abdominal pain)."

"Food poisoning" was reported on only 34 patrols. In nine cases, the food was definitely incriminated; the offending agents included canned orange juice, canned sardines, custard pie, beef, surveyed "Avoset" (stabilized cream), chicken, tinned ham, and tinned salmon.

Food poisoning aboard an operating submarine, by incapacitating the crew, could cripple the striking force of a ship. As an example, a submarine sighted an enemy carrier on 10 July and the following comment concerning the attack was made:

> Loss of depth on the one attack made was most unfortunate in that it prevented firing at carrier. The order to make ready the tubes was given rather late; this was combined with personnel errors in hurriedly preparing all tubes. At this time nearly all of the crew were handicapped by sickness from the food poisoning.

Constipation was an occupational condition among submarine personnel. It was most common in the first 2 weeks of a cruise. One pharmacist's mate during a 56-day patrol with a crew of approximately 75 men dispensed 3 quarts of mineral oil, 1 pint of castor oil, 2 pounds of Seidlitz powder, 3 bottles of cascara sagrada, and 20 soap suds enemas.

UROGENITAL DISEASE

The incidence of urogenital disease in submarine personnel on war patrols is presented in table 12.

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TABLE 12.—*Diseases of the urogenital system in submarine personnel on war patrol*

Diseases	Number patrols reporting	Number cases reported	Number sick days reported
Gonorrhea, urethra, acute	37	109	45
Urethritis acute, nonvenereal	33	67	26
Gonorrhea, urethra (diagnosis undetermined)	25	56	31
Prostatitis, unclassified	8	24	6
Penile lesions (diagnosis undetermined)	18	20	28
Syphilis	11	16	52
Renal disease (diagnosis undetermined)	10	15	22
Calculus, urinary system	12	13	35
Epididymitis, acute and orchitis, acute	10	11	25
Cystitis, acute	5	5	29
Balanoposthitis	1	1	0
Total	170	337	299

One man informed the pharmacist's mate that he had concealed venereal disease for a period of at least 6 weeks, including the period of the last refit. Examination disclosed the presence of multiple penile and perineal lesions, which proved to be syphilitic. Kahn tests of the rest of the crew were negative, however.

SKIN DISEASES

Most fleet-type submarines were equipped with two, 4-ton air-conditioning units installed in the ventilation supply lines. These were later supplemented by additional cooling and blower units. Without air conditioning and adequate ventilation, the habitability of a submarine on patrol would become so poor that skin diseases as well as lack of personnel endurance and efficiency would appear, and the safety and ability of the submarine to carry out her mission would be seriously compromised. The following excerpts from reports of war patrols describe the conditions encountered:

"Due to faulty air-conditioning units the boat was oppressively hot and humid . . . After 2 weeks of all-day submergence all the bunks were wet and sticky. Clothing in lockers . . . was green with mildew. Temperature of well over 100° F. and high humidity levels made it practically impossible to get any rest while submerged. There were two cases of heat exhaustion. The entire crew had prickly heat—in some it covered the entire body. Thirty percent . . . had some type of fungus infection." Following repair of the air-conditioning system, the commanding officer commented: "At last we have found out that submerged time need not be a taste of hell—this is the first patrol that this boat has been anywhere near livable. General improvement in the condition of personnel and reduction of heat rash and skin diseases was quite noticeable in comparison with previous patrols."

On another ship when the air conditioning failed "90 percent of the officers and men had 'prickly heat,' 68 percent had 'Guam blisters,' 20 percent had boils, and 12 percent had fungus infections of the ears."

DISEASE AND INJURY

The health of submarine personnel was generally very good, comparing favorably with that of destroyer personnel (table 13).

TABLE 13.—*Incidence per thousand of disease or injury of submarine personnel (1944)*

Class	Submarines	Destroyers
Injuries [1]	39.9	39.6
Communicable diseases transmissible by oral and nasal discharges	33.9	40.8
Venereal diseases	24.1	23.4
Other diseases of infectious type	16.9	22.1

[1] Exclusive of combat injuries.

Serious illness or epidemic disease required the interruption of only 29 out of 1,471 patrols. The illnesses interfering with these patrols are listed in table 14.

TABLE 14.—*Diseases limiting duration of submarine patrols*

Condition	Number of patrols
Excessive personnel fatigue	9
Illness of commanding officers	6
Acute appendicitis	2
Battle casualties	5
Multiple asphyxiations	1
Serious injury	1
Pneumonia	1
Mumps	1
Mental disease	1
Copper sulfate poisoning	1
Diagnosis unknown (fever)	1
Total	29

HABITABILITY OF SUBMARINES

The factors affecting submarine habitability included:

1. The efficiency of ventilating and air-conditioning apparatus.

2. Carbon dioxide accumulation, depletion of oxygen, and increased pressure and humidity.
3. Hot weather.
4. Overcrowding.
5. Deficiencies of the water supply and of sanitary tanks.
6. Fires.
7. Noxious agents such as chlorine gas and carbon tetrachloride.
8. Material damage incident to depth charging and accidental flooding.

Improvement in habitability of submarines took place as the war progressed. As noted in table 15, the percentage of "excellent" reports was doubled after 1942 and the percentage of "poor" reports was reduced to one-third in the last 3 years of the war.

TABLE 15.—*Habitability reports of fleet-type submarines*

	1941		1942		1943		1944		1945		Total	
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Excellent	0	0	8	8	24	16.5	41	14.1	33	16.5	106	14.2
Good	5	50	34	34	82	55.7	170	58.9	117	58.5	408	54.6
Fair	3	30	33	33	36	24.4	55	19.0	44	22.0	171	23.0
Poor	2	20	25	25	5	3.4	23	8.0	6	3.0	61	8.2
Total	10	100	100	100	147	100	289	100	200	100	746	100

Eight patrols were terminated because of environmental deficiencies, the nature of which included:

Number of submarines	Year	Factor limiting endurance
1	1942	Lack of air conditioning.
4	1942–44	Limitation of potable water capacity.
1	1942	Serious battery fire.
1	1942	Serious control room fire.
1	1944	Excessive copper-salt content of drinking water.

The relationship between the reports of "poor" habitability and the success of operation was not explicit. In 63 submarines experiencing "poor" habitability during patrol, 39 were successful. The majority of unsuccessful patrols were made in the early years of the war.

Ventilation and air conditioning were the subjects of critical comment in over 400 instances. Unequal distribution of air between the forward and after compartments of the ship and inadequate cooling capacity of the air-conditioning units were the most common defects. Other criticisms concerned material defects of the air-conditioning apparatus involving the hazards of outboard ventilation in heavy weather.

Poor living conditions often prevailed in cold-water operations. Metal fittings throughout the ship sweated constantly. Heaters had to be used sparingly in order to conserve the batteries. With sea water at temperatures of 27° F., single-hull portions of a ship were impossible to heat. There was ice constantly in the torpedo room bilges, and pipes containing water, such as shower drains, were frozen solid.

The P——— on her fifth patrol recounted an experience sometimes encountered on northern operations: "The first dive made . . . lasted longer than expected with no carbon dioxide absorbent spread. At the end of 14 hours all hands had difficulty in breathing, carbon dioxide concentration at the time being 2.5 percent. Eight hundred pounds of oxygen were bled into the boat with slight relief. Upon surfacing 2 hours later the concentration in the conning tower was 3.5 percent."

On the fourth patrol of the N——— (1943): "Air-conditioning installations proved inadequate. The highest temperature and humidity level recorded was 124° F. and 98 percent during a period lasting about 13 hours. . . . Excessive heat and humidity reduced the efficiency of all hands to a marked degree after about 2 weeks of operation."

EXCESS CARBON DIOXIDE, OXYGEN DEPLETION

Limiting values of oxygen and carbon dioxide, after submerging, were theoretically not attained until the expiration of a period of hours calculated from a formula which, although adjustable, was derived on the basis of peacetime complements and operating conditions. Adequate instruments to measure the amount of carbon dioxide and oxygen were not available and therefore the need for air purification was based on subjective evidence such as headache or dyspnea. When needed, varying amounts of carbon dioxide absorbent, which is caustic and irritative, was spread and the air was further revitalized by releasing oxygen or compressed air into the ship.

On several patrols excessive levels of carbon dioxide seriously affected personnel efficiency. The following comments were made:

> The formula used for calculating the time-limiting values of carbon dioxide and oxygen was not always applicable during wartime operations; the time at which symptoms of intolerance became evident did not necessarily follow the calculated time. In 22 out of 26 reports, the time when the air became vitiated was from 1 to 6 hours less than the calculated figure. Half of the reports came from patrols made in Northern areas where, because of weather conditions and the long hours of daylight, prolonged submerged operations were common. Moreover, the ships were cold and damp, requiring exertion on the part of each man to keep warm. These factors and the increased complement made it necessary to revitalize the atmosphere frequently.

Air purification was a matter of particular concern aboard submarines used as troop transports. "On the fifth patrol of the N———, when 109 Army Scouts (in addition to the crew of 96) were transported in the Aleutian area, high levels of carbon dioxide were experienced. This was particularly true when the Scouts were making ready to disembark. On the day when preparations were made to land the level was 4 percent."

SANITARY TANK-HEAD SYSTEM

Sewage from the heads, washrooms, and galley was collected in sanitary tanks. Military security prevented emptying the tanks except upon surfacing and under cover of darkness. They could be flushed with sea water only with difficulty, and during a long patrol, despite frequent emptying and the use of various disinfectants, the tanks became mephitic.

TOXIC GASES

Toxic gases were occasionally encountered in submarines. Carbon tetrachloride, when used as a cleaning agent, produced disabling physical effects and its use was abolished. Although chlorine gas formation was common, especially after flooding of the battery compartments, only two instances of serious effects from chlorine were reported.

WATER SUPPLY

In the early days of the war, the limited supply of fresh water was at times the cause for great concern and was a factor limiting the duration of patrols. Later, evaporating units capable of producing an adequate supply of fresh water were installed. Condensate water from the air-conditioning apparatus was collected and used for bathing, in washing machines, and for cleaning purposes. Impairment of potability of fresh water sometimes occurred. On a number of patrols contamination with copper sulfate took place; in one submarine the level was sufficient to endanger health of personnel and the patrol was terminated.

FOOD

Submarines had the deserved reputation of serving the best food in the Navy, but the supply of fresh meat, vegetables, and frozen foods was usually exhausted before the patrol was concluded. Occasionally, there occurred deficiencies in the quantity and variety of food because of unusually long patrols, inexperience in loading, poor quality of food, refrigeration failure, or accidental flooding of supplies. Considerable difficulty was sometimes experienced, especially at advanced bases, in the procurement of some types of food.

Typical comments in patrol reports were:

> Food was lacking in variety—a deficiency which probably may be traced to the inexperience of commissary department personnel.
>
> Inexperience in planning and procurement for such a long patrol made the diet unsatisfactory.
>
> Quality of the food was good, but ran out of several items because of carelessness in loading.

About 85 patrol reports mentioned having used vitamins, particularly for the lookouts. That the vitamins in submarine rations were ample was evidenced by the fact that only on two patrols. and then under the most unusual circumstances in the earliest months of the war, was there any evidence of avitamosis in the personnel.

One submarine, early in the war, reported that an average of 1.5 pounds of meat per man per day had been consumed. Total food consumed averaged 5.6 pounds per man per day on one 47-day patrol, 31 days of which were spent submerged. One commanding officer was of the opinion that serving a light lunch at noon "curbed the tendency to overeat from boredom, with a benficial effect on the crew." Aboard another submarine, "food consumption was observed to fall off noticeably, the decline being most noticeable during the fourth week." Others reported that the men lost their appetite after prolonged periods of silent running and depth charging. Two commanding officers reported an increase in food consumption during patrols in cold weather and a third reported that cold weather operations tripled the consumption of coffee. Cooks observed difficulty in baking under conditions of increased humidity within the ship, and more than one cook on a war patrol complained bitterly of the collapse of his cakes during depth charge attacks. Two commanding officers encouraged the crew to chew gum; one of these was convinced that it accounted for a "noticeable reduction in the number of gastrointestinal complaints usually observed during the course of a long patrol."

The rations provided submarines in World War II succeeded in meeting the requirements of limited bulk, keeping qualities, and ease of preparation. They provided a well-balanced diet, a maximum of food value, and a minimum of waste, but a master ration plan for the submarine service, flexible enough to allow for satisfying individual preferences, might with advantage have been prepared by Submarine Squadron Medical Officers. In addition, thorough training of the entire commissary team (commissary officer, commissary steward, cooks, bakers, and supply officer) would have eliminated some of the problems related to the submarine ration.

The one single item of food most often unfavorably commented on by commanding officers of submarines was the large amount of boned beef issued. Other comments related to:

1. The importance of ice cream in providing variety in the diet as well as nourishment. Ice cream rated high as a morale builder.
2. The necessity of giving submarines a high priority in obtaining supplies of frozen fruits and vegetables.
3. The importance of foods such as "Avoset," canned luncheon meats, sea food, "Nescafe," and jams,, particularly when available in small pack size in providing variety and enlivening what otherwise would have been a monotonous diet.

OVERCROWDING

Bunking facilities aboard submarines were designed for peacetime complements. With increased complements and the addition of new apparatus, space became more and more critical, and at times serious crowding was experienced. Adequate provisions for bunking and personal needs could not be made, but overcrowding produced no lasting effect on personnel efficiency.

PROTECTIVE CLOTHING

To maintain a reasonably long and alert watch in the most severe weather, bridge personnel must remain comfortable, warm, and dry. On cold-water operations the available items of protective clothing were often woefully inadequate.

LENGTH OF OPERATIONS

Early in the war little was known regarding the length of time the personnel could endure the physical and psychologic discomforts in submarines on war patrols. Experience modified some of the earlier ideas. Submarines frequently remained on station for from 40 to 50 days, but this reduced the efficiency of the men and they were no longer on their toes.

A patrol carried out in good weather with plenty of targets, with good fire control, and without being subjected to depth charges, could last much longer than one in which these features were absent. The monotony of a submerged patrol without contacts was very fatiguing unless some change of pace or diversion was introduced. If lulls in activity occurred, material reduction in efficiency would occur or fatigue become apparent. Although under such conditions aggressiveness and desire to close with the enemy had not slackened, the keen fighting edge of the crew was definitely impaired.

A high state of interest and aggressiveness was essential to the success of operating submarines and was closely related to personnel endurance and morale. The greatest single factor contributing to high morale was successful engagement with the enemy for then they ceased to be a "detail" and were instead a fighting unit. There was nothing quite so depressing to the crew of a submarine with a long record of success as a "zero run." As the war progressed and targets became less common, the "lethargy of long . . . days, rough sleepless nights, and limited exercise had to be mitigated by a clear portrayal of the part submariners were playing in the over-all strategical and tactical plans."

There were many comforts that were essential to maintaining morale. These included good food, mail, movies, books, magazines, phonograph records, adequate quantities of fresh water, mascots, church services, favorable publicity and the possibility of a period of "Stateside" duty. The great importance of adequate and comfortable facilities to permit rest and recuperation for the crew at the end of patrols contributed greatly to the sustained pattern of success that characterized submarine warfare in World War II.

PSYCHIATRIC CASUALTIES IN SUBMARINE WARFARE

Submarines made approximately 1,520 war patrols. Of these, the missions in 1,042 were "successful" and in 478 "unsuccessful." From these patrols 1,489 reports were available for study and the following conclusions were made: The psychic trauma sometimes experienced by personnel in the submarine service was as great, if not greater, than that experienced by any other group in the war. Being hunted, under forced inactivity in an environment of heat and high humidity (during the time when it was necessary to turn off all air conditioning and ventilation systems) were factors in emotional trauma. To this was added the strain of reconnaissance operations, mine laying, and days of patroling without enemy contacts. The caliber of leadership of the commanding officers was very high. There were only three instances in which the men lost confidence in the commanding officers, or the commanding officer lost confidence in himself, or his ship.

The following excerpts highlight some of the factors in emotional trauma:

> A terrific explosion jarred the boat. All hands not holding on to something were knocked from their feet. At 330 feet, fire in the manuevering room, all power lost. Thick toxic smoke filled the manuevering room and after-torpedo rooms. All hands aft were sick. We went up and down three times and had started down the fourth time before power was regained. In the maneuvering room the situation was bad. All hands were violently ill. For the first 2 hours we were in a mighty tough spot. Extreme discomfort was suffered from the accumulated heat and humidity. All hands stripped down to shorts and the men took off their shoes and socks.—The predicament of the ship was fully recognized by the older and more experienced men. As the youngsters folded up, the others took over. The most startling effect was the apathy engendered by the combination of heat, pressure, physical effort, and mental stress. Some without permission, others after requesting relief, would seek the closest clear space on the deck, lie down, and fall asleep. Often following a depth charge attack men would have nausea, vomiting, abdominal cramps, or diarrhea.

Two instances of hysterical paralysis were reported and other manifestations of hysteria were observed during depth charge attack, as noted in the following report:

> One man got hysterical and had to be held down by others. One man who had made 8 previous patrols became comatose for almost 2 days during which time he could neither talk nor understand what was being said to him. He would sit upright in his bunk for hours with all muscles tensed and during these periods had difficulty in breathing. When he recovered the only explanation he could give was that he had a bad dream. Another man during the first depth charging, who had had previous war patrol experience in Asiatic station "S" boats, broke down and later said that he had lost his nerve. On subsequent depth chargings this man proved unstable and broke down and cried on several occasions.

Despite the hazards under which submarine crews lived and fought, the actual psychiatric casualty rate was amazingly low (table 16). Out of 126,160 man patrols there were 62 psychiatric casualties—an incidence of 0.00041 per man patrol.

TABLE 16.—*Psychiatric casualties encountered aboard submarines*

Diagnosis	Number of patrols reporting	Number of cases reported
Psychoneurosis, anxiety	23	25
Psychoneurosis, hysteria	8	9
Psychoneurosis, unclassified	6	6
Psychosis, unclassified	5	5
Neuritis, unclassified	6	6
Paralysis, unclassified	2	2
Paralysis, facial nerve	2	2
Epilepsy	2	2
Migraine	2	2
Diagnosis undetermined:		
Syncope	2	2
Vertigo	1	1
Total	59	62

This low rate is probably attributable to the following: (1) Careful selection of personnel, (2) thorough and specialized training, (3) high morale associated with success of combat submarines, (4) adequate rest and rehabilitation facilities and frequent rotation of duty, and (5) medical examinations before and after patrol duty.

DEATHS ON PATROL

In nearly 4 years of war, only 62 deaths from all causes (including battle injuries) occurred aboard submarines on patrol (table 17).

TABLE 17.—*Deaths occurring aboard submarines on war patrols*

Cause of death	Number of men	Patrols reporting
Asphyxiation	26	1
Drowned—lost over the side	17	13
Killed—battle injuries	12	10
Killed—accidental	3	3
Suicide	1	1
Malignancy	1	1
Pneumonia	1	1
Unknown	1	1
Total	62	31

PERSONNEL SELECTION PROCEDURES

At the onset of the war, the only physical examination of personnel prior to assignment to duty in submarines was that prescribed in the Manual of the Medical Department (1939). Intelligence quotient and psychological fitness were not considered. These factors were later found to be of great importance. Under prewar conditions some of the requirements for selection of personnel for submarine duty were automatically covered by the performance of satisfactory duty afloat for 3 years. This automatic screening became inoperative when large numbers of personnel were received fresh from civilian life. The rapid influx required the modification of some of the physical requirements for enlistment—notably those of the teeth. Dental officers unfamiliar with the necessities of the submarine service had been rejecting almost 50 percent of the candidates because of slight underbite or overbite or missing incisors, because of the erroneous concept that the mouthpiece of the submarine escape appliance, the "lung," must be gripped firmly with the teeth. (The mouthpiece is gripped with the lips, primarily.) As a matter of fact the dental requirements for duty in submarines could be met, in the absence of marked overbite or underbite which made lip gripping of the mouthpiece difficult, if the applicant had sufficient number of opposing teeth for biting and mastication.

NIGHT VISION TESTING

Testing night vision became necessary in order to properly select night lookouts, or at least eliminate the night-blind. The first work on this problem began in April 1941 and was continued and greatly expanded during the war. The experimental phase was carried out at the Medical Research Laboratory, Submarine Base, New London, Conn.

Submarine personnel were also tested for their visual acuity as radar operators. Requirements were found to be normal near-vision acuity and normal photometric measurements.

SONAR TRAINING

One of the most important contributions made by the Submarine Force was the early development and application of selection procedures for sonar operators. The pioneer work of the staff of the Medical Research Laboratory of New London, formed the basis for the procedures developed for the selection of sonar operators for Fleet units.

PSYCHOLOGIC TESTING

Psychologic testing (using paper-and-pencil test) was used extensively in the selection of personnel for submarine duty. The early impetus for the development and application of these tests came from civilian research groups, such as the NDR Committee of Brown University Division. Many of these tests proved to be of great value in eliminating psychologically unfit personnel.

The submarine service became interested in intelligence tests early in 1942. This was necessary in order to assure the selection of persons of average or above average intelligence for submarine duty. In the beginning, however, selection interviews were conducted by Medical and Hospital Corps personnel who were not trained in psychiatry. The psychiatric selection interview by a psychiatrist with the Medical Examining group at New London was instituted in 1943. The combination of paper-and-pencil tests and psychiatric interview was employed. At first psychiatrists at the training centers had to interview as many as 20 to 30 men per hour throughout the day. This obviously was not only impracticable, but practically impossible. Much more effective service was rendered by using the paper-and-pencil psychological test for the original screening, and referring only those in the "failing" or "doubtful" categories to the psychiatrist.

In 1943, an "Interview Board" was established. This Board consisted of a representative of the staff of Commander Submarines, Atlantic Fleet, a representative of the submarine personnel division of Bureau of Personnel, and a medical representative from the staff of the Medical Research Laboratory at New London. These Boards traveled to various officer indoctrination units, where in cooperation with the medical departments they studied the records of the volunteers for submarine duty and interviewed the likely candidates. After this interview system was established, men selected for submarine duty were found to be much more likely to pass the detailed and rigid examinations than had been the case when groups of unscreened volunteers were selected. Many man-hours were thus saved and much disappointment and resentment in personnel was spared. Previously, candidates had been selected at one station and after traveling to another activity and being interviewed had often been found not qualified.

Personnel selection procedures at first did not always function well. Frequently selection officers failed to work together or did not know the part played by others in the selection system. Physical examinations were often done by untrained personnel, and examining facilities were lacking or inadequate in many instances. In fact, the situations encountered led one to wonder how anyone was properly selected for submarine duty. When a statistical accounting system was set up in 1944 and complete monthly reports of selection results were forwarded to all stations furnishing candidates, the efficiency in personnel selection improved to a great extent.

A representative of the submarine medical examining section of the Submarine Base, New London, visited activities throughout the United States and held indoctrination conferences with the classification and selection officers. Following these conferences, the type of men selected for submarine duty consistently improved and attrition dropped as much as 75 percent.

The Submarine Escape Training Tank was used by the selection group at New London to identify the emotionally unstable and psychiatrically unfit candidates. It was assumed, and at least partially established, that men who failed in the adjustment necessary for proper performance during lung training would be unlikely to make the adjustment essential for duty in a submarine.

LOOKOUT TRAINING

The submarine service was the first in the U.S. Navy to inaugurate night lookout training. This training was developed under the auspices of the Medical Research Unit at Submarine Base, New London, Conn. Following receipt of reports from the British concerning the importance of such training in lookouts, the Commander Submarines, Atlantic Fleet, became interested in the possibilities of this training for the submarine service and a night-lookout training table similar to that used by the British was set up in 1941. From the beginning, commanding officers were enthusiastic about this training, and the program was very popular with men.

The original trainer provided by varying lighting effects a reasonably realistic horizon simulating that at sea. A greatly improved version of the "Lookout Stage," embodying several improvements, was constructed early in October 1942. Similar stages of a "portable" type were constructed and distributed throughout the Navy for the training of all personnel. These had a realistic horizon, and moonlight, recognition lights, and sounds of distant gunfire could be simulated. Its advantages as a training device lay in its realism and the interest which it aroused in the student. Its value in indoctrination and preliminary training of beginners was unquestioned.

In March 1943, the Commander, Submarine Force, recommended the establishment of the Renshaw Recognition Trainer at submarine activities. This training, which was modified to fit submarine service needs, was included as a part of the night-lookout training program already in operation at the Submarine Base, New London. As the work in night visual, general lookout, and recognition training began to increase, it was obvious that a lookout school should be organized. This was established in February 1944. Later the Bureau of Personnel established lookout training schools in conjunction with recognition training at all training centers.

Officers assigned as instructors in these schools were given additional training in lookout work at the Medical Research Department, Submarine Base, New London, in order to enable them to train men in either basic training schools or in "L" divisions aboard ships. A course in lookout procedures had been added to the curriculum of the Naval Training School (Recognition) at Ohio State University early in July 1943. This obviated the need for transferring graduates to New London for additional instruction.

INTERIOR VOICE COMMUNICATION

On 1 May 1944, the Bureau of Personnel authorized the establishment of Telephone Talker Schools in all Class A, B, and C Schools, and assigned the operation to the Medical Research Department. Later the name of this school was changed to "Interior Voice Communication School."

It was found necessary to give training in the following:

1. How to increase intelligibility when using communication instruments.
2. How to formulate brief, efficient orders, and report the execution of orders.
3. How to efficiently operate and handle voice transmitting equipment.
4. The use of standard phraseology and procedures for interior communications.
5. Organization of sound-powered and broadcasting circuits under various battle and operational conditions.
6. Standard terminology for use on stations or submarines.

The following manuals were used in training:

1. "Submarine Telephone Talkers' Manual."
2. "Suggested Ship's Organization: "Chapter on Interior Voice Communications of fleet type submarines."
3. "Standard Submarine Phraseology."
4. "Standard Submarine Phraseology and Procedures."
5. "Instructors Handbook for Instruction in Submarine Interior Voice Communications."

One of the most important parts of the training program was teaching the use of standard procedures. A practical drill was developed that greatly facilitated instruction in voice communication procedures, phraseology, and terminology for the submarine crew. Scripts of orders and messages were used to force the student to utilize correct procedures, phraseology, and terminology, while simulating actual submarine operations.

SUBMARINE ESCAPE ("LUNG") TRAINING

In 1930 a submarine escape training tank was put into operation to permit the thorough training of all submarine personnel in the use of the "lung" under conditions that exist during an actual escape from a disabled submarine. All submarines were equipped with this escape apparatus. With the advent of World War II, "lung" training facilities were expanded, in order to handle the large numbers of men entering the submarine service. In spite of a great expansion in such facilities, many men who entered the submarine service at advanced bases did not receive "lung" training.

Although it was considered unlikely that the "lung" would be used for escape in wartime disasters, training in its use was continued throughout the war for the following reasons: *(a)* It was considered to be an excellent morale factor, *(b)* it gave a sense of security and comfort to the families of the men, and *(c)* it was used by the Medical Research Department of the Submarine Base, New London, Conn., in their selection program as a means of eliminating the emotionally unstable. Men who became excessively nervous during the training were disqualified for submarine duty on the grounds of emotional instability. If they "could not take" "lung" training, what could be expected when the depth charges were rolling? The "lung" was used by the men of one disabled submarine for a very dramatic escape, and the training given at New London enabled two of the men to make successful "free escape" without a "lung."

In order to escape from a sunken submarine, it is necessary to raise the pressure within a compartment of the ship from which egress is to be attempted, until it equals the outside water pressure. To do this, the compartment is flooded by admitting water. As the water rises, it compresses the air in the upper part of the compartment. When the water has risen to the top of the escape door, a hatch can be opened by hand and a buoy with an ascending line released through the hatch. Escape to the surface is made with the use of the lung.

Escape tank training included the following: *(a)* A pressure test of 50 pounds per square inch in the decompression chamber; *(b)* a lecture on construction, operation, safety features, and precautions in use of the lung; *(c)* shallow water training for confidence in breathing under water; *(d)* 12-foot training to attain proper relaxation and confidence; and *(e)* 18- and 50-foot training to permit the student to become skilled in the use of the lung so that should he be called upon to use this device to save his life, he would have no doubt as to its lifesaving qualities.

The number of men trained and qualified in "lung" escape is noted in table 18.

TABLE 18.—*Number of men trained and qualified in "lung" escape*

Fiscal year	Qualifications			Total
	18-foot	50-foot	100-foot	
1930–31	556	405	338	1,299
1931–32	770	189	179	1,138
1932–33	490	244	216	950
1933–34	562	252	141	955
1934–35	264	104	104	472
1935–36	454	84	84	622
1936–37	637	41	41	719
1937–38	1,813	121	121	2,055
1938–39	1,321	62	62	1,445
1939–40	1,375	189	149	1,713
1940–41	3,695	123	13	3,831
1941–42	4,621	2,231	1,405	8,257
1942–43	8,014	6,463	1,882	16,359
1943–44	13,569	12,590	811	26,970
1944–45	8,895	6,710	786	16,391
Total	47,036	29,808	6,332	83,176

The Dental Situation

On 7 December 1941 there were 759 dental officers (including 369 Reserves on active duty) to provide dental care for a combined Navy, Marine Corps, and Coast Guard of about 486,000 men. Three hundred and forty-seven dental facilities were in operation. These varied in size from the one-dental-officer clinic at the smaller stations to such large, superbly equipped dental clinics as that at the U. S. Naval Training Station, Great Lakes, Ill., which had 155 dental officers on duty.

After 4 years of war, on 14 August 1945, 7,026 dental officers (including 6,457 Reserves) were on active duty. They provided dental care for a Navy of about 4 million men and women. Of these there were 4,470 dental officers in the continental United States, 1,350 at foreign stations, and 1,206 afloat. There were 1,545 dental clinics in operation at Naval and Marine activities throughout the world, ashore and afloat. These stations included those listed in table 19.

TABLE 19.—*Dental facilities as of August 1945*

Type activity	Number	Dental officer complement	Prosthetic facilities
Ashore:			
Operating bases	70	1–12	9
Repair bases	4	1–29	3
Construction battalions (centers)	3	3–53	1
Supply depots	15	1–4	0
District dental officers	12	[1] 1	0
Naval hospitals	55	1–20	27
Dental schools	3	4–23	3
Pre-flight schools	4	1–8	0
Air stations	128	1–42	19
Training centers	13	65–353	13
V-12 units	31	1–2	0
Navy yards	5	10–46	4
Miscellaneous	65	1–24	10
Afloat:			
Fleet hospitals	9	3–8	7
Naval ships:			
Flag	13	[1] 1	0
Battleships	23	[1] 3	0
Carriers	36	1–3	2
Cruisers	72	1–3	0
Hospital	12	1–3	9
Transport	77	1–2	0
Transport for wounded	3	[1] 1	0
Tank and repair	89	1–5	12
Transport attack	241	1–3	0
Cargo attack	26	[1] 1	0
Miscellaneous	17	[1] 1	0
Amphibious forces:			
Base hospitals	13	1–13	?
Amphibious training centers	9	1–24	4
Marines:			
Aviation	13	1–16	2
Training	8	1–113	6
Divisions	6	[1] 33	[1] 1

[1] Each.

DENTAL PERSONNEL AND OTHER DENTAL MATTERS

About 1,000 dental technicians were on active duty at the outbreak of World War II. On 14 August 1945, 44 Dental Repairmen, 2,142 Dental Prosthetic Technicians, and 8,153 Dental Technicians, General, were on duty. Of these more than 1,200 were WAVES.

Generally, dental technicians were trained in the Navy; however, because of the need for experienced dental prosthetic technicians a number of qualified technicians from civilian life were rated as Pharmacist's Mates, Dental Technicians, Prosthetic, upon enlistment. (Bureau of Naval Personnel directive of March 1944.)

Prior to 7 November 1941, the course of instruction given at the Naval Dental School, Bethesda, Md., for Dental Technicians, General, was of 4 months' duration. A 5 months' course for Dental Technicians, Prosthetic, was given at all naval dental prosthetic activities. All ratings were eligible for the General Technician course, but only PhM1c, PhM2c, and PhM3c were eligible for the Prosthetic Technician course. In November 1941 these courses were shortened to 10 weeks for the General and to 4 months for the Prosthetic, and HA1c was also included in the ratings eligible for the General course. At this time the latter course was given only at designated naval training centers and at the Naval Dental School, Bethesda, Md. In January 1945, 102 naval dental clinics were also designated to train hospital corpsmen in dental specialties.

With the great increase in the size and number of dental clinics, maintenance and repair of dental equipment became a problem. To meet this need enlisted men had to be trained in such maintenance and repair work. A Dental Maintenance and Repair School, the first of its kind in the Navy, was established at the U. S. Naval Training Center, Bainbridge, Md., on 25 February 1945. Men completing this course were rated Dental Technician, Repair.

The peacetime dental standards for enlistment in the Navy established a requirement of at least 20 serviceable teeth; four opposing molars (two on each side), and four opposing incisors (two on each side). Gingival diseases, carious teeth, oral tumors, extensive periodontal disease, malocclusion, and wide edentulous spaces in either the maxillary or mandibular arches were considered disqualifying. These standards were rigidly applied in the cases of officer appointments, and in enlistments for aviation and submarine duty.

The reason for specifying 20 serviceable teeth, and the presence of opposing molars and incisors, was to reduce workload and costs, if subsequent prosthetic restorations were required.

Application of the peacetime dental standards resulted in the rejection of 1 out of every 5 selectees for the Army in 1941. In that same year, out of 340,000 applicants for the Navy, 7.8 percent were rejected for dental defects. The percentage of men with disqualifying dental defects was probably higher than that recorded, because in many instances, if a man was found physically disqualified, a dental examination was not conducted.

Because so many applicants could not meet the peacetime dental standards, the Bureau of Personnel and U. S. Marine Corps Headquarters jointly modified the dental requirements, specifying 18 serviceable teeth instead of 20, two opposing molars instead of 4, and not more than 4 missing incisors satisfactorily replaced. A carious tooth which could be restored by fillings was considered a serviceable tooth. Applicants with extensive dental infection, or who required immediate prosthetic or orthodontic treatment, however, were still not accepted for the services.

On 29 May 1943 the Bureau of Medicine and Surgery lowered the dental requirements so as to agree with the mobilization requirements of the Army. Only severe and irreparable dental defects were to be considered as disqualifying for inductees. Edentulous upper and/or lower arches, corrected or correctible by dentures, and malocclusion not interfering with minimum mastication and not resulting in pathologic dental changes were not considered disqualifying.

DENTAL TREATMENT

The lowering of dental standards marked the start of a vast dental rehabilitation program. To provide the necessary facilities, 97 dental activities were designated in October 1943 to give dental prosthetic treatment. Such treatment, without prior approval of the Bureau of Medicine and Surgery, was authorized, and dental prosthesis became the responsibility of the cognizant dental officer. Previously, prosthetic treatment without prior Bureau approval had been permitted only for personnel on sea duty or for those outside the continental United States.

This dental rehabilitation program attempted to make all Navy and Marine Corps personnel dentally fit, regardless of their dental condition. It was an extremely difficult assignment for the Dental Department because enlisted men were to be considered *not* physically qualified for transfer beyond the continental United States if they required prosthetic dental treatment. Later in the war, no personnel were to be considered qualified for duty overseas, until all dental treatment (operative and prosthetic) was completed. The responsibility for carrying out such treatment rested with the dental clinics at the naval training centers and at ports of embarkation. Dental treatment was given to personnel of the United Nations eligible for lend-lease aid, when they could not obtain adequate dental care otherwise, and to Army personnel in areas where no Army dental facilities were available.

Examples of the work accomplished during the war are the following:

29,654,343 restorations of all kinds
509,292 dentures—all types
27,232 bridges—all types
4,229,809 teeth extracted

In 1942, 646 fractures of the jaw were treated, 570 of them mandibular. In 1943, the total was 3,096, of which 2,780 involved the mandible and 316 the maxilla. In 1945, the grand total reached 4,355, including 3,304 mandibular, 409 maxillofacial, and 642 maxillary.

MATERIEL

The problem of obtaining dental supplies and equipment at the beginning of the war was acute. Facilities and equipment for dental treatment were not available to meet the increased needs. In lieu of new dental burs, used burs were saved, cleaned, oiled, and sent to the U. S. Naval Medical Supply Depot, Brooklyn, N. Y., for resharpening and reissue. By October 1942 the dental bur supply was further curtailed. Only certain angle and straight handpiece burs could be manufactured and of these only a limited quantity was produced. Because of the curtailment in supplies, dental facilities in continental United States could requisition supplies on a 3-month minimum, 6-month maximum basis. This held true throughout the war.

In December 1942 the Bureau directed conservation of all critical materials. These included amalgam scrap, precious-metal bench sweepings and trimmings, and polishing residue.

The equipment for dental clinics at the various advanced bases was standardized, depending upon the medical components of the base. The Dental Branch of the War Plans Section determined the dental materiel and personnel needs for each advanced base and specified the standard equipment. When dental components were required for an advanced base, commensurate dental personnel and equipment could be readily ordered.

Because of the shortage of dental equipment, a "shift" system was devised to keep available dental equipment in service 12 to 16 hours a day. This was particularly necessary at the larger training centers and navy yard dispensaries. In December 1945 this system was discontinued, because with demobilization in progress, personnel and equipment were in excess of immediate needs.

New types of dental facilities were built during the war. To provide dental treatment for small groups of naval personnel at isolated stations and at training schools, nine self-contained mobile dental operating units and one mobile dental prosthetic unit were built. The first mobile unit was placed in operation in the Eighth Naval District on 18 February 1945. The construction of "dental clinic ships" was recommended by Commander, Service Forces, Pacific Fleet, in June 1945, and construction of four such ships was authorized in August 1945. With the cessation of hostilities, however, this plan was abandoned.

TRAINING

Prior to November 1941 dental officers had been assigned to civilian educational institutions, as well as to the Naval Dental School, Bethesda, Md., for postgraduate instruction in oral surgery and prosthodontia. During the war the number of short postgraduate courses in oral surgery at these activities was increased and a course in ocular prosthesis was added to the curriculum at the Naval Dental School.

On 1 January 1942 the Surgeon General directed all dental officers to become proficient in the administration of first aid, treatment of burns, shock, and hemorrhage, disposal of the dead, and other duties related to the Medical Department, in order to assist the medical officers when occasion demanded. Aboard ship, dental officers also assisted medical officers in teaching first aid to the ship's company. First-aid training was made available to all dental officers, at naval hospitals, naval training centers, and at the Naval Dental School.

DENTAL DIVISION, BUREAU OF MEDICINE AND SURGERY

A number of organizational changes were made in the Dental Division of the Bureau during the war. On 16 October 1942 the Surgeon General established offices of district dental officers. Although some of the larger naval districts then had a District Dental Officer, it became necessary to assign a dental officer to each naval district to coordinate dental activities. This officer was to advise the Commandant and the Bureau regarding dental installations and assignments of personnel within the district, and to make reports to the Bureau and the Commandant.

A reorganization of the Dental Division was directed by the Surgeon General on 8 February 1943. This charged the Dental Division with "cognizance of professional standards for dental practice in the Medical Department," with conducting "inspections and surveys for maintenance of such standards," and with advising the Bureau on expansion of dental facilities, on Dental Corps personnel, on dental equipment and supplies, and on special authorizations for dental treatment. In order to carry out these functions, the Dental Division was divided into a Standards Section and an Inspections Section. The former had cognizance of professional standards; the latter was to conduct inspections and surveys for maintenance of established standards.

A Force Dental Officer was assigned to the staff of Commander South Pacific Forces on 1 June 1943.

The Office of Fleet Dental Officer was established in the Fleet on 17 January 1944 and on the Staff of CincPAC-CinPOA in December 1944.

In 1944 a Dental Section was established in the Headquarters and Service Company of the Medical Battalion of Marine Divisions of the Fleet Marine Force, with the senior dental officer acting as Division Dental Officer.

On 18 September 1944, the Dental Division of the Bureau was again reorganized. The Dentistry Division was directed to "study, evaluate, advise, and make recommendations on the dentistry needs, policies, standards, practices, and performances of dental activities in the Medical Department;" to make recommendations "pertaining to complements, appointment, promotion, advancement, training, assignment, and transfer of dental personnel;" and to "maintain liaison with such other BuMed offices or divisions or such other military and civilian agencies as may be required." An Office of the Chief of Division, a Dental Standards Branch, and a Dental Personnel Branch were set up to carry out the directive. The Chief of the Division was held responsible for the performance of all functions assigned to the Dentistry Division, and was directed not to adopt "major policies, methods, or procedures without the approval of the Chief of the Bureau of Medicine and Surgery."

Other changes of interest in the Dental Corps included the following: Capt. Alexander Gordon Lyle (DC) USN was nominated in March 1943, as the first Rear Admiral in the Dental Corps. The first woman dentist to be commissioned was Lt. Sara S. Krout (DC) USNR, WAVES. She reported to the U. S. Naval Training Center, Great Lakes, Ill., in June 1944. The first woman Dental Hygienist to be commissioned was Ensign Jessie Rathbone, USNR, WAVES. The Office of Inspector of Dental Activities and the Office of the Assistant for Dentistry were established in the Bureau of Medicine and Surgery on 18 September 1944 and 24 May 1945, respectively.

RESEARCH

Dental research had been carried on under the cognizance of the Naval Dental School for many years prior to World War II. During the war, research was accelerated and was closely coordinated with that of the Medical Department. As a result, valuable contributions were made to both medicine and dentistry. Of particular importance was the Dental Department's participation in rehabilitation. The results of the research project "Esthetic and Functional Hand and Digit Prosthesis and Eye Prosthesis," which was started 11 May 1945, made possible the development of prosthetic devices for the amputee and the acrylic eye for the blind. Other dental research included the following:

1. "Efficacy of penicillin in the treatment of oral fusospirochetosis." This was the first attempt in the Navy to determine a method whereby large numbers of men could be treated quickly and still be kept at their duties.
2. "Study of occurrence of caries in the same surfaces bilaterally and/or adjacently."
3. "Presence of Vincent's organisms in the mouth of patients being treated for syphilis."
4. "A portable dental operating light for field use."
5. "Effect of methyl methacrylate fillings on pulp tissue of dogs" (study incompleted).
6. "Relationship of dental occlusion to ear block" (carried out in the low-pressure chamber).
7. "Results of dental therapy in 50 cases of aerotitis media in submarine personnel based upon a new functional concept of eustacian tube blockage."
8. "A rapid dental treatment for the prevention of aerotitis media."
9. "Evaluation of a concept of dental treatment based on a functional classification of malocclusion."
10. "Dental treatment of trismus, tinnitus, otalgia, and obscure neuralgia."

SUCCESSES AND FAILURES IN FIELD DENTISTRY

The following observations were made by dental officers on duty in the various theaters of war:

1. "Insufficient prosthetic facilities were available in the forward areas. The trailer or truck type operating units would have been a solution had they been developed soon enough."
2. "Dental officers with administrative and organizational ability as well as battle

experience should be in charge of dental facilities in forward areas or large dental activities."

3. "Dental officer personnel fresh from civilian practice with little or no experience in handling officer and enlisted personnel should not be in charge of large dental installations."
4. "The hurried and selective form of dentistry, although objectionable, was the only solution during wartime."
5. "During the war it was absolutely necessary for medical and dental personnel to function as a unit rather than as separate entities."
6. "Maxillofacial teams made up of medical and dental officers and corpsmen were needed to efficiently treat the large number of patients with head and neck injuries."
7. "There was a need in the Dental Corps for enlisted personnel with stenographic and bookkeeping experience to handle records more intelligently and efficiently and to maintain files according to standards."
8. "The clinical and instructional phases of naval dentistry at those activities where instruction was given should have been separated to a greater degree. To obtain competent naval dental instructors, a number of dental officers should be trained in this field."
9. "There was a need for a large Reserve dental officer group trained in military dentistry. The time required by Reserve officers to make adjustments during war and the resultant discontent and misunderstanding might have been avoided to a large extent had a more active Reserve training program during peacetime been possible."
10. "Regular rotation of duty between continental United States and extracontinental stations ashore and afloat should be stressed during time of war. When this was initiated in the Pacific, morale among dental officers was considerably improved. A 1-year tour of duty in an active battle area was considered sufficient."
11. "Air conditioning was a necessity in ships' dental offices in the Tropics. In such environment, perspiration of the hands caused slipping of dental handpieces and instruments, and soft tissue injury occurred on several occasions because of this."
12. "A small prosthetic outfit should be available aboard all ships for emergency dental prosthetic service. This should include a small acrylic outfit to quickly construct acrylic crowns."

Chapter II

Experiences in Battle of the Medical Department of the Navy

Joseph L. Schwartz, Captain (MC) USN (Retired)

Pearl Harbor

At about 0800 on 7 December 1941, the first wave of aircraft from a powerful Japanese force attacked the United States Naval Base, Pearl Harbor, T.H. (figs. 66, 67, 68). Magazines in ships exploded, burning fuel oil covered the water, fuel dumps went up in flames, buildings and runways were struck by bombs, aircraft were destroyed before they could take to the air, and military personnel and civilians were strafed by machinegun fire as they sought cover on the ground. Even as the attack was still in progress, trained medical units of the Navy, ashore and afloat, went into action to collect and care for the large numbers of casualties.

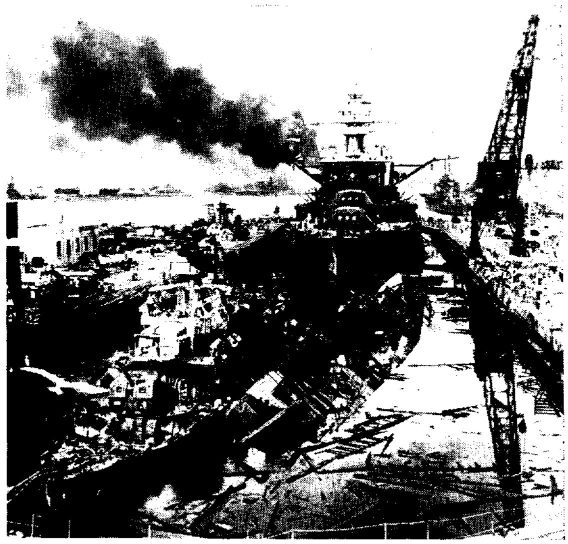

FIGURE 66.—Disaster at Pearl Harbor.

FIGURE 67.—Disaster at Pearl Harbor.

FIGURE 68.—Disaster at Pearl Harbor.

At the Naval Hospital at Pearl Harbor all treatment and operating-room facilities were set up and ready for use by 0815. Within 10 minutes after the attack began, casualties were arriving at the hospital, and in the first 3 hours approximately 250 patients had been admitted and treated. Altogether 546 patients and 313 dead were brought to the hospital that day. In addition, more than 200 ambulatory patients were treated and returned to their duty stations. By midnight of 7 December, the hospital patient census was 960.

Despite the large number of patients and the great variety of injuries treated, the supplies at the hospital were sufficient to meet the unprecedented demand, shortages appearing only in stores of plasma and tannic acid, which became depleted in the treatment of the large numbers of patients who had been burned. Some 60 percent of all patients admitted had clinically significant burns, in many cases the result of exposure to the flash of ignited gasoline or high explosive. Every conceivable type of wound and injury was observed, including a number of bizarre traumatic amputations. Although treatment of burns was left to the discretion of the individual medical officer, tanning agents were used in most cases, and variations occurred only in the agent selected, principally tannic acid, picric acid, gentian violet, triple dye, and silver nitrate. A few received wet saline dressings, sulfanilamide in mineral oil, or simply a heat cradle. Although many patients had been in the water and were covered with fuel oil, the large case load precluded any attempt at removal of the oil before treatment was instituted. It was noted subsequently, that the presence of oil on the burned areas did not impair the efficiency of treatment and healing progressed in the same fashion as if the oil had not been present.

Compound fractures were debrided and sulfanilamide powder was sprinkled in the wound; a plaster of paris cast was then applied, after which a roentgenogram was made and the position of the fragments was outlined on the cast with indelible pencil. This method of marking the position of the fragments provided invaluable information to the medical officer subsequently treating the patient. Sulfonamides were also administered orally for from 4 to 10 days after the initial treatment. The absence of infection in wounds of patients so treated proved those agents to be of value in combating infection, and it was shown that with early use of these drugs the time between injury and initial surgical treatment could be extended, when necessary, beyond the first 6-hour period.

A record of the patients admitted could not be kept at first because of the urgency for treatment and the very rapid rate of admission. Later, when it became possible to record admission data, identification was often delayed, for none of the patients wore identification tags and in many cases clothing was marked with several names. The Naval Hospital at Pearl Harbor, staffed by 41 medical officers, 54 nurses, and 331 enlisted men, treated more than 6,200 inpatients during 1942.

The hospital ship *Solace,* anchored in Pearl Harbor, was unharmed by the attack. By 0825, when the first patients began arriving, all was in readiness to receive a large number of casualties, which at the end of the day amounted to 132 admissions in addition to about 80 ambulatory patients who were treated and returned to their duty stations (fig. 69). The *Solace* received the Commendation Award from Admiral Nimitz for professional skill and devotion to duty.

Because of the large number of fleet units in the Hawaiian area and the need for additional hospital facilities there, the U. S. Mobile Base Hospital No. 2, was shipped to Pearl Harbor in November. This unit landed just 12 days before the Pearl Harbor attack, but had not yet been erected. Only the crew's quarters were up. Because of the experience in the erection of its prototype, Mobile Base Hospital No. 1, in Guantanamo Bay, Cuba, in the previous year, the packing and marking of the supplies and equipment and the arrangements for uncrating supplies for this hospital were so efficient that it was possible to break out needed items on short notice. As a result, even though U. S. Naval Mobile Hospital No. 2 existed only in crates, it provided personnel, supplies, and equipment to care for and treat 110 patients on 7 December. For this fine work, the Medical Officer in Command, Capt. William Chambers (MC) USN received the Distinguished Service Medal. Mobile Hospital No. 2 continued to operate throughout 1942 and was decommissioned in 1943.

Immediately after the attack the medical departments of the First and Third Defense Battalions at Pearl Harbor jointly established 3 dressing stations and within 3 hours had also outfitted a collecting and casualty dressing station and were treating patients from units of the Fleet.

The Naval Hospital at Aiea Heights, under construction at the time the attack occurred, did not admit patients until 12 November 1943. (During 1944 this hospital admitted 42,721 patients, of whom 5,256 were from Saipan and 2,848 from Guam and Tinian. On one day (3 July 1944) 1,169 patients were admitted.)

Medical Department personnel in fleet units at Pearl Harbor required no alert when enemy bombs and torpedoes struck ships anchored at Pearl Harbor. Even as bomb and torpedo bursts wreaked havoc in the *Arizona, West*

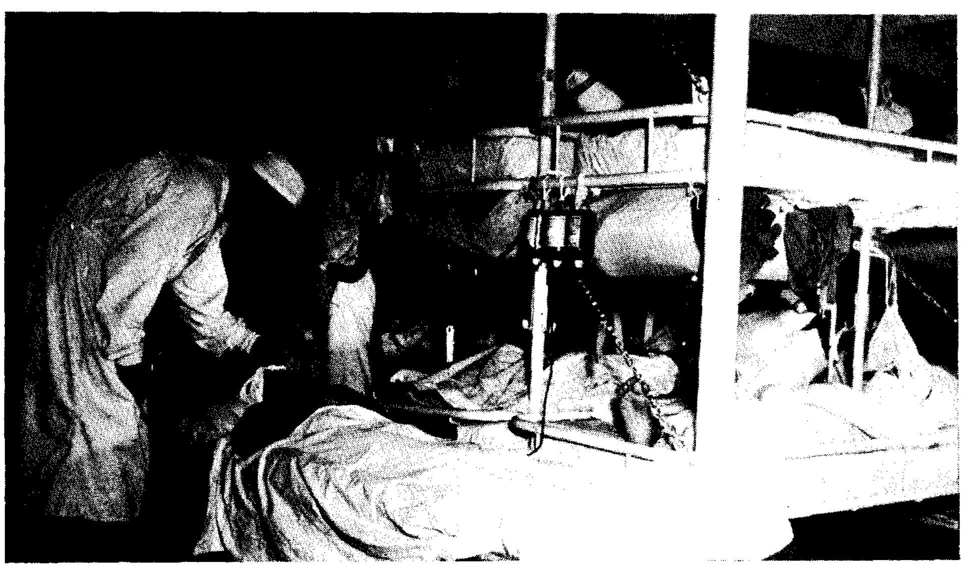

FIGURE 69.—Patients being treated for shock aboard the U.S.S. *Solace.*

FIGURE 70.—Survivors after rescue at sea—sickbay of PCE (R) *851*.

Virginia, Maryland, California, and other ships in the harbor, battle dressing stations were manned and the injured were treated promptly and effectively. The competence of the Medical Department personnel in first aid was, in many respects, equalled by that of the crew. Because of previous instructions and drills in first aid and transportation of the wounded, they rendered lifesaving service to their injured shipmates. The efficiency in treatment was not a matter of type or size of ship. It was of the highest order whether carried out in a battleship or destroyer (fig. 70).

The prompt and efficient manner of preparing for the treatment and evacuation of patients under fire, and the bravery and resourcefulness of Medical Department personnel in shore-based and fleet units attested to their high state of preparedness and training.

The Solomons Campaign

The early months of 1942 were fraught with disaster for the Allies in the Pacific theater, as in other parts of the world. Corregidor's valiant garrison had finally surrendered, Singapore had fallen, and landings had been made by a small force of Japanese in Western New Guinea, with the aim of taking Port Moresby, cutting our supply line to Australia, and bringing that continent under attack. In the last days of April 1942 a powerful Japanese naval force was reported entering the Coral Sea and all available American and Australian naval might was concentrated to meet this threat. The force consisted of warships and transports containing some thousands of troops for a landing in Papua. The memorable Battle of the Coral Sea, while costly to us in the loss of the aircraft carrier Lexington, was an important strategic naval victory in that the Rising Sun was effectively turned back from its mission.

A few weeks later, the Japanese sent an even mightier force to take Midway. Our own forces, at the cost of the aircraft carrier Yorktown, aborted the attack and routed the enemy fleet.

These victories, however, provided only a brief respite, for the Japanese forces in New Guinea were constantly being reinforced and a large base was being established at Rabaul in the Western Solomons. In addition, Japan was working feverishly to develop its gains in the East Indies and Malaya, and our supply lines through the Pacific to Australia and New Zealand were in imminent danger of being severed. Therefore, in order to consolidate our preliminary gains in the Southwest Pacific, to relieve some of the pressure on New Guinea and consequently on Australia, and to establish the first stepping-stone on the long march back to the Philippines, it was decided to mount an amphibious assault on Guadalcanal, a little-known island in the Eastern Solomons.

FIGURE 71.—Sickbay on Guadalcanal.

GUADALCANAL

The first echelon of the First Marine Division reached New Zealand on 14 June 1942, and on 7 August 11,000 men, a few units of fire, and a mountain of supplies were landed at Lunga Point, Guadalcanal.

In preparation for combat duty, the personnel of the First Marine Division had been carefully screened, and appropriate disposition made of men not physically fit. All hands had been instructed in first aid and immunized against smallpox, yellow fever, typhoid fever, and tetanus.

Prior to the landings in the Solomons, plans were completed for the medical care of the thousands of officers and men by the organization of the Medical Department into: (*a*) Battalion aid station units, composed of 2 medical officers and 20 hospital corpsmen, of whom 3 were detailed as company aid men, the remainder being assigned with the medical officers to the battalion aid station; (*b*) medical companies, consisting of 6 medical officers and 80 hospital corpsmen and divided into 3 sections: (1) collecting and sorting, (2) hospital, and (3) evacuation. Each medical company was capable of establishing a 72-bed hospital in the field (fig. 71).

The company aid men landed with and closely followed the initial assault wave, maintaining a position about 200 yards behind the front lines. They administered plasma and morphine, recorded on tags which were attached to the patient all treatment given, and applied necessary dressings and splints, thereby forming the first link in the elaborate chain of care established by the Medical Department (fig. 72). A few waves later, the battalion aid equipment and personnel were landed. On their arrival, stretcher parties (fig.

73), formed largely from rear echelon troops, were dispatched to bring the wounded back to the battalion aid station, where additional lifesaving resuscitative measures could be instituted. Set up at a distance of about 600 yards behind the line, these stations were constantly being moved forward as the assault progressed inland.

FIGURE 72.—First aid for wounded marines at a frontline battle dressing station in the Solomons.

FIGURE 73.—Collecting the wounded.

Soon the collecting party, the advance unit of the medical company, landed with ambulance jeeps (fig. 74) fitted to carry stretchers and semiambulatory wounded. These went inland to battalion aid, and evacuated casualties to the beach, where they could be loaded aboard boats (figs. 75, 76), and carried to transports anchored offshore. Because field hospitals early in the Guadalcanal campaign were targets for almost daily aerial bombing and/or artillery fire it became necessary to evacuate patients a distance of some hundreds of miles before operations and other definitive measures could be carried out.

FIGURE 74.—Continuing first aid during transportation by jeep.

FIGURE 75.—Carrying wounded aboard a landing boat for further transportation to an APA or hospital ship.

FIGURE 76.—Transfusion of wounded immediately upon arrival aboard a landing craft.

FIGURE 77.—Litter carry of wounded on Guadalcanal.

Evacuation and transportation of casualties

The usual method of evacuation of patients was by hand-carried stretchers (fig. 77) along the shortest trail to the rear. Men were then placed in the first available transportation—a jeep, an ammunition truck, or other vehicle—and taken back a distance of from 500 to 1,000 yards to be transferred to waiting ambulances, or else taken directly to a field hospital.

Early in the operation it was found that a litter squad of four men was inadequate to carry a casualty by stretcher over the type of terrain encountered, particularly in the heat of the day. This necessitated the employment of collecting section personnel as litter bearers from the front lines back to the first available transportation. To reduce the distance of hand carry, jeeps were sent to forward areas. Their small surface, low center of gravity, and ability to travel in difficult terrain made them especially valuable for evacuation, for with only slight alterations, the standard jeep could provide transportation for three or four stretcher patients and one ambulatory patient. The medical department did not, at that time, have control over these vehicles and frequently the lack of transportation made long carries by hand necessary.

Early in the campaign, lack of communication facilities and centralized control delayed the evacuation of patients from the beaches. Control boats had been provided for, but no communication existed between them and the beach medical section. Further, although arrangements had been made to station a medical officer in the control boat to direct medical supplies and the flow of casualties to the ships, this plan was for some reason abandoned. Perhaps one of the most unsatisfactory features of the early evacuations by sea was the lack of effective coordination of the evacuating ships. Great inequities occurred in apportioning casualties among the ships, resulting in the overcrowding of the medical facilities of some vessels while other ships were only partially used. Many ships failed to fly the Mike flag to indicate that they could take casualties. Some boats carrying wounded made unnecessary stops en route for other purposes, and frequently coxswains would automatically head for the nearest ship to unload their patients as quickly as possible.

With the establishment of the policy of

FIGURE 78.—Air transportaticn of the wounded.

evacuating from the island any patient who would not be fit for duty within 10 days to 2 weeks, evacuation by air as well as by sea was inaugurated. Although a few casualties had been flown out earlier in combat aircraft, the first transport plane, accommodating 18 stretcher cases or 36 ambulatory patients, arrived on 3 September 1942. By 18 September 1942, 147 patients had left Guadalcanal by this means.

As the war progressed and lines of communication became longer, air evacuation became of great importance, and both the Army and Navy increased their facilities for air transportation of patients. Further, nurses and corpsmen were specially trained for this duty and medical officers were assigned to screen those patients selected for transportation by air, with a view to assigning priority to those requiring specialized treatment in the fields of neurosurgery, ophthalmology, or plastic surgery, and to excluding patients with abdominal and chest wounds, who generally did not tolerate flight at high altitudes. Air evacuation was a tremendous boost to the morale of all personnel (figs. 78, 79).

During October and November 1942, more patients (2,879) were evacuated by air than by sea. Occasionally the transfer of patients from hospital to plane was even made while the field was under artillery fire.

Sanitation

Sanitation on Guadalcanal was a tremendous problem. The enemy, surprised by the attack, had left a great deal of equipment as well as refuse. This could not be burned because of the danger of inviting aerial attack. Further, all enemy latrines were unfit for use and had to be destroyed and new fly-proof facilities constructed.

During the first few weeks, epidemic gastroenteritis occurred. Later, catarrhal fever, dengue, and malaria were the major medical problems. Fungus infection of the foot, groin, and intergluteal fold proved to be of minor importance only.

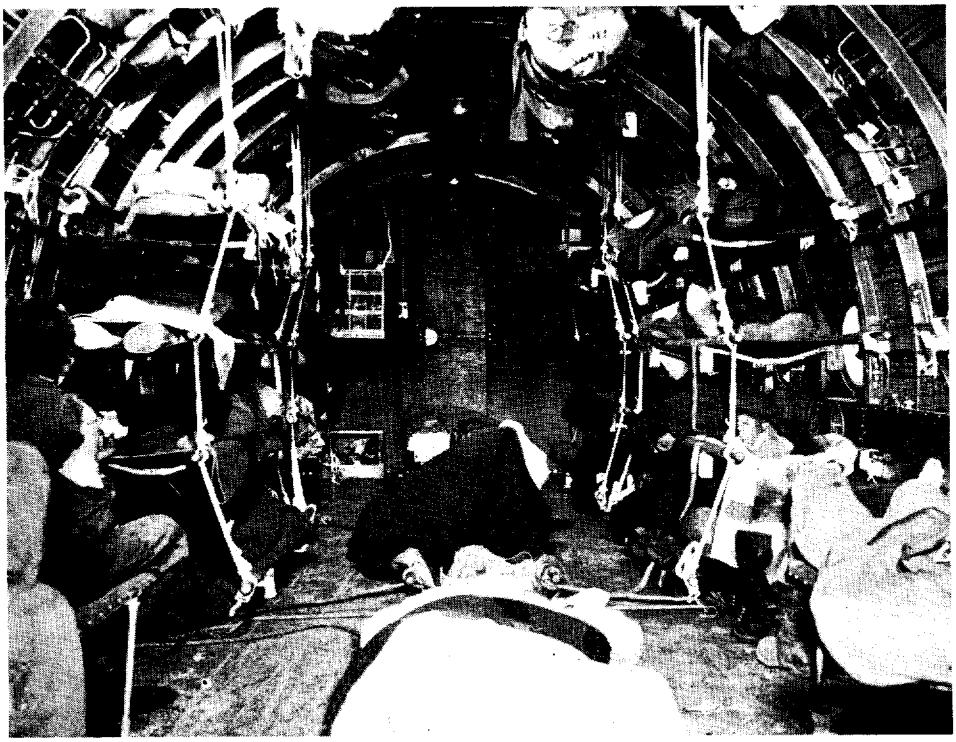

FIGURE 79.—Evacuation of casualties by air.

Malaria

Malaria did not appear until about 2 weeks after the landing. Suppressive treatment with atabrine was begun on 10 September 1942. Although instructions for its proper use were put out as a division order, it was impossible to get complete cooperation in the distribution and ingestion of this drug even under bivouac conditions. Lack of supervision by the responsible line officers became apparent when hundreds of tablets of atabrine were picked up from the ground by messmen after they had been distributed to personnel. Thus, medical personnel were obliged, in most instances, to stand at mess lines not only to dispense the medication but also to look into the mouths of recipients to see that it was swallowed. Quinine was used as a suppressive drug only in those by whom atabrine was not tolerated.

The lack of mosquito nets during the early phases was a factor in the high incidence of malaria. Although each man had both head and bed nets on embarking, most men lost or discarded their nets during the landing operation. Further, line personnel had little regard for the practical value of antimosquito equipment and believed that this equipment was more of a hindrance than a help. Their philosophy was that a man operating in the jungle, through steaming heat and pelting rain, far from any base of supplies and obliged to carry his every need on his back, had neither the time nor the strength to bother about mosquito bars, head nets, and gloves. His attention and energy were directed to the more immediate and urgent matters of killing the enemy and avoiding being killed. It was not appreciated by the line that a man infected with malaria was a casualty as surely as though he had been wounded by enemy action.

It was well known that the natives of the Solomons were reservoirs of malarial infection, and cognizant medical officers strongly opposed the introduction of native labor into the combat area of Guadalcanal. The commanding general recognized the soundness of this advice, but the gravity of the tactical situation required all available troops on the firing line and therefore natives were employed to unload food, ammunition, and gasoline from the ships.

The combination of an infected native population and a suitable mosquito vector spelled infection for the troops. Later Guadalcanal became the staging area for troops moving to the front in other campaigns, and the men carried malaria to other combat zones, where there were no natives. In the 20 weeks following the arrival of the Second Marine Division on New Zealand from Guadalcanal, 9,215 men (63.8 percent of the entire division) had malaria.

The First Marine Division and supporting troops landed at the beginning of the campaign during the dry season. Malaria did not appear until some weeks later, but with rapid progression it threatened to become a critical factor in the success of the operation. The use of atabrine saved the military situation on Guadalcanal.

In table 20, the number of admissions to the sick list in the First Marine Division for malaria is compared with those for other diseases.

TABLE 20.—*Number of First Marine Division patients hospitalized for malaria as compared with other diseases—Guadalcanal*

Month 1942	Malaria	Other diseases
August	22	900
September	239	1,724
October	1,941	2,630
November	3,212	2,413
Total	5,414	7,667

The number of men who were infected with malaria on Guadalcanal may never be determined, but it is safe to assume that almost every man who served on the island during the period of 7 August 1942 to 9 February 1943 fell victim to the disease.

Water

For the first 5 weeks after landing, water was obtained from the Lunga River and chlorinated by hand by Medical Department personnel. On 12 August a portable filtration and chlorination plant was set up on the west bank of the Lunga, providing 12,000 gallons daily. As the number of personnel increased and more water was needed to assure an adequate supply for all hands, the original chlorination unit was replaced by a mobile unit with a daily capacity of 30,000 gallons. Six portable units, each capable of chlorinating 12,000 gallons a day, were set up at different points about the island. Headquarters, Second Marines, also set up a water distilling plant on Tulagi.

Food

The food supply on Guadalcanal, inadequate at first, gradually improved as the operations proceeded, and enemy supplies captured in the first days added significantly to our limited stores. Food that was actually spoiled was surveyed but hunger often tempered the judgment of medical officers. As supplies arrived, the diet became adequate. Lack of equipment for the proper preparation of food was overcome by field and mess cooks, who showed great ingenuity in repairing and utilizing captured equipment. Had the enemy taken the time to destroy his ration dumps and equipment, the outcome of this operation might have been tragic.

Medical supplies

On landing, the battalion and regimental medical sections were instructed to carry only combat medical supplies and equipment. In some instances individual groups disregarded this order and overloaded their medical personnel with other equipment. This disregard of a carefully planned operation order often proved to be a serious handicap and contributed to the loss of valuable medical supplies.

The sinking of the *Elliott* by falling enemy aircraft resulted in the loss of practically all the medical supplies and equipment for E Company, First Medical Battalion. Division of supplies had been so well executed, however, that no shortage resulted. By sharing available supplies and using those captured from the enemy, it was possible to reoutfit this company and enable it to function as a field hospital within 48 hours after landing.

Practically all medical supplies destined for Tulagi, with the exception of the units carried by personnel, were lost. Under the supervision of the senior medical officer, the supplies remaining were pooled and added to those captured from the enemy, so that there was no shortage of any essential material during the first week or 10 days. After this, it was possible to obtain re-supply from the division depots on Guadalcanal. When the naval forces withdrew on the night of 9 August, the physical occupation of Tulagi and Gavutu had been completed and a field hospital was in operation.

With the exception of a few items, medical supplies on Guadalcanal were adequate throughout the campaign. Deficiencies were rapidly corrected by air transport from the base depot at Noumea, New Caledonia. After the landing, this depot furnished all supplies except antimalarial drugs which remained under the control of Malaria Control Unit, South Pacific. The arrival of the Seventh Marines, reinforced, on 19 September, gave the First Division an additional regiment of troops and a completely equipped medical company. In spite of their reception by enemy gunfire and repeated air bombardments on their first night ashore, the medical company was operating a tent hospital just west of the Lunga River within 48 hours after arrival.

By 10 December 1942 there were more than 45,000 military personnel on Guadalcanal. The medical supply officer of the First Division obtained and distributed medical supplies to this entire group, and the First Division medical section was able to fill requisitions despite the needs of many of the new units that had arrived with only a few days' supply. The Fourth Replacement Battalion was landed without any reserve supplies and the Eighth Regiment arrived with field units only. The Army was supplied from the First Marine Division reserves for the first 4 weeks of their action. Navy construction and aviation units had their own medical sections and the division medical supply officer was required to issue only supplementary supplies to them.

NEW GEORGIA

The First Marine Raider Regiment landed on 5 July 1943, about 500 yards up the Pundakona River on a sandy beach lined with mangroves. The battalion medical section, consisting of 3 medical officers and 32 hospital corpsmen, bivouacked with the troops until daylight in a drenching rain. At 0600, after discarding bed rolls and gas masks, the Northern Landing Group commenced the march to Dragons Peninsula. The movement from the Pundakona River to the Giza-giza River was made over three parallel trails previously cut by natives, with the First Raider Battalion in the lead. The way was obstructed by huge fallen logs, branches of trees, roots, and vines, and led through swamps and mud, and up and down steep coral hills.

On reaching the Giza-giza River after 10 hours and approximately 8 miles of jungle, the men, exhausted and thoroughly soaked by a heavy rain, slept in their ponchos. Another river crossing was completed by nightfall of the following day and another night was spent in a swamp with no protection from the elements. At 0800, 7 July 1943, led by native guides, the battalion moved out through mangrove swamps, over fallen trees, banyan roots, and coral out-croppings. Troops became so exhausted that they threw away all unnecessary gear and a portion of their food consisting of K and D rations. No plasma was carried and the only medical supplies available were those carried in the hospital corpsmen's pouches and in individual first-aid kits.

At 0700, 10 July, the battalion closed in on Enogai where intense fighting ensued. At the time battle was joined, the men had had no food and only 1 canteen of water in 30 hours. The observation was made that ambulatory wounded would immediately become litter patients when given morphine, and it was apparent that this drug must be withheld from all except those having extensive wounds and extreme pain.

Rushing between lines to administer first aid to a badly wounded marine during the action at Bairoko, PhM2/c Thaddeus Parker was killed instantly by a burst of enemy fire. His brave act, a source of inspiration to his fellow corpsmen and to the men of his company, served, however, to point out the importance of training troops to crawl back from the lines when wounded. On many occasions, men only slightly wounded called for help, and when their buddies or corpsmen went to their aid, they too were shot and injured or killed. Troops and corpsmen were cautioned not to go out in front of the line to get the wounded unless the lines were stationary or a withdrawal was being made or contemplated. If troops were advancing, the wounded would be behind the lines in a relatively short time. Had such a plan been faithfully carried out, fewer casualties would have been sustained.

The "Battle of Viru" began for the medical department of the Fourth Marine Raider Battalion on the morning they landed at Segi Point. It had been impossible, because of the lack of space on the APD, to take more medical supplies than could be packed in six "unit 5's."

Each corpsman carried a complete "unit 3," and each man in the battalion was given a supply of atabrine, halazone, salt tablets, aspirin, band-aids, and a morphine syrette, all of which were packed in a metal Carlisle Kit container. Once on the march to Viru, all supplies were cut off except for those contained in each "unit 3" and in the individual kits.

It was imperative that Viru Harbor be taken in order that water could be obtained, supplies landed, and the wounded evacuated, so the last stream was crossed in the late afternoon and plans were laid for the battle which was to take place the following morning. The rapidity of our advance precluded the development of front lines as such, and snipers and machine guns often operated in the rear of our troops. As a consequence, first-aid work was difficult, and the rapid movement of the fighting made the establishment of an aid station impracticable. About dark, preparations for moving the wounded on the trail to Viru were started. An aid station was established in a native hut at Tetamere Village and the work of renewing bandages, cleansing wounds, and administering plasma began.

At Vanguna, "unit 5's" were landed on the beach and later brought in after the village had been secured. An aid station, established in a Japanese mess hall, became the target of Japanese mortar and small arms fire. Water was not a problem here because the village was situated on a river bank.

From the experiences in these two operations the following observations were made:

1. Evacuation of the seriously wounded over jungle trails frequently resulted in their death.

2. Over such trails at least 6 men per litter were required, and they had to be rested for 15 minutes every 300 to 500 yards.

3. Plasma was required for every litter patient if shock was to be effectively prevented.

4. Morphine made a litter patient out of one who was ambulatory, and therefore had to be used with extreme caution in those with relatively minor wounds.

5. Dressings were not to be changed unless there was evidence of bleeding or infection.

6. First Aid Units Nos. 1 and 3 were found to be impractical. After removal of several battle dressings, the unit became a jumble. At times it was necessary to empty the contents on the ground in order to find a single item. A number of the corpsmen used the regular Navy battle pouches; these had a large flap which permitted rapid location of every item. They were also easier to carry because of the wide shoulder strap.

7. Special lightweight stretchers were provided but these were discarded because of their weight when wet. Stretchers made of lightweight waterproof material, with slots in the sides for poles, and weighing not more than 2 or 3 pounds when wet, were essential for long treks through the jungle.

8. Higgins boats equipped with medical supplies and fitted with brackets for holding stretchers would have been of great value in moving the wounded down rivers to the coast and out to ships. Often the rivers were the only means of transportation in the dense jungle.

Medical personnel were often handicapped in the treatment of casualties. No hospital facilities were available in the New Georgia area until 28 July 1943, 4 weeks after the campaign started, at which time a field hospital was hurriedly established on Kokorana Island. Previously, the nearest hospital was on Guadalcanal, 200 miles away and 20 hours by boat. No air evacuation was available except by emergency Dumbo (PBY) until August 1943. By that time, however, 90 percent of the casualties had occurred.

First-aid measures carried out in the battalion aid stations included debridement, foreign body removal, and bandaging. Sulfonamides, both locally and by mouth, were used extensively. In the forward areas plaster of paris splints were used a great deal and patients so treated reached the rear area in good condition.

Medical supplies for most of the New Georgia operation were provided by the Army. The original plan called for supplies for a total of 60 days; a 30 days' supply was to be carried by units in the field and another 30 days' supply was to be forwarded as soon as practicable. Sulfonamides, dried blood plasma, intravenous saline and dextrose solutions, battle dressings, morphine syrettes, first-aid packets, plaster, tetanus-toxoid, and other items that were expended rapidly in combat were to be available in amounts approximately 10 times the normal allowances. Individual jungle medical kits were supplied on the basis of one per officer or enlisted medical man and one per four other enlisted men. A 60-day supply of atabrine was kept on hand at all times. Most of the necessary supplies came from the medical supply depot at Guadalcanal.

The Forty-third Division, which had sole responsibility for medical supplies for the entire operation from 30 June to 28 July, experienced great difficulty in carrying out its plans. Before moving to the combat area, the Division secured supplies far in excess of the need, the tendency being to take all they could get. Accordingly, only a small portion of the huge stores accumulated on the beach could be taken along, and in the confusion of embarking for combat many essential items were left behind. The result was that instead of 30 days' medical supplies accompanying the units, it was estimated that only 10 days' supplies were brought along. Further, because containers were not clearly marked to show their contents, medical supplies on being unloaded were frequently hopelessly mingled with those in ration, fuel, and ammunition dumps. In less than 3 days after landing, additional medical supplies were urgently needed.

Some medical units waited until their supplies were exhausted, then radioed to Guadalcanal for air shipment. This same condition existed to a large extent throughout the campaign, and indicated a need for better medical supply handling.

SANITATION

Flies and mosquitoes were a serious problem throughout the campaign. Further there was a lack of screening, which in the tropics offered more protection to the health of personnel than armor plate. Because of these factors, combat units would often lose 25 to 50 percent of their combat efficiency from disease.

The Twenty-fifth Division showed a much more favorable malaria rate during the New Georgia campaign than it did at Guadalcanal during the noncombat phase. The commanding officer of that Division from the beginning had the advantage of the advice of a group of trained malaria control personnel regarding the pattern of the disease and methods of prevention. Equally important, the command consistently followed the recommendations made by the malaria control officer (fig. 80).

One of the most spectacular achievements of the Malaria Control Unit was their convincing proof that infected native laborers were the major factor in epidemic malaria and that they were responsible for a far greater loss of man-hours among the troops because of malaria than could be gained by their presence as laborers.

Infections and combat fatigue

Fungus infections occurred in about 25 percent of the entire New Georgia Occupation Force. In some units, notably Construction Battalions, the nature of their work was such as to prevent good personal hygiene. In one construction battalion 10 to 15 percent of the command appeared daily at sick call for treatment of fungus infections of the skin, and foot infection was seen in approximately 30 percent. The issue of socks was inadequate, bathing and laundry facilities were insufficient, and bathing at night was prohibited by malarial control directives.

The most serious medical problem in the New Georgia operation was the relatively high incidence of combat fatigue, exhaustion states, and "war-weariness." During the period from 30 June to 30 September, approximately 2,500 men were admitted with the diagnosis of anxiety reaction. Aviation units, which were

FIGURE 80.—Natives under supervision of Malaria Control Unit personnel oiling the pools on Munda, New Georgia.

FIGURE 81.—Evacuation of casualties in an LST.

not subjected to the severe living conditions found at the front line, and which were rotated after 2 months, suffered few casualties from combat fatigue.

Evacuation

A total of 8,225 patients were evacuated during the New Georgia campaign by air and 7,300 by sea. For the first 4 weeks of the operation, each LST evacuating casualties to Guadalcanal had only one medical officer, although there were from 100 to 200 casualties aboard (fig. 81).

Timing the arrival of evacuees at the beaches was a difficult problem. The LST's would arrive early each morning, unload during the day, and depart by 1800 the same day. The patients had to be rushed aboard immediately after the completion of unloading, whatever the state of the weather or enemy activity.

Because of the limited number of hospital beds in the New Georgia area, patients were evacuated on the day they were injured. Although the actual sailing time of an LST to Guadalcanal was only about 20 hours, many casualties who had received but little first-aid treatment did not reach medical installations on Guadalcanal until from 72 to 84 hours after injury. This time factor and the limited medical facilities aboard the LST's contributed materially to the incidence of gas gangrene and infection in the early days of the campaign. The percentage of patients with gas gangrene was high: The First Corps Medical Battalion had 24 patients with gas gangrene, six of whom died; Naval Mobile Hospital No. 8 admitted 20 patients with gas gangrene, of whom one died.

BOUGAINVILLE

The assault against the Japanese on Bougainville, the largest of the Solomon Islands, was via Empress Augusta Bay, a low swamp area. The medical section of the naval landing party (1 medical officer and 8 hospital corpsmen) provided first aid (fig. 82) and made provision for the evacuation of casualties (fig. 83). The First Marine Amphibious Corps assigned 3 medical companies to set up three 400-bed hospital facilities (fig. 84). The first was set up within a few hours after landing, but the erection of the other two was delayed for days because the medical personnel were ordered to unload ships. Thus the medical detachments were hampered in making the most efficient use of personnel and materiel.

FIGURE 82.—First aid in a foxhole in the jungle at Empress Augusta Bay.

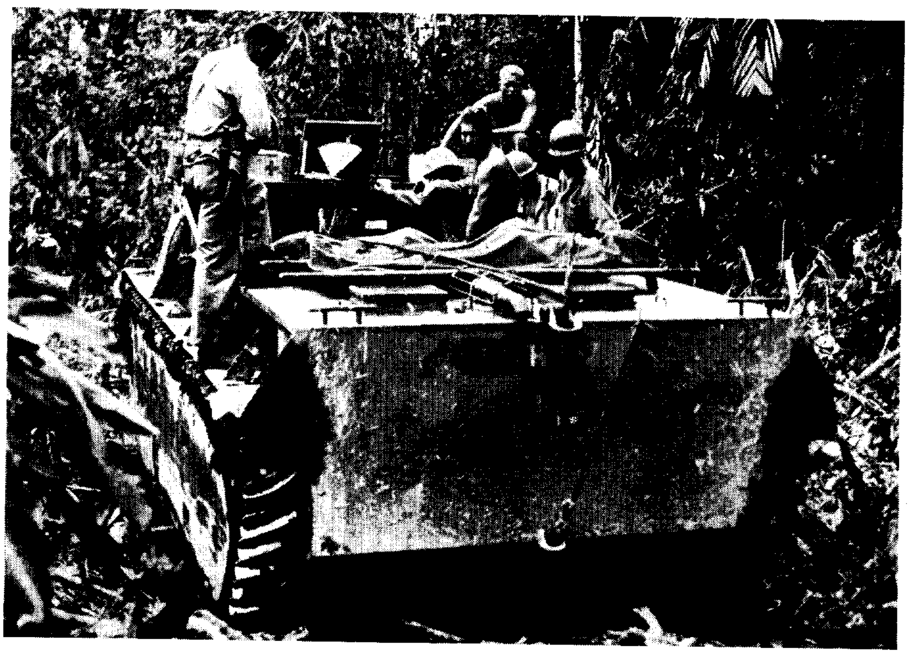

FIGURE 83.—Transportation of dead and wounded via amphibious tractor from the front lines on Bougainville.

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FIGURE 84.—Bomb shelter below sickbay on Bougainville.

Evacuation

The Solomons campaign was a joint Army and Navy operation, but on Bougainville the Navy Medical Department had the sole responsibility for the evacuation of all casualties from the Island. Under such centralized control, evacuation of casualties was carried out in a most creditable manner with a minimum of delay in transporting the sick and wounded to hospital facilities.

Disease

The incidence of disease on Bougainville was amazingly low and was the cause of no evacuations, although it was estimated that 50 percent of the troops were seeded with malaria. Mild diarrhea and dysentery were experienced by the majority of the personnel but the use of sulfonamides reduced the duration and severity of the attacks.

The diseases most prevalent in the First Marine Amphibious Corps were:

	Admissions
Malaria	296
Dysentery	103
Filariasis	[1] 92
Psychoneurosis	140
Combat fatigue	749

[1] Among men previously stationed in Samoa.

In contrast to this, the morbidity rate among the 30,000 Japanese on the Islands was terrific; 13,000 died. Of these, 3,000 were killed in action and the rest died because of illness, predominantly malaria, tetanus, beriberi, and dysentery.

The low morbidity rate among American troops, only about 1 percent, was attributable to the following sanitary control measures (figs. 85 and 86).

1. Administration of 100 mg. of atabrine to all troops.
2. Lectures, pamphlets, and motion pictures used in indoctrinating personnel in preventive measures.
3. Use of pyrethrum spray and mosquito-proof hammocks.
4. Effective action of Malaria Control Unit personnel.

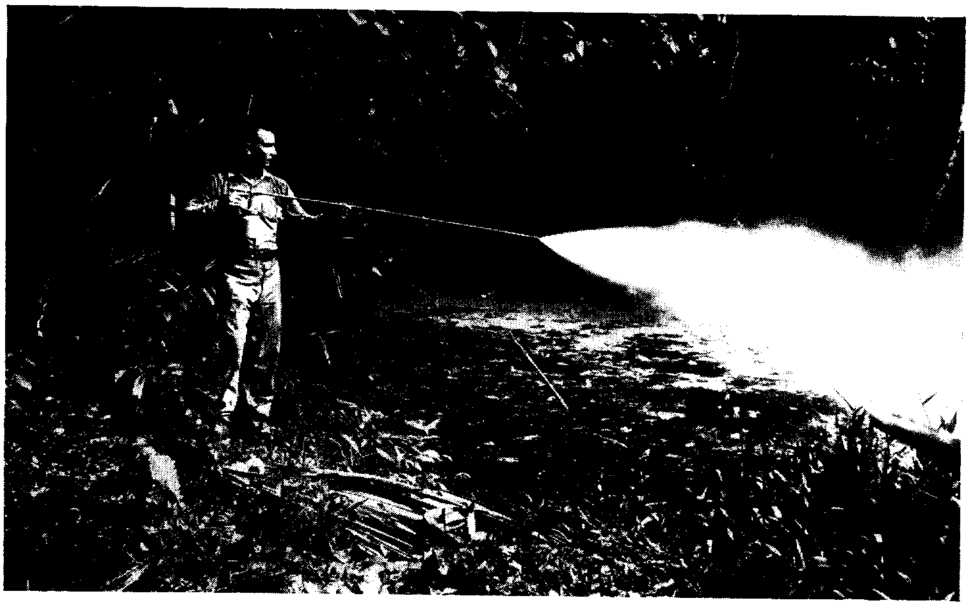

FIGURE 85.—Malaria Control Unit in action in the jungle.

FIGURE 86.—Mobile Malaria Control Unit in action.

New Hebrides

A large number of men were evacuated from Espiritu Santo because of asthma and allied conditions caused by pollens and molds. Some of the fungi had a predilection for the stuffing of pillows and mattresses.

A denguelike disease existed in epidemic form on the island. In some organizations it affected about 12 percent of the men.

In addition to the swamps and stagnant pools, there were numerous piles of tin cans, garbage, coconut husks and fronds, and other waste material, which served as breeding places for flies and mosquitoes. As a result, approximately 80,000 sick days occurred among Army and Navy personnel in 3 months, despite the efforts of the Sanitation and Malaria Control Units (figs. 87 and 88).

FIGURE 87.—Supply yard of Malaria Control Unit on Espiritu Santo.

FIGURE 88.—Malaria control on Espiritu Santo.

The natives were poorly nourished. Tuberculosis, yaws, malaria, filariasis, and intestinal parasites were common, and leprosy was seen occasionally. Physical examinations of a group of candidates for employment showed that 22 percent had filariasis and 18.5 percent showed positive smears for malaria. The natives from a nearby island had a filariasis rate of 51.5 percent.

On Espiritu Santo, naval medical officers organized the Espiritu Santo Medical Society, which was addressed by medical officers as well as local civilian physicians. Among the interesting lectures was that of Doctor Astaire, a Fijian physician who had graduated from the Fiji Medical School. He stated that he had never seen a case of measles or tetanus among the natives and only a few of cholecystitis, appendicitis, and leprosy. He believed that malaria, pneumonia, and mumps, of which there had been an epidemic two years previously, had been introduced by the white man.

Saipan

During the early phases of the assault on Saipan (June 1944), the scene of sand, blood, and wreckage was intensified by an atmosphere of extreme confusion. Seabee, Marine, and naval shore party detachments had dug into foxholes over the entire area above the high watermark. Shelling of the beaches was continuous, and the nerves of both officers and men were strained to the breaking point. To add grimness to the environment, the dead, both Japanese and American, had been collected and laid out to await trucks for transportation to a burial ground.

Into this melee, medical units were landed in LVT's and LCT's (fig. 89). The first groups to establish medical order were the medical sections of the beach parties. Composed of 1 medical officer and 8 hospital corpsmen from each troop carrier, they constituted the link between medical organizations afloat and ashore. Working in highly exposed positions for as long as 48 hours at a time without rest and subjected to the added hazard of strafing Japanese planes, they gave emergency medical treatment and set up casualty evacuation stations in the sand. During the long hours when the invasion forces were confined to the beaches, battalion aid stations acted as forward emergency and evacuation centers on the beaches. From these stations the company aid men went out to administer first aid, exposing themselves to enemy fire in order to reach the wounded. Their bravery was reflected in the heavy casualties among Hospital Corps personnel. Their sacrifices were not in vain, however, for the most important factor in saving of lives had been shown to be the early transfusion of plasma or whole blood (fig. 90) and the removal of wounded from the beaches to ships where lifesaving resuscitative measures could be promptly instituted. In the Fourth Marine Division, 161 medical officers and hospital corpsmen became battle casualties because they were unable to utilize protection or seek cover from enemy fire. Casualties in personnel during the first 5 days of the operation were enormous. One shore party evacuation station treated and evacuated 1,009 casualties during the period from D–Day to D–Day plus 3 under the most difficult conditions. Jeep ambulances with their loads of wounded were often hit by artillery fire; the landing of ammunition and gasoline near casualty evacuation centers on beaches that were subjected to continuous shelling did not lessen the difficulties of rendering first aid.

Medical supplies for this campaign were packaged in blocks, each of which contained a 30-day supply for 3,000 men. Items such as the Wangensteen suction apparatus and a sufficient number of intestinal clamps, airways, and oxygen apparatus were lacking.

Shortages of litters, tetanus antitoxin, blankets, blackout tents, and penicillin developed. Always in demand, litters were frequently not returned from ships, while breakage and loss in the burial of dead added to the shortage. Fifty more litters per troop transport, where landing force evacuation lines were long and casualties heavy, were recommended by the senior medical officer.

FIGURE 89.—First-aid station being set up on the beach at Saipan.

FIGURE 90.—Blood and plasma transfusions on the beach at Saipan.

FIGURE 91.—Transporting the wounded in a rubber boat.

The presence of coral reefs and the loss of small boats during the assault made evacuation of casualties difficult. Unfortunately, the most effective evacuation ship, the LCVP, could not be beached because of the coral reef, but the DUKW was useful in the evacuation of casualties over the reefs. Rubber boats were also utilized to transport the injured (fig. 91).

As the battle for Saipan progressed, the lines of communication became longer and the need for vehicles increased. Not enough jeep ambulances had been provided—only one was available for each medical battalion. When casualties were heavy, other jeeps were requisitioned, but frequently the requested jeeps were lost on the way.

Another important problem in evacuation during the early phase of the invasion was

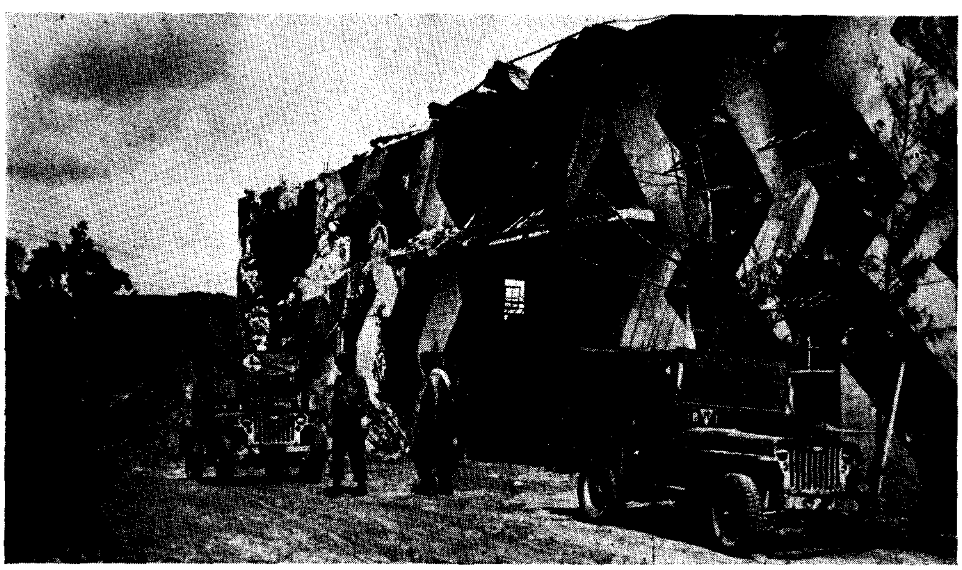

FIGURE 92.—Second Marine Division Hospital in a captured Jap radio station.

that of segregation of slightly wounded patients from the more seriously wounded. Sorting was extremely difficult on the beaches, where hundreds of wounded arrived at one time and mud vied with enemy fire to frustrate attempts at first aid and casualty evacuation.

Field hospital facilities

Hospital facilities at Saipan functioned very well despite the heavy admission rate, but a number of difficulties were noted in the field. No provision had been made for a movable lightproof shelter in which the wounded could receive adequate treatment on the beach during the night. The maintenance of a strict blackout was essential, and it was almost impossible to diagnose a surgical lesion or treat a wounded man under the pale blue gleam of a flashlight. Each corps hospital, however, had portable operating rooms that were easily blacked out and were of immense value. One medical company took over a small field hospital captured at Charon Kanoa, which in the early days of the operation was the only facility for surgery.

The best hospital facilities were those of the Second Marine Division. A former Japanese radio building (fig. 92), constructed of steel and concrete and surrounded by 10-foot revetments was rapidly cleared of rubble and damaged machinery with the assistance of a company of Seabees, and a hospital of 1,000 beds for the seriously wounded set up. Patients

FIGURE 93.—Emergency surgery in a hospital on Saipan.

with minor wounds were housed in tents. Eight operating tables were manned by specialized surgical teams for orthopedic, chest, abdominal, and head and eye injuries. Eleven other operating tables were available for use in treating shock, giving transfusions, and caring for minor injuries. A major factor in the excellent functioning of this hospital was the strong centralized organization of the medical battalion (figs. 93 and 94).

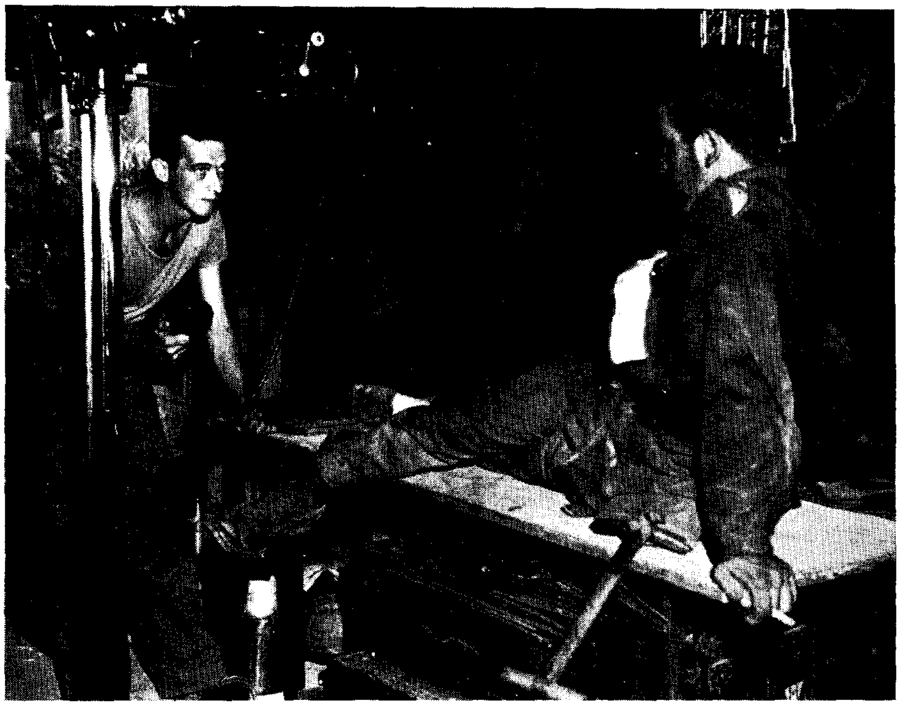

FIGURE 94.—Modern diagnostic procedures on a battlefield on Saipan.

Disease and combat fatigue

Diseases and combat fatigue accounted for about one-third of the admissions. In the Fourth Marine Division, there were 409 patients admitted for dengue fever, 680 for dysentery, 26 for fungus infection, 414 for combat fatigue, and 169 for psychoneurosis.

The high incidence of neuropsychiatric illness appeared to be attributable to a number of factors, among which were: (*a*) Leaders of small units, on the whole, did not demonstrate the inherent qualities of leadership. Junior and noncommissioned officers were often the first to "break," and a needless sacrifice of manpower resulted when others became panic-stricken at the realization that their leaders were no longer able to direct them. (*b*) The lack of proper orientation was probably a contributing factor. The fighting man wished to know what was going on, what was expected of him, and what he could expect. He also had to have a definite objective. Without proper orientation he was prone to absorb wild rumors and loose talk, and was thus subjected to constant mental stress. (*c*) It was likely that a loss of physical fitness contributed to the high incidence of anxiety reactions.

About 50 percent of those patients with a diagnosis of neurosis should have been diagnosed as combat fatigue. Another 20 percent were borderline cases in which fatigue and exhaustion contributed to the symptoms. Three or four days rest, a bath, and nourishing food resulted in complete recovery in from 75 to 80 percent of these patients.

Burial of the dead

One of the great problems confronting the Medical Department was the speedy and ef-

FIGURE 95.—U. S. Marines pay final tribute to their buddies in the Solomons.

fective burial of the dead and the disposal of the decomposing bodies in block houses and bomb shelters. On Saipan thousands of United States and enemy dead lay on the beaches and the rugged inland terrain. Prior to the landing, careful plans were made for burial of the dead and details were trained and equipped for this work (figs. 95 and 96). Because of the intensity of battle, however, there was often a delay of several days before burial or disposal of the large numbers of enemy dead could be started and the amount of sodium arsenite and oil for spraying the remains was frequently insufficient. Other factors that impeded the burial parties were: (*a*) Absence of identification tags with consequent delay in identification; (*b*) shortage of litters on which to carry the dead; and (*c*) lack of adequate communication facilities between burial parties and the Division Burial Officer.

FIGURE 96.—Bodies of Marines of the Third Division awaiting burial.

Evacuation

During the first week on Saipan, there were ample facilities in AH's and APA's for casualty evacuation. On D–day–plus–11, however, the APA's were withdrawn and there were then insufficient personnel and hospital facilities for the stream of wounded, averaging 500 per day.

Air evacuation was begun on D–day–plus–9 and 860 patients were evacuated, but because there were no flight surgeons to screen the patients and no medical attendants to accompany them, some died en route. At times, men wounded in combat who had been without food for days were evacuated without being fed. Further, on arrival at Eniwetok or Kwajalein, inadequate preparations had been made to care for these air evacuees.

Iwo Jima

Medical planning for the Iwo Jima campaign began in October 1944. In preparation for the operation, Medical Department representatives of the Navy, Marine Corps, and amphibious units that were to participate, held numerous conferences to discuss the tactical and logistic problems. The nature of the terrain on Iwo Jima was such that there could be no tactical surprise; the Marines had to land on the southeastern beaches, and make a frontal assault. Under the circumstances, heavy casualties were anticipated. For purposes of computing anticipated casualties, it was assumed that the period of active combat, from the beachhead landings to seizure of the objective, would be 14 days; that 5 percent of the entire attacking force would become casualties on the first and second days, 3 percent on the third and fourth days, and 1.5 percent on each of the remaining 10 days.

Casualty estimates, arrangements for hospital beds, and assignment of hospital and other ships for the evacuation of the injured from combat area were responsibilities of the Medical Logistic Section of CinC Pac POA.

On the basis of the Army Field Medical Manual, as modified by recent experience and the most reliable evaluation of enemy potential to be gained by aerial observation and combined intelligence, it was estimated that our losses would approximate 20 percent of the forces engaged. Of these 25 percent would be killed in action, 25 percent would be returned to duty locally, and 50 percent would be evacuated. Taking into consideration civilian casualties and enemy wounded to whom we were likely to be required to furnish medical care, definite plans were formulated with regard to evacuation policy, the number of beds and ships required for hospitalization and evacuation, and the volume of medical supplies to be ordered.

Each medical company and corps medical battalion had equipment for a 144-bed hospital, twice the number allotted prior to the Marianas campaign, making available approximately 3,592 beds. It was also planned by the Eighth Field Depot, scheduled to arrive about D–day–plus–10, to add to their stock a sufficient amount of cots, tents, blankets, and mess gear for another 1,500 beds.

The chain of evacuation of casualties included 4 LST(H)'s or evacuation control LST's, specially equipped with medical personnel and supplies and designated to make preliminary "screening" examinations of casualties and distribute them equally among the transports and hospital ships. One LST(H) was available for each of the invasion beaches, making two for each Marine division. All ships, LVT or DUKW, that evacuated wounded from beaches were to proceed to their respective evacuation control LST(H). Those casualties unable to endure the trip to a transport or hospital ship were to be transferred immediately to an LST(H) for treatment, while less seriously wounded patients were unloaded onto a barge alongside the LST(H) and then transferred to LCVP's for further transfer to transport or hospital ship.

Aboard each LST(H) were 4 surgeons and 27 corpsmen, increased on arrival at the objective by the transfer of one beach party medical section (1 medical officer and 8 corpsmen) from an APA, giving each LST(H) 5 surgeons and 35 corpsmen. At all times these beach party medical sections were on call by the Transport Squadron Commander.

Two hospital ships and one APH were designated to evacuate patients to Saipan, where 1,500 beds were available, and to Guam, where there were 3,500 beds. Air evacuation of casualties to the Marianas was to begin as soon as field facilities would permit. Experience gained in the Marianas campaign had emphasized the necessity of having the casualties screened by a qualified flight surgeon to insure proper selection of patients for evacuation by air. Medical personnel and adequate medical supplies and equipment were to be aboard each plane.

Sanitation

Because there was a possibility of epidemic typhus, scrub typhus, cholera, and plague at the objective, all personnel were inoculated against these diseases, in addition to the usual immunizations. The clothing of personnel of the landing force was impregnated with dimethylphthalate and DDT powder. As a means of controlling flies, which had been such a nuisance and a hazard to health in previous operations, the area was sprayed with DDT by carrier-borne aircraft and later, by land-based planes. A medical officer familiar with the procedure was detailed aboard a carrier as technical advisor, and the malaria and epidemic control team of the Fourth Marine Division was designated to furnish the technical ground supervision.

Supplies

The medical supply plan for the operation included an initial 30-day allowance carried with the assault forces, plus medical and sanitary supplies for 1,500 civilians, as well as the provision for "block" shipments which were to arrive at regular intervals. Approximately 50 percent of the supplies of the assault forces and all of the "block" shipments were to be palletized (packaged) and waterproofed. Plans also provided for adequate emergency resupply that could be sent by air if necessary.

Experience gained in previous operations had shown the great need for a blood bank. With the establishment of Whole Blood Distribution Center No. 1 at Guam (fig. 97), it became feasible for the first time to set up a blood center at the target area and plans were made accordingly. Up to this time whole blood had been obtained from hospital corpsmen, Marines, and occasionally from patients. LST(H) *929* was designated to carry the whole blood bank for distribution to the forces both afloat and ashore. When the military situation permitted, the blood bank was to be landed and

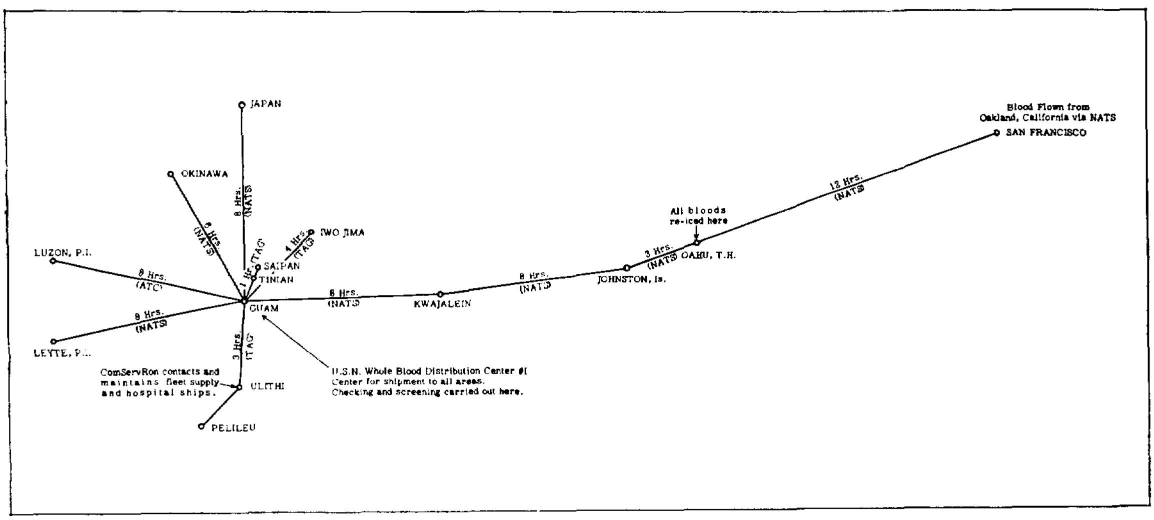

FIGURE 97.—One of the most important phases of military medicine was the rapid distribution of whole blood to every fighting front.

established ashore. All ships were ordered to receive whole blood in the quantities shown: Each APA, 16 flasks; LSV *Ozark*, 500 flasks; LST(H) *929*, 1,100 flasks (whole blood bank); each AH, 812 flasks; and LST(H)'s *930*, *921*, and *1033*, 16 flasks.

Additional whole blood was to be furnished by incoming AH's, or was to be flown in from Guam when air facilities were organized.

Embarkation

Prior to the operation, medical battalions were instructed to carry an additional 1,500 blankets, 5 million units of gas gangrene antitoxin, and 50 million units of penicillin. An inspection was made of the jungle kits and identification tags of each man in the division of all Medical Department supplies and equipment. All shortages were corrected. Medical personnel were given additional instructions in first aid, in the keeping of medical records, in the automatic exchange of litters, and in the handling of casualties in and out of boats. At the close of the training period, a practice landing was made to give the medical personnel an idea of what to expect when landing on the target.

A serious problem was the fact that surgeons who were to be called upon to perform operations during the battle had had little opportunity to perform any surgery during the 6-month period prior to the campaign. To correct this situation, a division hospital was operated during the preparatory period.

The medical personnel were embarked with the regimental combat team, as designated by the unit medical officers. When practicable, hospital sections of the medical companies were embarked on ships with the largest bed capacity in order to facilitate the care of casualties during the initial stages of the battle. Basic vehicles were combat-loaded with essential items of equipment and supplies to supplement those designated as "hand carry." Seabags were packed with battle dressings, plasma, serum albumin, and other items essential during the early stages of the assault. These were to be carried ashore by the assault medical company. Two and one-half ton 6 by 6 trucks, for the first time part of the medical

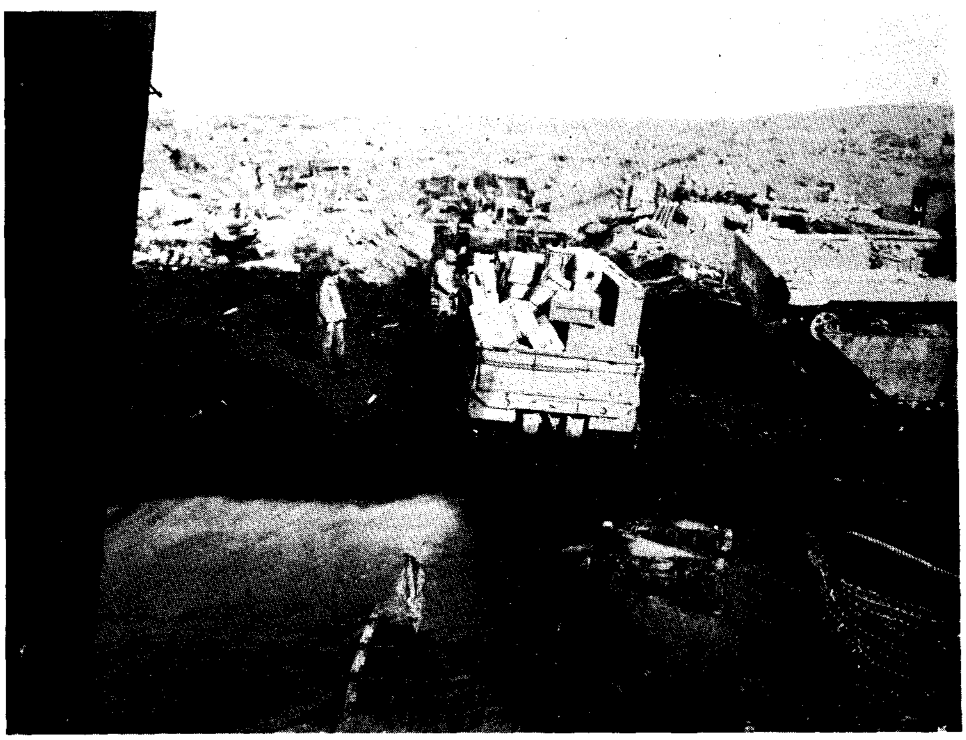

FIGURE 98.—Landing medical supplies on Blue Beach at Iwo Jima.

battalion, were combat-loaded with equipment and supplies necessary to establish surgical units ashore.

Landing of medical units

The Fourth and Fifth Marine Divisions, supported by the Fifth Fleet, began landing on the southeast shore of Iwo Jima at 0900, 19 February 1945 (fig. 98). The Third Marine Division, which had been held in reserve, was landed on D-day-plus-2. Company aid men were debarked with platoons, battalion aid station personnel with battalion command posts, and regimental aid station personnel with the regimental command posts. Shore party medical personnel in support of battalion landing teams were debarked prior to H-hour. Four medical shore party evacuation teams were landed between H-plus-30 and H-plus-120 minutes (0930 to 1100). Other division and corps medical units were landed as rapidly as the military situation would permit. In the early phase of the assault, aid-station personnel were separated into small groups and worked in shell craters or foxholes in the sand (fig. 99).

The grueling experience of all battalion corpsmen and medical officers was typified by the following account:

"Landing with the troops, immediately following the assault group, the chief pharmacist's mate was shot in the jaw as he stepped out of the landing boat. The medical party, carrying seabags filled with medical supplies, pushed inland some 75 yards and picked a spot for their station in an antitank ditch. They left some of the bags on the beach on that first trip, and when they returned to get them, many of the bags had already been ripped by shell bursts. Boxes of valuable plasma were smashed, but the worst blow came when the boat carrying all the litters was sunk on the way in.

Wounded men were lying all around. It was impossible to stand erect on the beach, and the corpsmen crawled from casualty to casualty to bandage wounds and administer morphine and plasma (fig. 100). Within an hour after the aid station had been set up, a shell exploded on one side and fragments injured several of the men. The medical officer, realizing that the revetment, though appearing to offer good protection for an aid station, was a logical target for Jap guns, ordered the men to pack up equipment, and move to a large bomb crater, where the medical personnel continued their work."

FIGURE 99.—Administering blood plasma in a foxhole on the invasion beach at Iwo Jima.

FIGURE 100.—First aid on the invasion beach at Iwo Jima.

In the fury of the battle there were many dramatic instances of rescue and treatment. A Marine who had been blinded and had both hands blown off, was groping his way toward the beach when a corpsman saw him and ran a gauntlet of fire to get him to safety. A corpsman in battle for the first time sewed up four chest wounds under fire and undoubtedly helped save the lives of the four injured men. A corpsman crawled to the aid of Captain Dwayne E. "Bobo" Mears, who had been shot through the neck and was in shock from the loss of blood. He buried the lower part of the Captain's body in the sand so that he would offer a smaller target for the Jap riflemen. It helped, but the captain died later aboard a hospital ship.

Care and evacuation of casualties

The care and evacuation of casualties during the Iwo Jima campaign was handled better than in any previous operation in the Central Pacific area. Notwithstanding the extreme bitterness of the combat and a casualty rate in excess of 1,000 per day during the first 21 days, evacuation functioned as a well-integrated and coordinated operation and the wounded received the best medical care commensurate with the military situation. By

FIGURE 101.—First aid and physical assistance to the wounded on Iwo Jima.

D-day-plus-33, a total of 17,677 casualties had been treated and evacuated.

Casualties were assisted in walking down from the firing line (fig. 101), or were brought by hand-carry, jeep, ambulance (fig. 102), half-track, or weapon carrier. Because of the rugged terrain, hand-carry frequently had to be employed to move the wounded to the beachhead over the rough lava cliffs and sharp-edged blocks of stone and lava. While the beachhead was being secured, casualties were evacuated from battalion aid stations directly to the beach, where they were turned over to shore and beach party installations set up in shell holes or in small pits dug in the volcanic sand (fig. 103). Plasma and other first-aid measures were administered while bullets sang overhead and mortar shells burst in close proximity.

After the troops were well established on the beach, the distance from the battalion and regimental aid stations to the beach was so short that casualties were evacuated by sea (fig. 104). When division and corps hospital installations were established on D-day-plus-9, evacuation was from battalion and regimental aid stations to the division hospital and from there to the beach or to the corps hospitals. Casualties were so high and space to set up hospitals was so limited that many of the hospital sections of the medical companies supporting the regimental combat teams that were landed early, remained on the beach to assist in the shore party evacuation stations until division and corps hospital installations were functioning. Initial treatment of casualties in regimental and battalion aid stations was so efficient (figs. 105 and 106) that many casualties who would otherwise have died reached the shore evacuation stations and corps hospitals in excellent condition. Serum albumin was exceptionally well suited for use by frontline medical units, because of the ease of administration, small bulk, and the excellent

FIGURE 102.—A wounded marine brought to the beach by jeep ambulance from the fighting front on Iwo Jima. Fifteen minutes later he was on his way to a hospital ship off the shore of the island.

FIGURE 103.—Marine stretcher bearers carrying the wounded into a foxhole for first aid.

FIGURE 104.—Corpsmen bringing the wounded from the front lines to evacuation ships on the beach.

clinical response. Its therapeutic effect was equal to that of plasma.

Casualties in Hospital Corps personnel were very high. In moving about to care for the wounded, corpsmen were subject to intense enemy fire and frequently were shot down alongside their patients. Although each division was assigned approximately 5 percent more corpsmen than were provided for by Tables of Organization, this was often insufficient. In the Fourth Marine Division the casualty rate among corpsmen was 38 percent. Often, because of urgent need for replacements, personnel were obtained from medical companies. In one division this policy was carried to such an extreme that on D–day–plus–8 one medical company had been reduced to a point where it was almost inoperative. This practice was contrary to established doctrine and in some instances left insufficient personnel in other areas to render proper care to the wounded.

Close liaison between the attack force surgeon and the landing force surgeon resulted in a well-coordinated chain of evacuation from shore to ship. On D–day, 19 February 1945, 30 APA's, 12 AKA's, LSV *Ozark*, and 4 LST(H)'s were available for the evacuation of casualties. The general plan for sea evacuation provided that an LST(H) be stationed 500 to 2,000 yards off each of the 4 beaches and that all casualties be evacuated to one of these ships.

During the early phase of the assault, prior to the establishment of fully functioning shore evacuation stations, the primary duty of LST(H)'s, was to render emergency treatment and receive casualties at night. In previous operations, casualties had been known to ride all night in open boats before finding a ship to receive them. After shore evacuation stations were established, the main purpose of the LST(H) was to effect an equitable distribution of casualties to APA's and AH's.

The work performed by LST(H)'s can be appreciated by the following: LST(H) *931* was stationed approximately 400 yards offshore. A pontoon barge was tied alongside for receiving casualties. A Jacob's ladder led from the barge to the main deck of the LST. On the barge was a small covered area that served as a supply shack. A number of litter bearers, two medical officers, and a talker to communicate with the control tower of the ship were stationed on the barge. LCVP's, LCM's, and Amtracs bearing casualties, temporarily tied up alongside the barge while the medical officer on duty went aboard to examine the wounded. Casualties requiring immediate attention were taken aboard the barge, where emergency treatment was carried out. To load patients in need of immediate surgery aboard the LST(H) a metal frame accommodating 3 stretchers was lowered to the barge by a tractor crane mounted on the main deck, just aft of the cargo hatch. The patients were then brought up and lowered directly into the tank well through the cargo hatch, which was always open and was outlined by luminous painted lines to prevent accidents during blackouts.

About 220 patients could be cared for on the tank deck and another 150 to 175 in the troop quarters. Patients requiring an operation were moved from the tank deck through the open hatch forward to the operating room. The normal complement of an LST(H) was 4 medical officers and 26 corpsmen, but often this was insufficient. The use of LST(H)'s as evacuation control ships although representing an important step forward in the chain of evacuation, left much to be desired. Used for the transportation of LVT's to the target, they were converted for casualty handling only after these had been discharged and as a result, were often covered with dirt and grease when turned over to the medical department. The illumination on the tank deck was usually very poor and the medical facilities were unsatisfactory. The number of medical personnel assigned was insufficient to care for the large number of casualties, even when the staff worked day and night. On D–day, between 0900 and 1530, a total of 2,230 casualties were evacuated by LST(H)—an average of slightly less than 6 casualties per minute.

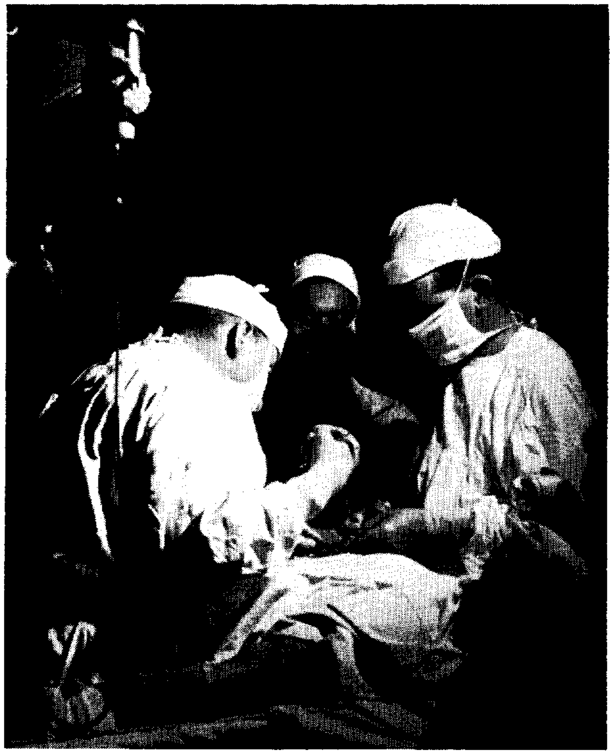

FIGURE 105.—Surgical care in an abandoned Jap dugout.

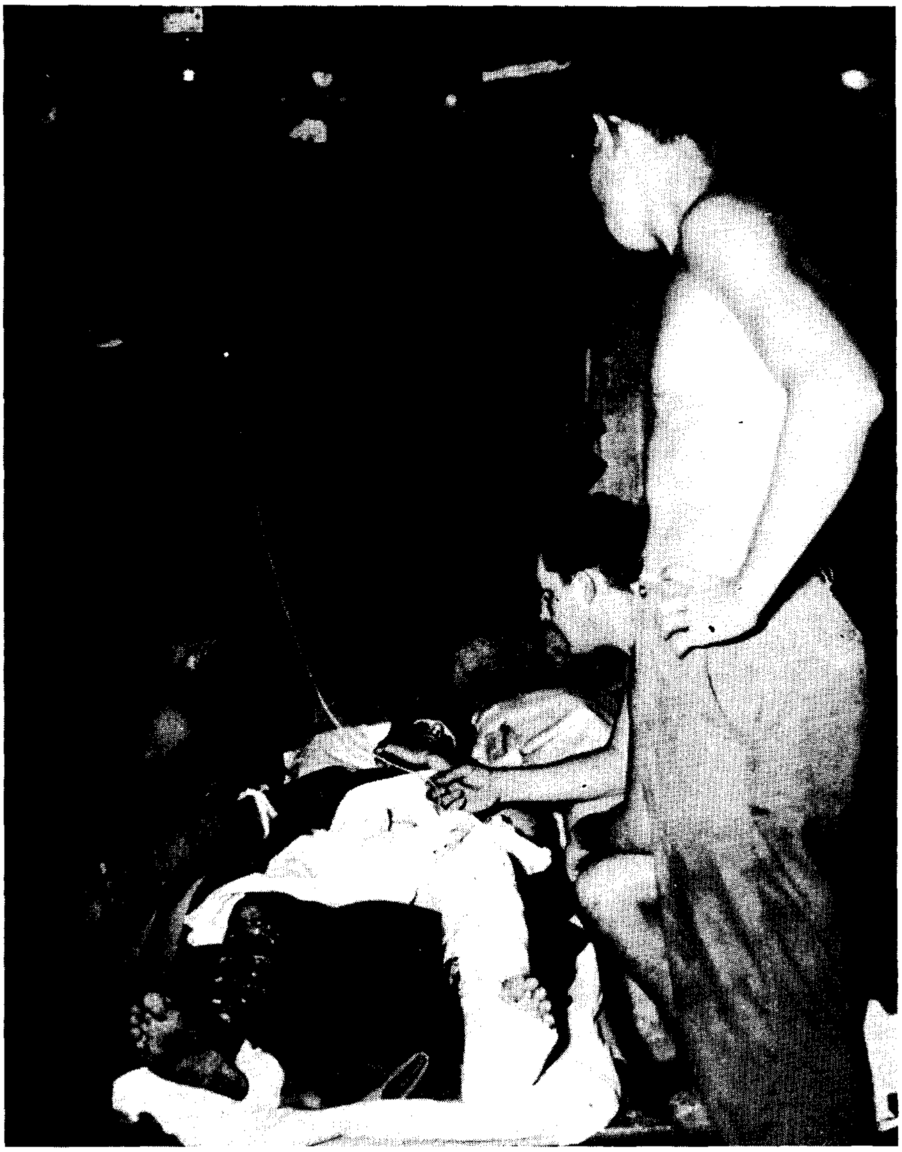

FIGURE 106.—Administering intravenous fluids in an abandoned Jap dugout.

The organization of LST(H) casualty evacuation control ships was as follows:

EVACUATION CONTROL LST'S FUNCTION

1. The primary functions of these ships are: (*a*) To control evacuation of casualties to available ships, maintaining adequate distribution for proper early treatment of casualties. (*b*) To act as a transfer station for transfer of casualties from LVT's and DUKW's to LCVP's where reefs intervene between ships and beach, in order to release LVT's and DUKW's for military operations. (*c*) For emergency evacuation from beaches when other ships are not available. (*d*) To expedite speedy resupply of strategic medical supplies to beaches and landing force. (*e*) To maintain an accurate record of evacuation, for Force and Corps Commands. (*f*) To render shock therapy to those casualties whose condition is so critical as to prevent further progress in the chain of evacuation.

ORGANIZATION

2. Each squadron of transports carrying assault troops will be provided with two evacuation control LST's. These ships are stationed 1,200 yards ahead of LST formation and 300 yards seaward of the TransDiv Control vessel centered off the colored beach it is serving and directly ahead of the transport division to which it evacuates. Each evacuation control ship

is provided with a 3 by 12 pontoon barge alongside as a casualty transfer platform and unloading station for those casualties to be retained aboard the LST for treatment until their condition warrants transfer.

3. The TransDiv Commander will keep each evacuation control LST, serving his beaches, informed of ships available for casualty reception, notifying them 1 hour in advance of those ships departing from transport area, insofar as practicable.

4. Two LCVP's equipped as ambulance boats will be sent from each assault TransDiv to its casualty evacuation control LST as soon as assault troops are landed. These boats together with the two LCVP's on each evacuation control LST will serve as ambulance boats. Ambulance boats will fly a VICTOR flag at all times. One ambulance boat shall be sent to each beach area after assault troops have landed to stand by to land and receive casualties when directed by the Beachmaster. Litter and splint exchange should be made at each ship to which casualties are evacuated. All other resupply items for these boats will be made at the evacuation control ship except on request of Evacuation Control Officer.

These boats shall be equipped with the following prior to leaving the mother ship:

Tarpaulin	1
Life jackets	17
Water canteens	6
Struts for litter loading	—
Hospital corpsman with first-aid kit	—
Bandages, 3-inch	36
Bandages, 2-inch	36
Plasma, units	10
Morphine syrettes	20
Cotton rolls	6
Sulfadiazine, bottles	2
Flashlight	1
Litter units	10
Tongue blades, box	1
Scratch pad and pencil	1

5. The evacuation control LST duty officer will keep an up-to-date record of location of all ships assigned him for casualty reception. He will direct coxswains of ambulance boats to ships assigned by the Evacuation Control Officer. He will also direct coxswains of ambulance boats to exact location on the beach to deliver medical supplies and receive casualties as shown by beach markers (VICTOR flag).

6. Each evacuation control LST is recognizable by a large white "H" painted amidships on both sides. They are located 300 yards directly seaward of their corresponding TransDiv control vessels. They fly an oversize VICTOR flag and display a GREEN light at night. They have pontoon barges alongside and stand out 1,200 yards ahead of the LST formation.

7. Four surgeons and twenty-seven corpsmen are attached to each evacuation control LST. The senior surgeon is designated as the Evacuation Control Officer and is responsible for proper distribution of casualties to available ships assigned by the TransDiv commander. Two-section 4-hour watches will be maintained, beginning at 0800 on D-day, until ships are relieved by orders from Attack Force Commander, relieving at 0800, 1200, 1600, 2000, 2400, and 0400. The appended watch bill will serve as a guide giving titles, number of personnel, and times of watches.

8. Evacuation Control LST's shall make a dispatch report to Squadron Commander and Attack Force Commander at 0900 and 1700 daily, giving a report of casualties on board at that time, using the following form:

(Example: Bed 65 X NE 20 Total 150 X Dead 7 X 0900)

9. Copies of Form A (copy appended) giving date, name, rate, serial number, and disposition of each casualty evacuated will be sent to Landing Force Commander (Corps Hdqts.).

The casualty evacuation officer on the casualty evacuation control LST(H) endeavored to distribute the casualties among the different ships so that no one transport would be overburdened at any time. Unfortunately, this did not always work out. Sometimes the coxswain failed to heed the directions given him or misunderstood them, and sometimes when he arrived at a designated location the ships were not there. Some casualties spent as many as 8 hours in small craft before being taken aboard a ship.

The APA, although not designed for casualty handling, or properly equipped for this purpose, often bore the brunt of the initial casualty load from the beach assault. In the Iwo Jima operation, they received 4,956 wounded by 1745 of D–day–plus–2. The experience of APA *118* was typical of the transports in casualty evacuation. APA *118* dropped anchor about 20,000 yards offshore on D–day and unloaded its troops on schedule. It then moved in to about 4,000 yards from shore and began discharging cargo and supplies. At 1400 on D–Day casualties were received aboard, the majority of whom were severely injured and required emergency treatment. During the next few days, casualties were loaded aboard the ship in groups of from 3 to 75. Throughout much of this period, the medical staff worked day and night operating on and caring for the wounded. As a general rule the ship withdrew out to sea at night, but on two occasions she anchored about a thousand yards offshore and obtained protection by a smoke screen.

The large number of wounded at Iwo Jima emphasized the need for hospital ships, two of which were originally scheduled for the operation. Commencing on D–Day–plus–1, these ships, the *Samaritan* (AH 10) and the *Solace* (AH 5), augmented by the *Pinckney* (APH 2), the *Bountiful* (AH 9), and the reserve hospital ship, *Ozark* (LSV 2), inaugurated a series of shuttle trips from Iwo Jima to Saipan and Guam. By 21 March (D–day–plus–30) a total of 4,879 casualties had been evacuated on these ships.

The only function of the hospital ships was the transportation and care of the sick and wounded, and if some of them could have remained in the area during the early phases of the operation to care for the slightly wounded, many casualties could have been returned to duty in a few days. The loss of manpower occasioned by their departure aboard hospital ships and transports to Saipan or Guam, would have been obviated.

Some hospital ships lacked proper equipment for taking patients aboard (figs. 107, 108, and 109). These ships received many boatloads of injured men from LCVP's, but some had no Welin davits with which to lift the boats to the ship's deck level, and the transfer of patients had to be made over the ship's gangway. This slowed the rate of transfer of patients and as a result, boats loaded with wounded gathered off the gangways of the hospital ships and were obliged to stand for hours in the hot sun with their patients unprotected.

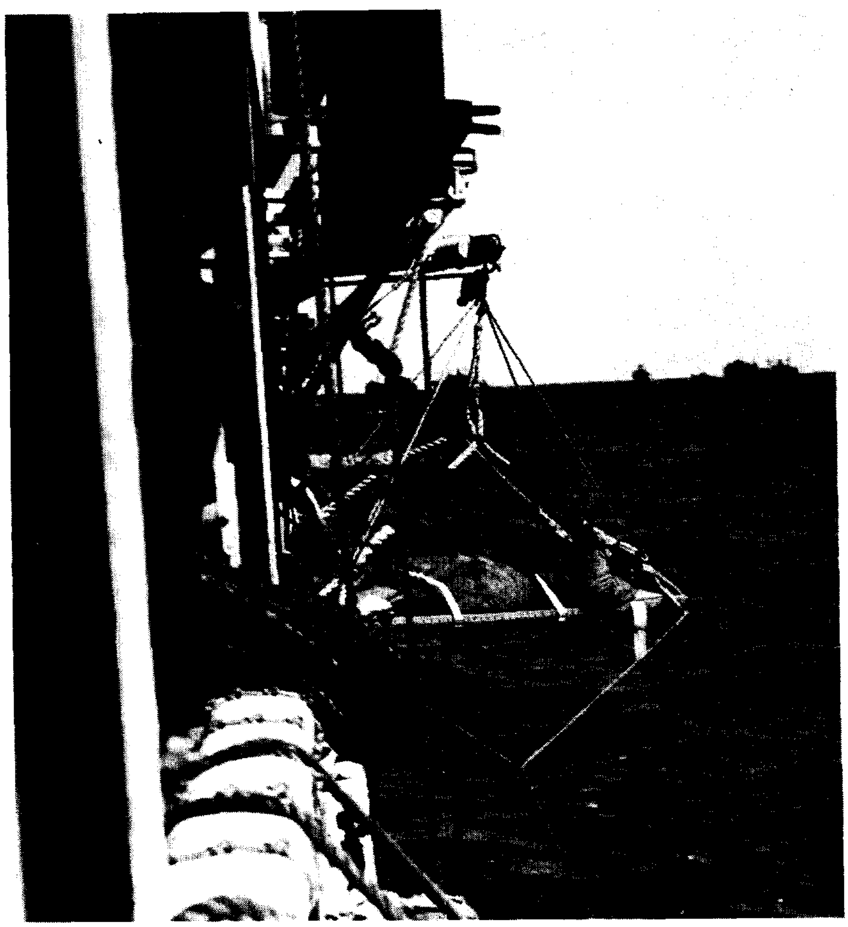

FIGURE 107.—Hoisting a patient aboard the U. S. S. *Solace*.

FIGURE 108.—Transferring patients from an LCV to Hospital Ship H.M.S. *Lancaster.*

Air evacuation from Iwo Jima to the Marianas, which supplemented evacuation by hospital ships and transports, was initiated on D–day–plus–12 and was originally planned for 350 patients per week. The very high casualty rate, however, together with the shortage of ships for transporting casualties, necessitated revision and as many as 200 a day were evacuated by air. There were times when, because of unfavorable sea conditions or lack of facilities afloat, air evacuation was the only means of getting casualties off the island. With the first casualty evacuation planes, there was an air evacuation unit, consisting of two flight surgeons and several hospital corpsmen who screened all casualties to be evacuated by air. By 21 March (D–day–plus–30), a total of 2,393 patients had been evacuated by air. The casualty evacuation planes also brought in whole blood from Guam.

The weakness of a fixed policy for evacuation was again demonstrated at Iwo Jima where a "15-day evacuation" policy had been established. In the early stages of the invasion, there was no place to segregate casualties who would be ready for duty in 15 days or less, and when hundreds of casualties were being evacuated over beaches that were under heavy enemy fire and clogged with vehicles and equipment of all kinds, sorting was not feasible. Time, space, and the combat situation did not permit convalescent camps to be established and such beds as were available ashore were needed for those seriously wounded.

There were a number of ways in which the effectiveness of the chain of evacuation might have been improved. The communication system could have been more efficient during the first days. Casualty evacuation officers aboard the LST(H) often did not receive reports as to which transports were available for loading casualties, with the result that some ships received more than their share while others received very few. Ambulance craft experienced great difficulty in finding the proper vessels. In many cases, the APA stood well offshore, and during rainy, rough, or foggy weather they were difficult to contact. It sometimes occurred that by the time the ambulance craft had reached the approximate station where the transport was supposed to be anchored the ship had already moved.

Despite difficulties such as these, the chain of evacuation operated more smoothly than in any previous action in the Central Pacific. The use of LST(H)'s as casualty evacuation ships represented a most important factor in medical care and unquestionably saved many lives.

Hospitalization

The establishment of hospital facilities on Iwo Jima was delayed because of limited space, difficult beach conditions which interfered with the landing of supplies and equipment, and the constant hazard of enemy artillery and sniper fire. As a result, until D–day–plus–9 nearly all hospitalization was provided by the units afloat. During the early days of the operation, effective hospitalization was provided by four LST(H)'s.

Medical Battalion, Company A, landed on D–day–plus–6, just south of Green Beach, and began to set up an operating room and hospital facilities with provision for expansion. Within 8 hours a hospital unit with 110 beds was established and began to receive casualties. During the next few days, hospital facilities were expanded.

A neurosurgeon, an ophthalmologist, and a neuropsychiatrist were included in the staff of the corps medical battalion and the services of these specialists were made available for all troops engaged in the Iwo Jima operation.

A detailed account of the activities of the Fourth Marine Division Hospital will illustrate the work of hospital units at Iwo Jima. On D–day–plus–6 the division surgeon and commanding officer of the medical battalion located a site for the Fourth Marine Division Hospital, near a good road leading to the front lines and to the evacuation beaches. The Fourth Engineer Battalion bulldozed 5 long trenches, providing space for 4 batteries of 6 storage tents each, 1 battery of 3 storage tents, and the division medical dump. On either side of the road were uncovered water reservoirs. Two of these were used as operating rooms, one as a receiving room, and the other two for Headquarters and Staff Medical Battalion and for the malaria and epidemiology control team. Many times while mortar shells were landing nearby, surgical operations were going on. The engineers had constructed an entrance ramp and erected a wooden framework over each reservoir, with a tarpaulin stretched over the framework. The hospital was receiving casualties on D–day–plus–9, and 6 operating rooms

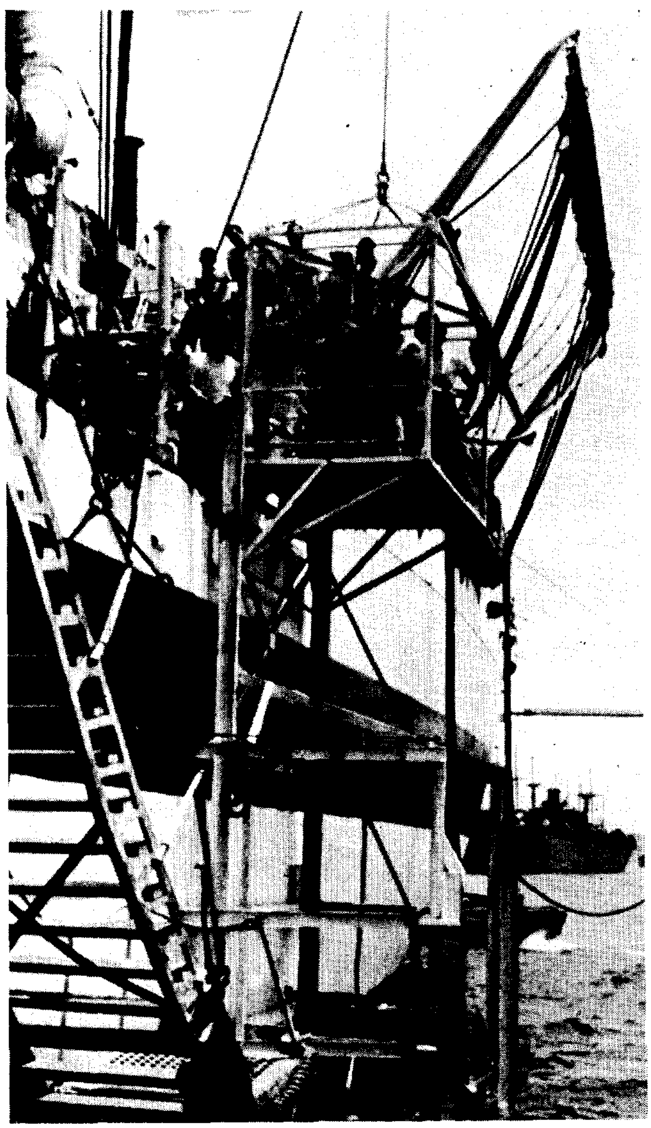

FIGURE 109.—The U.S.S. *Samaritan* anchored off Okinawa. Transferring a patient from a small boat via an elevator rigged over the side of the ship.

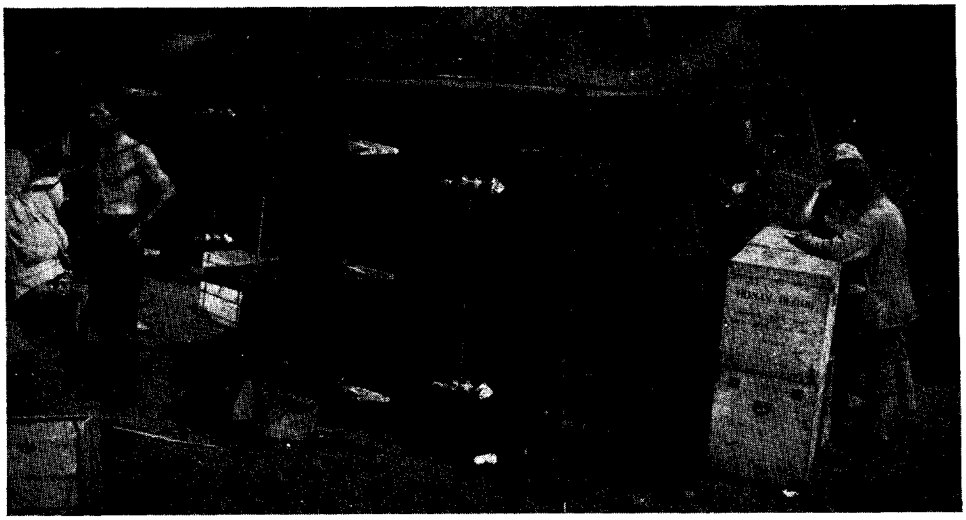

FIGURE 110.—Refrigerator units for the storage of blood plasma and vaccine sera.

and 350 beds were available on D–day–plus–15. It was staffed by 3 medical companies and surgical detachments from 2 companies.

A division central medical supply room was established in the hospital area and the surgical instruments of all five medical companies were pooled, permitting simultaneous sterilization of many sets of instruments, thereby materially lessening the delay between operations.

Sanitation

Because of the porosity of the soil, sanitation presented no major problem. Sunken barrels with prefabricated tops served as heads. The water supply was adequate, being obtained from water trailers.

No outbreaks of intestinal or communicable disease occurred and there were no epidemics. Neither the interrogation of prisoners nor the study and laboratory findings of malaria and epidemic control teams revealed evidence of malaria, dengue, filariasis, typhus fever, cholera, plague, yellow fever, smallpox, diphtheria, or venereal diseases in serious proportions.

Supplies and equipment

One of the innovations was the mobile blood bank facility (figs. 110 and 111). The main items of equipment were two 150-cubic-foot refrigerators, one flake ice machine, three electric generators, one 2½-ton truck, and one ¼-ton truck. The initial supply of whole blood was received aboard on 14 February at the Saipan staging area. Guam furnished 1,456 units, and ships departing from the area furnished an additional 406 units to the bank. Beginning on D–day, the facility furnished whole blood on request to all units ashore or afloat. At all times throughout the operation, the supply of whole blood was ample. This was undoubtedly a material factor in saving many lives.

The field medical unit was of high quality. Oxygen units were extremely valuable because of the high incidence of penetrating chest wounds. Improvised portable fracture tables were used to great advantage. Portable plywood operating rooms proved extremely useful; when water seeped into some of the medical installations at high tide, the slightly elevated deck in these huts kept them dry.

The carbine which was issued to Medical Department personnel in the field for defense purposes was not satisfactory. It was impossible to treat a patient and handle a carbine at the same time; 45-caliber pistols were better suited for this purpose.

The jeep ambulances proved to be the most valuable single piece of motor transport in the medical organization. The Army's 3/4-ton ambulance, used by the 38th Field Hospital,

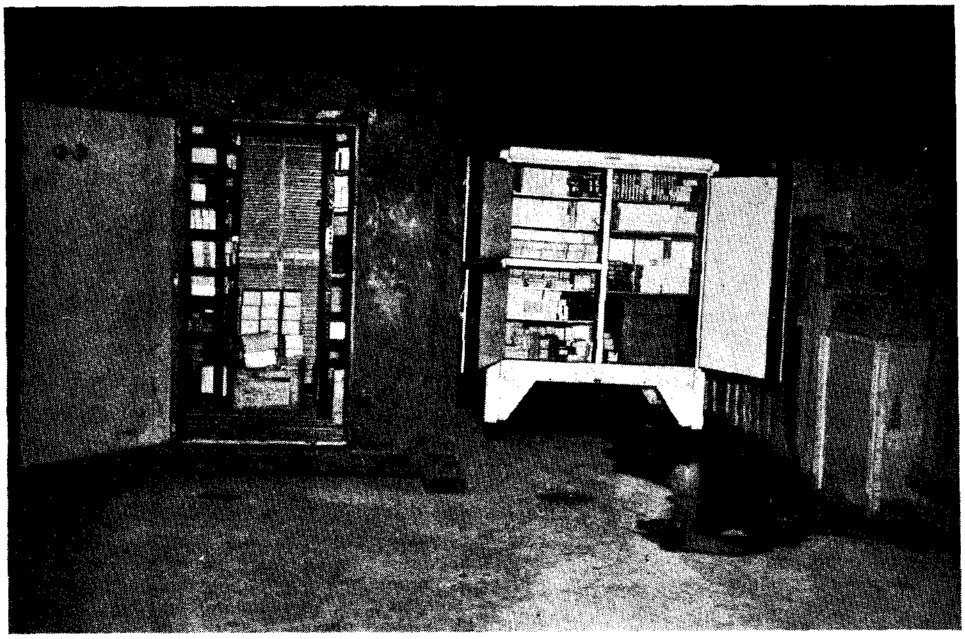

FIGURE 111.—Portable electric refrigerator for storage of biologicals, blood, and plasma.

demonstrated its superiority over the Navy's ½-ton ambulance for casualty evacuation. The Army ambulance could go anywhere that the Navy ambulance could go and transported the casualties in much greater comfort. The Weasels were most valuable in the early stages of the operation; they were among the few vehicles able to get off the road and negotiate the soft volcanic sand. Many DUKW's were also used in the evacuation of casualties, but not enough were available in the early period of the campaign. They were capable of negotiating heavy surf without difficulty and were more manageable alongside a ship than were the amphibious tractors. For days at a time, when no small boats were able to get through the surf, nearly all casualties had to be removed by means of amphibious vehicles, for the most part DUKW's. In almost every operation undertaken in the Pacific area, the DUKW saved the day for casualty evacuation.

Medical records

Deficiencies in the handling of medical records in earlier operations led to a reorganization of this work prior to the Iwo Jima landings. A program of indoctrination for personnel handling records under combat conditions was inaugurated and the importance of making legible entries on emergency medical tags and in aid-station logs and reports was stressed. Nevertheless, reliable records could not be maintained during the first few days because the battle was so intense and loss of personnel and equipment so great that it was difficult or impossible to maintain complete records at regimental and battalion aid stations or at evacuation stations.

Dental service

At Iwo Jima, as on all combat operations, the work of dental officers and technicians was invaluable. Dental officers, in addition to carrying out their regular duties, also assisted in the sick bays and operating rooms. They administered supportive therapy, gave anesthetics and aided in identifying the dead.

Casualties

Table 21 lists casualty and evacuation figures.

On 24 March (D-Day-plus-33), there had been a total of 24,244 casualties (20,950 incident to battle), including 4,893 deaths. Of these casualties, 17,677 had been evacuated. Casualties among medical personnel were very heavy;

TABLE 21.—*Casualties and evacuation—Iwo Jima*

1. Casualties to 13 March 1945 (D-plus-22):

	KIA		WIA		MIA		Total	
	Officers	*Enlisted*	*Officers*	*Enlisted*	*Officers*	*Enlisted*	*Officers*	*Enlisted*
3d MarDiv	35	633	127	2,673	2	120	164	3,426
4th MarDiv	84	1,481	272	5,647	1	95	357	7,223
5th MarDiv	78	1,390	225	5,185	4	197	307	6,772
Corps Troops	1	7	10	83	0	3	11	93
Corps Artillery	0	5	0	11	0	0	0	16
Total	198	3,516	634	13,599	7	415	839	17,530
Grand total	3,714		14,233		422		18,369	

2. Total battle casualties to 1800, 21 March 1945 (D-plus-30):

	Strength	KIA	WIA	MIA	Total	Percent of strength
3d MarDiv (less 3d Marines)	15,681	816	3,162	92	4,070	25.9
4th MarDiv	21,737	1,731	6,058	74	7,863	36.1
5th MarDiv	23,218	1,893	6,188	180	8,261	35.5
VAC LanForc (less 3d, 4th, 5th MarDiv)	9,491	63	324	7	394	4.1
Total	70,127	4,503	15,732	353	20,588	29.3
Percent of total casualties	----------	21.9	76.4	1.7	100	----------

3. Evacuated by water to 21 March 1945 (D-plus-30):

Ship	Stretcher	Ambulatory	Total wounded	Dead	Total dead and wounded
Samaritan 1st trip	400	212	612	11	623
Samaritan 2d trip	400	201	601	8	609
Samaritan 3d trip	[1]	[1]	[1]	[1]	603
Samaritan 4th trip	[1]	[1]	[1]	5	603
Solace 1st trip	490	147	637	3	640
Solace 2d trip	400	269	669	9	678
Solace 3d trip	[1]	[1]	[1]	[1]	568
Bountiful	[1]	[1]	[1]	[1]	555
Pinkney (APH)	390	232	622	8	630
Ozark (LSV)	199	208	407	1	408
LST's (H)	7	1	8	5	13
Transports (APA)	2,606	2,213	4,819	18	4,837
Other ships	[1]	[1]	[1]	[1]	4,240
Total	4,892	3,483	8,375	68	15,007

4. Evacuated by air to 21 March 1945 (D-plus-30). 2,393 casualties.
5. Summary of casualty evacuation to 21 March 1945 (D-plus-30):

Hospital ships	4,879
Other ships	10,126
Air	2,393
Total evacuated	17,398

[1] No breakdown available.

in one division alone, casualties of hospital corpsmen in each of 6 battalions exceeded 50 percent. In 4 battalions, casualties exceeded 60 percent, and in 1, they were in excess of 68 percent. Battle casualties for all division medical personnel exceeded 25 percent.

Okinawa

The offensive against the inner defenses of the Japanese Empire which began with the attack on Iwo Jima in February 1945 was carried a step further in April with the launching of the mighty amphibious attack on Okinawa. The personnel of the Medical Department in the attack on Okinawa now included many veterans of earlier campaigns, who had learned much in the hard school of war; now they had ample opportunity to apply their techniques and skills.

As in previous campaigns, careful medical planning preceded the Okinawa operation. This provided for: (1) Care of the sick and wounded

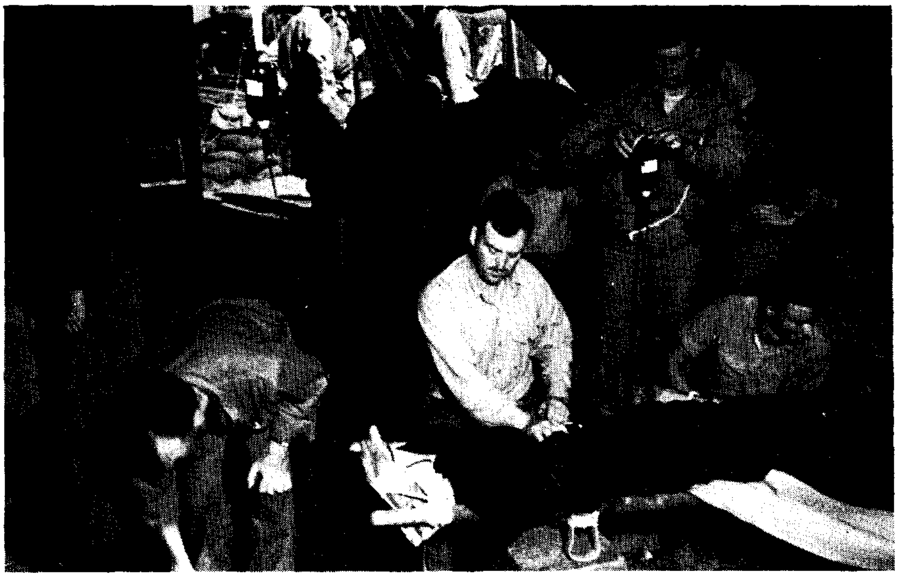

FIGURE 112.—Hospital tent on an Iwo Jima airfield. Note the 2 flasks of blood being administered simultaneously.

(including medical care for the civilian population); (2) evacuation of the sick and wounded; (3) sanitation; and (4) medical logistics. Numerous conferences were held by the surgeons of the Fleet Marine Force, Pacific (First and Sixth Marine Divisions), the Amphibious Forces, Pacific, the III Amphibious Corps, and the Tenth Army, in order to coordinate the medical mission of providing care for nearly 500,000 men of the expeditionary force and 350,000 naval personnel aboard the more than 1,600 ships.

Plans included the establishment of field hospitals for both the First and Sixth Marine Divisions (figs. 112 and 113). Two evacuation hospitals were to be attached to the III Amphib-

FIGURE 113.—Advanced hospital at Koza, Okinawa. Many casualties were treated here and returned to duty.

ious Corps to provide specialists' care for wounded and to assist in the evacuation of casualties. Eight LST(H)'s were to be equipped as beach evacuation control vessels, 4 to be assigned to the Northern Attack Force (the III Amphibious Corps), and 4 to the Southern Attack Force (the XXIV Army Corps). Evacuation from the beaches at Kerama Retto by the Western Islands Attack Group was to be by LCVP directly to 6 hospital ships, 2 APH's, and 2 APA's converted for casualty evacuation. Two of them were to remain at the objective at all times to receive the critically injured. Casualties were to be moved to rear area hospitals in the Marianas, Hawaii, and the United States as rapidly as circumstances would permit. Adequate supplies of whole blood were to be provided for each transport.

Medical planning was based upon experience gained in previous operations. The First Marine Division assigned a medical officer of wide experience in clinical medicine as the representative of the Division Surgeon to investigate health conditions during the operations on Leyte, Guam, and Saipan. Since many of the diseases expected on Okinawa had already been encountered in the Marianas and Philippines, a study of the medical department's experiences in those places proved of great value.

All units of the First Marine Division were instructed in the value of sanitation and the need for sanitary measures during combat. Sanitary squads were trained to operate with each combat team, and to assist in mosquito and fly control. Their work was to be supplemented by that of a malaria and epidemic control unit. Latrines were to be provided by burying 50-gallon drums to about three-quarters of their height and fitting them with prefabricated seats in such a manner as to keep out the flies.

The necessary equipment and supplies to bring all units of the First Marine Division up to standard strength were obtained from the medical supply facilities at Guadalcanal and Espiritu Santo. In numerous instances, however, probably because of a lack of coordination between the various supply facilities, shortages made it necessary to request supplies from Pearl Harbor. First-aid jungle kits, which had been found to be far superior to the standard first-aid packet used at Cape Gloucester and Peleliu, were available for most of the combat troops, but there were not enough vials for salt and atabrine tablets, or bottles for fungicide solution. It was only with great difficulty that sufficient supplies were finally obtained to equip approximately 7,000 jungle kits. Efforts to obtain adequate supplies of brandy, which had been found to be valuable in the treatment of combat fatigue, shock, and exposure were unsuccessful because of disapproval of requisitions by higher medical authority. Plans were made for the extensive use of serum albumin. All supplies and equipment not carried by combat units were dispersed in the five medical companies. Each infantry battalion was assigned 40 hospital corpsmen, permitting the use of two corpsmen to each platoon. Members of each combat unit were assigned as litter bearers. These litter bearers, who were dispersed among the various rifle companies, were trained in first aid and the evacuation of casualties from the frontlines to aid stations.

The Sixth Medical Battalion (Sixth Marine Division), debarked at H–minus–2–hours, and units began landing at H–plus–2–hours. Negligible enemy opposition was encountered. Installations for the emergency handling of casualties under field conditions were set up within 1 hour. All medical equipment was ashore and the Sixth Marine Division hospital was established and functioning by L–day–plus–2. After landing, all organizations dug in, and made preparations against air attack and sniper fire. During the first few days the food consisted of K rations, and the water supply was limited. An insufficient number of blankets had been provided, and some discomfort was experienced by the men because of the rapid change from a tropical to a temperate zone.

A mobile surgical trailer (fig. 114) which had been constructed by medical officers in the training area, proved of great value many times during the Okinawa operation.

The experiences of the III Corps Medical Battalion, Corps Evacuation Hospital No. 2, and Corps Evacuation Hospital No. 3 during the debarkation and landing were unfortunate.

FIGURE 114.—A mobile operating room directly behind the front lines on Okinawa.

As a precaution against enemy air or surface action, personnel and equipment of each of these units had been embarked in three sections on different ships. In following the loading plan it had been impossible to embark the desired number of personnel with their equipment, and on several ships, only a small percentage of those originally assigned could accompany their supplies. In consequence, there was an insufficient number of men to safeguard medical property effectively when it was discharged on the beaches, previous experience having proved that unloading on the beach, unless supervised, would result in extensive loss of materiel. Notwithstanding urgent requests by the units involved and by the corps surgeon, medical supplies were dispersed on numerous landing beaches, which necessitated the expenditure of much effort on the part of medical personnel in attempting to locate and collect their equipment and supplies. It also entailed the loss of valuable time in setting up hospital facilities, nullified the purpose of combat loading, and retarded the employment of medical members for the care and evacuation of wounded.

The Okinawa operation proved the need for a large pool of trained Hospital Corps personnel replacements. The First Marine Division had 478 casualties among Hospital Corps personnel during the campaign in southern Okinawa. Of these, 49 were killed in action, 226 wounded in action, 17 injured, and 186 were sick. Dispatches for urgently needed replacements of medical personnel resulted in some replacements being obtained, of whom only a few had been in combat and had any idea of the duties expected of them. It was the consensus of the medical staff that the best solution was to order a minimum of 100 extra hospital corpsmen to each Marine division at least 2 months prior to an operation. These men could then be trained under experienced personnel. After training with line regiments, the corpsmen could be transferred to the medical battalion where they would be immediately available as replacements.

Battle afloat

Medical units of the fleet also made plans for participation in the operation. Not only Hospital Corps personnel but also entire ships' crews were trained in first aid and the handling of casualties. Battle dressing stations, first-aid stations, and supplies were widely dispersed throughout each ship. Ample medical supplies to meet all anticipated needs were provided aboard the ships and concrete barges, AK's, and AKS's were available for replenishment. Careful preparations to provide the fleet with fresh whole blood in ample quantities throughout the operation were to pay liberal dividends in lives saved during the "kamikaze" attacks by Japanese planes, for these attacks resulted in the largest number of casualties the fleet had experienced during the entire war (fig. 115).

During the initial landing and assault phase of the Okinawa operation, while combat units were experiencing only light opposition, the ships of the Fifth Fleet and supporting units were being subjected to heavy and persistent Japanese "kamikaze" air attacks. The careful plans which the medical staffs had made prior to this operation, while valuable, could not be designed to cope with "kamikaze" attacks directed against small ships.

FIGURE 115.—Hangar deck, U.S.S. *Bunker Hill*—264 men were wounded and 392 killed when hit by two "kamikazes."

Aboard destroyers the medical department could not function as a well-trained, carefully drilled unit because each man was required to render first aid when and where he could. As an example, the U. S. S. *Morrison*, a radar picket and a popular target for the "kamikaze" pilots, was hit by four of them in a period of 10 minutes and rapidly began to go down. Any attempt to establish the main dressing station in a safe area on that ship was futile since such an area did not exist and consequently medical personnel and materiel had been dispersed. The chaos and annihilation were indescribable. The wounded were given such first aid as was possible. Arresting hemorrhage was the sole objective. Only one man was taken to a dressing station and he was trapped there. During the 2 hours that the survivors spent in the water, little more than encouragement could be administered by the medical staff. The heavy layer of fuel oil covering the survivors masked injuries. The medical officer and the uninjured corpsman (one corpsman was killed, another had a compound fracture) swam from group to group giving medical aid where possible. Even after rescue by an LCS, only emergency treatment could be given to the *Morrison's* 90 wounded, because the rescue craft was immediately called upon to take aboard an additional 25 casualties from an LSM(R) which had also been sunk by "kamikaze" planes.

The experiences of the medical staff of the U. S. S. *Morrison* and LCS were repeated over and over in units of the battle fleet, as the Japanese made a desperate attempt to force its retirement. Enemy planes made attacks on 3 hospital ships during the operation. The U. S. S. *Relief* was attacked on 2 April 1945 and the U. S. S. *Solace* on 20 April, but no damage was done. On 28 April the U. S. S. *Comfort* was hit amidships by a "kamikaze," killing 29 and wounding 33. On the same day that the *Comfort* was attacked, the U. S. S. *Pinkney* (APH-2) was also hit amidships by a "kamikaze" resulting in 22 killed, 11 wounded, and 19 missing. Notwithstanding these attacks, the hospital ships carried on their mission and maintained regular shuttle trips from the target to the hospitals in the Marianas.

During the early stages of the Okinawa operation, as a result of repeated "kamikaze" attacks, naval casualties exceeded landing force casualties. Then it became apparent that floating hospital facilities were urgently needed at the objective during the night to care for the wounded men from ships bombed or struck by suicide planes. Hospital ships, under orders to retire each night, were not available. When the two converted APA's, the U. S. S. *Crescent City* and the U. S. S. *Gosper,* arrived, they were designated as casualty ships and were stationed offshore to provide hospitalization at night. Four PCE(R)'s, also available for casualty evacuation from screening ships, proved well suited for rescue purposes.

Casualties

Casualties in the Okinawa operation through 27 May 1945 totaled 38,420. Of these, 28,447 were incurred by Marine and Army combat troops and 9,973 by Navy. The ratio of Marines killed to wounded was 1 to 5; Army, 1 to 4.25; and Navy 1 to 1. The fleet, under constant enemy air attack, including almost daily "kamikaze" attacks, suffered severe casualties. Probably for the first time in naval history the number of killed and missing exceeded the number of wounded.

Medical and surgical problems

Disease and nonbattle casualties ashore were never a serious factor on Okinawa. About 6 percent of the complement became ill. The surgeon, Tenth Army, during the month of April, evacuated personnel for the conditions listed in table 22.

TABLE 22.—*Disease conditions requiring evacuation from Okinawa*

Diagnosis	Number	Percent
Dermatosis	130	10.6
Diarrhea and dysentery	80	6.5
Psychoneurosis	115	9.4
Combat fatigue	305	24.8
Hepatitis	106	8.6
Insect-borne disease	20	1.6
Meningitis	3	0.2
Others	470	38.3
Total	1,229	100.0

Ample fresh whole blood was available to fleet and shore units throughout the Okinawa operation. During April and May a total of 36,684 pints of blood were distributed to base

FIGURE 116.—The bush master. An amphibious tractor equipped as a mobile amphibious operating room.

and fleet hospitals. Of this amount 12,500 pints were shipped by air. In the field hospitals alone, 1,273 surgical operations were performed and 1,057 pints of blood were used.

The First Marine Division in this operation converted amphibious tractors into mobile operating rooms (figs. 116 and 117). One of these mobile operating units was ambushed, but its armor prevented damage to personnel or equipment. The ease with which the mobile operating unit could be effectively blacked out proved invaluable, for it permitted the surgeon to take the patient into a well-lighted operating room at once instead of trying to work with a flashlight under a tarpaulin or in a small crowded blackout tent. During heavy rains and in deep mud they afforded a dry, protected room, and the surgeon had a clean, dry deck on which to stand, in contrast to standing ankle deep in mud and water. Another possible use of these amphibious operating rooms as visualized by the medical staff (although not employed in the Okinawa operation) was to bring surgical facilities to the patient, when evacuation of the patient to a surgical facility was not possible because of terrain, heavy fire, or the accumulation of a large number of seriously wounded in a small area. Utilization of the amphibious tractor as a surgical facility received the enthusiastic support of the line as well as of medical personnel. The amphibious tractor was also found to be useful for moving the collecting station or aid stations (fig. 118); equipment and personnel could be placed in the tractor which could then proceed to the new site across any type of terrain.

The III Corps Medical Battalion, with the aid of a Seabee medical section, converted a discarded radar trailer into a mobile operating room, and on L–day–plus–1 the unit was landed on Blue Beach No. 2 where it functioned as an adjunct to the shore party medical section. It later rejoined its parent organization, to render continuous service throughout the remainder of the Okinawa operation.

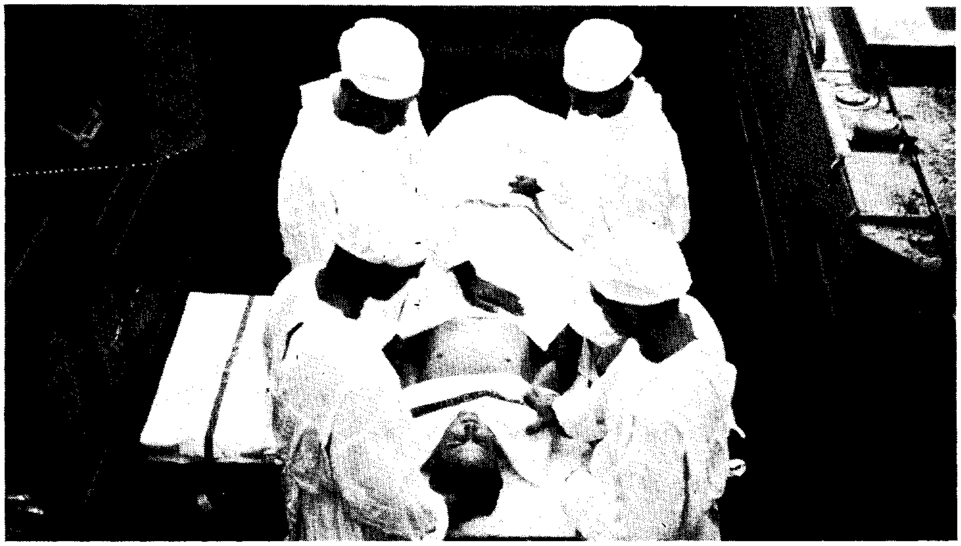

FIGURE 117.—The bush master's operating room in use.

A valuable supplement to the hospitalization program was the operation of a rest camp in a nearby area during the final 3 weeks of the campaign. This camp, an annex to the III Corps Medical Battalion, provided a place to which physically exhausted men could be sent to recuperate. They were thus removed from a hospital atmosphere, and often after a few days' rest could return to their regiments in the line.

Care and evacuation of casualties

The care and evacuation of casualties at Okinawa was well handled. No serious delays occurred at any time, even though transporta-

FIGURE 118.—Transferring the wounded men from amphibious tractor to a landing barge.

tion of casualties was complicated by bomb craters, blown-out bridges, and torrential rains that made the roads almost impassable. Ordinary vehicles bogged down in many instances, and DUKW's and Weasels were required to keep the evacuation moving. Throughout the campaign, evacuation over the primitive roads of Okinawa was slow, bumpy, and shock-producing. In some instances, casualties had to be transported 30 miles to a hospital from an evacuation beach, but in spite of such difficulties, the Sixth Marine Division reported that not once did the elapsed time in transporting a patient from the front to the division field hospital exceed 5 hours, with an average of only 2 hours.

In order to obviate the necessity of bumping patients for miles over bad roads, the Sixth

FIGURE 119.—Evacuating casualties from the front lines by a cub plane.

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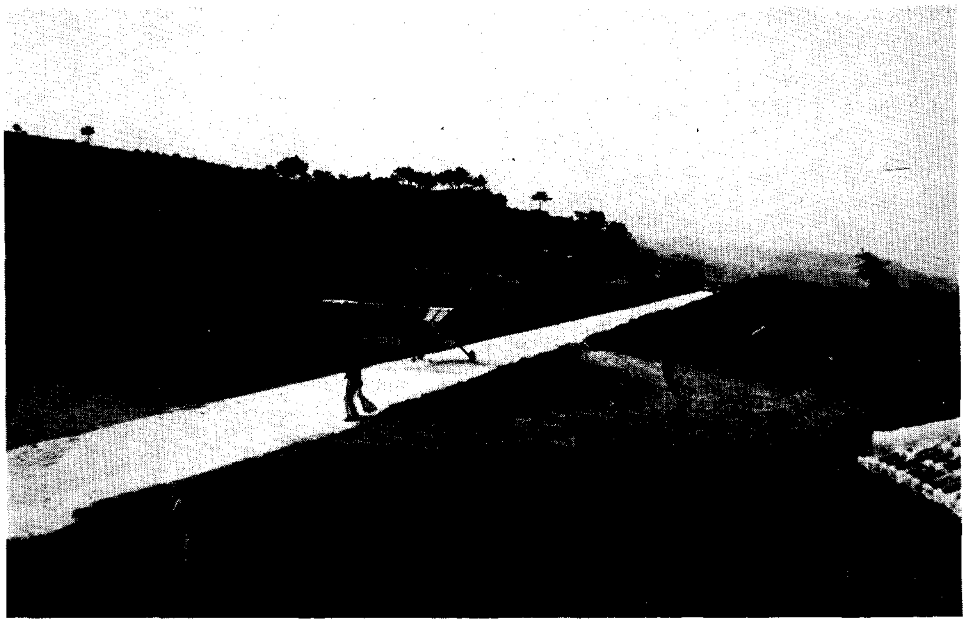

FIGURE 120.—Cub plane taking off from the road-runway with a Marine casualty on board.

FIGURE 121.—Injured man receiving treatment aboard plane.

Marine Division, during its campaign in northern Okinawa, worked out a plan for evacuating casualties by water. Daily an LST(H) was stationed at the nearby port of Nago and all patients who were in condition to be moved were evacuated by this means. From the division field hospital casualties were loaded aboard DUKW's and carried directly to the LST(H), which then distributed them to hospital ships.

During the latter part of the operation in southern Okinawa, extremely heavy and persistent rains rendered roads almost impassable, and it was difficult to move patients even a few miles. Moreover, the wide reef in this area, and rough weather, rendered the sea lanes perilous. In this exigency both the First and Sixth Marine Divisions inaugurated air evacuation by cub planes, which took off from sections of concrete road near their collecting stations and landed on strips adjacent to the division or corps hospitals. Thus the seriously wounded were rapidly and comfortably transported from frontline installations to hospitals where surgical specialists were available. The First Marine Division alone evacuated approximately 800 casualties by cub planes between 11 and 30 June 1945 (figs. 119 and 120). Air evacuation

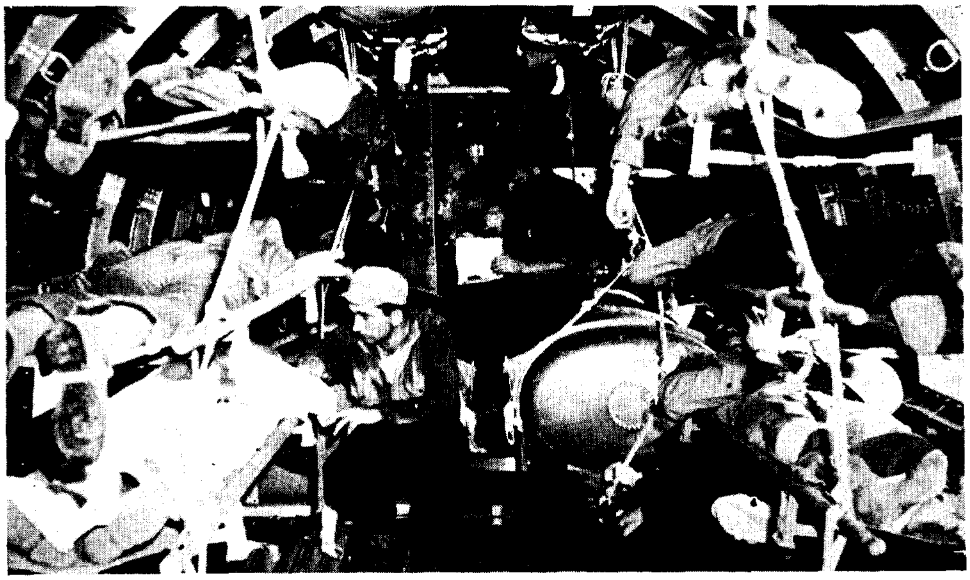

FIGURE 122.—Wounded aboard a transport plane being evacuated to a hospital.

undoubtedly saved many lives and did much to boost morale.

Daily air evacuation from Okinawa to Guam was put into operation by the Naval Air Transport Service and the Army Transport Command early in April. The majority of the seriously wounded were evacuated by hospital ships, but thousands of other casualties were flown out (figs. 121 and 122). Thus local hospital facilities were never overtaxed.

Number of casualties evacuated by hospital ships	11,731
Number of casualties evacuated by surface vessels other than hospital ships (APA, APH, BB)	1,405
Number of casualties evacuated by air (NATS, ATC)	11,771
Total	24,907

Sanitation

Medical intelligence regarding Okinawa placed undue emphasis on the menace of scrub typhus, malaria, schistosomiasis, and snake bite, and underestimated the danger from filariasis. Filariasis was present in the blood of 20 to 35 percent of all natives in every age group. Scrub typhus was not observed, which was surprising because the natives were infested with body and head lice. An extensive investigation of snails, flukes, and leeches on Okinawa failed to reveal any cercaria. Malaria vectors were found. The snake menace failed to materialize; only about a dozen cases of snake bite were reported, no fatalities occurred, and the systemic reactions were not serious.

Okinawa presented many features of medical importance and interest, because practically every disease known in Japan was found there. Had the military forces been called upon to invade Japan, the knowledge gained at Okinawa regarding malaria, dengue, filariasis, diarrhea, dysentery (amebic and bacillary), the venereal diseases, leprosy, tuberculosis, encephalitis, meningitis, Weil's disease, hepatitis, and others would have proved of great value.

At the very outset of the Okinawa operation, effective sanitary measures were instituted. Beachheads were sprayed with DDT from carrier-based planes, beginning on L–day–plus–3. Attached to the combat teams were sanitary squads consisting of 1 hospital corpsman and 19 Marine enlisted men, assigned duty which included sanitation and insect control in the combat area and disposal of enemy dead. The malaria and epidemic control units attached to the Marine divisions performed a valuable service in epidemiologic investigation and in the control of flies and mosquitoes.

Devotion to duty

Examples of conspicuous heroism of medical personnel on Okinawa were numerous. The gallantry and devotion to duty of the hospital corpsmen was stirring, and their heroism under fire was recognized by appropriate awards. As examples are the following men who received the Congressional Medal of Honor:

Bush, Robert Eugene, Hospital Apprentice, First Class, USNR.

Willis, John Harlan, Pharmacist's Mate, First Class, USN.

Halyburton, William D., Pharmacist's Mate, Second Class, USNR.

Pierce, Francis J., Pharmacist's Mate, First Class, USN.

Whalen, George Edward, Pharmacist's Mate, Second Class, USNR.

Williams, Jack, Pharmacist's Mate, Third Class, USNR.

Lester, Fred Faulkner, Hospital Apprentice, First Class, USNR.

Medical Action Afloat

Medical Department personnel of fleet units gave efficient care to the wounded under the severest handicaps imaginable. Both during the Philippine invasion and off Okinawa, under bombing and "kamikaze" attacks that smashed their dressing stations or sank the ship on which they were working, they rendered heroic service (figs. 123 and 124).

The U.S.S. *Pecos,* the last source of fuel for ships in the Tjilatjap area was ordered to intercept two destroyers that had picked up the *Langley's* 450 survivors. Transfer of the survivors from the destroyers took place at 0400 under adverse weather conditions. The boatswain had an especially difficult task in keeping the motor launch steady in the heavy seas while the wounded were hauled aboard. Practically all the survivors were suffering from shock or exhaustion; many were injured. In the sickbay the medical officer and five corpsmen worked unceasingly treating shock, applying splints, and bandaging wounds.

Within 6 hours after the injured had been taken aboard, enemy bombs tore a great hole amidships and started a fire in the *Pecos.* The ship began to sink. Injured men in the forward part of the ship could not reach the main dressing station, and the pharmacist's mate

FIGURE 123.—First aid aboard U.S.S. *Nevada* after Jap "kamikaze" attack.

FIGURE 124.—U.S.S. *Franklin* after "kamikaze" attack—patients being transferred to U.S.S. *Santa Fe.*

there carried on alone. To an already over-crowded sick bay were brought newly burned and injured patients. The medical officer describing his experience said:

> When I heard the machine and antiaircraft guns rattle, I knew that we had about 30 seconds before we would sustain another hit or near miss. We would treat a patient for a few moments and then drop down alongside him, the pharmacist's mate on one side and I on the other, and wait for the ship to jump. As soon as the ship stopped shuddering we would again attend the injured until the next bomb burst. Often the interval was less than a minute.
>
> After 4 hours of this we were ordered to abandon ship. The injured officers and men were carried from the sickbay up the slanting deck to the side of the ship. Kapok-filled mattresses were lashed to those most severely injured and then lowered over the side A well man accompanied each injured man in the water. Men tore down doors and broke out wooden panels to obtain floatable supports. Others made use of bamboo poles which the commanding officer had taken aboard before leaving Tjilatjap; one 10-foot pole gave support to 4 men.

The *Pecos* went down at 1355, with no other vessel in the vicinity. In response to a flare set off by the men in the water, one of the destroyers that had given the *Langley's* survivors to the *Pecos* that morning, arrived at the scene. When the medical officer and the corpsmen got aboard the destroyer, the chief pharmacist's mate in that ship had already laid out all medical equipment on the table in the officers wardroom. It was about 0100 the next morning before all the men had been taken aboard and cared for. "A destroyer with 350 men aboard in heavy weather is not the most comfortable ship in the Navy, but the sick and injured received adequate treatment and were secure in their bunks."

Casualties in fleet units at sea occurred not only from torpedoes, aerial bombs, and gunfire, but also, later, from the unique Japanese weapon—the "kamikaze"—the first of whose attacks was delivered in April 1945.

When the *Princeton* was struck by a heavy aerial bomb carried by a "kamikaze," flames from the explosion caused terrific damage. Both the forward and midship battle dressing stations were rendered useless; the main battle dressing station in the sick bay and the after battle dressing station also had to be evacuated. Casualties included 7 deaths, 92 missing, and 191 wounded, but all patients received prompt, effective treatment. About 1530 the same day, the U.S.S. *Birmingham* came alongside to aid in salvage. A few minutes later a terrific explosion from the after part of the *Princeton* blew off her stern; blast, flames, and debris swept the *Birmingham.* Over half of the *Birmingham's* personnel were wounded or killed by the *Princeton's* explosion. On the main deck alone about 150 men were seriously or critically injured. The executive officer wrote:

> I really have no words at my command to describe adequately the splendid conduct of all hands, wounded and unwounded. Not only was there not the slightest evidence of panic, but there was not a single instance where anything but praise could be given the men. Men with legs off, with arms off, with gaping wounds in their sides, with the tops of their heads furrowed by fragments, would insist, "I'm all right, take care of Joe over there" or "Don't waste morphine on me, commander, just hit me over the head."

At the time of the explosion, the *Birmingham's* senior medical officer was in the U.S.S. *Santa Fe* assisting in the performance of surgical operations. The dental officer was among the first killed, and only the junior medical officer was available. He and the 14 hospital corpsmen, assisted by the officers and men of the ship's company, not only rendered first aid but also performed many surgical operations, including exploration of 5 patients with perforated abdominal wounds, of whom 2 died. Of the 420 wounded patients treated, only 8 died.

On the U.S.S. *New Mexico,* a "kamikaze" landed on the superstructure killing 30 men and wounding 129 others. It was not possible to evacuate the wounded until 13 days later. For the first 4 days following the explosion, the personnel were almost constantly at general quarters and under repeated air attack. This condition placed medical department personnel under a serious strain. Battle dressing stations had to be fully manned during the day to provide first aid for casualties; definitive treatment, for the most part, could not be carried out until night. Critically wounded were put into an air-conditioned ward, but many of the seriously wounded, as well as those with mental illnesses, were of necessity placed in poorly ventilated compartments. The repeated gunfire produced a state of anxiety among the wounded, and their retention aboard the battleship had an adverse effect upon the morale of the crew. "Too much emphasis cannot be placed upon the importance of early evacuation of the wounded from a combatant ship," reported the *New Mexico's* senior medical officer. This, he considered, was as essential as rearming or refueling.

As a direct result of the increased "kamikaze" attacks, nervous tension was high in personnel in ships. Increasing numbers of men had "vague mental complaints," exhibiting irritability, depression, anxiety, and fatigue. The senior medical officer of the aircraft carrier U.S.S. *Cabot* observed that the time required to complete various tasks had increased by as much as 50 percent. Continuous action, "kamikaze" attacks, lack of recreation and rest, and lack of replacement of personnel were all contributing factors in the occurrence of "nervous fatigue." "The action in Lyngayen Gulf," wrote the commanding officer of the U.S.S. *Southard,* "was the severest that the present ship's crew had ever experienced. The numerous calls to general quarters, the sight of suicide attacks on ships in company, the necessity of staying at general quarters during daylight hours for 3 days prior to S-day, and a suicide dive on our own ship, all contributed to the severe nervous strain. As a result, a few members of the crew 'cracked up.' Those who were unable to continue under the nervous pressure were not 'green' and untried personnel, but were men who had been on board ship for a long time."

When the U.S.S. *Maryland* was struck by bombs 29 November 1944, practically all her major medical department installations and equipment were destroyed. However, because of adequate distribution of supplies to the four battle dressing stations, the ability to render efficient and effective treatment was not jeopardized and Medical Department personnel carried on, often despite their own serious injuries. The senior dental officer, who had received second degree face burns, administered to the wounded until ordered to bed.

On 7 April 1945, a Japanese dive bomber crashed into the U.S.S. *Maryland.* At the moment the plane struck the ship, medical officers and hospital corps personnel at their battle dressing and collecting stations were ready to receive casualties. Operating tables were set up. Blood, plasma, serum albumin, sulfonamides, morphine, petrolatum, splints, bandages, dressings, and instruments were ready. Medical Department personnel wearing flashproof clothing immediately proceeded to the scene of damage and fire regardless of exploding 20-mm. shells, cared for the injured, controlled hemorrhage, applied splints, and administered morphine while stretcher bearers filled out casualty tags. Even before the fires were extinguished, the injured had received first aid and had been evacuated to collecting stations where transfusions of blood and plasma and other supportive treatment were administered. At the battle dressing stations, a well coordinated surgical operating team was ready to carry out definitive care and treatment for the seriously injured.

The reaction of personnel during emergency at times was unusual. "During all of the excitement of being hit, firing at the enemy, seeing mangled bodies, and wounded shipmates," wrote one senior medical officer, "no one exhibited any hysterical reactions or maniacal tendencies, nor was there any unnecessary shouting. Everyone rose to the occasion and performed his duty. The hospital corpsmen behaved with admirable calm and were too busy aiding the wounded to become excited. So strong was the fighting spirit and sense of duty of the men at gun stations that cases were reported of critically injured personnel, with a hand or foot blown off, carrying on at their stations."

When the U.S.S. *Pensacola* was hit, 3 officers and 14 men lost their lives and 120 officers and men were wounded. Medical care and treatment were so prompt and thorough that not one death occurred among the wounded who survived the first hour. Medical Department personnel were tireless in their efforts and rested only when exhaustion made rest mandatory.

When the U.S.S. *Terry* was hit, the crew showed great proficiency in giving first aid to the wounded. Medical officers who subsequently received the wounded found them in excellent condition—hemorrhage had been checked, shock treatment had been given, and wounds efficiently dressed. This efficiency in first aid was achieved because of the continuing instruction given the crew.

FIGURE 125.—First aid to Filipino mother and her child on the invasion beach at Leyte, Philippine Islands.

FIGURE 126.—Hospital corpsmen with a Marine division on Saipan administering first aid to civilians.

Prisoners of War and Enemy Civilians

The military operations on the islands of the Pacific, particularly on Saipan, Tinian, Guam, Philippine Islands, and Okinawa, presented the medical companies of assault battalions with the problem of providing medical care not only for military personnel but also for the thousands of civilians on these islands, many of whom had been wounded. About 10 percent of

FIGURE 127.—Hospital facilities for enemy civilians were established at the earliest opportunity.

FIGURE 128.—Sick call for natives in the Solomons.

the population were sick and required treatment (figs. 125 and 126) ; tuberculosis, pneumonia, diseases of the eye, and helminthic infections were common, as was malnutrition. On Tinian a 100-bed G-6 unit for civilian use was to have been landed between J-4 and 6, but this was delayed. Therefore, the 2d and 4th Marine Medical Battalions jointly set up a hospital to accommodate 1,250 patients and made use of 2 surgical LST's for operating room requirements.

On Saipan, no hospital facility was available for enemy civilians until 2 months after the island was secured, at which time the Army set

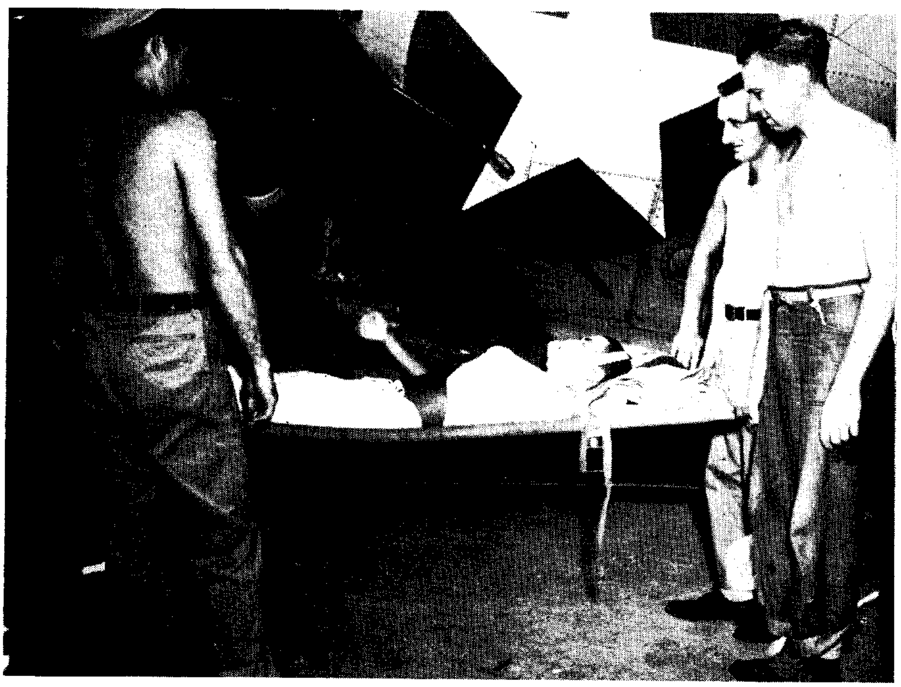

FIGURE 129.—Wounded Japanese prisoner of war being carried aboard a V2F for transportation to a hospital on Guadalcanal.

FIGURE 130.—Dental care for a young Majuro.

up a 500-bed hospital. In the meantime an average of 950 patients a day sought treatment at the military government sick bay. A Civilian Public Affairs unit was landed, but the Public Health Surgeon and the pharmacists accompanying him had no equipment or supplies

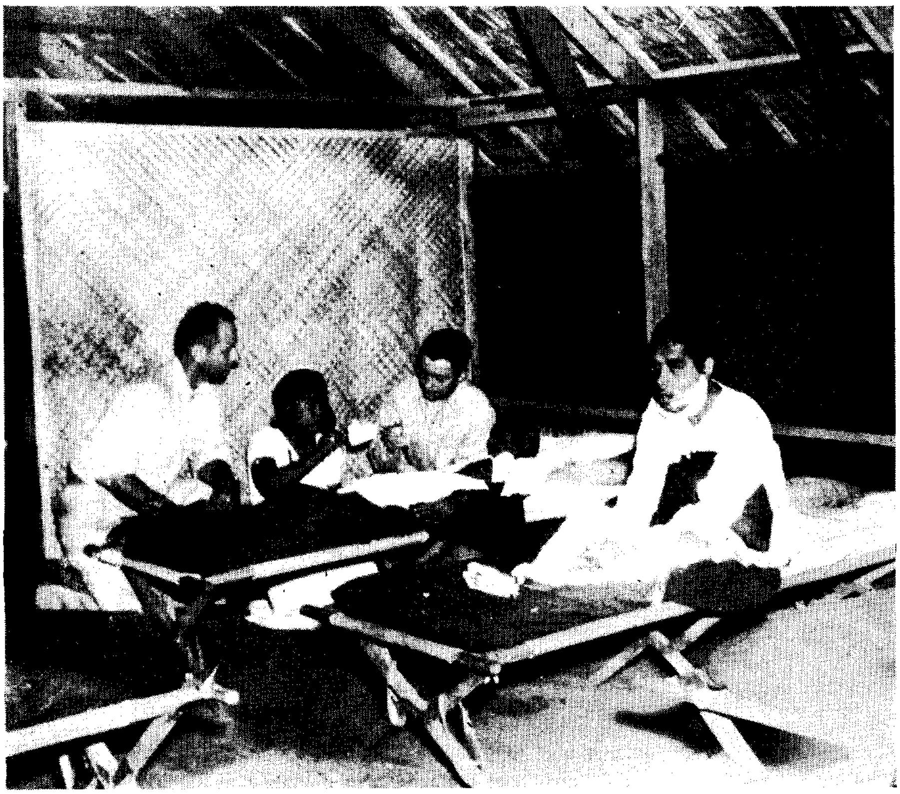

FIGURE 131.—Hospital care for natives on Majuro landing.

other than two field medical kits. To provide medical care for civilians required medical personnel in the ratio of 2 medical officers and 8 corpsmen for each 6,000 population.

Japanese propaganda had convinced the native population that the landing of United States forces on the island would result in their death or torture, but the highly efficient and humane treatment of the natives by medical personnel attached to combat troops or Military Government hospitals (figs. 127 and 128) provided most effective counterpropaganda. On Okinawa, many native children and women had self-inflicted wounds, which had been made in a desire for death in preference to capture. The natives were both astonished and grateful for the merciful attention given them.

Prisoners of war requiring medical care (fig. 129), were given the same treatment as our own casualties, and were evacuated to a Corps Medical Battalion, hospital ship, prisoner of war ship, or other ship, for further care and disposition.

For the civilians in these islands, adequate hospital facilities were erected with the assistance of native labor (figs. 130 and 131) and native women, instructed in nursing care, proved to be excellent nurses.

Normandy

The invasion of Normandy on 6 June 1944 heralded the beginning of the largest amphibious landing in history. The medical logistic plan provided that the care of casualties from enemy action during the invasion was to be an Army commitment. Naval medical activities were to care for casualties resulting from loading accidents or near-shore enemy action; they were to receive from the Army any naval casualties returned from the far shore and any patients who were in poor condition on arrival at a near-shore unloading point. The return of casualties from the far shore was to be a Navy commitment for which purpose LST's were to be used (fig. 132). Alterations were made in the 106 LST's allotted to make them suitable for casualty handling, and each had sufficient medical supplies and equipment to provide sur-

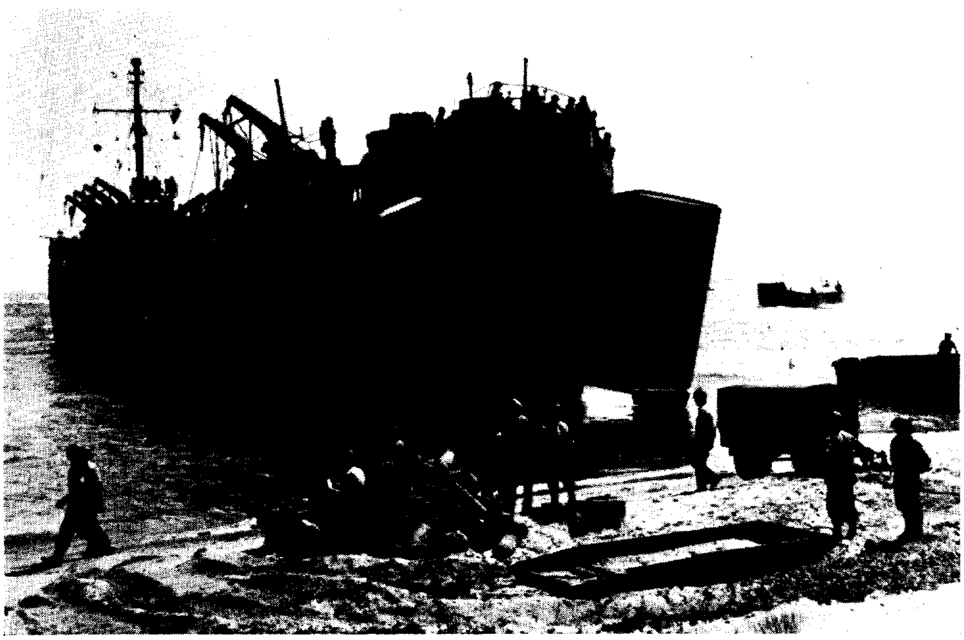

FIGURE 132.—LST landing men and supplies on the beach in Southern France.

gical and nursing care for 200 patients on the return trip to the United Kingdom. To resupply them, medical supply dumps were established at Southampton, Portland-Weymouth, and Brixham.

It was estimated that 0.17 percent of the landing force would become casualties and it was planned that initially all ineffectives, except nontransportables, were to be evacuated. Later there was to be established a policy of holding casualties ashore for 7 days, then if conditions permitted, for 15 days, and eventually for 30 days or longer. The plan of evacuation further provided that: (*a*) Except for ineffectives occurring in landing craft en route to beaches, for whom first aid was to be given, no casualties would be evacuated seaward until the assault battalions had landed; and (*b*) all seaward evacuation of wounded was to be controlled by navy beachmasters, who were to determine the means and the ships to which they should be sent. During the early hours of the assault on D-day, medical personnel functioned as independent units wherever and whenever they reached the beach, no attempt being made to contact each other. Initially, 6 medical sections of the Sixth Beach Battalion and 3 medical sections of the Seventh Beach Battalion were committed to the Omaha Beach, and 6 medical sections of the Second Beach Battalion were committed to the Utah Beach (casualties among the latter: 1 officer and 7 men killed and 12 men wounded). By D–day–plus–1, all remaining medical sections of the beach battalions had landed on the designated beaches.

The first naval medical elements landed at H–hour–plus–40 minutes. On Omaha Beach the military situation was such as to limit medical service to primary first aid. This situation prevailed until late on D–day. The initial casualties on Utah Beach were relatively light and general organization was more readily established.

During the early hours of D–day on Utah Beach, all possible means of seaward evacuation were used, including DUKW's, LCVP's and LCT's (figs. 133, 134, and 135). Jeeps fitted to carry litters were used to transport patients to evacuation craft; as many as 200 casualties per hour were loaded in this way. Most of the casualties were transferred to LST's, although

FIGURE 133.—(Foreground) Casualties being carried aboard an LST on an invasion beach in France.

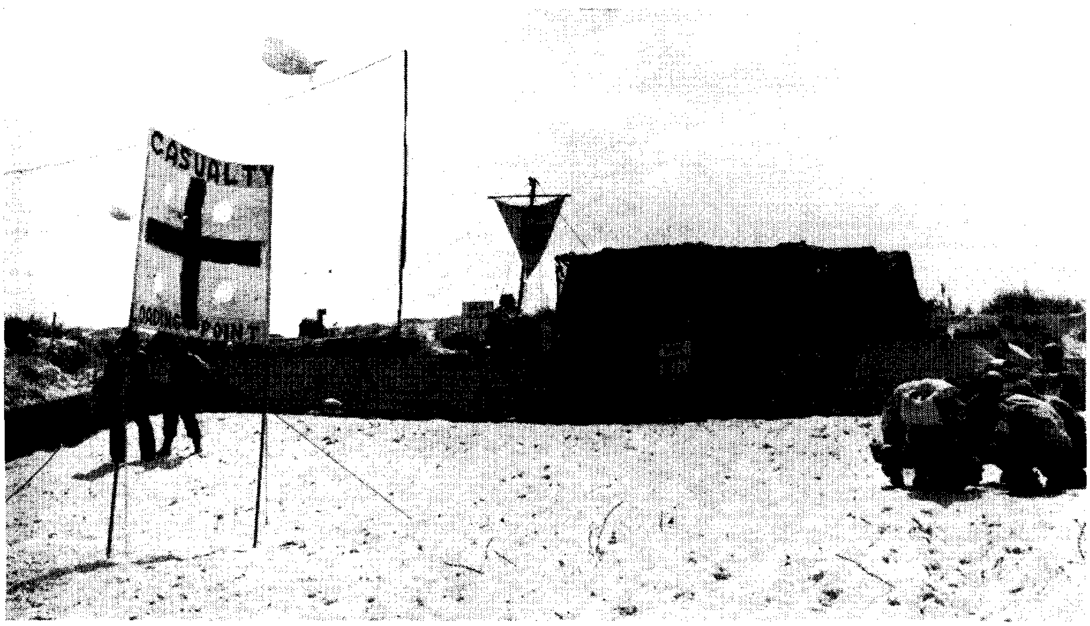

FIGURE 134.—Casualty loading station on a beach in Southern France.

in some instances patients were conveyed to hospital carriers and other ships, particularly during the early hours when LST's could not beach. At times it was necessary to transfer casualties from DUKW's to LCT's offshore.

In the shore-to-ship phase any boats used in the amphibious operations were to be used to evacuate casualties from the beach, while LST's were to provide the main casualty lift for shore-to-shore evacuation. LCT's were to carry ambulatory patients; transports were to provide casualty lifts as the military situation per-

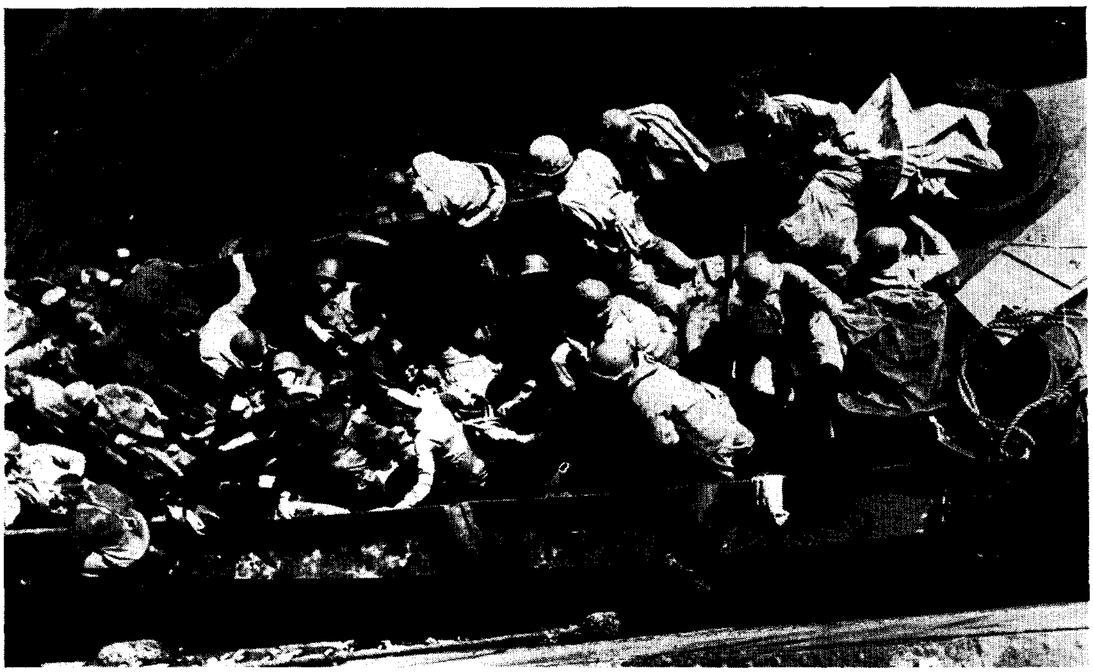

FIGURE 135.—Bringing the wounded, including German prisoners, to U.S.S. *Texas*.

mitted; hospital carriers were to be available after D-day-plus-1; and hospital ships were to be used for evacuation to major ports in the United States.

Converted assault LST's were the principal casualty carriers. The conversion was evolved from experiments conducted during the fall of 1943 by the Planning Division of the Bureau of Medicine and Surgery jointly with the Sixth Amphibious Force. The basic structural changes provided for were: (*a*) Demountable brackets (fig. 136) to accommodate 147 litters arranged in tiers 3 high—24 tiers along the starboard bulkhead and 25 along the port bulkhead of the tank deck; (*b*) in the afterport corner of the tank deck one slop sink, a light over the sink, double electric outlet, and folding counter for portable sterilizer and trays, all enclosed by a removable metal cage; (*c*) suitable stowage facilities for litters and bracket arms on lateral bulkheads; (*d*) two mounting brackets for operating lights mounted in a suitable location over a mess table in the crew's mess room.

Special equipment for each converted LST included:

Item	*Number per LST*
Litter, metal pole	300
Special Unit A, Emergency surgical dressing	16
Special Unit B, pouch, medical officer's individual equipment	4
Special Unit C, pouch, hospital corpsmen's individual equipment	40
Medical resupply unit for beach battalion (beach bag)	16
Bunk strap	400

On D-day, there were 103 LST's in the task force. Of these, 54 had been structurally converted for casualty handling, the remaining 49 being implemented only with additional medical personnel and supplies. The concept of providing all LST's with the means to treat casualties proved invaluable during the initial period of the assault. As evacuation became organized, only designated LST's were assigned the evacuation task.

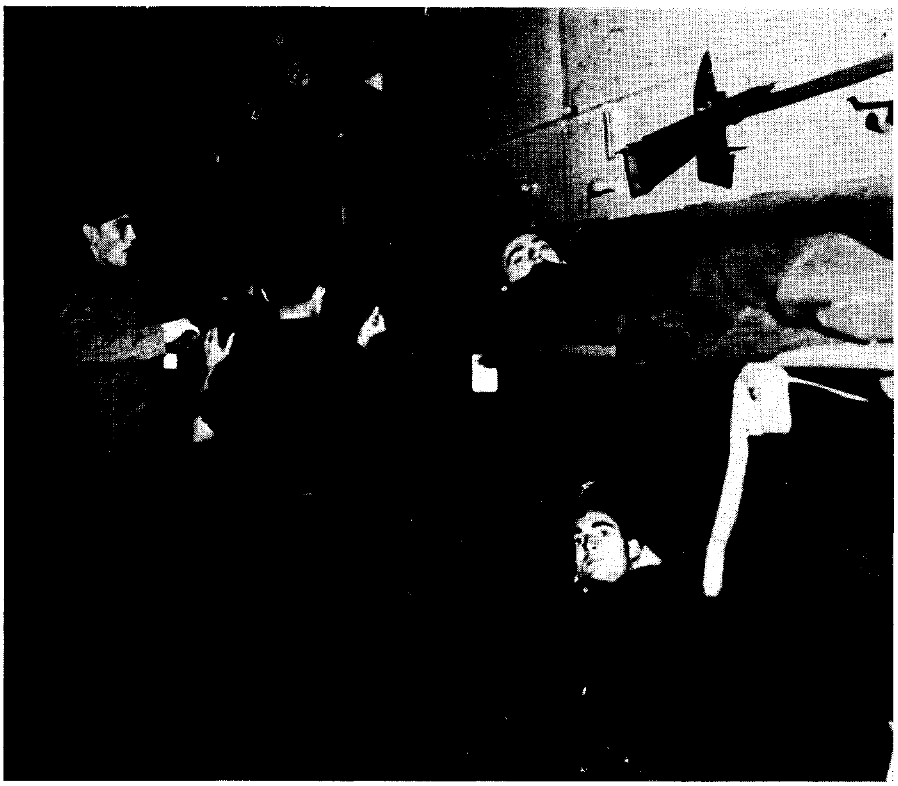

FIGURE 136.—LST showing the demountable brackets.

Hospital carriers proved to be unsatisfactory for evacuation of casualties largely because they had to anchor far from the shore, were furnished no casualty-handling equipment, and medical personnel embarked had had no special training in the evacuation of casualties. British hospital carriers were available but some difficulty was experienced in transferring casualties to them because the United States-type litters did not fit well in their Higgins-type ambulance boats.

The near-shore medical facilities at Portland, Plymouth, Falmouth, and Southampton functioned satisfactorily for the most part. One exception occurred at Portland, from D–day–plus–4 to D–day–plus–7, when 67 LST's waited to unload patients. Operational units responsible for the military success of the Normandy landings insisted on the priority of loading, regardless of casualties. Because of this, the LST's were retained outside the breakwater, necessitating unloading of casualties to LCT's from which they were transferred to other LCT's made available specifically for this service. In one period of 3 hours, 1,100 patients were disembarked in this manner. Approximately 12,834 patients were unloaded at Portland by D-day-plus-22, and 6,065 at Southampton.

Battle casualties were efficiently recorded, and information was supplied to the central recording section within a few hours after debarkation. By 5 July (D-day-plus-29), 23,377 casualties had been reported to the Service Force Casualty Section; 22,455 were known to have debarked in England. A breakdown of the 23,377 casualties showed: U.S. Navy, 2,078; U.S. Coast Guard, 76; U.S. Army, 17,247; Allies, 1,298; and prisoners of war, 2,678.

Casualties on D-day-plus-114 included: U.S. Navy, 2,433 (363 dead and 2,070 wounded); U.S. Coast Guard, 117 (25 dead and 92 wounded); U.S. Army, 41,147 (124 dead and 41,023 wounded); Allies, 1,899 (5 dead and 1,894 wounded); and prisoners of war, 9,911 (4 dead and 9,907 wounded). Of these, LST's carried a total of 41,035, the average casualty lift being 123.

The ratio of Army to Navy wounded was approximately 11 to 1. The Navy received slightly more wounds per man, and of the Navy wounded a higher percentage had severe wounds. Burns and blast injuries, wounds of the head, face, and neck, and simple fractures were higher among Navy personnel. In the Army, wounds of the extremities were 13 percent higher than in the Navy. Accidental injuries of the extremities were approximately four times higher in the Navy than in the Army. The percentage of chest wounds among Army personnel was nearly twice that of the Navy. The incidence of disease in the Army was approximately double that in the Navy.

Sicily

The Medical Department plans for the invasion of Sicily included the following: (*a*) Provide medical and surgical care for all personnel on Navy vessels from the time of embarkation until they landed on the invasion beaches, (*b*) evacuate the sick and wounded from the beaches during the assault phase, until adequate medical facilities were established ashore, and (*c*) thoroughly indoctrinate boat crews in first-aid procedure.

The wounded were evacuated to AP's, APA's, and AKA's. The average number of casualties for each AP and APA was 40 to 45. Army hospital facilities were operating ashore by D-day-plus-2.

About 15 hospital ships and hospital carriers were available in the Mediterranean; 2 of these were Army hospital ships and the remainder British and Canadian. The plan for their operational control by higher echelon was complicated and therefore a certain amount of confusion resulted. These ships had to be used for the evacuation of casualties after the transports left the combat area, and often too much time was required to obtain their services or they failed to arrive at the appointed hour. As a result, Army hospitals in Sicily became overloaded awaiting their arrival.

The experience with hospital ships in the Sicilian operation prompted the inauguration of certain changes concerning their use, and all, regardless of nationality, were placed under the operational control of Allied Force Headquarters. They operated on a prearranged schedule during the crucial period of D-day to D-day-plus-5.

Army transport planes began the evacuation of patients from Omaha Beach on D-day-plus-4, 10 days ahead of schedule. By D-day-plus-10 there was little need for hospital ships and LST's, and air transport proved adequate. During a storm from D-day-plus-13 to D-day-plus-16, when it was impossible to evacuate patients by sea, the air transports succeeded in evacuating about 1,890 patients. By D-day-plus-17, air evacuation was used almost exclusively, except for ambulatory patients who were evacuated by ship.

The Commander of the Sixth Amphibious Force made the following comments regarding Medical Department facilities in the Sicilian invasion:

1. The methods of handling casualties seemed adequate.

2. Further training of boat crews in the use of casualty handling equipment was indicated.

3. First-aid training seemed adequate—the majority of patients received on board were in good condition.

4. The number of medical personnel in all echelons was adequate.

5. Medical personnel in transports, although very busy during and immediately following the action, could possibly have handled more casualties.

6. Dental officers were not fully utilized in the team play.

7. The number of Hospital Corps ratings was sufficient for this operation. With a capacity load of casualties, their services, of necessity, would have been more restricted.

8. Evidence of the need for more intensive training of hospital corpsmen in transports was apparent. Every vessel carrying a medical officer should have one operating room technician and each APA should have two. These technicians should receive their training prior to being assigned to duties afloat.

9. Medical supplies and equipment on hand were adequate for needs, and in most instances would have been adequate for a capacity load.

10. Medical preparations for this operation were generally excellent throughout the force.

11. What few deficiencies were noted or complained of in the vessels afloat, could be traced to a failure on the part of the senior medical officers to comply with directives. In a few instances, there appeared to be lack of foresight and imagination.

The following comments regarding converted LST's were made by the Force Surgeon:

1. Toilet facilities on the tank deck were inadequate.

2. Structural factors made transporting of patients in litters into troop spaces difficult.

3. The top tier of stretcher racks was inaccessible owing to its height from deck.

4. The platform at the afterend of the tank deck was located directly below the forced draft ventilators; this created undesirable air movement and precipitation of moisture in the surgery area.

5. Future alterations should include openings from the tank deck into the troop spaces.

6. Improvement should be made in sanitary facilities.

7. Better access should be provided for the handling of litters.

8. The receiving ward, wash room, and operating room should be located in the troop spaces with entry and egress provided to the tank deck.

9. Demountable ladders should be provided to the escape hatches.

10. Permanent stowage space should be allocated in each ship for such supplemental medical materiel as may be authorized.

Hospital carriers (British type)

Comments:

1. Attached ambulance boats were not adapted to carrying Navy standard pole litters and were difficult to load.

2. These vessels had no casualty-handling equipment other than that which was required to hoist their own special ambulance boats for unloading casualties.

3. Medical personnel in these vessels had no special training for the task.

4. In the operation, their movements were controlled by the British Ministry of War Transportation, a fact which led to much confusion and materially interfered with efficient employment.

5. In spite of the difficulties listed above, between D-day and D-day-plus-11, these vessels completed 6 trips, evacuating approximately 2,272 casualties.

Salerno

The following observations were made during the operations at Salerno (fig. 137):

1. The long distance to the medical storehouse at Casablanca made barter with the Army and other ships in the vicinity the most feasible method of securing supplies. Fortunately, an excess of materiel at Arzew was sufficient to meet some of the immediate needs.

2. Commanding officers in some instances failed to acquaint the medical officer with the plan to be followed.

3. Medical reports were not always received after the operation, and often those received showed a complete lack of familiarity with the reports.

4. There was marked congestion on the beaches. In some instances the medical beach party was set up too close to the main road, and too near the unloading areas, which might draw aerial attacks. The only marking, a vertical red cross which had been promptly spread on the ground near the shelter, made the medical station even more readily discernible from the air.

5. Sandbag protections should have been more substantial and high enough to protect a man seated on the ground. These protective areas should have been large enough to enclose 20 patients and all medical personnel. Multiple small enclosures were found to be preferable to larger single barriers.

6. The work of the beach medical officers (fig. 138) was carried on with a high degree of skill and courage. Prompt treatment was accorded all patients, including some civilians, all of whom should have been treated ashore

FIGURE 137.—Landing supplies on the beach at Salerno, Italy

258015—53——10

FIGURE 138.—Rendering first aid on the invasion beach.

and not aboard ships, as happened in a few instances. Patients often were sent to ships not equipped for their care. The evacuation of patients to any ship available was not good practice, because on a small ship with limited personnel and equipment the care that could be given was no better than that available on the beach. Evacuation of patients from shore to ship during the period between the departure of transports and the arrival of hospital ships was considered undesirable, and beach medical officers should have been prepared to provide treatment for patients until proper facilities for evacuation became available.

Dental Officers' Experiences in Battle

During the war dental officers showed great professional capability and ingenuity under all environments. When they were prisoners of war, they made alloy for dental amalgam by filing the Philippine pesos (these had to be smuggled in), and extracted mercury by heating calomel. Sterilizers, chairs, and cabinets were constructed from junked material, and dental instruments were fashioned from many items in everyday use.

The professional abilities of the dental officer are exemplified in the following exerpts from their letters to the Bureau:

U.S.S. *Vincennes*

During the battle, the sick bay was destroyed by gun fire and the senior medical officer and all the corpsmen except one were killed. It is of interest to note that the man on the operating table receiving treatment at that time escaped from the compartment and survived. Casualties of various types came to my dressing station for medical treatment. Many were burned, one was without an arm, one crawled in with his leg dangling and his face and arms burned.

While we were administering first aid (which consisted mostly of supplying battle dressing, stopping hemorrhage, and relieving pain), our compartment received direct hits from enemy shells. Later, the ship listed and the compartment began filling with water. I sent a metalsmith, who had just been treated for minor burns, to find an escape hatch while the one remaining corpsman and I moved the medical supplies and the patients away from the inpouring water. An escape hatch was found in the compartment forward and through it we hoisted all the unconscious patients. Upon my arrival topside, I found that the ship had been abandoned. I walked across the starboard side of the ship, which was now facing skyward, and slid down into the water. Upon looking back and before a minute had passed, I could see the ship's stern pointing sharply into the air and then it quickly disappeared beneath the surface of the water.

Later, on finding a raft, many wounded were lifted aboard and given first aid. Before abandoning ship, I had pocketed morphine syrettes and burn jelly, both of which were used to treat the wounded aboard the raft. Soon after daybreak we were rescued by the destroyer *Mugford*. The wardroom in this ship was converted into an emergency operating room and the seriously wounded were treated. All members of the Medical Department who were not seriously injured gave treatment to men.

U. S. S. *Solace*

This report will deal briefly with maxillofacial injuries. A few statistics will be presented, although the figures represent an *unfair* minimum, for there were considerably more maxillofacial injuries embarked on this vessel than the figures indicate. The reason for the discrepancy was that frequently casualties were brought aboard with a diagnosis of *multiple wounds*, and in these patients the treatment of thoracic, abdominal, or intracranial wounds took precedence over the maxillofacial injury. Critically ill men were given minimum or no maxillofacial treatment; in many of these patients the dental officer didn't even see the patient because the maxillofacial injury was of secondary importance.

The figures in table 23 indicate the number of maxillofacial injuries treated in the *Solace*.

TABLE 23.—*Maxillofacial battle casualties treated in the "Solace"*

Operational theater	Mandible	Maxilla and/or malar bone
Tarawa	11	3
Kwajalein	3	1
Eniwetok	11	3
Saipan (2 operations)	14	4
Guam (2 operations)	13	4
Iwo Jima (3 trips)	28	10
Okinawa (7 trips)	23	9
Total	103	34

Mandibular fractures were three times more common than maxillary fractures. Often, a patient had extensive lacerations of the face, with exposure of the antrum of Highmore or a parotid fistula, and yet the maxilla escaped fracture. Simple fractures of the alveolar process usually presented no problem other than the decision whether to extract the teeth involved in the fracture. The most difficult to handle were comminuted fractures of both jaws. Fortunately, these were relatively uncommon. Chemotherapy was routinely employed; an attempt was made to maintain an optimal blood level of penicillin and sulfadiazine, using 20,000 units of penicillin intramuscularly every 3 hours, supplemented by sulfadiazine, throughout the critical period. Penicillin and the sulfonamides were in a large measure directly responsible for the great reduction in infections. Even where infection could be anticipated because of the necessity to work with only the most meager asepsis, little serious infection occurred.

When this vessel functioned as a fleet station hospital (at Manus and Ulithi), the dental service and EENT were the most overworked departments. One of the most frequent messages received was a request for so many dental appointments for such-and-such ship. It became quite obvious that here was an excellent indication for the expansion of operative and prosthetic facilities. More of this type of dentistry might have been concentrated at fleet anchorage; at no time were there enough dental officers in this area to meet the demand.

The maxillofacial surgeon was particularly useful in a hospital ship during the embarkation of fresh casualties and the subsequent evacuation trip to the nearest base hospital. He could institute early treatment; this was particularly important. He was needed on hospital ships but the greatest need for his services was at base hospitals established near the action theaters. Here elective treatment could be instituted, and definitive work could be carried out at a State-side hospital. It was important fully to organize early treatment in maxillofacial injury.

Over 60 percent of our patients were victims of one form or another of high explosive fragmentation shells. Other types of traumatizing agents were: (*a*) Bullet wounds (about 30 percent); (*b*) operational trauma (about 3 percent); and (*c*) miscellaneous trauma, such as from *booby traps* (about 2½ percent).

I was impressed with the many tracheotomies performed right on the beachhead in the instance of maxillofacial injury. The uneventful manner in which these patients recovered from tracheotomy sold me on the benefits of this operation. All patients who had a tracheotomy were comfortable and resting well in spite of gross swelling and damage to facial tissues.

Another and more dramatic first-aid surgical procedure frequently instituted by the battalion medical officer in the frontline, to check severe hemorrhage in facial injury, was the ligation of the common carotid artery and the internal juglar vein. I thought the ligation of the external carotid might have solved the problem in a patient brought to my attention, but I didn't fully realize the difficulty of dissecting and identifying anatomical structures in a bleeding patient while both the physician and the patient were under enemy gunfire. It was considerably more expedient to locate and ligate the common carotid artery than it was to dig for the external carotid branch. After all, the operation was a heroic, lifesaving gesture. In two of these patients I saw the clearly defined signs of Horner's ocular syndrome and throughout my entire period of observation the symptoms did not improve. However, the patients were very much alive and were undergoing maxillofacial treatment.

In the large majority of comminuted fractured jaws, it was the general policy to establish adequate drainage as soon as possible. For this purpose a Penrose drain (rubber, through and through) was usually the method of choice. When a facial bone was exposed, the tissues were *not* sutured.

It was particularly desirable to have all dental patients concentrated in one ward. The psychological benefits alone were indications for setting up such a ward. These patients prefer to remain together. They wear similar types of appliances and bandages and submit to similar types of treatment and medication. A nurse or senior corpsman is always on watch to supervise medication and diet, and in other ways follow out the maxillofacial surgeon's orders.

The Navy Dental Corps has accomplished in a creditable manner a task never before attempted. However, it is suggested, in the event of future emergencies, that: (*a*) A larger Reserve Corps be maintained; (*b*) essential dental treatment be accomplished in the training and embarkation areas; and (*c*) greater attention and more practical instruction in oral hygiene be given naval personnel.

U. S. S. *Mindanao*

At the time of the explosion I was sitting at my desk in the dental clinic, situated far forward on the starboard quarter below the main deck. My dental assistant was preparing a tray for surgery. At the sound of the first explosion no one moved; we were too stunned. Somehow one got the feeling that the bulkheads were caving in.

After the second explosion I thought the ammunition magazine directly below the next compartment forward (sick bay) had exploded. The explosion was so loud I was certain that it was somewhere within the ship. I dashed out into the main passageway; it was jammed with men. Then came the third and fourth reports in rapid succession. I had expected at any second to hear the general quarters sounded. I started for my battle dressing station below deck just forward of the fantail. When I reached the ladder leading up from the crew's forward berthing, I could go no further. The passageways were packed with men. I dashed up the ladder and started running over the topside. As I ran I noticed big holes in the deck where 8-inch shells had struck. I saw a seaman, a young man who had sung with our orchestra, lying near the ladder leading to the sickbay. He had been decapitated.

Not until I had reached the quarterdeck did I know what had happened. I looked across the bay; the *Mount Hood* had disappeared beneath the surface—14,000 tons of steel had sunk in less than 6 seconds.

The medical supplies from the midbattle dressing station locker were broken out. I set up a first-aid station near the gangway on the quarter-deck, using a fire and rescue gear chest for a table and electrical outlet boxes for medicine and bandage trays. Patients began coming over the side in a steady stream, some on stretchers, some ambulatory.

The most critically ill patients were sent forward to the sickbay where our ship's surgeon was already busily operating. The slightly injured were treated at the first-aid station. Two pharmacist's mates from ships alongside were designated as my assistants. In a very short time word was passed that the sickbay, the treatment room, and the medical passageways were filled. Patients were then laid out on deck in the Chief Petty Officer's mess, and soon that too became filled. Finally no more patients could be accommodated below.

The first major injury treated at our first-aid station was a fractured femur. An "M" on the forehead indicated that morphine had already been administered, so the leg was slipped through a Keller-Blake splint and made secure. The patient was then removed from the improvised operating table and placed on the deck.

The next patient had a long scalp wound. His face looked chalky. His mouth twitched a little and he died.

Many of the victims were so caked with dried oil as to be hardly recognizable as human beings. Some had been blown off the decks of their ships, later to be lifted into lifeboats from the sea of oil. At one time I had two patients lying on the deck with tourniquets about their legs—each had severed arteries. One man had an ear missing, another a leg severed at the shoe top. Facial and head injuries were numerous. All wounds were cleaned, painted with merthiolate, dusted with sulfanilamide powder, and dressed.

U. S. S. *Cascade* (Destroyer Tender)

Aboard the *Cascade*, a space of 24 by 14 inches with three ports was provided on the portside amidships, main deck, for the dental department. The office was equipped with two Ritter Units, Ritter chairs, Weber x-ray, air compressor, Castle lights, two desks, and a large steel cabinet. An extra steel locker was obtained so that all dental material could be stored and secured in the dental quarters.

We arrived in Pearl Harbor 19 June 1943. The tremendous amount of dental treatment needed by destroyer personnel was immediately apparent. The crews of destroyers and personnel of shore based ComDesPac were cared for.

The ship left Pearl Harbor in November 1943 and proceeded to Funafuti in the Ellice Islands. Here the need of dental treatment for personnel of destroyers, tankers, AK's, LSTs, and shore based SeRons was tremendous. The lack of small boats for transportation from those ships without dental officers to the three or four ships that did have dental facilities prevented or delayed the treatment of personnel badly in need of dental care.

At Kwajalein, Marshall Islands, the same situation as to dental treatment prevailed. We left Kwajalein on 20 May for Majuro, where six Japanese civilian prisoners were brought aboard for dental treatment (surgical). It was apparent that they had received no dental care whatever.

On the *Wisconsin*, which had a complement of 2,739 officers and men, it was interesting to note that 197, or approximately 7 percent, showed oral fusospirochetosis, and 119, or about 4 percent, showed gingivitis in varying form. A reduction occurred in the ensuing months; other factors than treatment and educational procedure were considered responsible for this. Among the factors were: No contact with civilians, mineralized water, and alcoholic beverages.

A system of sterile treatment procedure had been adopted in the Dental Department. Although it was agreed that this method was not perfect, it still was considered to be superior to routine procedures previously employed. This was one factor that led to the decision to use the dental office for the treatment of minor head and neck injuries, in addition to jaw fractures. By so using the dental office, the sick bay could be relieved of much congestion during the times when hits were being made on the ship.

MARINE—SOUTH PACIFIC

At the time of the Pearl Harbor disaster, I was with the First Marine Division, Fleet Marine Force, then encamped in tents at New River, N. C. At this time the tables of organization allowed one dental officer to each regiment and medical company, and one for Headquarters Company, Headquarters Battalion. With a full division of three infantry and one artillery regiment and five medical companies, this allowed 10 dental officers for a reinforced division of 20,000 men. There was no allowance for a division dental officer, so I was attached to Headquarters Company, Medical Battalion, as a spare.

The equipment, both medical and dental, consisted of World War I field units in a sad state of depletion and disrepair. A new supply table had been issued, however, and the task of disposing of the old units and fitting out the medical and dental departments with full field equipment according to the new supply table was given to the Division Dental Officer. The new supplies were very difficult to obtain, and it was not until just before embarking for overseas in July 1942 that all medical and dental units were completely equipped and adequate reserve materiel was on hand.

Later, a field operating light was added to the dental unit, and each dental officer was also equipped with a field unit which included an electric engine, a Castle field light, and a foot engine for use in case of current failure. A portable field generator supplying current was included in the units issued each Regimental Medical Unit, Medical Company, and Headquarters Company, Headquarters Battalion.

The dental condition of the troops was deplorable. The few dental officers attached, even by working continually, could not hope to correct the condition of the large percentage of the personnel. The situation was not to improve, for with the entry into the war, emphasis was on training, movement overseas, and combat conditions. Arrangements were made with the Army at Camp Davis, 50 miles south, to care for the few prosthetic dental cases, because a field prosthetic unit was not included in the Division medical equipment at this time.

Arriving in Wellington, New Zealand, in June, two dental units were set up in a small temporary hospital near the docks, which had been taken over from the New Zealand Army, most of whose personnel were in the Far East.

Two more units were put in operation at Paekakariki, 40 miles to the north, where feverish construction of a camp was underway in the cold rains and mud. Only emergency treatment could be attempted, because all hands were busy day and night moving gear from ships to camp—only to reverse the procedure when the rest of the division arrived and we were all embarked for Guadalcanal (22 July 1952). A typical tent-type dental clinic is shown in figure 139.

The dental officer attached to Headquarters Battalion was left with the rear echelon at Wellington. The dental officers attached to the First, Fifth, and Eleventh Regiments and A, B, and C Medical Companies; in addition to the Division Dental Officer, embarked. An accident aboard ship on 3 August prevented the B Company Dental Officer from landing, leaving six dental officers to hit the beach at Guadalcanal on 7 August. After 3 weeks the failing eyesight of the dental officer in A Medical Company necessitated his evacuation. The five remaining still proved ample to man the three offices we managed to set up and keep in operation through the ensuing months of bombings and shellfire.

The Division began withdrawal from Guadalcanal on 9 December 1942. The following 6 weeks in the brush outside Brisbane, Australia, were a nightmare of rain, mud, lost and misplaced equipment, and inadequate supplies. Sufficient equipment was finally located in the scattered dumps to establish offices in five areas. Some supplies were secured from the Army, including a field prosthetic unit. Then came the order to pack up for Melbourne, and the usual loss of equipment recurred.

At Melbourne, camps were established in and around the city and dental officers assigned accordingly. The rear echelon, still well supplied and equipped, had rejoined the dental officer. All division reserve medical and dental supplies and equipment originally left in Wellington, New Zealand had been moved to Noumea, New Caledonia, and were now unavailable to us.

It was during this noncombat status of the Division that a need for dental officers to take care of the great load of work became apparent. Recommendations made through the Division Surgeon later resulted in the increase by 20 of the Marine Division Dental Officer Complement, the official recognition of a Di-

FIGURE 139.—A Navy dentist administering dental treatment in one of the typical tent-type dental clinics at an advanced base.

vision Dental Officer, and the addition of one field prosthetic dental unit to the equipment of a Division.

Another Marine Report

Reported to Medical Field Service School, Camp Lejeune, New River, N. C., 1 June 1943. The instruction received here aided immeasurably in understanding problems—military and medical—to be met in the field.

Reported to 'E' Company, Fourth Medical Battalion, Fourth Marine Division, 24 July 1943, leaving North Carolina for Camp Pendleton, Calif., 11 August 1943. An extensive training program was undertaken during the remaining months in the states. Working in conjunction with the medical officers, the dental officer instructed corpsmen in first aid, field hospital organization and function, and medical problems to be faced in combat.

Debarked from San Diego for Roi-Namur, Kwajalein, Marshall Islands. Medical companies functioned on ship because of the lack of land area during this operation. Transports in the lagoon received wounded from the beach evacuation stations. Dental officer screened patients and cared for all oral and facial injuries, and treated preoperative shock.

Duties With the Marine Corps

The following observations were made:

1. Dental officers assigned to the Marines should have a good working knowledge of anesthesia.
2. Dental needs of personnel in Marine Divisions should be completed before their assignments in the field. Because of the constant movement of these divisions, innumerable difficulties were encountered in setting up dental facilities. If all necessary work were done prior to leaving the continental limits, the number of dentists assigned to a division could be reduced.

Chapter III

Mobile and Base Hospitals

Lucius W. Johnson, *Rear Admiral (MC) USN (Retired)*

The rapid movement of large military forces with their housing and equipment by land, sea, and air has been the subject of study by military leaders for many years. The military surgeon, on his part, recognized that medical and hospital facilities must be just as mobile as the forces they were designed to serve, and that completely equipped and fully staffed hospitals must accompany troops wherever they might go.

Mobility as a characteristic of hospitals has always been elusive. In order to determine what supplies, equipment, transportation, organization, and administration would be best suited for a mobile unit, the Bureau of Medicine and Surgery in 1940 set up U. S. Naval Mobile Hospital No. 1 as an experimental unit. Trial and error seemed to be the only logical basis on which to begin the quest for mobility. As this required a willingness to confess errors at any point and to begin again, we were continually retracing our footsteps and starting out on a new angle. A great deal of progress in mobile hospital design was nevertheless achieved, although most of the problems still remained unsolved at the end of the experiment, to provoke our successors to continue the search.

Beginning in September 1940, materials for the hospital were assembled at the U. S. Naval Medical Supply Depot, Brooklyn, N. Y. While that work went on the carpenter's gang were busy building tent floors, marking the parts of the prefabricated buildings, and designing bases for the many machines. On 5 October the hospital was officially commissioned and the watches set. This gave it a definite status although it was still but a jumble of boxes,

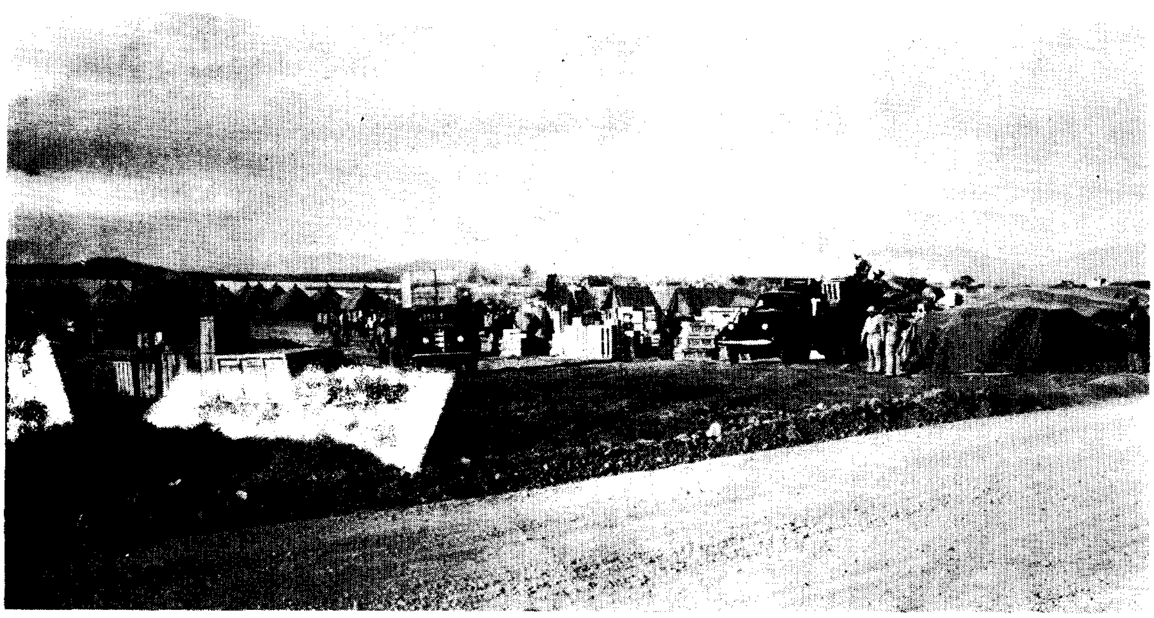

FIGURE 140.—U. S. Naval Mobile Hospital No. 1. "It started from chaos like this."

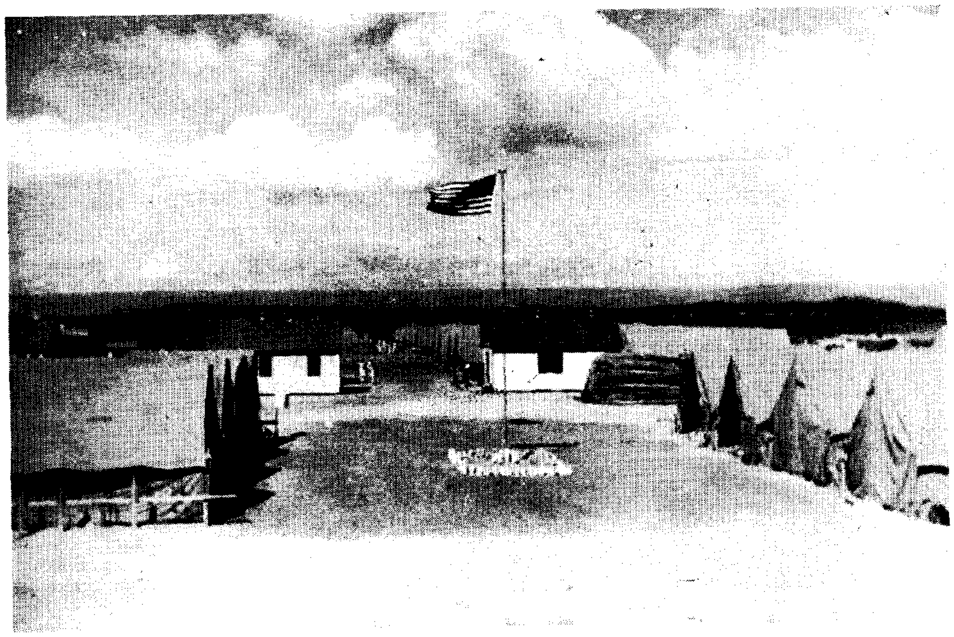

FIGURE 141.—U. S. Naval Mobile Hospital No. 1.

barrels, bales, and crates on Pier 65, North River. Twenty days later the materials and the personnel were embarked for the U. S. Naval Station, Guantanamo Bay, Cuba. Unloading, which was begun early on the morning after arrival, continued without interruption, night and day, until it was completed (fig. 140).

One fact which remains indelibly fixed in the minds of those who have taken part in an expedition of this sort is the enormous amount of physical work required to get a hospital erected and in operation. One husky 6-footer among our hospital corpsmen straightened his weary back after 16 hours of strenous work,

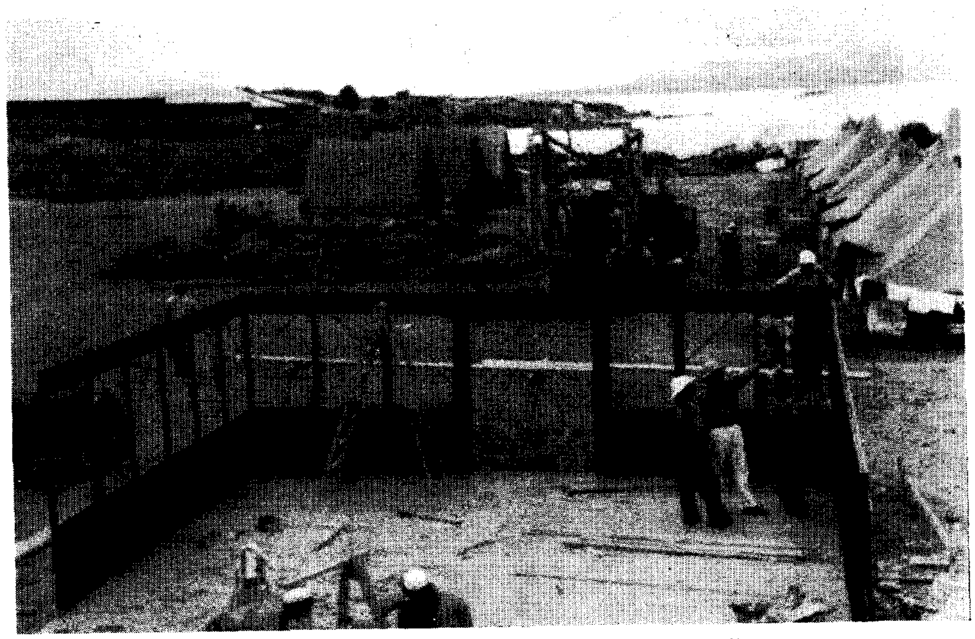

FIGURE 142.—Erecting one of the sectional buildings.

the first day ashore, and groaned, "I didn't know that the birth of a hospital involved such painful labor."

Ditching, clearing, leveling, excavating, erecting tents, making tent floors, moving several thousand boxes, bales, and crates, and constructing foundations for machinery and footings for buildings, all called for labor around the clock. In spite of the arduous work, a boy-scout enthusiasm pervaded everyone. Commander Thomas B. Magath (MC) USNR, of the Mayo Clinic, was present as an observer. In his report he expressed what all of us felt about the spirit and versatility displayed by the enlisted men: "Probably the most interesting part of the whole experiment was to observe the efficiency of the hospital corpsman. Not only was he able to be a good mechanic, electrician, or plumber, but he was able to clear land of virgin brush, lay water lines, erect shower baths, build concrete foundations for buildings and, of course, carry out with usual naval proficiency laboratory and operating room techniques and general nursing care. These men immediately gain respect and admiration" (figs. 141, 142, 143, and 144).

A large number of artificers were attached to our unit. Without them to show the way and to figure out the technical details of construction, the building of the hospital would have been delayed indefinitely. In the group were several older men from the Fleet Reserve, all of fine character and great ability in special lines. They were so determined that none of the younger men should do any more work than they did that they would not admit any fatigue. As a result several of them broke down and became so sick that they had to be sent home. Those able and devoted older men need to be watched, so that their services may not be lost through excessive fatigue.

Medical and dental officers did many things that were far removed from their normal duties. For 2 months the chief of the medical service was in charge of erecting tents. The urologist had the job of sorting several thousand packages and locating lost articles. The laboratory officer laid water pipes and was the best man in the outfit with an air hammer. Our radiologist was in charge of digging latrines and clearing the brush from the site. The psychiatrist became expert in planning and building shower baths. All of them worked at these unfamiliar tasks with the same enthusiasm that they gave to their usual duties.

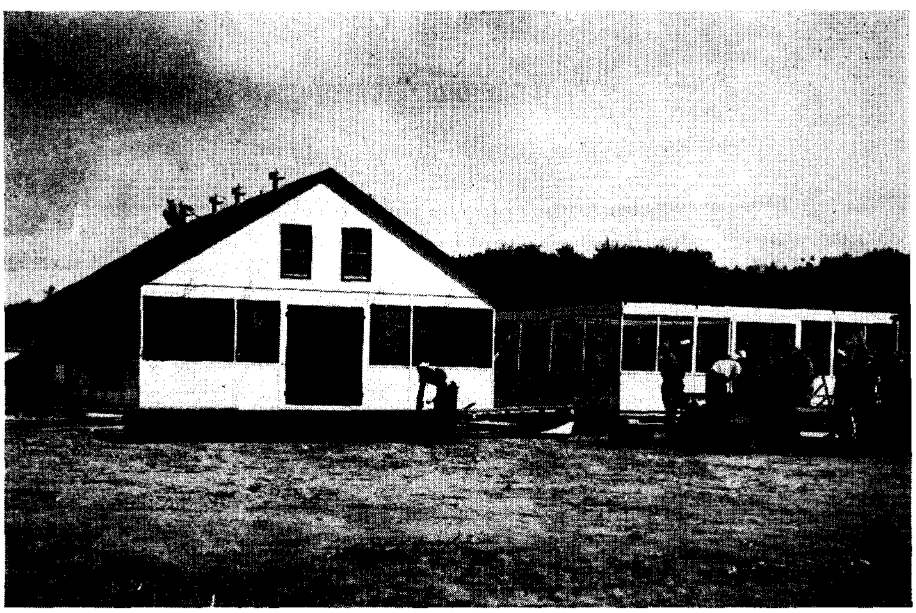

FIGURE 143.—Erecting another of the sectional buildings.

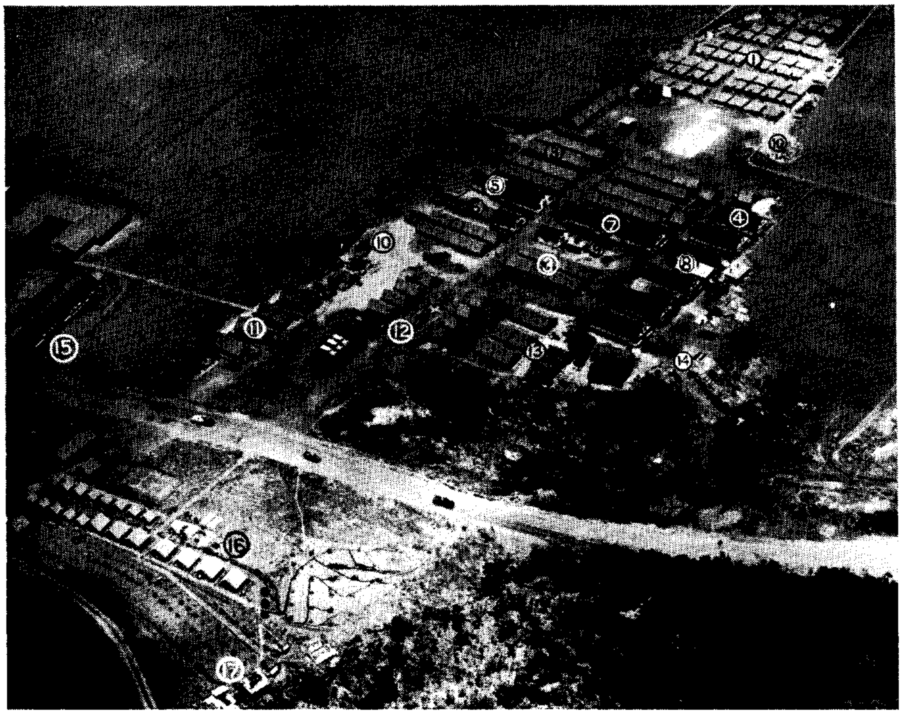

FIGURE 144.—Aerial view of U. S. Naval Mobile Hospital No. 1. (1) Enlisted staff quarters, in tents. (2) Recreation area; movie shack and screen; volleyball court. (3) Tent wards; 25 patients in each ward; utility tents at ends of wards. (4) Medical ward, in prefabricated building. (5) Operating room at left. At right, surgical ward in prefabricated building. (6) Tent surgical ward, operating room at right. (7) Building containing dental clinic, laboratory, pharmacy, and cold storage. (8) Five mess halls in prefabricated buildings; galley and water heaters between buildings; bake ovens at right. (9) X-ray building, with generator shack at right. (10) Two 20-kw. generators. (11) Maintenance area. Electrical, machine, and carpenter shops, lumber pile. (12) Administrative area. Offices on each side of central flag pole. (13) Storage and issue tents; bag room; bulk stores under tarpaulins. (14) Incinerator, hillside type. (15) Laundry. (16) Officers' quarters. (17) Water-purification plant and storage tanks.

The civil engineer proved to be particularly valuable. We were fortunate in having a young Reserve officer with wide experience in all kinds of construction. He displayed zeal and imagination, allowing nothing to interfere with his determination to build whatever we wanted.

As a part of the mission of the Medical Department of the Navy, the unit was assigned the following definite task:

1. To erect a hospital.
2. To provide the best possible care of patients.
3. To keep the hospital as mobile as possible.
4. To keep the Bureau of Medicine and Surgery informed of all the information we might gain, so that improvements could be incorporated in plans for future mobile hospitals.

Ever since the Spanish-American War, there has been intense interest in the loading of ships for military expeditions. On that occasion the transports sailed away from the beaches at Daiquiri and Siboney, in Cuba, as soon as the soldiers had been landed. Still in the holds of the ships were the field hospitals, field guns, and ammunition which were to be desperately needed during the battles which followed. This lack of foresight was the subject of bitter comment by both Clara Barton of the Red Cross and Col. Theodore Roosevelt. When the latter became President, he directed that a careful study of the matter be made, from which stems our present methods of last-in-first-out stowage of materials in ships carrying military expeditions.

For this mobile hospital a plan of loading was worked out that would give us at once the things that would be urgently needed on landing. These carefully laid plans went so far awry that it would have been ludicrous if it had not been so serious. The reasons are worth telling, so that others may avoid them. By arrangement with the ship's officers, the tents, tools, ranges, latrine boxes, and other essentials were placed in the top layer of No. 6 hold. We saw the hatch closed and left for the night, serene in our feeling of intelligent planning, but the stevedores worked long hours that night stowing piece lumber on the hatch cover of that hold. Nothing moves more slowly than piece lumber, so the work of unloading No. 6 hold was not started until late on the day of arrival. Even then, the order was to move all heavy articles first so that the dock could be kept clear. As a result, the first to be unloaded were caskets, ward furniture, and other objects that would not be needed for several weeks.

The limited docking facilities further complicated our situation. It was necessary to clear the dock quickly, to make room for another ship due to arrive shortly. All available trucks were pressed into service to move our goods, which were taken to the hospital site about 2 miles away, too rapidly for our men to identify or segregate them. Thousands of boxes, barrels, crates, bales, and cartons were dumped promiscuously about the 8-acre site. This work continued until after midnight. For a time, a motor-driven flood light was provided, but this soon ran out of gas and for the greater part of the night the work was done in darkness. No intelligent supervision was possible. This indiscriminate dumping meant that many days of labor by a large gang were necessary to find the things needed first. Thousands of packages had to be handled repeatedly, thus wasting hundreds of hours of manpower. Some of the most needed items were not found until well into the second week.

These details are mentioned to show how unforeseen complications can nullify the best-laid plans. Looking back at the experience, the thing that stands out most prominently is the great number of fine ideas that went wrong. They looked foolproof and wonderful as we talked them over but when we tried them out they did not work. Eventually, we adopted as our slogan, "How could we be so dumb?" I remember one case marked "Med. in glass bottles" and another labeled, "Delicate instruments. Handle with great care." Both of these were moved gingerly, and were the first articles to go under cover when a tent became available. When they were opened, the former was found to contain a coil of rope and the latter 6 mop handles.

On the thirteenth day after arrival, the hospital, in tents, was ready to receive patients other than those requiring major surgery. Installation of the refrigeration machinery was not completed until 70 days after landing, and it took 3½ months to set up the laundry machinery.

Although this hospital proved to be much less mobile than had been hoped, we were able to send out a completely mobile unit of 100 beds. The hospital was shipped by air to a base several hundred miles away and set up in a suitable location, where it served throughout the exercises. Under the able direction of Lt. Comdr. Warren E. Klein (MC) USN, this "Mobilette" accompanied a force of Marines on maneuvers.

U. S. Naval Mobile Hospital No. 1 was moved to Bermuda in September 1940. There it served our forces for many months.

It was demonstrated that mobility, as a quality of military hospitals, existed in inverse proportion to the service it was prepared to give. The field hospital could be moved quickly because it did not have the heavy equipment that enabled the evacuation hospital to carry out definitive treatment for all classes of patients. A point to be remembered is that when a hospital stays in one place for a considerable time it loses mobility. Gradually, concrete foundations replace wooden ones, strong walls replace tent pins, machinery is put on permanent bases, and everything tends to put down roots and grow fast.

The lessons we learned were the subject of a report to the Bureau of Medicine and Surgery, helping to correct errors and deficiencies when planning later base and mobile hospitals. Much of the credit for these improvements belongs to Rear Admiral Kent C. Melhorn (MC) USN, one of our most forceful and clear-thinking medical officers.

An amusing but irritating incident will illustrate how easily hard-earned knowledge can disappear or be hidden. After my return to the United States I was discussing our experiences with a medical officer who had been concerned with the Washington end of the project.

"You weren't the first to find out about those deficiencies," he told me. "We already knew about some of them through reports of Marine expeditions."

"Then why wasn't I told about them? Why did we have to learn them all over again, wasting time, effort, and money?"

"Because those reports were confidential," he replied. "As long as I am responsible for them, confidential reports remain locked in the safe. Nobody sees them or knows what's in them but me."

Lions and Cubs

Advanced bases, like other operations of World War II, were on a scale never before imagined. The far-flung network of bases touched every climate, from that of Iceland to the Tropics. Some bases moved into areas formerly little known to man. As a security measure, code words were used to designate the bases when they were being assembled. Lion meant a unit designed to provide all necessary services, including medical and hospital, for an advanced base of 50,000 or more men. Cub meant a unit designed to serve a smaller advanced base. Sometimes a scion from a Lion served as a Cub.

By the time the first Lion went overseas, the construction battalions had been inaugurated. It was intended that they would erect hospitals, but because the hospitals were part of a military force, combat requirements often took precedence over medical and hospital needs. When work of higher military priority took the Seabees away from construction work on the hospital, the medical officers and hospital corpsmen took up the work and hurried it on to completion. It was difficult for a physician, even when he became a medical officer, to conceive of anything more vital to a command than hospital service. This point of view drove them to strain, night and day, for completion of the hospitals in order that they might be able to care for the sick and wounded. It also caused from time to time, considerable friction and unhappiness.

Each mobile hospital presented its own problems of arrangement, erection, and operation. These depended on location, terrain, the source of supplies, the mission of the hospital, and other variables. Because I was senior medical officer of Lion One, the Medical Department of which later became U. S. Naval Base Hospital Number 6, that outfit is presented in detail.

Lion One

Advanced Base Unit, Lion No. 1, was established at Moffett Field Naval Air Station, Calif., on 15 July 1942. The organization followed, in general, that of a medical department division afloat, with the various divisions included in the command retaining a considerable degree of independence. This allowed the head of each department latitude in planning, all the plans being coordinated by the division commander.

All the officers except the senior medical officer and the executive officer were naval Reservists. It is fitting to record here a tribute to the work and the character of those Reservist, physicians and dentists. Without complaint they sacrificed incomes, practices, and hospital positions they had worked hard for years to win. Some were unable to keep up their insurance because of their reduced incomes, and their families had to give up their usual standards of living.

Most of the physicians had had little or no training in the Navy's way of doing things. They came full of desire to do their part and to learn how to work in a world of unfamiliar customs and traditions. Many had been the leading practitioners in their home communities and their clinical work was on the highest level. No sick men ever had more devoted and skillful care. The specialist units were of the greatest value. We had six associate professors from Stanford University Medical School who had worked together for years. They knew how to cooperate and made a wonderful team. Physicians and dentists are commonly looked upon as individualists with little inclination to work together, but our men quickly fused into a well-rounded harmonious group. Their whole interest was concentrated on finding ways to make their special training and knowledge most valuable in the service of their country.

As the years pass I realize more and more clearly how much the success of our enterprise was due to the physicians and dentists who came to us as Reserves. There is a strong tendency for personnel in the armed services to become hidebound and cloistered in their thinking. When war comes there is an infusion of new blood into the services which makes them aware that there is another world outside their circle. This comes often as a shock, but it is invaluable to the career people in the services.

Lion One was established at Moffett Field, in the suburban area south of San Francisco. Materials had been assembled at the Advanced Base Supply Depot in Oakland, Calif. The men were housed in two-story wooden structures, relics of World War I, in such condition that they quickly became known as "Splinter City."

The organization of the medical department was along the following lines:

1. Providing for sick call.

2. Arranging with the station dispensary for care of our sick and their transportation to the Mare Island Hospital.

3. Examining health records, checking identification tags, giving necessary inoculations.

4. Doing complete physical examinations of all personnel.

5. Establishing a dental clinic, preparing a dental record, and beginning dental treatment for those requiring it.

6. Making bag inspections. Each person was required to have all the necessary articles of clothing, including the special articles needed for expeditionary duty. Hammocks and lashings were required for all enlisted men.

7. Interviewing all officers, to learn their professional, musical, dramatic, athletic, teaching, or other special abilities. Planning for recreation and amusement was considered essential.

8. Lecturing to officers on the mission of Lion One, their special obligations, naval courtesies, administration, records, morale, and policies, and lecturing to chief petty officers on their duties with regard to discipline and their obligation to look out for the welfare of the men under them.

Great attention was paid to hardening the men in preparation for the strenuous duties that were anticipated. There were daily periods of physical exercise, drills, and competitive athletics. Minimum standards of physical accomplishments were set up for men and for officers of all ages. Cross-country hikes were made at least once a week. Swimming instruction was given to all who needed it. Teams from the various divisions competed at least weekly over the obstacle course. Thanks to the excellent leadership of Lt. H. H. Martin, an orthopedic specialist of Riverside, Calif., the Hospital Corps usually won the weekly contest.

The stay at Moffett Field gave us time for careful physical and mental examination of men and officers. It was possible to eliminate many who would have broken down under strain and have become a source of danger to their associates. The Navy shoes and the issue of cotton socks were found to be totally unsuitable for wear in the field. Eventually field shoes like those used for the Marines, and woolen socks of good quality were provided.

Classes in first aid for all hands were taught by an instructor from the Red Cross, and physicians with years of experience in handling surgical emergencies were surprised to

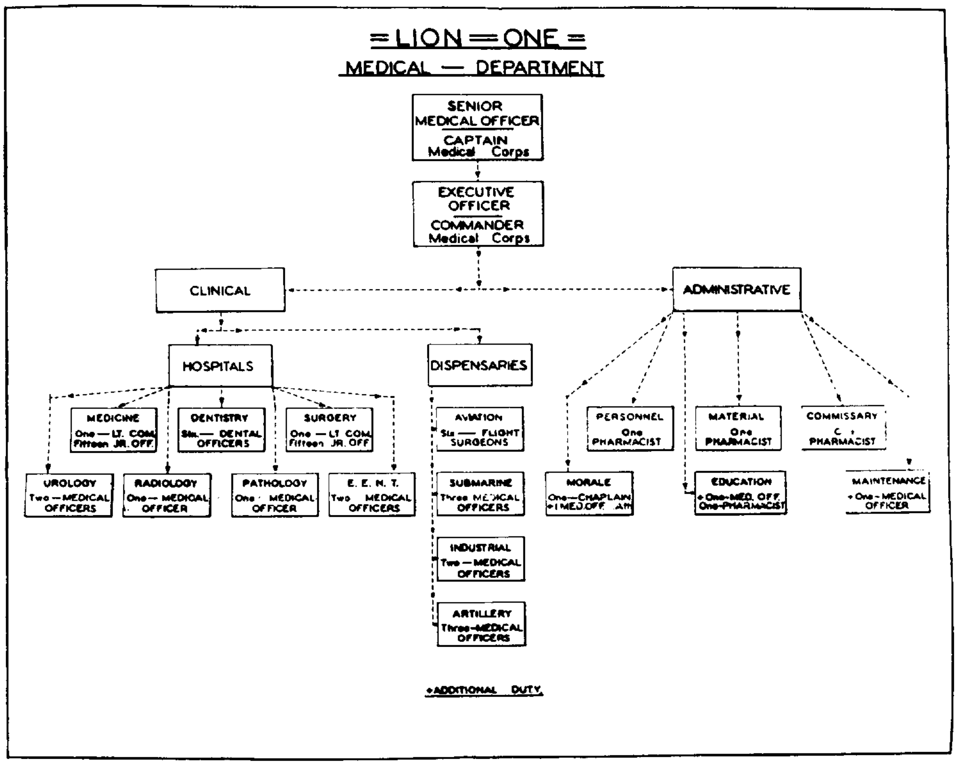

FIGURE 145.—Lion One medical department organization.

find how much useful information they gained from this instruction. All medical and dental officers were required to qualify as instructors in first aid. Courses in gas warfare, small arms, and antiaircraft were also made compulsory for all hands.

Most of the men of the Hospital Corps were newly recruited and had little knowledge of hospital work or care of the sick. Training courses for them were organized in the civilian hospitals of cities near by. The authorities of these hospitals were quick to realize the urgent need for instruction of these green men, and gave admirable cooperation.

Instruction of the hospital corpsmen, who were being trained for work in the operating room, included practice on the sewing machine. The wife of one of our medical officers undertook this teaching. Many special articles such as binders, glove packets, and special dressings were made in the surgical workroom.

Our planning was based on the information that the medical facilities at our destination would consist of three 200-bed hospitals and about 20 dispensaries. The medical officers and hospital corpsmen were divided into appropriate groups to provide service for these activities. Teams were organized and specially trained for rapid handling of shock, transfusions, burns, and other combat injuries.

Based on the limited information that we had about our future location and duties, the plan of organization shown in figure 145 was adopted. Each head of a section was told that he was expected to exercise as complete control as possible over the personnel and activities under him. This recognized the probability that the various parts of the organization would be so widely scattered that centralized control would be impracticable.

Commissioning ceremonies for Lion One were held on 15 July 1942. In December orders were received to divide the medical staff into three task forces, each containing all the elements necessary for a 200-bed hospital. These groups sailed separately, beginning in January 1943, the last one reaching our base at Espiritu Santo, New Hebrides Islands, on 24 April.

FIGURE 146.—Anatomy of a quonset hut; laying the frame.

Soon after our arrival I was fortunately able to visit Naval Base Hospital No. 2 at Efate, which was commanded by Captain John Porter (MC) USN. This hospital had been established for several months and had already met and solved most of the problems that were to confront us. Thanks to the lessons learned from this well-planned and smooth-running institution, we were saved many of the mistakes we might otherwise have made.

On 9 April a dispensary and wards were opened in tents, and 10 days later they were

FIGURE 147.—Anatomy of a quonset hut; erecting the ribs.

FIGURE 148.—Hospital completed.

transferred to quonset huts. This type of building housed most of our wards and departments. It was soon found that placing several of the 20- by 36-foot huts end to end made a good working unit. Longer units were tried with increasing satisfaction, the longest one, 340 feet, proving to be best of all. Our hospital site was in a coconut grove. The rows of trees were 25 feet apart and the 20-foot buildings fitted snugly between the rows. Buildings at right angles, with a frame structure to join them, provided very useful units. Quonset huts were found to be extremely useful for nearly all hospital needs as well as for quarters.

The work of erecting the buildings (figs. 146 and 147) was under the direction of the 44th Construction Battalion, which deserves great credit for excellent planning and for carrying

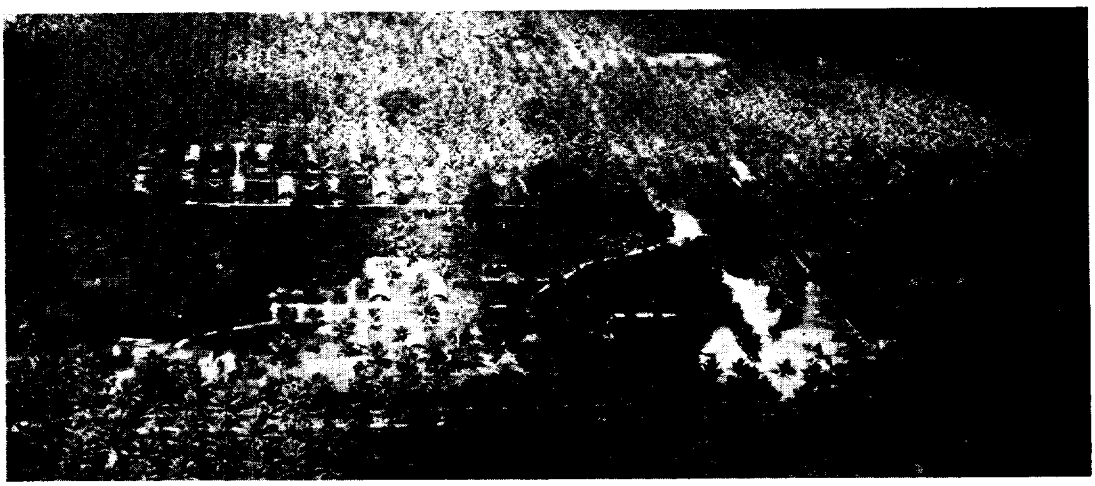

FIGURE 149.—Hospital completed in a coconut grove.

out the work under most difficult conditions. Two hundred and fifteen of our men worked under their direction. As hospitals have a rather low priority, the Seabees were frequently pulled off the job, but our men rapidly became proficient in the work and the buildings went up rapidly. Officers and men worked alongside each other, in the rain and mud, with a fine boy-scout spirit. It was found advisable to build first the access roads; second, the quarters for the enlisted men; third, hospital offices; fourth, outpatient clinics; fifth, hospital wards and mess hall; and sixth, officers' quarters (figs. 148, 149, 150, and 151).

It was soon evident that the time of the Senior Medical Officer would be about equally divided between (1) sanitation, (2) dispensaries, (3) construction, and (4) receiving and evacuating patients. Competent medical officers were therefore detailed to superintend each of these activities.

Sanitation was early recognized as a vital factor for survival in the Tropics. We were fortunate in having a man trained in public health work, Commander James A. Beauchemin (MC) USNR, who had a special gift for inducing people to comply willingly with his recommendations. Practically anything one may do for advancement of the public health interferes with the prejudices, the profits, or the comfortable routine of someone. That someone is often powerful enough to offer obstinate resistance. For this reason, salesmanship is often more important to the sanitarian than scientific knowledge.

Sanitation had received little attention before our arrival. It was the rainy season; as much as 7 inches of rain fell in a day. There were no roads and the soil was deep and rich. Men, machines, and supplies were dumped ashore, frequently at night because of enemy pursuit. Ruts made by machines quickly filled with water and became the breeding places for millions of mosquitoes. Food wastes were dumped promiscuously and there was widespread pollution by men who either knew no better or could not be bothered. Dysenteries and mosquito-borne diseases took such a heavy toll of personnel that it was difficult to maintain watches or to get work done.

Many large industrial areas were soon developed. It was necessary to have wide dispersion for military reasons. Twenty-seven separate sickbays and dispensaries with accommo-

FIGURE 150.—Pharmacy in a quonset hut.

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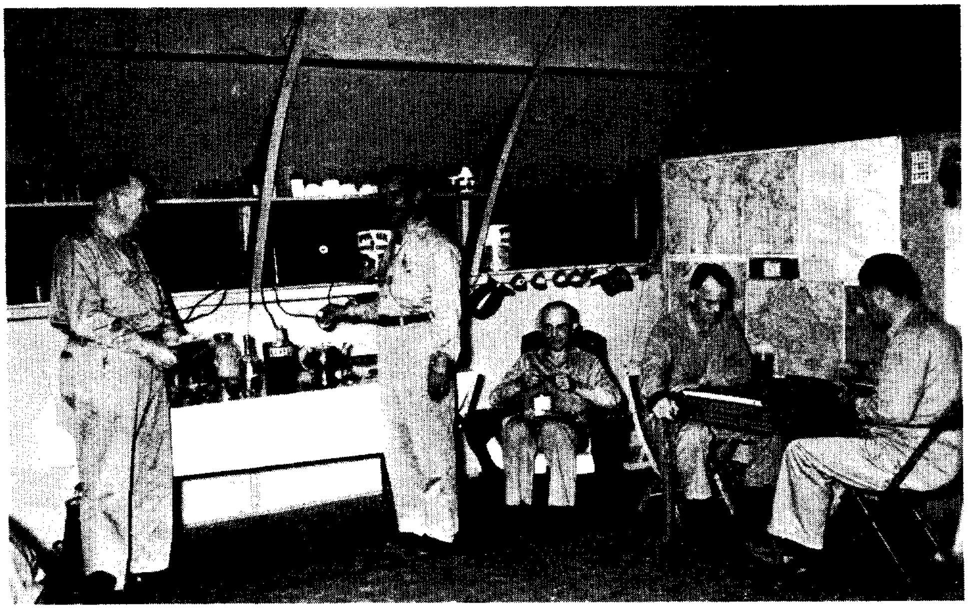

FIGURE 151.—Officers' quarters.

dations for more than a thousand men were placed in operation on a 24-hour basis. The plan was to send those who were disabled for more than 24 hours to the main hospital.

Patients came to us by ship and by airplane. Hospital ships brought hundreds of sick men at a time while other ships received large numbers for evacuation to the rear. This reception and evacuation of patients required careful planning to make it work smoothly, requiring the entire time of a number of officers and men. On 12 July 1943 authority was received to expand to 1,000 beds and on 25 August the hospital was designated as Naval Base Hospital No. 6.

The following is a summary of the problems and solutions:

1. Sanitation and public health are of the greatest importance in the field and also at a newly established base. Military planners may forget this vital point, even though many expeditions have failed because of it, unless the medical officer brings it to their attention. This must be done with tact, because military leaders resent the idea that a physician can tell them facts about their own specialty. Men skilled in sanitation should be with the first troops to land in a new area.

2. In hospitals on Guadalcanal, only 3 percent of the patients were battle casualties, while 97 percent had malaria, dengue, or dysentery. This ratio should be considered as normal in base hospital planning for the Tropics.

3. Before embarking, the men should be carefully screened in order to eliminate those physically, mentally, and temperamentally unfit.

4. In any military outfit, the combat requirements always take precedence over medical and hospital needs.

5. Last-in-first-out stowage in ships or other means of transportation is essential. An officer should be assigned to keep close watch with the loading officer and should know exactly what material is stowed in each compartment of the hold. He should be alert to detect any unauthorized changes or removals.

6. Spare parts and blueprints for all machines are essential. If possible, the machines should be set up and operated before they are packed.

7. The contents of cases will not always agree with the labels unless each package is opened and inventoried before being shipped. Errors, pilfering, and substitution will occur.

8. Avoid tents for quarters and for hospital use whenever possible.

9. Hospital bed capacity must always be very elastic. Usually a large number of patients will be brought to the hospital before it is ready to open. Often a number greater than the normal bed capacity will be sent in, without notice, at any hour.

10. It is essential that every officer and petty officer know the men under him intimately. He must be familiar with their attitudes, qualifications, athletic and musical abilities, matrimonial difficulties, and personal, legal, and financial problems.

11. Minor ills, such as sunburn, sore feet, and influenza, can disable large numbers of men for long periods. The best treatment is prevention.

12. The officers and men in the Medical Department can be depended on to show great versatility and ingenuity in meeting emergencies. They will perform with success and enthusiasm duties far removed from their usual occupations.

13. Planning: The officer in charge of constructing the hospital should visit the site in advance of the arrival of the materials, and plan the layout to fit the terrain. He should pay special attention to the brush or trees to be cleared, areas of insect breeding, water and power supply, roads, and means for disposal of wastes. Providing for recreation and entertainment requires careful consideration; these are important morale builders.

14. Careful packing and marking of equipment are essential. Blueprints of each machine should be in the same crate with the machine. Labels and marking should be used which will not smear in handling or come off when wet. Whenever possible, boxes should weigh not more than 250 pounds; if heavier, they will get rough handling.

15. The power plant requires careful study of the prospective needs for heating, lighting, water pumping, cooking, kitchen machines, refrigeration, sterilizers, and laundry. Consideration should be given to the type of materials for construction, methods of transmission of power, availability of various types of fuel, spare parts, and maintenance. Several types of reliable mobile generators are available.

16. Housing: Tents are the most mobile type of shelter, but the fire hazard is great, they last only 4 to 6 months, and are the most costly. Prefabricated buildings are more convenient and comfortable, and permit giving better medical and surgical care, but require more room in shipping.

17. Food: Good cooks and palatable food are important for morale, as well as in the care of the sick.

18. Motor transport: Jeeps, passenger cars, ambulances, several sizes of trucks including at least one with a crane, motorcycles, plenty of spare parts, tires, air compressors, lubricants, and full equipment for repairs will be needed.

19. Periods of strenuous activity will be followed by dreary days of sitting about with nothing to do. Avoid loss of morale by planning athletics and musical and dramatic occasions. You will find plenty of talent in any large group.

U. S. Naval Base Hospital No. 12

The somewhat different problems of completely nonmobile base hospitals and the ways in which they were solved under war conditions are best illustrated by an account of the operations from 1 March to 30 September 1944 of U. S. Naval Base Hospital No. 12. This was one of three hospitals cited for the Navy Unit Commendation, the other two having been awarded to the U. S. Naval Hospital Pearl Harbor and to the U. S. Naval Mobile Hospital No. 2 for their heroic services on 7 December 1941.

In preparation for handling casualties from the proposed cross-channel invasion, the Navy on 28 February 1944 took over the old Royal Victoria Hospital at Netley, near Southampton, England (fig. 152). When the Medical Officer in Command, Captain C. J. Brown[1],

[1] Now Rear Admiral (MC) USN.

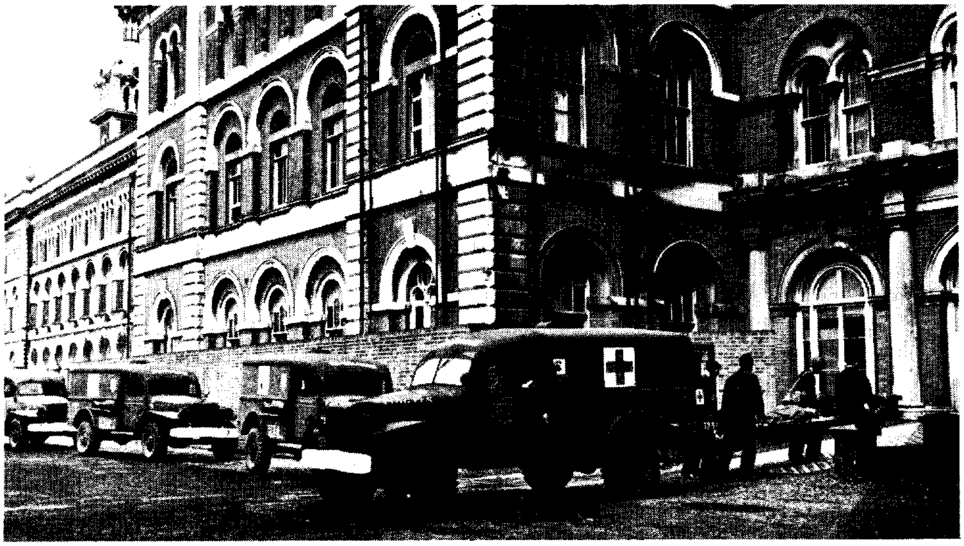

FIGURE 152.—U. S. Naval Base Hospital No. 12, Netley, Hants, England.

arrived with his Executive Officer, Captain J. W. Miller, and a few advance units of personnel, it was obvious that tremendous effort would be required to put the installation into shape for efficient functioning in the short space of time remaining before D-day.

Most of the buildings had been constructed about the middle of the nineteenth century and were in a poor state of upkeep and repair. The roof leaked, hundreds of windowpanes were broken, extensive cleaning and painting were required, the deck was in bad shape, lighting was very unsatisfactory, wards and rooms were poorly heated if at all, the supply of gas and hot water was inadequate, galley equipment and refrigeration were obsolete and insufficient, linen rooms and storerooms were in chaotic condition, there were no wards suitable for neuropsychiatric care, and most of the furniture and equipment that was not completely unserviceable, required extensive repair.

In order to be ready to receive large numbers of casualties by the rapidly approaching deadline date, the aid of a construction battalion was obtained, but because of military demands on the time of these Seabees much of the cleaning, painting, repair work, and installations had to be completed by hospital personnel. To remove unserviceable furniture, equipment, and debris from the buildings and grounds, carry out the most essential cleaning, and sterilize mattresses, pillows, and blankets, required 2,900 man days.

Intensive effort was exerted to obtain necessary equipment and supplies from every available British and American source. The bulk of equipment for a 1,000-bed base hospital was gathered from various U. S. Army depots. Among special items installed were 150 space heaters with 16 fuel tanks, 60 lavatories, 32 showers, 3,000 feet of shelving, 12,000 square feet of lockers and partitions, galley equipment with cold rooms and refrigerators, electric transformers and wiring, and a roentgenographic machine.

In addition to the clean-up and equipping program, organization and training of the hospital personnel was rapidly carried out during the weeks prior to D-day. The medical officers were given intensive courses in first aid, gas defense, treatment of shock and burns, and the handling of casualties on a large scale. Plans were perfected for the sorting of casualties and their transportation within the hospital, with particular attention to the handling of shock and burn cases. To eliminate confusion when large numbers of patients were received at one time, a method of current empty-bed check was adopted under which triage was conducted in person by the Chiefs of Surgery, Medicine, and

Neuropsychiatry. Each Chief of Service was thus able to assume immediate responsibility for a group of incoming casualties, was currently familiar with the bed situation, and could foresee and plan the work of his departments.

In preparation for expected sudden demands, supplies of penicillin, plasma, and blood were located and a central surgical supply room was organized. In the Orthopedic Department, 7,000 plaster bandages were prepared. Resuscitation rooms, burn wards, and locked wards were provided. The three steam hydraulic elevators were repaired and a system of handling baggage and valuables inaugurated, permitting rapid collection and equally rapid evacuation. Operating suites were prepared so that 6 operations could be conducted simultaneously, and operating teams were organized, with hospital corpsmen trained in operating room technique and dental officers trained to assist in anesthetic procedures.

Because the hospital was within 12 minutes flying time from enemy airfields and was located adjacent to important military targets, organization for air-raid defense was required. Personnel were indoctrinated in the use of underground shelters, gas cleansing centers, fire fighting apparatus, and rescue equipment. Frequent casualty-handling drills were carried out. Medical stores and personnel were dispersed in shipboard fashion. Look-out stations were manned 24 hours a day. Frequent night alerts, requiring all hands to man emergency stations, with the ever-present threat to patients and staff, were very disturbing, particularly after numerous robot bombs began landing in the vicinity and shaking the buildings with their explosions.

During March, April, and May, even while the installation and organization were in the process of being brought up to an operating condition conforming to Navy Standards, 1,554 inpatients were treated. On D-day, as many beds as possible were cleared for reception of battle casualties, 212 patients being evacuated by hospital train and 56 others sent to duty. Casualties then began arriving by ambulance from hospital carriers and LST's, usually in large groups. Daily admissions of 100 to 200 were common and on several occasions 200 to 300 were admitted in the course of a few hours. Such mass admissions were an all-hands procedure. On 11 June there were 357 admissions, on 6 September 420, and on 22 September 283 convalescent patients were evacuated while 409 new casualties were being admitted.

During June, July, August, and September, 8,076 patients, including 4,226 battle casualties, exclusive of neuropsychiatric cases, were admitted. Despite the fact that, starting with an installation in an extreme state of disrepair, the hospital had been prepared to receive them in the short space of 3 months, and that the personnel labored under every conceivable handicap of material shortages, overwork, and subjection to air-raid alerts, the results obtained were outstanding. The mortality rate among the wounded in battle was only 0.26 percent and the surgical mortality, 0.70 percent. To quote from the Navy Unit Commendation so justly awarded, "—the brilliant results obtained in the professional care of great numbers of battle casualties, constitute an exceptional and distinctive record of achievement, in keeping with the highest traditions of the United States Naval Service."

Chapter IV

Medical Procurement and Supply

Kent C. Melhorn, *Rear Admiral (MC) USN (Retired)*

Lewis G. Jordan, *Captain (MC) USN*

William L. Engelman, *Captain (MC) USN*

At the beginning of the war the functional organization of the Bureau of Medicine and Surgery (BuMed) did not concentrate control of materiel in a single office. This resulted in considerable overlapping and duplication of effort. There were conflicts of authority between the Planning and Finance Divisions of the Bureau and the Naval Medical Supply Depot, Brooklyn, related to materiel planning, the determination of requirements, and the procurement, inspection, and distribution of materiel. The Surgeon General had a management survey made by a firm of business consultants. As a result on 10 November 1943 the Materiel Division, BuMed, was established in Brooklyn, as an organizational entity housed in but administratively separate from the depot. This located the Division in the immediate vicinity of the New York offices of all the important manufacturers with which it did business—a most advantageous arrangement. A Division branch office was maintained in Washington for liaison with the Bureau.

Before 10 November 1943, a special department of the Brooklyn Medical Supply Depot had discharged various responsibilities for the Bureau of Medicine and Surgery. These were transferred to the new Materiel Division, which was given a wider range of authority than its depot predecessor. In addition, authority over certain areas of responsibility previously discharged by the BuMed Planning and Fiscal Divisions was transferred to the Materiel Division. Therefore, when in this article the Materiel Division is given credit for actions taken before its creation it is done to simplify the narrative.

The Materiel Division was given plenary authority over the Medical Supply System, including materiel planning, requirements determination, procurement (less purchasing done by NPO, New York), inspection, inventory control, and operational and management control of Naval Medical Supply Depots and Naval Medical Supply Storehouses (MSS's) in the Continental United States. Operational control of overseas MSS's was exercised by the Area Command, but the Materiel Division exercised management and technical control.

At the end of the war the Materiel Division had a staff of about 150 officers, enlisted men, and civilian employees and occupied 25,000 square feet of office and laboratory space, in comparison with the half dozen people in the Brooklyn depot who handled the very small materiel operation before the war. Procurement volume rose dollarwise from approximately $1,000,000 per annum in fiscal year 1940 to a height of $120,000,000 per annum during fiscal year 1944.

In 1941 medical stores were distributed from three Naval Medical Supply Depots, one at Brooklyn, N. Y.; another at Mare Island, Calif.; and a third at Canacoa, P. I. The latter was lost when the Japanese invaded the Philippines.

At the end of hostilities there were 2 large continental Naval Medical Supply Depots, with numerous satellites (fig. 153). The depot at Brooklyn together with its Annex at Edgewater, N. J., had over 1 million square feet of storage area. Brooklyn also controlled the activities of a supporting half million square foot Medical Stores Section in the NSD, Me-

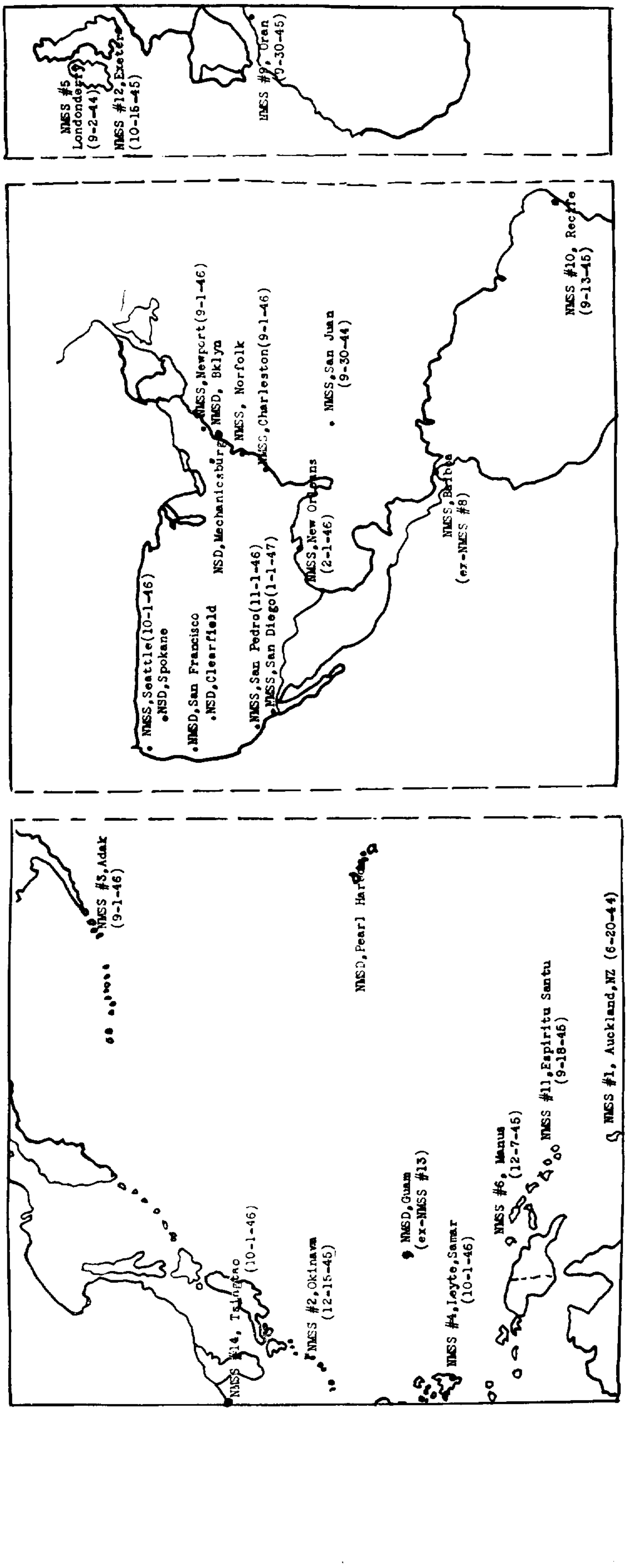

FIGURE 153.—Medical supply facilities, United States and extracontinental.

chanicsburg, Pa., and satellite storehouses averaging 40,000 square feet each at Newport, R. I.; Norfolk, Va.; Charleston, S. C.; and New Orleans, La. These made issues to minor local medical activities ashore and afloat.

The depot at Mare Island had been replaced by a new depot at Oakland, Calif., with a capacity of over 600,000 square feet. The Oakland Depot also controlled the activities of supporting Medical Stores Sections in the NSD's at Clearfield, Utah, and Spokane, Wash., with a combined total of several hundred thousand additional square feet, and satellite storehouses at San Diego and San Pedro, Calif., and Seattle, Wash. Thus, this continental complex had a combined area of approximately 3,200,000 square feet of space, and at its peak stored up to 40,000 tons of materiel worth over $100,000,000. The techniques of continental supply distribution remained relatively unchanged. The main difference was in the amounts involved.

Early in the war it became evident that under the conditions then existing the overseas forces ashore and afloat and the Fleet Marine Force could not be supported satisfactorily from continental depots. Starting in 1942 relatively small naval medical depots were established at Pearl Harbor, T. H., and at Balboa, C. Z. For the Atlantic Area medical supply storehouses (MSS's) were established at San Juan, P. R.; Recife, Brazil; Casablanca, Morocco; Londonderry, Ireland; and finally at Exeter, England. All of these served usefully throughout the war. The concept of MSS's located at strategic ports ideally fitted the pattern of naval operations in the Atlantic. Fleet employment was mainly for convoy escort and for air and surface antisubmarine and surface raider patrol measures. In addition, the MSS at Exeter played an important role in the Normandy invasion.

During early 1942 when the Japanese were still sweeping forward in the Pacific, MSS's were established at various places in Australia, New Zealand, Noumea, and Espiritu Santo, and proved invaluable. Initially all those MSS's were supplied by automatic shipments. Subsequently replenishment was by requisition. After the Battle of Midway the offensive in the Pacific gradually passed to our side and the Naval and Marine Corps forces which attacked and conquered the Solomons, New Britain, and New Guinea were mounted out of these facilities.

With the perimeter in the South and Southwest Pacific firmly held, a new phase began to develop. The MSS's in Australia, New Zealand, Noumea, and Espiritu, and the Supply Depot at Pearl Harbor, progressively lost value as the war moved north and west. Some of these facilities were dismantled and moved forward to Guadalcanal and Manus, where they served usefully for many months until they, too, got off the direct line of communications.

Geography and the augmented might of the fleet produced a new type of warfare in the Pacific. Development of new supply techniques and the increasing number of cargo vessels available made it possible for the fleet to remain underway for extended periods in distant forward areas. It ranged swiftly into enemy home waters for strikes at Japanese bases and had the endurance to constantly contain the Japanese Fleet within the range of its shore-based air support. This ascendency of the Pacific Fleet in what were formerly enemy seas made possible the mounting of major amphibious forces which were escorted to and supported at the distant assault objectives with surface and air protection. Their materiel requirements were provided by a magic carpet composed of hundreds of cargo ships on a conveyer belt schedule.

The vastly increased quantities of materiel required by constantly larger and more frequent assault operations made necessary the return of responsibility for primary supply support to the continental medical supply depots. Pacific MSS's were now off the routes of communications between the Continental United States and the zone of combat operations. It was not until we got to Guam that a land mass large enough to use as a major staging area was secured. The last MSS was erected in Guam. Its mission was mainly local supply, rehabilitation of MarDivs, and the storage of emergency stocks which could be called for when needed. It was more efficient and economical of materiel and shipping to supply from the United States than to routinely ship to Guam, off-load, and later reship to more forward areas. Thus, the place in medical supply of the Pacific MSS's was taken over by floating supply and block shipments to the assault and garrison forces. Medical supply afloat at the end of the war was furnished from 28 AK's and 8 barges. Block loads were prepackaged units of medical and dental materiel delivered at destination by cargo ships. When an objective was secured, the occupation forces at the new base were supported for a short time by automatic shipments for current maintenance and accumulation of its prescribed stock levels, after which they went on a requisition basis.

As far as the public could see, the most visible drama of naval medical supply took place in the Pacific with the Service Force Pacific, the Fleet Marine Force Service Regiments playing the most prominent roles. We must, however, keep in mind that behind the advertised players in any show is a supporting cast and the director and producer, without whom nothing can start or go forward to successful accomplishment; they are the base of the pyramid. The Materiel Division in Brooklyn and the Medical Supply Depots and their controlled Medical Stores Sections supplied the muscle which was flexed by the Service Force and Service Regiments and it provided the sinews which supported the less publicized but very important and equally efficient medical supply operations in the Atlantic, Africa, Europe, and continental United States.

The relations between the Bureau's Materiel Division on the one hand and the Medical Sections of the planning and operational staffs of the Theater or Area Commanders on the other were intimate and cordial, and the techniques of coordination and integration of their respective thinking and actions makes a fascinating story.

Bureau planning stemmed from directives from higher authority. The Joint Chiefs of Staff (JCS) developed broad, sequentially progressive, and time-phased strategic plans. These were passed to the Departments for preparation of subsidiary tactical plans and preparation of estimates of the logistic requirements to implement them. The Chief of Naval Operations (CNO) developed the Navy plans and with the assistance of the Bureaus and the area operational commanders determined its total requirements for accomplishment of the role assigned the Navy. The several Departmental requirements for personnel, facilities, and materiel were consolidated by the JCS and forwarded to the War Production Board and the War Manpower Commission. These agencies, which had the authority to divide the national assets between the civilian and military economies and the demands of our Allies for Lend Lease, compared the over-all estimate of requirements with the national productive capacity of industry, the supply of basic materials, and the available manpower resources, and determined if it was feasible to provide the military with what was asked. If the demand could be satisfied, implementation of the supporting programs went forward. If the demands could not be satisfied, the scope of planning was reduced to what was supportable, or the operations were postponed until the requirements could be accumulated.

This over-all feasibility test had the value of precisely indicating the bottlenecks and zones of scarcity which required corrective action. Logistic materiel deficits were sometimes compensable by assigning priorities for scarce materials, productive capacity, and industrial manpower among competitive programs, by enforcing use of alternate materials and fringe production by the less essential programs, and by cancelling programs for desirable but not really essential items.

Thus, deciding upon a date for the "Kick-off" of major combat operations was intimately related to a reasonable expectancy that industry could deliver enough of all the essential material to mount out and maintain the operation, and the acceptance as a calculated risk of unforseeable delivery failures.

When the scope and timing of operations had been set, it was up to the Materiel Division to buy what was needed and to get the goods into its depots in time to meet the mounting out shipping dates prescribed by higher authority and the forces in the field. This required effective organization, superior administrative and operational direction, imagination, courage, initiative, sound judgment, and a tremendous amount of hard, exacting work.

The magnitude of the problem that had to be met, and was met, was defined at the beginning of this article but will be summarized here to emphasize why personnel who accomplished what was done had reason to be proud of the results achieved. This was a sixty-fold (6,000 percent) increase in the scope of the medical supply operation within a period of less than 24 months, in a highly competitive environment. Manpower, materials, productive capacity, all types of equipment, and facilities construction were in limited supply and could only be procured by unremitting, intelligent, and strenuous effort.

That this was done is attested by the fact that very few significant Navy medical supply failures occurred during the war. If anyone did not get the exact item he asked for it was due to the following policy: In order to more effectively use available manufacturing capacity and to conserve scarce materials and skilled manpower, government and industry agreed to limit the variety of similar purpose items produced. This resulted in greater production of the most needed items. If it was manufactured it was supplied to the Navy consumer. That the Naval Medical Supply Depots fulfilled their portion of the mission can be supported by the fact that the Oakland depot received an "A plus" rating from the War Manpower Commission for efficient organization and utilization of personnel. This was as high a rating as was awarded to any Navy Supply Depot operation during the period of the war, and possibly the highest. Brooklyn was but a step behind.

The medical elements of Area or Theater and Fleet Command Staffs and the overseas MSS's effectively contributed to the success of medical supply. They evolved efficient new techniques in the planning and implementation of getting sufficient quantities of the right items to the right places when they were needed. They kept the Bureau, the Materiel Division, and the depots constantly advised of changing conditions and requirements in the areas under their respective cognizances.

While the Pacific areas presented more novel medical material problems to the Navy than other regions, certain of them were common to all. Some of the more significant solutions arrived at, which have already been summarily referred to, will be outlined below in detail by categories of programs:

Advanced Base Program

The establishment of Advanced Base Units was first considered early in 1941 in connection with Lend-Lease and the development of bases in the Western Hemisphere. About April 1941, the Brooklyn Medical Supply Depot received a directive to purchase and assemble supplies and equipment for two 600-bed hospitals and two 200-bed hospitals, which were to become the medical components of destroyer and seaplane bases. At this critical period, cargo ships were being sunk at an alarming rate and shipping space was at a premium. In preparing allowance lists for such units, the shipping weight and cube of the material and equipment had to be held at a minimum. Supplies were provided for a 6-month period and the total allowance was divided into three and two echelons respectively for the destroyer and seaplane bases. Some equipment was duplicated and shipped on different vessels in the event that one was lost. Such a division of the material also allowed the splitting off of one or more parts to form two or three hospitals of smaller size if the situation required dispersion of facilities. The allowance lists for these main bases included a number of small satellite dispensaries to be set up within the base as sick call and aid stations. The Medical Supply Depots furnished all medical supplies and equipment for the medical components. BuDocks supplied housing, utilities, transportation, construction, and maintenance facilities, while BuSandA furnished office supplies and equipment and consumables.

Late in 1941, destroyer bases became known as LIONS and the seaplane bases as CUBS. By this time another component, the ACORN was added to the list of Advanced Base Units. The ACORNS were originated to provide shorebased aircraft groups in amphibious forces and advance bases, with necessary support and services upon landing in combat zones. They required a high degree of mobility. The medical component of an ACORN provided a 100-bed mobile dispensary in specially packed Field Medical Units and was divided into two echelons. Upon landing, the unit was housed in tents, which were replaced by huts when the base was consolidated.

In the procurement of material for ACORNS, considerable difficulty was experienced in obtaining large quantities of special cases in which to pack the Field Medical Units. In addition, the standard hospital furniture as purchased under existing specifications did not lend itself to export shipping because of the large weight and cube and variety of shapes of the packing cases. An extensive revision of specifications and the redesigning of many items was needed, so that they could be shipped in a "knocked down" form. In addition, net items of equipment had to be provided to meet totally new or unanticipated medical problems in the field.

Upon the outbreak of war, the material and equipment assembled for the original bases were diverted from the Lend-Lease program and shipped to combat zones. Additional LIONS, CUBS, and ACORNS were scheduled and assembled during the first half of 1942. By August 1942 schedules for each type of advanced base units had been promulgated, with assembly points and loading dates designated. At that time the assembly points included Oakland-Hueneme, Calif., Norfolk, Va.; Davisville, R. I.; and New Orleans-Gulfport, La.

The readiness date for each component was set at 6 weeks prior to the scheduled loading dates. In accordance with the CNO schedule, the Naval Medical Supply Depots assembled the necessary supplies and equipment for the scheduled units and were, with few exceptions, able to meet readiness dates. In addition, during the latter part of 1942, the Brooklyn Medical Supply Depot set up allowance lists for 100-, 50-, 25-, and 10-bed continental and extra-continental dispensaries, Carrier Aircraft Service Units (CASU's), construction battalions, and 10-bed Mobile PT Bases, the latter specially packed similar to the ACORN. At this time, the depot established a schedule for Advanced Base Components in advance of CNO requirements, because continual demands were being made for Advanced Base Components over and above the CNO schedule. The procurement program for material and equipment was expanded to meet the requirements of the newly constructed Naval Supply Depots at Mechanicsburg and Clearfield for assembly and processing of the Advanced Base Components. This system enabled BuMed to ship all components to the tidewater assembly points intact, well in advance of the readiness dates.

By March 1943 it had become apparent that LIONS, CUBS, and ACORNS were too large and included many components that were not required in all theaters of the war, while some facilities that were required for certain operations were omitted. To correct this, the LIONS, CUBS, ACORNS, and PT bases were subdivided into individual functional components and letters of the alphabet were assigned to each group of components, with numeral subgroups for the various units within the group. The Medical and Dental components were designated as "G" components.

On 15 March 1943 CNO issued the first edition of the catalogue of advanced base functional components, from which area commanders could choose the necessary functional components to comprise the LION, CUB, ACORN, CASU, or PT bases required for the specific task at hand. During the late spring and early summer of 1943, preparations were made to have all Bureaus assemble material for individual components at inland depots, so that intact shipments could be made to loading ports. On 4 August 1943, the CNO issued the original schedule of individual components, and soon thereafter instituted Advanced Base Sections at Naval Supply Depots to supervise, process, and report on material for all scheduled Advanced Base Components.

Since BuMed had a well-established advance base section already functioning in the inland depots, it was requested to continue processing and assembling the BuMed material until the Advance Base Section of CNO could organize and establish similar facilities for the other Bureaus. On 1 September BuMed had set up a serial list of "G" components 1 to 10, inclusive—in accordance with CNO schedule of 4 August. Other "G" components were added later. The material and equipment were accumulated in the depots well in advance of the availability date and marked with the assigned serial number. The serial numbers of the availability schedule were revised with each subsequent monthly revision. In October 1943 a BuMed Scheduling Officer was appointed at Washington and at the Naval Medical Supply Depot, Brooklyn, N. Y. The former acted as BuMed liaison officer with the other Advance Base Sections at Washington, and the latter released and controlled material and shipments of all "G" components from Brooklyn. During November 1943 the Advanced Base Program of the Bureau was made the responsibility of the newly created Materiel Division.

Dental coverage was provided by G–13 to G–16 inclusive. Under ideal conditions one dental officer was needed for every 750 men. Due to lack of personnel, one dental officer frequently had 1,500 to 2,000 men to care for. These small one-man dental clinics were not economical; consequently, when the size of the base justified, dental clinics were tailored to size and ordered in.

Preventive medicine units. In malarious areas a G–17 unit was provided. These malaria control components had ample supplies, equipment, and well-trained entomologists. During the establishment of new bases and until sanitation had been brought up to standard, a G–18 epidemiology component should have been provided. These components had the necessary laboratory equipment and supplies to determine the source and type of organisms producing the various outbreaks of dysentery and other epidemic diseases.

The following list indicates the "G" type of facilities provided:

G–2	600-bed dispensary[1]
G–4	200-bed dispensary[1]
G–5	100-bed dispensary
G–6	100-bed dispensary (mobile)
G–7	50-bed dispensary
G–8	25-bed dispensary
G–9	10-bed dispensary
G–10	10-bed dispensary
G–11A	First-aid sub-dispensary
G–13	Sub-dispensary—Dental
G–14	Sub-dispensary—Dental (mobile)
G–15	Sub-dispensary—Dental Prosthetic lab
G–16	Sub-dispensary—Dental Prosthetic lab (mobile)
G–17	Malaria control component
G–18	Epidemiology component
G–19	Malaria and epidemic control component (1–G–18 plus 2–G–17's)
G–20	Optical repair component, base type
G–21	Optical repair component, mobile type
G–22	Rodent control

[1] Often after their arrival at an advanced base, some of the dispensaries were expanded to several times their original bed capacities. In some instances they became medical command activities known as fleet or base hospitals.

The total cost of a fleet hospital of 1,000 beds, including waterworks, sewage and garbage disposal plants, buildings, galley, laundry, shops, and other supporting facilities, was estimated at $1,500,000.

Extracontinental Medical Supply Storehouses

These being primarily medical type installations, CNO made BuMed responsible for planning and coordination. The Brooklyn Medical Supply Depot and subsequently the Materiel Division therefore not only provided the medical and dental material but made arrangements with BuDocks for buildings, utilities, and maintenance equipment and vehicles, with BuSandA for operational and administrative equipment and supplies, and with BuPers for personnel.

Upon receipt of CNO activation orders, the Materiel Division was responsible for interbureau coordination to insure delivery of all materiel and personnel at tidewater in time to meet the shipping date. The Area Commander was responsible for assigning lift-tonnage and arranging for erection of the facility at destination.

The Materiel Division, after consultation with the Professional, Dental, and Preventive Medicine Divisions of the Bureau and reviewing available medical intelligence reports, established basic item-quantity lists of common use medical and dental materiel. Supplementary lists were made of additional items required in areas where various diseases were endemic or where bad hygienic conditions were anticipated.

Each listing was estimated to provide stores for 10,000 men for 30 days. These MSS Load Lists were distributed to the continental Medical Supply Depots and to the medical elements of Area Command logistic planning staffs. These lists were frequently adjusted to correspond with issue experience reported from the field. The Officer in Charge of each MSS was required to submit at least monthly by airmail recommendations for item eliminations or additions, item-quantity adjustments, and concise information relative to his operation and conditions in his area.

The fastest method of getting a MSS into business was by automatic shipments at short intervals of a sequential series of these (10,000/30) load-lists. It was recognized that if issue experience did not correspond to forecast, stocks would promptly get out of balance. This liability was accepted, but corrective action was taken at the earliest opportunity; namely, when the OinC started his reports. The shorter the pipeline between continental depot and MSS the sooner the correction could be made, the MSS placed on a requisition basis, and automatic shipments cancelled.

Medical Supply from Floating Outlets

As mentioned earlier, medical supply of the fleet, the Fleet Marine Force, and overseas Advance Bases from continental depots did not work out well. This was particularly true of the fleet. With the frequent and often unpredictable movements of the numerous ships it was practically impossible to deliver the requisitioned shipment to the consignee within an acceptable period. Consequently, medical supplies on board reached such low levels that ship medical department effectiveness was seriously impaired.

This inability of the fleet freight service to deliver shipments set up a vicious cycle of reordering which resulted in ever increasing quantities of material being immobilized in the pipeline. Thus, while the continental depots were being unnecessarily depleted of sorely needed stocks and the consumer was suffering from supply malnutrition, the pipeline swallowed everything and regurgitated very little. A great deal of this impounded and therefore useless materiel was composed of essential items in over-all short supply. Something had to be done to break this impasse.

The Service Force, Pacific, (ServPac) started medical supply afloat during September 1942 by putting moderate quantities of a limited list of items on board tankers. The space available for medical stores was limited. Tankers, however, did contact the fleet, they had a quick turnaround, and there were many of them. The results of this venture were very satisfactory. Not only did tankers give medical stores to the fleet but on occasion they supplied sorely needed items to Advance Bases.

Due to the limited space available on the tankers, it was decided to use other ships which regularly contacted the fleet, supplied items in universal demand, had an acceptably quick turnabout, and could afford sufficient space for storage and retail issue of a broad list of items. Another consideration was that there be enough, but not too many, of these vessels in the trade so that constant coverage could be effected but none of them would have to wait long periods before discharge.

AK's fitted the pattern ideally. There were, however, only a few in operation at the time, so it was necessary to use some fast dry-provisions AK's. Reefers were also tried for a while, but did not work out well due to the then slow turnaround and certain difficulties in breakout for retail issue.

The so-called Medical AKS or Castor load was worked out to supply 100,000 men for 30 days with a list of approximately 800 of the most essential medical and dental items.

Due to the enthusiastic work of ship's medical officers and hospital corpsmen, the cordial support of commanding officers, the helpful advice and aid from supply officers, and wide broadcasting about this service throughout the fleet, the program was a spectacular success. Consequently, with the exception of hospital ships, all direct requisitioning on continental medical supply depots was abolished. If items not on the AKS Load List were desired, the ship sent the requisition to ServPac where, if it was approved, rapid supply was effected.

As additional AKS's were commissioned, they had built-in medical store and issue spaces. With the increased number of AKS ships (this eventually reached 28) it was found advisable to reduce the AKS medical load to 60,000 men for 30 days' size. Each ship made a voyage issue report by airmail to ServPac. These reports recommended additions, deletions, or adjustments of quantities, and gave the numbers and types of ships supplied together with other pertinent information. A constant running analysis of these reports cumulatively provided the information upon which the load list was kept up to date.

While the AKS program was being developed it became evident that an auxiliary service would be needed to cover gaps in the availability of AKS issue ships at certain anchorages from time to time. To overcome this deficiency five barges with medical stores sections were commissioned during 1943, and four additional barges in early 1945. These were really floating MSS's carrying over 1,500 items in quantity to supply 150,000 men for 30 days. They were anchored near fleet concentration anchorages and Advance Bases, and supported both on demand. Unlike a MSS built ashore, the barge shipped its anchor when the war shifted and was towed to a more active area, where it was ready to start issues upon arrival. The importance of this mobility was demonstrated when barges were towed to Saipan, Manus, and Leyte from rear areas, and helped those localities mount out attack forces destined for still more advanced areas.

Advanced Base Supply

In the operations plans, ComServPac was charged with supplying all medical materiel for operations under the control of CincPac-CincPOA.

With respect to Advance Bases, ServPac had the responsibility of planning all the details of the base buildup when the assault forces had secured the objective. Thus, all the medical department personnel, hospitals, dispensaries, sanitation, and other medical elements of the base had to be requisitioned, the shipments scheduled, and construction accomplished. In addition, medical supplies had to be furnished in sufficient quantities to provide current maintenance and stock level accumulation.

Only the mechanism of furnishing medical supplies is pertinent to this article. This was accomplished by means of a variety of so-called Block Loads. The assault forces carried in with them quantities of materiel sufficient for their own needs and, with combat resupply shipments, had more than they consumed, so that there was always a sizable residue available for the early advance base forces, when the Marines withdrew. Therefore the first automatic block shipment for the Advance Base was usually scheduled to arrive about 10 days after the objective was estimated to be secured. With their own organic supplies together with the assault residue, they had a good interim supply.

Automatic shipments were sent in at 10-day intervals and each shipment had enough supplies for 20 days for the personnel involved. Thus, the base accumulated 10 days toward its stock level, usually 90-days' supply, with each shipment. When it was calculated that the desired stock level was achieved, the automatic block shipments were reduced to maintenance quantities. The base was required to submit a monthly stock status report to ServPac at the earliest possible date and to get on a monthly requisitioning cycle as soon as possible, in order to even out the stock imbalances created by automatic supply.

These monthly stock status reports were analyzed and were consolidated with those of all other bases. The tabulations were then used to adjust the block load lists to conform with experience. Three types of blocks were provided for base forces: the Standard Maintenance Block, the Standard Maintenance Supplemental Block, and the Standard Maintenance Block, Dental.

The Standard Maintenance Block contained balanced medical supplies sufficient for 3,000 men for 30 days (weight 1½ long tons; 4 measured tons). This was supplied by the Navy Medical Supply Depot, Oakland, Calif., through requisitions originated by ComServPac. The contents of the "block" were changed from time to time to conform to recommendations and suggestions made by the senior medical officers of the various bases, and in the target area.

The Standard Maintenance Supplemental Blocks were used in conjunction with the Standard Maintenance Block to supply base forces in the developmental phase of a new base with additional supplies for combat casualties. Such supplies were usually furnished for the first 30 to 90 days depending upon the estimated time required to secure the target.

Standard Maintenance Block, Dental—During the early part of the war dental supplies were furnished in accordance with the strength of the forces to be supported and were a part of the standard block. In 1945 the dental block was developed, based on the number of dental officers rather than on the number of personnel to be served. Supplies in this block were sufficient for 10 dental officers for a period of 30 days. This block was too large. A smaller block sufficient for 2 dental officers for 30 days more nearly met the needs of the forward area.

Supplies for Military Government–A civil affairs block was developed. This contained sufficient supplies for 20,000 civilians for 30 days. Hospital beds were provided by "G" components housed in tents.

Marine Combat Supply

As was mentioned early in this article, Marine combat supply during the early phases of the war in the Southwest and South Pacific was effected from MSS's in those areas. Later in the Southwest Pacific the Marines derived logistic support from the Army. In the South Pacific the MSS's afforded support to Marine combat forces through July 1943. Thereafter Marine combat supply in the Central Pacific was the responsibility of ComServPac. Thus, through the Saipan-Guam operations ServPac provided directly the medical materiel to mount out the MarCorps, for combat resupply, and for the rehabilitation of the combat forces at the staging area upon completion of the assault operation. Subsequent to Guam the FMF organized Medical Stores Sections in their Depots and Service Regiments under the control of the Force Surgeon, and did most of the detailed medical materiel planning. They submitted requisitions to ServPac, which arranged for the delivery of the materiel where requested, either into combat shipping at United States ports, or at the mounting out area, or in ships at the target, or lastly at the rehabilitation site.

MarCorps service elements received and distributed this material together with other categories of supplies for Marine Forces. There were Medical Supply Sections in the Sixth Service Base Depot in the Hawaiian Area, the Fifth Service Field Depot on Guam, the Eleventh Service Battalion on Saipan, and the Twelfth Service Battalion on Okinawa. These sections stocked field medical units and bulk medical supplies. Resupply was obtained from Naval Medical Supply Depots and Storehouses via ComServPac.

The initial medical supply scales (blocks) were based on those used by ServPac. The scales, which were based chiefly on usage rates, were altered from time to time on recommendations from the field. These scales acted as a guide to the division or other medical officers for preparation of requisitions for submission to the Medical Supply Section of the Marine Supply Depots.

The Fleet Marine Force Rehabilitation Medical Block was 30 days' bulk supplies for 3,000 men. Blocks were varied according to the type of organization and to meet particular situations; the number of blocks was in proportion to the number of troops supplied. From 20 to 50 percent of medical field units were required to reoutfit Marines following combat. In other words the loss of medical field units during each major engagement was from 20 to 50 percent.

The Fleet Marine Force Maintenance Block, contained sufficient supplies for 3,000 men for 30 days, and was used following the cessation of combat and also while reoutfitting and reforming for the next operation.

Reserve or combat back-up.–These were block supplies held in cargo ships anchored at advance bases ready for quick transit to the combat zone in case of loss or depletion of the initial and combat resupply shipments. Combat resupply was also based on the needs of 3,000 men for 30 days. The medical personnel attached to the Headquarters Service Command prepared requisitions based on directives received from CinCPac-POA for combat resupply to be shipped to the target at stated intervals. Such requisitions were forwarded by ComServPac to the Navy Medical Supply Depot, Oakland, with the necessary instructions as to packaging and time of delivery. The Depot Quartermaster, San Francisco, specified place of delivery and was responsible for loading. The medical supplies, as well as other combat resupply, were divided equally among the ships assigned for Marine Force use.

Corps Evacuation Hospital.–Fleet Marine Force Pac had three corps evacuation hospitals. Prior to each operation one or two of these hospitals were assigned to the corps headquarters and one was held in reserve. Each had a capacity of 600 beds.

Hospital Ships carried a reserve medical company outfit which could be landed as required. A reserve supply of these medical company outfits was held at Pearl Harbor and Guam, packed and ready for immediate loading.

Waterproof Packing.–In the early stages of the war medical materials packed for domestic commerce were shipped and off-loaded onto beaches and held in open storage. This exposed medical material to the elements and resulted in damage and losses of considerable magnitude. This loss continued until methods of waterproofing were devised and manufacturers and depots could obtain the necessary waterproofing materials. By early 1943 supplies were waterproofed before being sent to combat areas. Later, supplies for the frontlines were waterproofed and palletized on sled pallets.

Whole Blood for Transfusion

The first shipment of whole blood to the Pacific left the West Coast for the Whole Blood Redistribution Center, Guam, on 16 November 1944. Machinery had been set up for reicing at Pearl Harbor and Kwajalein and for handling at Guam. All whole blood was shipped from the West Coast via air to Guam. The Center on Guam reexamined all shipments, discarding containers showing excessive destruction of red blood cells or evidence of contamination.

Prior to an amphibious operation, hospital ships were provided with blood for distribution to the forces taking part in the operation. LST *929* was specially outfitted with reefers for storing blood and with equipment for making the ice required for packing it. Further, reefer mounted trucks transported blood to the mobile blood bank and to the front. The Marines used a mobile blood bank for the Iwo Jima and Okinawa operations. At a later date each Marine division was supplied with a mobile blood bank.

Materiel Shortages and Defects

Every effort was made by MatDivBuMed to provide Navy Medical Supply Depots with sufficient supplies to support all naval forces in the United States and overseas. At one time or another, however, various items were in short supply throughout the service. The medical supply depots prepared and forwarded to overseas Area Commands a list of shortages and estimated dates of item availability. Many special items were disallowed because they were not essential. Essential items in short supply were controlled and issue restricted to those considered most needful.

In the fall of 1943, criticisms of the equipment supplied to fleet hospitals were received from the South Pacific, following which the Commander, South Pacific established a board to standardize fleet hospitals. In accordance with the findings of the Board, it was agreed that Bureau of Yards and Docks would develop plans based on preliminary architectural drawings provided by Medicine and Surgery, and that the Buréau of Yards and Docks and the Bureau of Supplies and Accounts would provide nonmedical materials not in Bureau of Medicine storehouses, for Fleet Hospitals 114, 115, and 116.

Hospital beds were provided for all new bases in the form of "G" components or fleet hospitals. The absolute minimum requirement, for the base to be self-supporting, was 2 beds for 100 of population. An average of 3.5 beds were supplied by the Navy. In estimating the bed requirements for new bases, consideration was given to the prevalence of tropical diseases such as dengue, malaria, and dysentery, and to

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the density of the native population. The larger the number of natives present, the greater the danger of outbreaks of disease among the forces.

The above is of course only a summary of the highlights of medical supply during the war. Readers interested in making a detailed study of medical materiel logistics are referred to current operating manuals. These publications include the refined concepts, techniques, and operational practices now in use and developed as a result of the experiences of World War II. It is our hope and belief that we will not, in the next emergency, have to take all the faltering steps we did in the past, but be ready with adequate and tested mechanisms to meet any situation.

Chapter V

Development of Medical Services for Marine Corps Forces in the Field

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Before World War II this nation had never participated in any war that necessitated the capture of strongly defended island bases or large land masses on which an opposed landing had to be made. Nor was there much to be gained by studying previous military engagements of other nations. Historically, the only opposed landing had been at Gallipoli, and this was far from successful.

The Fleet Marine Forces, in conjunction with the fleet, had made numerous practice landings on islands in the Caribbean area. Although the forces actually landed were small, the lessons learned proved invaluable, particularly those taught by experiences in loading supplies, equipping vessels with medical supplies, and evacuating casualties. Unfortunately, these landings never included a protracted operation ashore. Had this been done, the problems of messing, sanitation, and long lines of evacuation would have become apparent. Fortunately, the Bureau of Medicine and Surgery in 1937, established a board to study, modify, and develop the medical equipment and supplies considered necessary for the support of a Marine Division in a combat landing. Even though the equipment procured was based on experiences in World War I, such a study proved to be of value as the equipment developed was fairly satisfactory.

The First and Second Marine Divisions were activated in the fall of 1941 and early in 1942. The personnel of these divisions comprised some of the best officers and men of the regular Marine Corps, plus Reserves and Volunteers. Their spirit was excellent and they went wholeheartedly into their training. The medical personnel consisted of a few regular medical officers and Hospital Corps personnel, plus Reserve medical officers and volunteer corpsmen. None of the volunteer corpsmen had ever received any Hospital Corps school training, and most of them were uninformed regarding the supplies, equipment, and function of the Medical Department. The Medical Department lacked automotive equipment, surgical instruments, and an adequate allowance of medical personnel for frontline troops. Necessary surgical equipment and supplies were secured from local hospitals, but additional automotive equipment and personnel did not become available until late in the Guadalcanal campaign. In the 4 months that intervened between the activation of the division and the departure of the Second Marine Division for Guadalcanal, the training was intensive and thorough. All corpsmen were instructed in the technique of administering plasma, adequate splinting, and the control of hemorrhage. Dental officers were trained in administering anesthesia and also to work as a team with the otorhinolarynogologists in treating gunshot wounds of the jaws and face.

The result of the time and effort spent in this training was evident in the high efficiency of the Medical Department personnel. A few practice landings made on the beaches of southern California had been helpful, but here again the troops never made any extended stay ashore and therefore many valuable lessons were missed.

Realizing the deficiencies of automotive equipment and personnel for evacuation, a jeep was secured and with minor alterations converted so that it could carry two stretcher cases, two sitting wounded, and the driver. This design was submitted to the Marine Corps Headquarters who unfortunately, rejected it. It was resubmitted and later approved, but not in time to take the necessary number of jeeps to the battle area. Just prior to embarking for Guadalcanal, two jeeps were allotted and necessary alterations were made locally. These two vehicles proved invaluable, but many more could have been used. In the late stages of the Guadalcanal campaign, five factory modified jeep-ambulances arrived at Guadalcanal and were immediately recognized by all as a vital means of evacuation of wounded in small island campaigns.

There was no information available to the Medical Department concerning the place and time of the Guadalcanal landing or regarding the supporting medical services in the rear. The *National Geographic Magazine* furnished the best source of information concerning the south sea islands, together with a report from the Malarial Commission of the Rockefeller Foundation covering the period from 1930 to 1940.

The menace from malaria was evident from the Rockefeller report, but the only protection against mosquitoes was the clothing worn, a head net, and a cot-type mosquito net. It was futile to issue nets to frontline troops because the only personnel who could use them were those in rear areas and field hospitals. Accordingly, all available quinine powder and tablets on the Pacific Coast were secured. Many types of capsules for powdered quinine were tried, but they all congealed in temperatures over 90° F. The quinine powder, therefore, had to be taken in bulk form. This proved to be a great handicap in the administration of prophylactic doses.

In addition to large amounts of quinine, a sufficient amount of brandy in 2-ounce bottles for medical use for 5,000 men for 6 months was obtained. This brandy reduced the incidence of war neuroses during the campaign. When estimating other supplies, the treatment of casualties occurring in naval vessels in our vicinity was anticipated and additional supplies of blood plasma and large battle dressings were included.

We embarked on 1 July 1942 and on 7 August 1942 the First Marine Division reinforced, landed on Guadalcanal, Tulagi, and adjacent small islands. The landing at Guadalcanal was virtually unopposed, so all personnel and equipment got ashore and the medical units became well organized before much enemy resistance was encountered. At Tulagi, the situation was different; there was stiff enemy opposition and casualties were moderately high for 3 days. It was here that the medical department met its first real test. Fortunately, the island was small and lines of evacuation short, so that all casualties reached their combat transports within a short time after being wounded.

Two major defects were noted: First, there were no blackout aid stations where a patient could be treated at night and evacuated. Later, some first-aid stations obtained excellent blackout tents which were designed at the Field Medical Research Laboratory in Camp Lejeune, N. C. The second defect was that line officers and men alike disregarded all rules of sanitation. When the local water supply was destroyed during the engagement, personnel drank water from any source. The dead, both our own and the enemy, could not always be buried without some delay because of battle conditions. Human excreta was deposited indiscriminately and this materially increased the number of flies. Within a week diarrhea appeared. It was fortunate that the enemy had no forces to counterattack at this time.

As a whole, the medical aspects of the operation were successful. Particularly, the death rate from wounds was low because adequate amounts of plasma and sulfonamides were administered early. On Guadalcanal, because of the larger land mass, defects in sanitation were not penalizing. Within a few weeks after landing on Guadalcanal, malaria was prevalent, but the adequate amount of quinine and some atabrine on hand permitted thorough treatment.

In September the Malaria Control Officer on the Staff of Commander, South Pacific, advised the use of atabrine (four tablets per week) as prophylaxis. This was difficult to inaugurate as word got around that atabrine damaged the liver and decreased sexual powers, but by diligent effort this fear was gradually overcome.

In spite of atabrine prophylaxis, the number of cases of malaria continued to increase. By November 1942, 16 percent of the combat troops were ineffective—4 percent from wounds and 12 percent from malaria. Beginning on 15 November, one tablet of atabrine per day was given to men in the Second Regiment. Within 2 weeks the number of admissions for malaria decreased over 50 percent. This dosage was not approved by the Malaria Control Officer and was not reported at this time because of specific instructions not to give more than 4 tablets per week. After 1 December, all Marine troops coming into the area were given one atabrine tablet per day, and from then on the number of ineffectives among the combat troops because of malaria was less than 5 percent. A small supply of mosquito repellant, "Skat," was provided in the middle of December, but because it produced skin irritation and evaporated rapidly, it was not utilized effectively.

During the Guadalcanal campaign it was early discovered that giving plasma and blood in one or two veins was not sufficient to overcome the severe shock and blood loss that followed gunshot wounds of the liver and kidneys. As a result, all patients with liver and kidney wounds were given infusions through the veins of all four extremities simultaneously. Plasma was given in both arms and one leg, and saline and glucose in the other leg. While this was going on, blood donors were secured from troops in rear areas and, as soon as cross matching was completed, citrated blood was substituted for the plasma. The first patient on whom this new technique was employed was an aviator who had sustained a wound extending from the twelfth dorsal vertebra around nearly to the umbilicus, seeming to cut him almost in two. Someone had jammed a shirt into his side, on which pressure was maintained to stem bleeding. When he arrived, no pulse could be felt in the wrist and it appeared that the patient was dying. The "four-way" infusion described previously was started after cutting down on the veins in all four extremities—the petcocks on the infusion sets were opened wide. Within 15 minutes the pulse appeared at the wrist. Blood was substituted for the plasma and in an hour and a half the blood pressure had risen and stabilized around 110/70. The transfusion was continued for another half hour and the patient was prepared for surgery. During this period of preparation the patient received 8 units of plasma, 9 pints of blood, and 2,000 cc. of saline dextrose—a total of 11,500 cc. in 2 hours. This patient made a complete recovery despite his very extensive injury, which also involved the kidney and colon. This is believed to be the first time that a "four-way" transfusion had ever been used and that such large amounts of plasma and blood had been given in such a short interval. This "four-way" transfusion was later used successfully on other patients with wounds of the liver and kidney.

In the forward areas patients with burns were treated with 5 percent sulfanilamide ointment locally, pressure dressings, plasma, saline, and dextrose. About 24 hours after the sinking of one of our large aircraft carriers, 76 patients who had second degree burns of from 30 to 50 percent of their body surface were received. Many of them had been burned while swimming through flaming oil. The burned areas involved the legs, arms, upper chest area, and face. Each patient received an average of 4,000 cc. of plasma and 2,000 cc. of saline and dextrose via the femoral vein, during the first 72 hours. All these patients were treated in a field hospital for 2 weeks before they were evacuated. There were no deaths. Because the burned and wounded areas were clean, no secondary infection was evident at the end of 2 weeks. This is believed to have been the first time that severely burned and wounded patients had been treated with sulfanilamide ointment and plasma under combat conditions. Under field conditions, when a large number of casualties were received, it was impossible to administer sulfonamides or other drugs either orally or parenterally because sufficient medical personnel were not available.

Keeping a record of the casualties evacuated from a combat area is one of the most important functions of the Medical Department, both in the forward and rear areas. In the forward area the record simply listed the name, rank or rate, serial number, diagnosis, and date of evacuation. Unfortunately, because of lack of coordination in the rear areas, large numbers of patients were lost track of and it was most difficult to find out if personnel had been evacuated to the United States or if they were still in base hospitals in the rear. When health records, pay accounts, service records, and personal effects were left in the rear areas, it became a tremendous task to try to get the patient, his personal effects, and records together. Although attempts were made to establish casualty clearing sections in later campaigns, the problem was never adequately solved. A thorough study of casualty recording and reporting should be made and an adequate system developed so as to prevent a repetition of this confusion.

Establishing a satisfactory operating room during combat was found to be particularly difficult with the equipment provided. This included a tent, a light portable operating table, and a battery spotlight. The tents could not be blacked out and there was no protection against flies and mosquitoes; so that clean surgery was impossible. A portable plywood hut (16′ by 16′) was finally secured from an aircraft tender and this proved to be ideal for an operating room. This hut, known as the "Dallas Victory Hut," was well screened, had a good solid oak floor, and flaps for blacking out. Following the Guadalcanal campaign, each medical company was provided with one of these portable operating rooms. In the later campaigns it was found possible, by presterilizing instruments, to have the portable operating room set up and functioning within 6 hours following the landing of a medical company.

In 1944 the Marine Corps Headquarters asked several contractors to design a portable plywood hut, 16′ by 16′. As a result 16′ by 16′ huts that weighed about 1,200 pounds were manufactured. These could be erected in 2 hours by 4 men, and could be shipped in a package 4′ by 4′ by 8′. Future developments along this line should be encouraged, as these plywood operating rooms proved to be the only way that major surgery could be carried out satisfactorily in the field.

Medical Department brandy was first used in the field in the Guadalcanal campaign to combat fear and combat fatigue. Each aid station and field hospital was provided with brandy so that the medical officer could administer this to men who manifested early signs of fear or combat fatigue. Four ounces of brandy were added to each canteen of water and two or three swallows of this given to a dehydrated patient (on an empty stomach) was usually sufficient to induce a sound sleep. Following this, he would be ready for the frontlines again. With some patients this procedure had to be repeated two or three times; in no instance did a patient try to take improper advantage of the medication.

Near the close of the Guadalcanal campaign, a Medical Department combat landing plan was designed. This plan listed the supplies and equipment to be landed with each medical unit and showed a diagram of the Medical Department personnel and lines of evacuation from the frontlines back to the rear areas and evacuation points. It was a great aid in coordinating the medical activities in a division and also provided for better teamwork between the forces ashore and the supporting amphibious forces. This combat landing plan was later used with slight modifications by the Marine Corps divisions and was also used as a training guide in the Field Medical Schools.

The First and Second Marine Divisions were sent to Australia and New Zealand, respectively, for reoutfitting and reorganizing. Upon arrival, the weather was cold and rainy and there was not enough coal available to adequately heat the living quarters. Six weeks following their arrival, the Second Marine Division had an average of 250 admissions for malaria each day from among the 13,000 men who had been in the Guadalcanal area. This high admission rate severely taxed the field and the base hospital at Wellington. Had there been more information on the prolonged use of atabrine as a suppressive agent, this high admission rate could have been materially reduced. However, no suppressive therapy was used and each admission was treated with quinine or various combinations of quinine and atabrine. Atabrine therapy alone was also used. In spite of the various antimalarial drugs used, the admission rate remained high. In two battalions that had been in the Guadalcanal area therapeutic studies were started under similar conditions for an equal length of time. In one battalion all newly admitted malaria patients were given 30 grains of quinine for 10 days, followed by 10 grains for 30 days. In the other battalion all new admissions were given 6 tablets of atabrine for 3 days, 3 tablets a day for 7 days, followed by 1 tablet a day for 30 days. These battalions were observed for 2 months. In the battalion receiving atabrine, the recurrence rate was nearly 70 percent less than in the battalion receiving the quinine. This was convincing evidence that, of the two, atabrine was the drug of choice in treating malaria. In the recurrences nearly all smears disclosed *Plasmodium vivax;* in a few patients a mixed infection with *Plasmodium malariae* and *P. vivax* was noted. Four months after leaving the Solomon Islands, however, all smears revealed only *P. vivax.*

In July 1943 the Second Marine Division received orders to prepare for the attack on Tarawa in the Gilbert Islands. The Division Surgeon was one of the 8 staff members included in the advance planning. All medical sections were thoroughly indoctrinated in the Medical Combat Landing Plan and intensive drills were held, both day and night. Medical supplies, which were rather difficult to secure, were finally obtained, including 6,000 units of plasma. All corpsmen were trained to give plasma. Boat bags were procured and packed with essential first-aid items, such as battle dressings, plasma, sulfanilamide powder, and splints. These bags proved to be a great aid in landing medical supplies, for corpsmen could easily carry this bag ashore, in addition to their personal equipment.

As no amphibious force surgeon was present, the division surgeon was assigned the additional duty of training and coordinating the medical departments of the transports. This was of value in the operation of the plan, as all Medical Department personnel from the frontlines back to and including the transports knew what their functions were and how other units were to function.

All personnel landed were thoroughly indoctrinated in the proper disposal of galley waste and human excreta, and all drinking water was placed in cans and salted just prior to the landing. As a result, there were no admissions for gastrointestinal complaints. There were, however, a few admissions for heat exhaustion in one battalion because they failed to carry out the order to salt the drinking water.

Intelligence reports indicated that there were approximately 4,000 enemy troops on Tarawa. From experience in previous operations it was realized that the bodies of nearly all of the 4,000 enemy troops would have to be disposed of in addition to our own dead. Three methods of disposal of the dead were considered. The first idea was to take all bodies out to sea and weight them for sea burial. This was considered to be impracticable because of the large number of boats and working parties required. Second, cremation of the enemy dead was considered, as this was the common practice of the Japanese, but this, too, was impracticable because of the large amounts of fuel oil necessary and the length of time required for cremation. The method of disposal finally evolved was burying our own dead in long graves made by bulldozers and the enemy dead in bomb craters which were then covered over by bulldozers. This proved to be satisfactory although the water level was only 6 feet below the ground level. The plan was well conceived but was carried out under great difficulty. Most of the bodies had been exposed to the heat for from 4 to 7 days, and the odor was almost beyond human endurance. Within an hour the working parties of 300 men would become so nauseated they could not continue working. Within a week, however, all exposed bodies on the island were buried. This disposal of the dead had to be carried out by the assault forces who were already exhausted by 4 days and nights of a terrific fight. They readily helped in burying our own dead, but were bitterly opposed to burying the enemy dead. In conference with the high Naval Command in Pearl Harbor, following this attack, it was finally agreed that in future operations a battalion, in conjunction with the grave registration units, Seabees, or other personnel, should be assigned the sole duty of disposing of the dead.

On 20 November 1943 the attack on Tarawa was started. One hundred and twenty-five amphibious tractors were utilized in landing the initial assault companies. Casualties in the assault companies ranged from 50 to 70 percent. By noon of D-day about 300 troops had secured a small area on Red Beach 2, adjacent to the pier. A small number of troops were landed on this beach in the afternoon and evening of D-day, and by the morning of D-day-plus-1 about 100 yards of the beach had been secured but only to a depth of 25 to 75 feet. During this period the only medical supplies available were those that were carried in by Medical Department personnel in kits or boat bags. Because of the terrific number of casualties, no organized evacuation could be effected at this time, but casualties were evacuated as rapidly as possible by any and all hands available. They were taken directly to AP's throughout that day and night by amph-tracts or any other type of boat at hand. By the morning of D-day-plus-1, the main points of evacuation had been established and were functioning smoothly. On D-day-plus-1, additional troops began to land, additional medical supplies had been secured, and all casualties were receiving adequate amounts of plasma before being evacuated.

Approximately 2,500 casualties were evacuated during the 4 days of the attack. During this time nearly 4,000 units of plasma were used, or an average of a little less than 2 units of plasma for each casualty. A large percentage of the plasma was administered by corpsmen. The time spent in training corpsmen to give plasma contributed largely to keeping the death rate at the low of 2.3 percent of those wounded.

On D-day-plus-2, Companies "A" and "B" of the Second Medical Battalion were ordered ashore on Betio and Bairiki Islands, respectively. Both of these companies established operating room facilities and were ready to operate 6 hours after landing.

Many casualties arrived aboard the transports within 1 hour after being wounded although some were not received until as long as 12 hours after being hit. The low death rate of 2.3 percent during the Tarawa campaign was due to the following factors: First, the heroic work of the medical officers and corpsmen under terrific odds; second, the use of large amounts of plasma during the evacuation; and third, the thorough indoctrination of all medical personnel, including those in transports, in the medical plan.

The plan to have a senior medical officer from the Transport Divisions on the control ship to properly distribute the patients to the transports was not carried out in the Tarawa operation. This resulted in the overloading of several transports; some received from 50 to 75 casualties in an hour or two. This caused some delay in treatment. It is essential that a senior medical officer, thoroughly acquainted with the capacity and capabilities of the staff of each transport, be assigned to the control ship.

The use of APH's in an attack was considered highly desirable, as this type of ship could carry in assault forces and also had a complete staff of specialists and large sickbays, so that specialized treatment could be provided. The use of AH's was also highly desirable, but since they could not go into the transport area until D-day-plus-1 or later, it was seldom possible for them to receive casualties directly from the beaches. Their main function, therefore, was that of relieving the overloaded transports of casualties for evacuation to base hospitals.

In the Marianas campaign, an attempt was made to use medical officers aboard control vessels. These medical officers were not assigned until the last minute and as a result did not know the capability of the medical sections and capacity of the transports employed. Air evacuation from the Marianas campaign was started on D-day-plus-14. At first, the casualties were not properly screened and many were evacuated by air who were in poor condition. This resulted in several near fatalities. In the Guadalcanal campaign, all casualties who were to be evacuated by air were properly screened and all arrived at the base hospitals in good condition.

The Medical Department with the landing forces in the Marianas functioned in a highly commendable manner. Unfortunately, many of the jeep ambulances assigned to the divisions were not loaded and as a result, evacuation of of casualties from the forward areas was unnecessarily delayed. In the Marianas campaign it became apparent that mobile surgical units were necessary if the Medical Department was to keep up with the rapidly advancing attack. Following this operation, recommendations were made for a complete mobile surgical unit. To meet this need, the Bureau of Medicine and Surgery and the Marine Corps developed an air-conditioned surgery complete with sterilizing equipment in a trailer, 8 by 18 feet. The Marine Corps furnished the trailer with air-conditioning equipment and the Bureau of Medicine and Surgery furnished the sterilizer bank, operating table, operating lights, and all types of surgical equipment. Because all units to go into this trailer had to be specially designed and manufactured, it was nearly 1 year before these surgical trailers reached the field. They were not delivered in time for the Iwo Jima or Okinawa campaigns, although they were ready for the attack on the Japanese mainland. The continued study and improvement of such mobile surgical units is highly desirable.

As a result of the experiences in the Tarawa and Marianas campaigns, amphibious trailers originally designed by the Marine Corps to land essential supplies and equipment were converted into armored amphibious sickbays. They offered protection from shrapnel and small-arms fire to the casualties in battalion and regimental aid stations, and could be loaded with large amounts of supplies and medical equipment. Hauled ashore by amphibious tractors, they were immediately available to properly care for a large number of casualties. Armored amphibious sickbays were considered to be a prime requisite in handling casualties near the frontlines. If such aid stations had been available at Tarawa, adequate medical supplies would have been available early, even if only one or two were successfully landed. They certainly would have been ideal for the landing at Iwo Jima, where the aid stations on the beaches were under fire for several days.

After the Guadalcanal and the Tarawa campaigns, it became evident that certain additional medical and surgical specialists should be assigned to the Marine Corps Divisions. In response to requests coming in from the field, one psychiatrist and one ophthalmologist were added to the Headquarters Company of each medical battalion. In the Iwo Jima campaign, the operations reports indicated that the psychiatrists were able to segregate and control evacuation of all neuropsychiatric patients. This took a great workload off other medical officers who were then able to concentrate on the care of the wounded. The work of the ophthalmologist also afforded much better care for those with eye wounds.

The Hospital Corps pouch furnished to the medical personnel attached to the Marine Corps was too narrow and too deep. Following the Tarawa operation, a study was started at the Field Medical Research Laboratory at Camp Lejeune on developing and improving the Hospital Corps pouch. A modification of the Navy Hospital Corps pouch was developed and adopted, which made all supplies accessible, with separate compartments for morphine syrettes and other small items.

The sick call cases furnished with the field medical equipment early in the war were found to be highly unsatisfactory. These were simply fiber suit cases which were easily broken and were not waterproof. When they were opened, the contents were found scattered. Late in the Guadalcanal campaign and following it, the standard Marine Corps field desk was converted to sick call cases. Separate compartments were built into these field desks for standard size ointment jars and bottles. When the desk was opened up and the legs extended, the needed equipment was immediately available. This sick call case was later modified at the Field Medical Research Laboratory and became a part of the field equipment issued to all Medical units with Marine divisions.

Although we had entered World War II with no experience in the employment of medical units in an opposed amphibious landing, we had learned a great deal by the spring of 1943, as is shown in the following order issued on 1 April 1943:

SENIOR OFFICER PRESENT:

EMPLOYMENT OF MEDICAL UNITS

The following are basic instructions for the Amphibious Employment of medical units of this Division:

1. *GENERAL PRINCIPLES*
   a. *Medical supplies:*
      (1) Combat loaded.

(*a*) Initial requirements to be available for debarkation with medical personnel.

(*b*) Remainder to be unloaded with combat team material.

b. *Medical personnel:*

(1) Combat loaded.

(*a*) Combat team and landing team personnel normally will be with their original Headquarters (Annex "A").

(2) Will be equipped with shoulder holster and a pistol for self-defense when directed.

2. *SHIP-TO-SHORE*

a. *Medical personnel will land as follows:*

(1) In approximately the same wave as Headquarters to which attached.

(*a*) Company Aid Corpsmen.

(*b*) Battalion Aid Station.

(*c*) Regimental Aid Station.

(*d*) Medical personnel with Division troops.

(2) Earliest possible time following Shore Party Command Group:

(*a*) Shore Party Medical Personnel.

(*b*) Collecting Section.

(3) When tactical situations permit.

(*a*) Hospital Section.

(*b*) Medical Battalion.

(*c*) Malaria Control Unit.

b. *Supplies and Equipment* (paragraph 5):

3. *ASHORE*

a. Company Aid Corpsmen will give wounded emergency treatment in Company Zone of Action.

b. Battalion Aid Station will evacuate casualties from frontlines to Battalion Aid Station, treat and prepare casualties for future evacuation.

c. Regimental Aid Station will establish near Regimental Command Post and along line of drift from Battalion Aid Station.

d. Landing Team Shore Party (Medical) will be composed as follows:

(1) Collection Section Medical Company: 1 Medical Officer, 11 Corpsmen, 3 Marines, and 1 Jeep Ambulance (combat loaded).

(2) Pioneer Platoon: 1 Corpsman.

(3) APA: 1 Medical Officer, 8 Corpsmen.

e. The following are assigned duties at Shore Party Aid Station:

(1) Medical Officer (Collecting Section Medical Company): Segregation and treatment of patients at Shore Party Aid Station.

(2) Medical Officer (Pioneer Company):

(*a*) Coordination of evacuation stations and report to Division or Shore Party Commander on evacuation.

(*b*) Treatment of casualties occurring in his immediate area.

(*c*) Designation of Corpsmen to record patients evacuated to APA and also 1 Corpsman on APA to record patients received. (Data to include name, organization, diagnosis, and serial number.)

(3) Medical Officer (Collecting Section) and Medical Officer (Pioneer Company): Litter, blanket, and splint exchange.

(4) Medical Section (APA): Evacuation by boat to APA, and in addition assist Company 1 Section.

f. Collecting and Shore Party Medical Personnel: Establish such emergency Field Hospital as necessary to care for casualties after the APA's depart and before Hospital Section can establish Field Hospital.

g. Hospital Section: Set up Field Hospital, receive, treat, and separate casualties for evacuation.

h. Medical Battalion (less 3 companies):

(1) Establish Division Hospital and be prepared to receive, treat, and evacuate patients from units in the area, or to relieve other Medical Companies when necessary. Their ambulances will be available to aid casualty evacuation from all units, which they serve. When established, the following will be notified:

(*a*) Division Surgeon via Commanding Officer, Medical Battalion.

(*b*) Any unit served.

i. Malaria Control Unit will unload on order. For duties, see Senior Officer Present, Malaria Control.

4. *INSTRUCTIONS TO MEDICAL PERSONNEL*

a. *Employment in Combat:*

(1) No Medical Officer will be assigned to a unit smaller than a Battalion except Medical Officer in Pioneer Battalion.

(2) Medical Officer will remain with respective Aid Stations during combat.

(3) Medical personnel will take same precautions regarding concealment, camouflage, and local security as combat troops.

b. *Handling Casualties:*

(1) Attach medical emergency tag to all casualties when first treated. Fill in *name, organization, nature of wound, and treatment.*

(2) Battalion, Regimental, and Shore Party Medical Section will log all casualties passing through, showing *name, organization, nature of wound, injury or sickness,* and *disposition.*

(3) Shore Party Medical Section will classify wounded in accordance with method of transportation and expected recovery.

(*a*) Ambulatory.

(*b*) Litter.

(*c*) Nontransportables.

(*d*) Patients who will become effectives in 10 days will not be evacuated.

(d) Casualty reports will be made through normal channels to Division.

c. *Chain of Evacuation:*

(1) Through Battalion Aid Station via Regimental Aid Station to beach, to APA or hospital.

d. *Exchange of Supplies:*

(1) Particular attention will be given to exchange of litters, splints, dressings, and plasma between Battalion and Regimental Aid Stations, Shore Party Medical Section, and ship or hospitals.

e. *Disposition of Dead:*

(1) All dead will be tagged, collected at Battalion Aid Station, and disposed of as directed.

(2) The Graves Registration Section, plus 2 dental technicians from Combat Team will function under direct control of the Chaplains. Two Form "N" will be prepared, and in the case of dead who cannot be definitely identified otherwise, Form NMS H–4 (Dental Chart) will be prepared and securely attached to original certificate of death.

5. *SUPPLIES AND EQUIPMENT*

a. *Individual:*

(1) Medical Officer	Unit One
(2) Dental Officer	Unit Two
(3) Corpsmen (Medical)	Unit Three
(4) Corpsmen (Dental)	Unit Four

b. *Battalion Aid* (Infantry):

(1) Two Jeep ambulances.

(2) Units 1 to 5 inclusive, 3 each of units 6 and 7, 4 unit-9, 1 unit-10.

(3) Sick call chest.

(4) Bulk supplies (packed in waterproof pouches):

(*a*) Battle dressings, large	100
(*b*) Battle dressings, small	500
(*c*) Benzedrine	1,000 tablets
(*d*) Morphine syrettes, packet	50
(*e*) Plasma	60 units
(*f*) Plastic leg splints	12

(Battalion Aid Station will be divided three ways and loaded in landing craft.)

c. *Regimental Aid* (Infantry):

(1) Same as Battalion Aid (Infantry).

d. *Artillery Regiment:* H&S and Artillery Battalions.

(1) Same as Battalion Aid (Infantry) less 1 Jeep ambulance and 10 canvas litters.

e. *Special and Service Troops:*

(1) Same as Battalion Aid (Infantry) less Jeep ambulance. Twelve folding litters in place of canvas litters.

f. *Collecting Section* (Medical Company):

(1) Same as Battalion Aid (Infantry) less 1 Jeep ambulance and sick call chest. Twelve folding litters in place of canvas litters.

(2) Additional Aid Station Equipment—120 units of plasma, 5 expeditionary cans, 1 lister bag, and 1 utility box.

(3) 20 percent bulk supplies of Medical Company.

g. *Medical Company* (less three collecting sections):

(1) Initial Group:

(*a*) 1 Jeep ambulance, combat loaded.[1]

(*b*) Two 4 by 4 one-ton trucks, combat loaded.[1]

(*c*) 2 field ambulances, combat loaded.[1]

(*d*) 1 trailer, water.

(*e*) 1 one-ton trailer, cargo.

(2) Secondary Group:

(a) Remainder of equipment and supplies of 72-bed hospital included in No. 1 priority.

(3) 40 percent bulk supplies of Medical Company.

h. *Medical Battalion* (less 3 Medical Companies):

(1) H&S Company:

(*a*) 1 Jeep.

(*b*) Officer equipment.

(2) Two Companies (Medical):

(*a*) Supplies and equipment for two Medical Companies. When additional Medical Company is assigned to Infantry, Regimental, or Artillery Regiment, their supplies and equipment will be divided as Medical Companies normally with Infantry Regiments.

[1] This equipment will include portable surgery with necessary instruments and sterile packs to enable them to perform abdominal surgery within first 24 hours; 50 stretchers, 50 blankets, 50 cots, and four tarpaulins.

Chapter VI

Medical Service With Amphibious Forces in the Saipan Operation

Eugene R. Hering, *Captain (MC) USN*

During the amphibious assaults on Japanese strongholds in the Pacific from Guadalcanal to Okinawa, the United States Marines suffered approximately 95,000 battle casualties. The thousands of wounded in the first few days of the assaults on Tarawa, Guam, Peleliu, Saipan, Tinian, and Iwo Jima would have taxed the efforts of even a dozen well-equipped major hospitals. To provide every phase of medical attention, from initial first aid to definitive treatment, was the mission of the medical service of the Amphibious Forces in the Pacific. In addition it was necessary to maintain the health of the 300,000 troops who were often encamped in disease-infested areas. Instituting preventive medicine measures, supervising sanitation, weeding out the physically unfit, training medical officers and corpsmen, and welding these personnel into a smoothly functioning organization, were some of the problems facing the Field Medical Service of the Navy Medical Corps. The Medical Department of the forces afloat who closely supported the Landing Force also had similar, almost overwhelming, tasks to perform.

The initial planning for field medical service was done by a handful of medical officers who by long association with the Marine Corps foresaw the need for building up of this specialized branch of the Navy Medical Corps. No training school existed for this particular function of the Medical Department and only a few officers had availed themselves of the opportunity to attend the Army School of Field Medicine at Carlisle, Pa. As a result, all through the war there was a lack of medical officers well versed in staff administrative work and the tactical employment of medical troops in the field, to administer the large force that eventually was on duty with the Marine Forces in the Pacific.

The modernization of equipment and the promulgation of new doctrines appears to have been based on local decisions rather than on directives emanating from the Bureau of Medicine and Surgery, perhaps because there was no department in the Bureau dealing exclusively with Field Medicine. It was not until late 1942 that liaison between the Bureau and the Headquarters Marine Corps was established; in fact a full fledged amphibious medical service was not created until 1946.

This slow development of the Medical Service shows the need for continuous medical preparedness in times of peace. Our modern Amphibious Forces actually came into being with the inception of the Fleet Marine Force. There had been landing maneuvers prior to this time and much study of the problems of landing an attack force had been undertaken by Marine Corps Schools, but the formation of the Fleet Marine Force served to crystallize the aims of the medical components and gave to this specialty in military medicine the status it deserved. The Navy doctrine for landing operations, first conceived in 1934, was developed in the maneuvers in 1935, 1936, and 1937, which revealed the immense problems involved and indicated a solution for some. The Landing Operations Doctrine then evolved was logical and sound for the size of the units involved. It was then realized that extensive medical support was needed, for the reports of those maneuvers were unanimous in their recommendation for the assignment of more medical personnel. This is understandable when one reads that the hospital section of a provisional medical company in the brigade maneuvers on Culebra in 1939 consisted of one medical officer and six hospital corpsmen.

Early in 1940 two medical companies were formed. As they were rather an orphaned outfit, with no one to look after their pay, messing, accountability, and zone of operation, a headquarters and service company was authorized soon after and the brigade surgeon was given additional duty as commanding officer of what was then designated the Brigade Medical Battalion. Two more companies were added later the same year and when the division was formed a fifth company came into being to give more medical support. This then was the sum total of our Medical Field Service at the start of the war.

Following experiences at Guadalcanal, and with the formation of more marine divisions, the need for additional medical support became apparent. An independent medical battalion of five medical companies was formed and sent to the South Pacific as reserves to give medical support where most needed. These companies never functioned efficiently in that capacity because of the tactical situation which prevailed. Eventually the battalion was reduced to three companies plus a headquarters section and became the Corps Medical Battalion, employed as an echelon of medical support in the rear of the division.

As the scope of operations progressed and forces of almost Army dimensions were activated, the medical needs increased proportionately. To meet this need, three corps evacuation hospitals were organized and trained, the first one being ready in time for the Iwo Jima operation.

During the final operation of the war in the Pacific, the medical support of the two divisions engaged consisted of the organic medical sections of battalions, regiments, and separate battalions, the organic medical battalions of each division, one corps medical battalion, and two corps evacuation hospitals.

On V–J Day approximately 700 medical officers, 230 dental officers, 90 Hospital Corps officers, and 10,000 hospital corpsmen were on duty with the Marines in the Pacific theater. This was a far cry from the handful of medical personnel available to Capt. Warrick T. Brown (MC) USN, on the 1939 maneuvers.

The responsibility of the medical service of the forces afloat was well stated in the doctrine of 1938. The need for hospital ships and especially fitted casualty carriers was clearly shown and their use was outlined. That more of these ships were not available at the start of the war and that the few available were initially not better fitted into the tactical plans of the forces afloat is not surprising, in view of the uniform lack of all types of service vessels in the Navy at that time. Although the need for specially built assault transports had been apparent for some time, it was not until 1941 that such ships were actually in operation. One concept that greatly affected our medical planning was the doctrine, enunciated in the Transport Doctrine of the Amphibious Forces of the Pacific Fleet, that an assault transport could care for 150 litter cases and up to 325 ambulatory wounded. This doctrine was probably born of necessity, because of the lack of hospital ships and casualty carriers, but it was a dangerous concept and wholly inconsistent with adequate care of casualties. It was part of a pattern of thought which permeated the forces afloat and influenced the establishment of hospital facilities ashore. It was the "bed for a casualty" type of thinking; in other words, as long as the wounded man was in a bunk and out of sight of the troops, part of the medical mission was accomplished. It must be recognized that war wounds are surgical problems, best handled by a trained surgeon during the golden hours of early surgery. When one considers the facilities and personnel required to care for 150 seriously wounded patients, as well as for 325 patients with minor wounds, it becomes apparent that 3 medical officers with limited equipment, regardless of their talent or heroic efforts, will not suffice.

Early in the war, our forces did not enjoy the mastery of the sea and air which characterized the later amphibious operations. Transports were forced to retire to the open sea in the late afternoon to insure space for maneuvering to avoid air and submarine attacks; they could not return to the transport area until an hour after daylight. This was the weakest link in our evacuation chain and medical service. On a hotly contested beachhead it was impossible to establish surgical installations ashore until D-day-plus-2 or 3, and with no ships available for the evacuation of patients at night those casualties that occurred in the late afternoon or during the hours of darkness often spent many hours on the beach or in open boats, before reaching facilities that could provide definitive treatment.

Hospital ships and ships fitted as casualty carriers (APH's) were not available in sufficient numbers to cover the entire theater of operations, and because of the dangers of enemy attacks, they were used cautiously. At Tarawa they were kept about 80 miles away and did not anchor to take on casualties until the operation was completed. One hospital ship took approximately 265 casualties from the transports and the other did not receive a patient. At Saipan no hospital ship was available until the third day, and thereafter only at irregular intervals. In the final operation at Okinawa 2 hospital ships and 2 casualty carriers were present at all times. It is ironic that the only hospital ship to suffer major damage and casualties was steaming away from the scene of combat fully lighted, while those that were lying in close support, just off the landing beaches and within the protecting ring of our pickets and transport area defenses, suffered no damage.

The use of LST's for casualty handling and distribution was developed relatively early in the South Pacific campaigns. Designated LST (H)'s, and staffed with surgical teams from rear echelons for each operation, these ships became an important link in the chain of evacuation. One LST (H), the *464*, was completely refitted as a hospital ship to give close support off the beach. She proved ideal for giving early definitive care when further evacuation could not be accomplished. In the Central Pacific campaigns, until the Iwo Jima and Okinawa operations, there was a lack of this type of vessel; 6 had been lost by explosion of ammunition just prior to the Saipan campaign, necessitating a complete revision of plans.

At Iwo Jima, one LST employed as an LST (H) received and distributed almost 2,600 casualties. Okinawa saw the employment of these ships in sufficient number and with adequate staff and equipment to carry out their mission. Plans for later operations called for even greater use of these craft for casualty handling.

One of the greatest burdens placed on the Field Medicine Department was the supervision of sanitation and the institution of preventive medicine measures. Although the staff manuals and operation orders maintain that measures for the prevention of disease are a command function, too often the tremendous importance of this administrative phase of a military operation was overlooked. As a result, the record of our fight against tropical disease was not an outstanding one.

There are many reasons for the failures in this field. Medical Intelligence was for the most part entirely lacking or so distorted that no accurate picture of the diseases prevalent in an area was available. Initially it was actually believed in certain commands that white men could not contract filariasis. The intensity of malarial infection was underestimated. Very little information was available regarding scrub typhus. In the later campaigns the pendulum swung completely over, and on the last operation, Okinawa, the troops were fully prepared for any diseases and health hazards that might exist.

When it became apparent that disease was taking a far greater toll than Japanese bullets, specially trained malarial and epidemiological control units were organized and assigned to marine divisions. These organizations were of inestimable value in that they provided well-trained personnel whose sole function was in the field of preventive medicine. The entire program fell short of fulfillment, however, because there were no labor details to carry out the recommendations of these units. A sufficient number of trained and equipped personnel were never available to carry out preventive medicine measures on a large scale. Regardless of the indoctrination and discipline of combat troops, they are incapable of doing both the fighting and the necessary house cleaning.

Eventually details of 50 men from the Seabees were assigned the mission of carrying out disease prevention measures for each division. This arrangement was still inadequate, for these personnel were never available for sufficient training. Their prime mission was the building of roads and airports, so that their use for sanitation and disease control was limited.

The answer to disease control on a large scale is the formation of a trained and equipped unit acting directly under control of a section of the Medical Department whose primary mission is sanitation and epidemic control. With the threat of bacteriological and atomic warfare and the need for trained personnel for decontamination, such a unit assumes added importance.

The Saipan operation, as the midphase of the offensive against the Japanese, lends itself well to a portrayal of amphibious medical service, afloat and ashore. There was both furious resistance on the beachhead reminiscent of Tarawa and prolonged fighting over rugged terrain that gave the Medical Department an opportunity to establish itself fully ashore and assume its vital role.

It is well to emphasize that in the assault on Saipan the Medical Department personnel had many advantages over those engaged in the earlier campaigns. First, there were more ships, planes, men, and supplies; and relative mastery of the sea and air was ours. Second, malaria and the rigors of a tropical climate were absent. Third, there were honest and forthright reports, both written and verbal, of preceding operations, pointing out mistakes and making recommendations for their correction. Fourth, 50 percent or more of the medical officers and hospital corpsmen had been in combat and therefore knew the demands to be made upon them. Fifth, the outfit, by bitter experience in battle, appreciated the Medical Department and spared no effort to provide the medical unit with assistance in training, planning, and intelligence concerning the coming operation.

The most important phases of an operation is the training period preceding it. It is during this period that the lessons learned in previous combat are evaluated and translated into operating doctrine while the replacements for those lost in previous combat are welded into a team that will act with automatic precision in the face of whatever hazards are encountered.

The training period officially began on 15 January 1944 on the broad high plateau of the northern end of the "Big Island," Hawaii. Battalion, regimental, and separate battalion medical sections, besides carrying on the routine sickbay activities, closely participated in all of their organization's field problems. The medical companies, for the first time, were bivouacked together under the administration of headquarters company of the medical battalion. These companies were rotated through three types of training. An Army hospital on the outskirts of the bivouac area provided hospitalization for our sick. Two medical companies and various specialists from other companies served on the staff. This allowed for basic training of technicians and kept professional interest alive. A field hospital in the bivouac area, which was staffed by 2 medical companies, gave both medical officers and corpsmen a chance to thoroughly familiarize themselves with the equipment they were to work with in the field. The third type of training consisted of participation in field problems for 1 month and establishment of the medical company installation in a variety of locations and situations.

Classes were held throughout the division for basic training in plasma administration, record and supply work, blackout precautions, evacuation of tanks, loading of DUKW's and amphtracs with simulated casualties, and many other details. Every medical officer and corpsman in the division was given training in the care and firing of small arms. Most of the company aid men on their own initiative mastered all of the various weapons carried by the Marines of their platoons, including the 50-caliber machine gun; bazooka, 37 mm. gun; and light mortar.

As a forerunner to actual planning, comments from all medical officers who participated in the Tarawa operation were secured and evaluated. Amphibious warfare is an ever-developing science and comments on any previous operations were considered, not in the light of mistakes that occurred, but rather in regard to the lessons learned. Several elements of doctrine regarding supplies, equipment, and tactical employment were evolved from these lessons.

Experience had shown that the field units, as issued, were of little value for battalion and regimental use. On the way into the beaches at Tarawa, many corpsmen had been hit and their equipment lost with them. Thus if a corpsman detailed to carry in "Unit X" was lost, there was a shortage of battle dressings; if the men detailed to bring in the boxes of plasma became casualties, there was a shortage of plasma. The equipment and supplies as issued were individualized too much. To offset this, assault medical packs made from the canvas carrying case and filled with such vital items as battle dressings, plasma, morphine, and sulfa drugs were prepared in identical loads for all units of the division. These assault packs, plus litters and plywood splints, were the sole initial allowance of the battalion aid sections. Further, the jeep ambulance was loaded with splints, litters, blankets, extra plasma, and a compact sick call chest.

For immediate resupply, one amphibian tractor stationed off each regimental beach was assigned to the Medical Department and carried a full load of litters, blankets, and splints, as well as resupply units in 50-pound cases, containing plasma, battle dressings, morphine, and sulfa drugs. These amphibian tractors were to lie alongside the logistical control boat and be available to any section of the regimental beach on call.

Vehicles were combat loaded with medical company equipment in such a manner that when landed they could proceed at once to their designated location inland and set up a surgical installation. The rest of the supplies and equipment, sufficient for 30 days, was to come ashore when general unloading started.

Because heavy casualties were expected on the beachhead, collecting sections were equipped and personnel trained to function in the same capacity as battalion aid stations. Also, because it was believed that the regimental commanders would be so involved in the heavy fighting as to prevent them from assuming responsibility for the assigned medical companies, the medical plan called for all companies to come under division control once the transport areas were reached, and to land on division order only.

One glaring error in the planning was overlooking the problem of civilian casualties. Previous operations had been on sparsely settled atolls or islands, where the problem of handling large scale civilian casualties did not arise, but early in this campaign it fell to the division medical service to provide humanitarian care for civilians at a time when the medical personnel were already taxed to the utmost in caring for the wounded.

On Hawaii the morale of the troops was never higher. Good food, a healthy climate, and 5 months of hard training had molded them into a confident, poised unit. Embarkation of medical personnel and equipment started the first week in April 1944 and proceeded smoothly, due mostly to the direction of the medical officers who had attended the transport loading school. As dock space allowed only one regimental combat team to load at a time, there was a continuous flow of equipment and supplies from our encampment at Camp Tarawa down to the docks at Hilo, 60 miles away. A chart showing the location of all medical supplies and equipment aboard the various transports was included in the administrative order. Medical personnel of the assault waves were loaded and with their respective troops and medical companies were distributed among 5 transports to reinforce them initially for casualty handling. The over-strength allowance of medical officers was distributed among the LST's having no medical officers aboard to take care of troops en route.

D-day for the Saipan operation was 15 June 1944. Long before that time our naval gunfire and bombing had been crashing into the beachhead and selected inland targets, until it was difficult to believe that anything could live in that area. This same impression had been rudely shattered at Tarawa, however, and every glass available was trained on the beachhead by those not in the assault, as the leading amphibian tractors left the line of departure and wallowed in toward the reef. There followed breathless moments as they came closer and closer, then geysers of water could be seen in and around

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the first vehicles and all illusions of an easy landing were gone.

The first casualties reached the transports at 1015 and from then on almost every returning boat brought its load of wounded. The two Marine divisions that landed abreast that day suffered 1,750 casualties before the next morning. What was occurring ashore could be surmised in part from the reports of the individual battalion surgeons. Much, however, must be read between the lines as the heroic sacrifices that characterized the performance of the troops and medical units alike is imperfectly brought out in the documents of battle.

The Sixth and Eighth Regiments landed abreast with two battalions of each regiment in the initial assault. Company aid men went ashore with their respective platoons, whether in the first wave or the succeeding ones. The battalion aid sections landed uniformly in the fourth and fifth waves. Collecting sections were scheduled to land in the first waves of the second trip of the amphibian tractors, and landed at approximately H–plus–90–minutes.

Excerpts from the records relate the highlights of the first few days. From the Second Battalion, Sixth Marines: "Medical section landed in the fourth and fifth waves on Red Beach at H-plus-21-minutes. The battalion surgeon was hit by a mortar shell in the first 10 minutes. The aid station was set up on the beach and wounded treated where they fell and evacuated in amphibian tractors. Bandsmen attached as litter bearers did a magnificent job. Supplies were adequate with the exception of litters. Two hospital corpsmen were killed and 10 wounded during the first 24 hours. Pharmacist's Mate Third Class Robbins was killed on D-night while manning a machine gun in his company."

From the Third Battalion, Sixth Marines: "Corpsmen with I Company landed in the first wave at 0830, corpsmen with K and L companies landed in the second and third waves, respectively. The battalion aid section landed at H-plus-20-minutes and set up in Japanese trenches on the beach. Forced to move, as artillery made direct hit on an amphibious tractor, setting it afire and making the position untenable. At 1500 moved inland about 200 yards and set up in Japanese dugout near battalion command post. A shortage of litters—some wounded were evacuated in ponchos. Two corpsmen were killed in action and eight wounded the first day. On the morning of D-day-plus-2, the battalion bore the brunt of a Nip tank attack, knocking out 29 enemy tanks. One corpsman was killed and three wounded during this encounter."

The Second and Third battalions of the Eighth Regiment landed almost 1,000 yards to the north of their intended area. When Eighth Regimental Headquarters landed at H-plus-60-minutes, the entire section including the regimental aid group landed on a beach with no troops in front of them. Casualties were extremely heavy and the regimental medical section functioned in the capacity of a battalion aid station until the two assault battalions could be maneuvered into their proper position. The medical section of the Second Battalion of the Eighth Regiment suffered heavy casualties when an artillery shell landed in the aid station, killing one corpsman and seriously wounding the battalion surgeon and three corpsmen.

Because of the heavy casualties in the immediate beach area, the collecting sections assigned to the assault battalions served both as aid stations and evacuation stations for the first 2 days. Shore party medical sections and Navy Beach Party medical sections were committed uniformly on D-day-plus-1. When these sections assumed the evacuation station responsibility, collection sections moved forward to work in close conjunction with battalion aid stations. They were returned to their respective medical companies on about the sixth day, by which time adequate ambulance transportation was available almost to the frontlines.

Meanwhile, the medical companies on the transports were working unceasingly to assist the ships' medical departments in the care of casualties. Enemy fire on the beaches was so intense that it was impracticable to land and establish medical facilities ashore. On D-day-plus-1 reconnaissance revealed a Japanese civilian hospital in the Charan Konoa area on the right flank of the division, miraculously unscathed by our preinvasion bombardment. As evacuation at night was highly unsatisfactory due to smoke screens laid to protect the ships from enemy air attack, C and E Medical Companies were ordered ashore at 1200 on D-day-plus-1 in order to provide some measure of definitive treatment to casualties during the hours of darkness. E Medical Company landed at 1700 but was forced to dig in immediately because of heavy enemy shelling. C Medical Company landed at 0730 on D-day-plus-2 and the two companies proceeded to the Japanese hospital and were in a position to perform surgical operations by nightfall.

On D-day-plus-5, E Medical Company was moved to the north to the junction of the major road network to act as a screening agency for all casualties, as well as to provide a surgical unit nearer the center of the zone of action, for treatment of nonevacuables. It was replaced at the Charan Konoa by a fine surgical team from the Army.

No records are available for the first 2 days of the casualties received at the Charan Konoa installation, but in the next 7 days, 398 casualties were admitted and 46 major surgical procedures were performed. If one remembers that only casualties that could not be evacuated to ships at night were handled here, the immense importance of the early establishment of this hospital is more fully realized.

A summary of the chain of evacuation at this stage follows (fig. 154). Initially, the nearest medical personnel put casualties in any amphibian tractors available. Aid stations and collecting sections established evacuation points on landing, and on D-day-plus-1 evacuation was consolidated through shore party medical sections. Regimental medical sections began to channel casualties through their installation on D-day-plus-2. Beginning on the evening of D-day-plus-2, all casualties occurring late in the evening or at night were evacuated to the medical companies at Charan Konoa. With the establishment of E Medical Company at the major road junction, all casualties, both day and night, were channeled through this installation. In daylight all casualties capable of being further evacuated were sent to ships, and at night were either retained at E Medical Company or sent to C Medical Company in Charan Konoa.

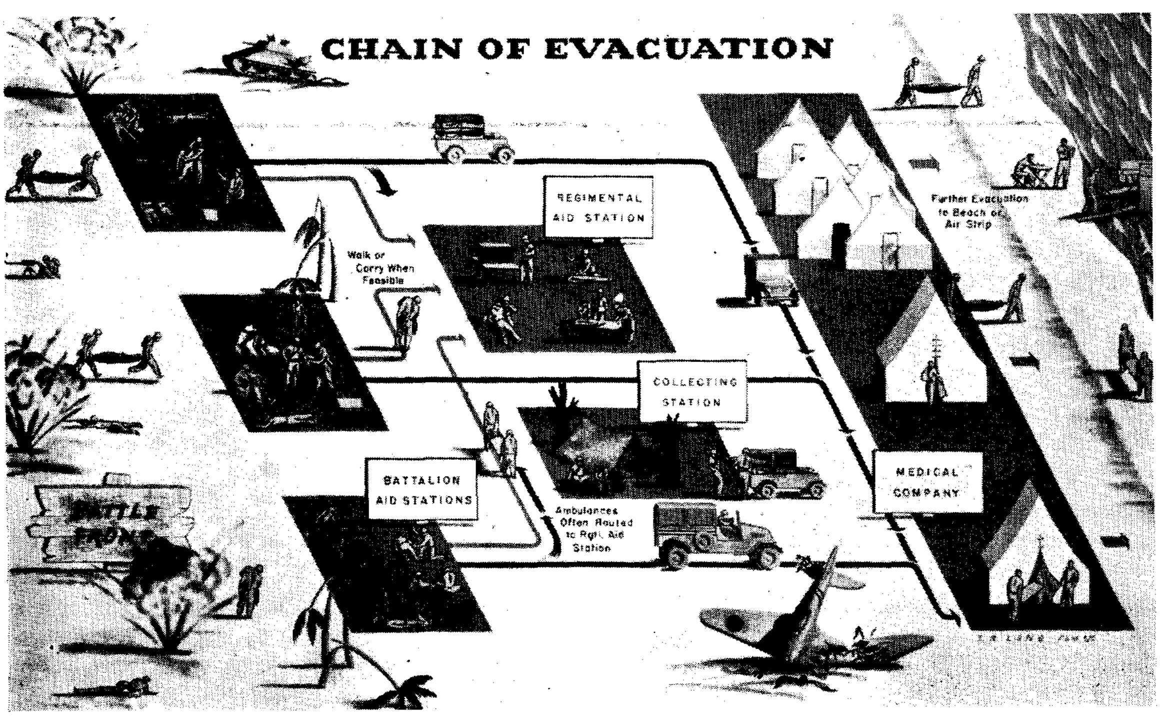

FIGURE 154.—One chain of evacuation of the wounded.

Casualty evacuation from the beach was undertaken in amphibian tractors, any tractor leaving the beach being utilized. The original plan called for one LST(H) off each division beachhead, to act as a casualty clearing station to insure reasonable distribution of casualties among the transports. Owing to changes in the designation of the vessels assigned to this task, the plan was not carried out and casualties were transferred to any LCVP available at the tractor transfer line. The LST (H) assigned to the Second Marine Division beachhead received its first 100 casualties while still in the transport area, 22,000 yards from the beach. When the 100 casualty mark had been reached, this LST (H) came alongside the U. S. S. *Monrovia* and discharged all the casualties to that ship. As there were no hospital ships or other especially fitted vessels for casualty handling, the transports were the sole agency to care for the tremendous load of casualties which occurred the first 3 days.

Although the medical officers and corpsmen worked unceasingly, an analysis of the battle casualties in immediate need of definitive care as compared with facilities available shows the overwhelming demands on the Medical Department afloat. Of the 1,750 casualties which occurred the first day, an estimated 20 percent or 350 were either killed outright or beyond medical assistance. Forty percent or 700 were slightly wounded and not in need of immediate definitive treatment. The remaining 40 percent or 700 required immediate treatment. Approximately 40 transports were in the area, available for casualty handling. This meant that even if an absolutely equal distribution of patients could have been made, each transport would have had 17 to 18 casualties demanding immediate treatment in the first 20 hours and the expectation of as many more for the next 2 or 3 days. Actually, with no distribution agency functioning, several of the APA's bore the brunt of the casualty load. Evacuation to the ships at night was extremely difficult, if not impossible in most cases, due to the smoke screen that fogged the transport area during air alerts.

On D-day-plus-3 the first hospital ship arrived and was immediately loaded with the casualties that had accumulated. As our transports were forced to leave the area on D-day-plus-2 because of threatened Japanese surface attacks, casualties from the Second Marine Division were channeled to APA's supporting other organizations, increasing the demands on already overloaded ships.

The Medical Department's participation in this operation can be divided into two phases. Due to the withdrawal of our transports, the division was unable to land much of its vital supplies, ammunition, and three of the medical companies. These medical companies had not been ordered ashore until noon of D-day-plus-2, as the tactical situation ashore would not permit their utilization. By the time the order to land reached them, it was too late for them to disembark and they accompanied the transports to sea, assisting in the care of the casualties already aboard. From a military standpoint, the division was reduced to improving its local position until the transports returned and supplies could be built up for the further occupation of the island.

During the first phase, from D-day until D-day-plus-6, the policy was for immediate evacuation, except for nonevacuables. Those patients who required it were given immediate definitive care during the hours when evacuation to ships was impossible. The second phase began with the establishment of the division hospital ashore on D-day-plus-7, at which time the extent of definitive care given to all casualties was governed by the capacity of the hospital and the speed of evacuation to supporting hospital units ashore or afloat.

Immediately on the return of the transports to the transport area off the Division Beach, D Medical Company and the division hospital, consisting of A and B Medical Companies, were landed. All three medical companies moved directly to the group of damaged buildings that had formerly housed the main Japanese radio installation. Although filled with debris and partially smashed by our preinvasion bombardment, these buildings could accommodate 300 patients and offered housing for a hospital installation which is seldom available in battle. They were strategically located near the major road network, both to the frontlines and to the beach evacuation station. Built of reinforced concrete and surrounded by 15 feet of earthworks, they offered a large measure of protection from direct fire and from light artillery and bombs. With the able assistance of working details from the Seabees and engineers, debris and damaged machinery were quickly cleared, overhead and bulkheads were repaired, and an operating room with 6 operating tables was set up. On the night of D-day-plus-7, 37 casualties were treated, on the second day 58, and on the third day 159. As more space was cleared, additional operating units were set up. Three surgical huts were used as clean operating rooms. Deep trenches dug by bulldozers offered protection for the patients in case of air raid.

On D-day-plus-11, C Medical Company was moved to this installation. Although the total bed capacity of 4 medical companies is set at 576 beds, by pooling our facilities, this reinforced division hospital was able to accommodate almost twice that number of sick and wounded. In the majority of instances, to maintain a casualty census of this size in the division zone of action would not be good practice. The division had another operation to undertake, however, immediately following the Saipan campaign, and the guiding principle was to retain every patient who could be readied for this second assault.

During the campaign, 3,612 of the 5,156 patients admitted to the medical companies were returned to duty in time for the Tinian operation which began 2 weeks after Saipan was secured.

A good road network fanned out to all frontline units, and although the distance to the front increased to as much as 5 miles before the battle ended the many advantages of the initial installation outweighed the disadvantage of the longer ambulance haul. Evacuation seaward was easily accomplished with the use of DUKW's loading directly at the hospital and necessitating no transfer of personnel before they arrived aboard ship. Although the frontlines were at times less than a mile forward and artillery and mortar fire occasionally fell in the area, no casualties were sustained from enemy fire. Snipers were active in swamps around Lake Susseppe, 400 yards to the east, but were cleared out by the division reconnaissance company after several days.

Under the direction of the medical battalion commander, the 4 medical companies were molded into an evacuation hospital. A central admission and triage ward was set up which distributed casualties according to type to the various surgical teams set up for each specialty. C Medical Company set up 400 beds to accommodate the acutely ill, mostly dysentery, dengue, and recurrent malaria. E Medical Company admitted patients with chest and eye injuries and A and B Medical Companies took the orthopedic and abdominal cases. Those with minor injuries were distributed among all four companies, depending on the bed capacity at the moment.

Centralization of the service elements of the four companies relieved the medical officers of a great many of the details of administration. Supply, messing, guard detail, transportation, and sanitation were all handled by Headquarters and Service Company of the battalion. The direction of the combined mess by a dental officer was especially noteworthy. He procured fresh food from the transports daily and with the aid of 15 Negro messmen from division headquarters, served 1,200 hot meals 3 times a day. A damaged frame building to the rear of the main hospital, which was screened, provided a completely flyproof galley, and the hot meals thus available on D-day-plus-9 undoubtedly played a large part in the early return to duty of many patients.

During this period, we had three cardinal aims:

(*a*) Hospitalization of those who would return to duty within 30 days.

(*b*) Hospitalization and treatment of nonevacuables, until their condition improved sufficiently to allow their safe evacuation by air or to hospital ships.

(*c*) Definitive treatment of those for whom earliest possible care was necessary to give them the best chance of recovery.

The statistical report of the Second Marine Division Hospital, as presented in table 24, analyzed 2,088 cases of battle injuries and 2,466 cases of disease, combat fatigue, and nonbattle casualties.

TABLE 24.—*Statistical report—Second Marine Division hospital*

Type of injury	Number	Pentothal sodium anesthesia	Ether anesthesia	Spinal anesthesia	Operative	Cast	Ship	Air	Duty	Deaths
Intracranial	34	2	0	0	7	0	12	5	6	11
Chest (intrathoracic)	72	0	0	0	6	0	51	7	0	14
Abdominal	51	0	12	13	22	0	41	4	0	6
Chest and abdomen	13	0	2	2	4	0	6	0	0	7
Spinal cord	12	1	4	0	5	0	3	7	0	2
Extremities	1,031	175	1	0	122	208	488	133	399	8
Eye	59	4	0	0	9	0	20	12	27	0
Abdomen and extremities	14	1	2	1	4	0	10	0	0	4
Chest and extremities	17	4	0	0	3	1	16	0	0	1
Chest and spine	3	0	0	0	2	0	2	1	0	0
Chest, spine, and abdominal	1	0	1	0	1	0	1	0	0	0
Shrapnel, multiple	134	13	0	0	11	1	61	23	78	2
Miscellaneous, wounded	617	32	1	0	32	0	132	29	464	1
Disease, combat fatigue, and non-battle casualties	2,466	0	0	0	0	0	97	57	2,312	0
Total	[1] 4,554	233	23	16	228	210	940	272	3,286	56

[1] There is a discrepancy of 204 between total admissions from the daily admission records and the report of admissions, because many marines with minor wounds came in for treatment and then without authorization left the hospital to get back to their organizations on the frontlines before their case records were completed.

Note: No record was kept of the number of local anesthesia employed. Local anesthesia was used in all débridements where a general anesthesia was not employed.

In this series, 124 casts were applied and 15 amputations performed. Of 41 patients with abdominal wounds, 21 were operated upon, the mortality rate being 28 percent. Of the remainder, some were evacuated immediately to a hospital ship.

The importance of the presence of an ophthalmologist is demonstrated by the following: Of 112 patients with eye injuries, 53 were carried under some other diagnosis because the eye injury was secondary. Twenty-two patients required immediate major surgical treatment for (*a*) penetrating injuries of the cornea with foreign bodies in the iris, (*b*) destructive injuries to lids and orbital tissue involving extraocular muscles and adjacent structures that required débridement or control of hemorrhage, (*c*) penetrating wounds of the sclera requiring suturing to prevent lost of vitreous, and (*d*) enucleation of remnants of the eyeball. Eighteen patients with retinal detachment were received. These were diagnosed only because an experienced ophthalmologist was available. Five patients had intraocular foreign bodies visible with an ophthalmoscope and 18 had intraocular foreign bodies demonstrable by roentgenogram. Thirty patients had severe corneal injuries and embedded foreign bodies. Twenty-nine patients had serious eye lesions associated with burn or face injury.

Pooling of medical companies cannot be done where long lines of evacuation exist or where the road network does not converge. The effectiveness of these units, however, was the basis for the reorganization of the medical battalion. Medical companies supporting the regiments were permitted to have a maximum of 60 beds and the majority of the medical services of the division were concentrated in 2 hospital companies where all the specialties were represented.

While the attack was being pressed, medical officers and corpsmen in the frontlines, without exception, bore up under the ordeal and added heroic chapters to the fine record of the Field Medical Service. The battalion medical section of the First Battalion, Twenty-ninth Regiment, suffered 27 battle casualties out of a complement of 40. Both medical officers were wounded, yet despite their wounds they remained on duty for hours until relieved. Three Navy Crosses were awarded to members of the section for that day's work—two posthumously.

The final massive amphibious assault of the war in the Pacific, at Okinawa, demonstrated the rapid strides that were being made in the handling of casualties. Although they were not put to the test initially, due to the almost unopposed landing, the facilities available afloat reflected the planning and thought given to this phase of the operation and undoubtedly would have been sufficient to handle the casualties from a furious beachhead resistance. In contrast to the operation at Saipan, 9 months previously, 2 LST(H)'s and a total of 8 ships well-staffed, equipped, and trained in their mission were in operation shortly after H-hour 1,000 yards off each division beachhead. At least two hospital ships were on hand at all times. Several casualty carriers (APH's) were available in the transport area to care for naval and landing force casualties, and APA's reinforced initially by medical personnel of supporting corps evacuation hospitals and surgical teams, representing all specialties, were also available.

As the fighting progressed farther from the original landing beaches, LST (H)'s were employed to pick up casualties at selected landing beaches up and down the island, sometimes almost at the flank of the fighting, thus saving long ambulance hauls over dusty and vehicle-choked roads. Efficient and ample air evacuation facilities were also set up early with the result that approximately half of the casualties were evacuated to rear bases.

Following the breakthrough at the Shuri Line, a rapid advance of from 3 to 4 miles was made on the entire southern front. Before hospital facilities could be moved up in close support, heavy rains lasting almost a week made the roads leading from the front practically impassable. Several medical companies employing surgical trailers, were able to get up for close support, although evacuation for a time was extremely difficult or impossible.

After some initial difficulty, an LST(H) was able to make contact with an evacuation station in Naha Harbor and took many casualties out, distributing them each night to hospital ships or APA's. The corps surgeon made arrangements with boat pools for LCM's and LCT's to carry patients from the flanks of the fighting to beaches opposite the rear hospital installations. LVT's evacuated some patients directly to supporting naval gunfire ships. Finally, a small strip of land was cleared and L–5 planes evacuated almost 1,400 casualties. With the use of five different agencies, an almost hopeless situation was averted, demonstrating the flexibility of the evacuation facilities and the demands occasionally placed on them. Captain O. B. Morrison (MC) USN, who directed the evacuation, was commended for accomplishing this extremely difficult task.

An amphibious operation requires a vast amount of planning, forethought, and training on the part of both the line and the staff. This includes the staff medical officer, who builds his plans in accordance with the best intelligence estimates, the surgeon, who molds his men into a smoothly functioning team, and the company first-aid man, who must learn all the tactics of the fighting man in addition to mastering lifesaving first-aid measures. There is no place for the man not thoroughly indoctrinated in the part he is to play.

The Medical Department must keep pace with the rapid strides in the development of tactics and weapons. The devotion to duty and untiring efforts which marked the performance of the medical men in the amphibious forces will not suffice if we do not keep abreast of the changing picture and constantly train medical personnel to act as the core of an expanding force in time of war.

Chapter VII

Medical Service in the Seventh Amphibious Force

Emmett D. Hightower, Captain (MC) USN

Two major problems confront military medical services: (*a*) the treatment of wounded men and their return to duty, and (*b*) the treatment of those acutely ill. Because seasoned and well-trained personnel are of inestimably more value than raw recruits and there is always only limited manpower, it is imperative that the medical service not only strive to shorten the period of healing, making possible early return to duty, but also institute hygienic and preventive measures to limit the incidence of disease.

Warfare in the Southwest Pacific involved island-to-island moves and presented, in addition to the task of caring for combat casualties, hazards to the health of both combatant and noncombatant personnel from malaria, enteric diseases, scrub typhus, and tropical skin diseases. Further, there existed the potential danger of mental breakdown from combat, close restraint, the confinement of long months at sea, and a lack of recreational facilities.

In World War II the health standards of the troops and the survival rate among the wounded were unequalled. Perhaps one of the most important factors contributing to this fine record was the cooperation of military commanders with the Medical Department. Directives relating to preventive measures were disseminated for compliance to all units by dispatch or letter. The health records of all newly arrived men were reviewed, because many men reported who had not received the necessary inoculations. Malaria discipline was rigidly enforced, although not always successfully. With many small craft constantly in touch with the beach, the malaria rate was higher in the early days than it should have been. As an example, an LST beached overnight in a New Guinea port and 25 members of her crew contracted malaria.

No serious epidemics of disease occurred in ships of the force, nor were there any serious outbreaks of food poisoning. Respiratory infections were not a problem among personnel afloat, although on one occasion six officers on a destroyer escort had virus pneumonia and the ship was unable to get underway for a week. The hot, humid environment caused prickly heat of varying degrees in practically all men. It was necessary to transfer some to a temperate climate.

The hygiene and sanitation in all ships was maintained at a high standard, which was remarkable considering the fact that they were manned by inexperienced men who had little time for upkeep. The limited supply of fresh water was the greatest problem in small craft. Opportunities for bathing were limited and it was necessary to use a minimal amount of water in the scullery and washing machine. Despite these limitations, no ill effects attributable to a lack of water were noted.

Because the early symptoms of mental breakdowns were not always discernible, the problem of prevention remained unsolved. In most men it appeared to be caused by environmental factors rather than combat, and was related to the close confinement and monotony of many months at sea, together with the lack of recreation and entertainment facilities.

CASUALTY CARE AND EVACUATION FOR ASSAULT LANDINGS

The number and type of landings that were to be made on enemy-held islands required a smoothly functioning system of casualty care and evacuation. Because the distances to rear bases became greater as operations proceeded and casualties occurred while en route to as well as on the landing beaches, and because some time was required for Army facilities to become operative, it devolved upon the amphibious forces to furnish means for early and adequate surgical care of the wounded at the far beach. Transportation and care of patients while en route to the rear was also necessary. Therefore, the medical plan was based on the assumption that the forces afloat would be responsible for treatment and transportation of casualties until the Army hospitals were operative ashore. The time varied, depending on the resistance encountered, terrain, weather, and speed of cargo unloading. Close liaison was maintained with the Army Medical Department at all times—the teamwork left nothing to be desired.

In every assault landing each ship assigned had the maximum medical facilities for the care of casualties, and preparations were always made for a large number of them. The Seventh Amphibious Force contained amphibious craft exclusively. No APA's were assigned to it permanently. For almost a year after the Southwest Pacific campaign began, it was necessary to transport casualties in LST's, LCI's, and even LCT's. While these types are not desirable for long hauls, they could be used for short distances.

The operation at Lae, New Guinea, on 4 September 1943, involved the landing of 16,600 Australian troops from 13 LST's, 20 LCI's, and 4 APD's in an area firmly held by the Japs. Each of the LST's carried one medical officer and equipment for emergency surgery. One of the LCI's had a medical officer aboard, the rest only corpsmen.

There were 2 Army General Hospitals at Buna and Army casualty clearing stations at Milne Bay and Morobe, totaling about 3,000 beds. The U.S.S. *Rigel* and the LST *464*, the first LST which had been converted to a hospital facility, were at Milne Bay to receive Navy casualties. Evacuation from the beach was the responsibility of the engineer special brigade and a regimental medical detachment.

The landing was unopposed and casualties were few, but air attacks on the convoy while en route resulted in 37 naval personnel killed and 40 wounded, and among the embarked troops 36 were killed and 51 wounded. The wounded were cared for aboard DD's, APD's, and LST's and were returned as soon as possible to the rear. This experience was not forgotten. Obviously, if air attacks were to be a feature of the approach to the landing beach, a ship should be designated and equipped with facilities to care for casualties sustained while en route.

The Finschhafen, New Guinea landing was made on 22 September 1943. One week following the landing only 134 casualties had been returned to the rear areas. This operation demonstrated the need for a naval medical officer and hospital corps personnel to be with the naval beach party. The medical officer would be able to classify and move the wounded more quickly because of his knowledge of the bed capacities of the ships and the medical specialists available on them. He also could render treatment in the event personnel of the beach party sustained injuries.

The landing force at Arawe, New Britain, on 15 December 1943, consisted of about 4,000 men. By the time the assault was made, the force surgeon had organized several surgical teams, each composed of 2 surgeons and 10 hospital corpsmen. They constituted a mobile unit that could be shifted from ship to ship on short notice. For the Arawe landing, two teams were placed in LCT's, no LST's being used. Casualties were light, the majority occurring on D-day. About 60 men were killed or wounded. The wounded were treated by the surgical teams and evacuated via APD's.

The use of the surgical teams in LCT's was a makeshift for this particular operation and it was not intended to employ them again in this manner. The conversion of LST's for the care of casualties entailed the installation of a watertight hatch in the tank deck bulkhead, thus affording access to the forward troop compartment from either port or starboard. Spaces were converted into a receiving room, sterilizer and scrub-up room, and operating room, without interfering with the ship's capacity to carry troops and cargo. Thus, wounded could be brought in over the ramp, onto the tank deck, and passed into the receiving room through the hatch. The ship's medical officer was responsible for triage, those requiring surgery being prepared for the surgical team, and those with minor injuries being treated on the spot. The flow of patients was from forward to aft, from the receiving room to the troop sleeping spaces. These "surgical" LST's were obviously of limited capacity and it was not desirable to use them for transporting wounded for long distances, but the lack of hospital ships and the nature of the warfare made their use imperative if the wounded were to receive early definitive treatment.

In the Cape Gloucester invasion on 26 December 1943, 24,000 men were landed. This operation marked the first time that surgical teams were embarked in LST's converted for casualty care, and the first time that a naval beach party functioned. The beach party medical officer worked in conjunction with the medical elements of the First Marine Division in the evacuation of casualties. In addition to the surgical teams, one medical officer was carried by each LST engaged in the landing. Naval Base Hospital No. 13 was by this time in commission at Milne Bay. It had a capacity of 400 beds. Other rear area reception centers consisted of Army hospital facilities at Buna, Finschhafen, Goodenough Island, and Milne Bay.

The casualties suffered in the initial phases of this assault were 6 killed, 37 wounded, and 124 missing. These for the most part were due to enemy air attack. The wounded were transferred after initial treatment by APD and LST to LST *464* and later to Base Hospital No. 13 at Milne Bay.

The value of the surgical teams was clearly demonstrated in this landing and all future plans for casualty care were based on their presence on the assault beach. The pattern for the over-all care and evacuation of casualties was by this time completed. The beach party medical sections received the wounded on the beach and were responsible for their evacuation. LST's with surgical teams were distributed in initial and succeeding echelons of ships and some of them were designated to remain on the beach or to lie off the beach as long as necessary. As their facilities became overtaxed they would unload patients into departing ships. There remained only the organization of more surgical teams and the conversion of more LST's for casualty care.

Throughout the spring and summer of 1944 assault landings continued, about 81,000 troops being landed. Because lines of communications lengthened with each new landing, the transporting of casualties in amphibious craft was avoided when possible. Early and adequate surgical treatment at the far beach was stressed. Each assault echelon was accompanied by surgical teams and the wounded were transferred to large, fast ships for return to the rear. An APH and one AH were available for the first time at the Aitape-Humboldt-Tanamerah landings.

While these operations were in progress, rear area bases were being consolidated in preparation for future campaigns. Both Army and Navy medical facilities were brought forward. Naval Base Hospital No. 15, with 1,000 beds, was commissioned at Manus. Outlying dispensaries and a G-2 component made another 1,000 beds available there. Base Hospital No. 17 was moved into Humboldt Bay and Base No. 16 into Woendi. These facilities permitted hospitalization in the forward areas and obviated the necessity for the long trip to Milne Bay, Brisbane, and Sydney.

A blood bank was established in LST *464*. It furnished whole blood for the surgical teams prior to their departure. The Army 24th General Hospital at Hollandia also established a blood bank and provided blood to naval facilities when it was needed. Donors for both these banks were obtained from service personnel exclusively.

A total of about 85,000 troops were landed at Leyte on 20 October 1944, with the help of APA's temporarily assigned to Seventh Amphibious Forces. Preparations were made for a large number of casualties and the following medical plan was evolved:

A-minus-3-day.—Two APD's to accompany and afford medical services to the minesweepers which were engaged in clearing channels to the landing beaches.

A-day—Eight surgical teams in LST's. Five surgical specialty teams (orthopedics, anesthesia, urology, chest surgery, and ophthalmology). Seventeen LST's with one medical officer. Eighteen APA's, each with 3-5 medical officers aboard. The ship capacity on A-day accommodated 3,105 stretcher and 7,025 ambulatory patients.

A-plus-1-day—A hospital ship to be present from 0600 to 1800.

A-plus-2-day—Seven LST's with surgical teams. Twenty-four LST's with one medical officer. Seven APA's; total bed capacity being 1,785 stretcher cases and 4,300 ambulatory.

A-plus-3-day—One hospital ship.

A-plus-4-day—Six LST's with surgical teams. Sixteen LST's with one medical officer. Total bed capacity, 525 stretcher and 1,400 ambulatory. LST *464*, with a fresh supply of whole blood.

A-plus-5-day—One hospital ship.

A-plus-7-day—One hospital ship.

The hospital ships assigned to this operation were the Army-staffed *Mercy, Comfort, Tasman,* and *Maetsuycker*. In addition, the Navy hospital ships *Solace, Relief,* and *Bountiful* were available at Ulithi. Casualties were light. At the end of the second day there were 83 men killed and 145 wounded.

Japanese plane attacks on naval shipping were heavy and suicide planes were encountered for the first time. On the first day there were 9 killed and 40 wounded in the ships anchored in Leyte Gulf. Because of this vicious air action, all ships were moved out of the Gulf as rapidly as possible after they unloaded. Hospital ships were not permitted to enter the Gulf until the situation improved, and even then they were not allowed to remain longer than 2 or 3 hours at midday. Due to the abominable weather, the Army hospitals could not be set up as rapidly as anticipated, and with ships forced to depart early the LST *464* became the most important medical facility afloat for several days.

Several lessons were learned at Leyte. For example, means must be devised to furnish medical assistance quickly to ships struck by bombs or suicide planes. The necessity of leaving surgical team LST's beached after unloading was emphasized. One or two surgical LST's must be held in reserve to send to beaches overwhelmed with casualties or left without medical facilities.

The operation at Lingayen Gulf on 9 January 1945 was a major amphibious assault from bases in Leyte and New Guinea, 2,150 miles away. Ships in convoy were in danger of enemy air, surface, and submarine attack for the greater part of that distance. Intelligence indicated strong enemy resistance and heavy casualties were anticipated. The following preparations were made:

S-day:

Blue Beach: Two Seventh Phib beach parties; 2 from APA's; 6 LST's with surgical teams; 11 LST's with 1 medical officer. Nine APA's with 3 to 5 medical officers; 1 APH with 8 medical officers; 1 LSV with 2 medical officers.

White Beaches 1 and 2: Two Seventh Phib beach parties; 1 APA beach party; 3 LST's with surgical teams; 4 LST's with 1 medical officer; 5 APA's with 3 to 5 medical officers.

White Beach 3: Two APA beach parties; 2 LST's with surgical teams; 1 APA with 4 medical officers.

S-plus-2-day:

Blue Beach: Two APA's with 4 medical officers each.

White Beaches 1 and 2: Two LST's with surgical teams; 1 APA with 4 medical officers; 1 APH with 8 medical officers.

S-plus-4-day:

Blue Beach: Seven LST's with one medical officer.

White Beaches 1 and 2: One LST with surgical team; 11 LST's with 1 medical officer.

Six of the LST's with surgical teams were beached to provide casualty care after unloading. Beach party sections had orders to place only those patients in need of surgery aboard the surgical LST's, and to send the other wounded directly to APA's. This was done so that LST's would not become crowded with minor cases, leaving them free to care for those requiring actual surgery. APA's were scheduled for early departure from the area, and it was deemed advisable to evacuate as many wounded as possible in them.

The APH's had about 8 medical officers aboard, and a bed capacity of over 1,000; they were held in the transport area as evacuation ships. When their bed capacity was reached they sailed, because it was not advisable to expose them to air attacks. There were no hospital ships available at Lingayen, as none was permitted in waters of the Sulu and South China Seas until the middle of February.

Three PCE(R)'s were given additional medical personnel and supplies and assigned to rescue duty only. These ships were fast and maneuverable and were able to go alongside stricken ships to render medical aid and take off survivors. One was kept at anchor near the flagship, within easy visual signaling distance, so that it could be dispatched on a mission without delay. The others were placed at strategic places in the anchorage areas. One LST with surgical team embarked was held in reserve to act as relief for LST's on the beach whose personnel needed a respite.

Opposition was light, except on White Beach 2, and the landing forces advanced inland rapidly. By the end of the sixth day only 727 wounded had been evacuated to the rear. Had casualties been heavy, evacuation facilities would have been somewhat strained because, with the hospitals at Leyte Gulf filled to capacity with sick and wounded, it would have been necessary to transport those from Lingayen as far as Hollandia and Manus. This would have interfered with the schedules for the resupply echelons of large ships. With favorable weather and surf conditions throughout the initial phases of the landing, cargo was moved ashore rapidly and the Army was able to erect its field and evacuation hospitals very early.

Whole blood for this operation was obtained both from the LST *464* and from the Whole Blood Distribution Center at Guam. All ships departing from the transport area were directed to deliver their unused supplies of blood to the beach parties for further transfer to the Army.

The operation at Bataan-Corregidor on 15 February 1945 entailed the forcing of Mariveles Bay and the capture of Corregidor. One paratroop regiment, a regimental combat team, and a battalion made the landing. Three LST's with surgical teams were assigned. Casualties were heavy. The first wave of paratroopers suffered 178 casualties due to the drop. Three were killed and 175 had fractures and dislocations when wind carried them onto adverse terrain. Within 3 days the surgical LST's had over 600 seriously wounded aboard. The hospital ship *Hope* arrived in Subic Bay and took the patients from the LST's, thus easing the situation. The *Hope* was the first hospital ship that was allowed on the western side of the Philippines and she came at an opportune time.

With a deluge of fractures, dislocations, and burns, the surgical teams almost ran out of supplies, but plaster, blood, and plasma were flown in from Leyte before the shortage became acute.

Dental facilities. With hundreds of small craft in the Seventh Amphibious Force on missions that kept them at sea for long periods, it was mandatory that dental facilities be provided. Accordingly 10 mobile dental units were organized and placed in LST's and LCI's. These units consisted of a dental officer, a dental technician, and a portable dental machine. Upon completion of the dental treatment on one ship, they moved to another. Their services were invaluable. Facilities for prosthesis were available in the U. S. S. *San Clemente* and the U. S. S. *Dobbin,* of the Seventh Service Force.

AMPHIBIOUS TRAINING CENTER

An amphibious training center was established at Milne Bay, New Guinea in January 1943 and functioned until October 1944. Its primary purpose was the training of troops in the methods used in amphibious assaults. Medical officers received instruction in the care and evacuation of casualties and were briefed regarding reports and returns, sanitation of ships, and prevention of diseases prevalent in the area.

THE LST *464*

With the establishment of the base at Milne Bay and the beginning of operations in the New Guinea-Bismarck-Archipelago area, a floating hospital facility was urgently needed. There were no hospital ships in this force, so the LST *464* was converted into a hospital. The tank deck was partitioned into offices, operating room, laboratory, x-ray room, isolation ward, and storeroom.

Its function was threefold: To make medical facilities available to personnel of small craft that had no medical officer aboard; to receive and care for casualties brought from the landing beaches; and to furnish medical facilities to the personnel who were constructing advance bases, prior to the time the advance base dispensaries or hospitals were in operation.

The *464* was staffed with a surgeon, internist, dermatologist, urologist, EENT specialist, Hospital Corps officer, and initially about 40 hospital corpsmen. Later, an anesthetist and psychiatrist were added. Additional surgeons were placed aboard for temporary duty if needed. The total bed capacity was 175, but the limited messing and laundering facilities on this type of ship made a rapid turnover of patients desirable.

In the early operations at Lae, Finschhafen, Arawe, and Cape Gloucester, the *464* was stationed at advance bases, usually Cape Sudest, Morobe, or Buna, in order to receive casualties from the amphibious craft and transport them to hospitals in Milne Bay. After Humboldt Bay was seized, the *464* proceeded there to act as station hospital ship for the construction battalion and other personnel who were building the base. She remained in Humboldt Bay to furnish supplies and whole blood, and to make her facilities available to small craft.

When the attack on Leyte was made, the *464* was used primarily to furnish blood to ships and to care for casualties if necessary. In the latter capacity she inadvertently assumed a stellar role. Because of the intense enemy air attacks, the hospital ships were not permitted to enter the Gulf. Because the weather prevented Army hospital facilities from being erected as early as planned, the *464* became the main facility for the care of the casualties in the area. She was armed and had no distinctive markings of a hospital ship and was, therefore, under air attack frequently. Her staff worked to the point of exhaustion and most of them had to be relieved because of fatigue. After several days, hospital ships were permitted to enter the Gulf, but remained only a few hours, so that the only assistance they rendered was that of taking out the patients from the *464*.

With the completion of the Leyte Operation, the *464* remained in Leyte Gulf to act as station hospital ship for small craft until late in March 1945 when she was sent to Subic Bay for the same purpose. In September she was ordered to Jinsen, Korea, where she remained about 3 weeks to furnish medical services to naval personnel.

Chapter VIII

Medical Aspects of Naval Operations in the Mediterranean

Frederick C. Greaves, *Rear Admiral (MC) USN*

The Mediterranean campaign began with the Allied landings in French Morocco and Algeria on 8 November 1942, and continued through the North African, the Sicilian, the Italian, and the Southern France campaigns to the final downfall of Nazi Germany on 8 May 1945.

Organization of the Naval Medical Department

The first contingents of United States naval personnel to arrive in North Africa after the landings included medical department officers and men and sufficient equipment for the dispensaries at the proposed bases. Quonset huts for housing were available. In many cases, when the new bases were established, permanent buildings were requisitioned when they were found to be more suitable than quonset huts. No serious difficulties were experienced in acquiring quarters of suitable size from the French Government by requisition through the U. S. Army. Such quarters, however, were always deficient in plumbing and electric lighting facilities. It was usually possible to improve them by substituting American equipment, and these facilities were eventually improved to a point where they approached Navy Medical Department standards.

Only dispensary facilities were provided for the new bases. Patients requiring hospital care and treatment were transferred to the nearest U. S. Army hospital. As the U. S. Navy installations in the theater grew beyond the scope originally contemplated, particularly in and near Casablanca and Oran, the need arose for U. S. Navy base hospital facilities, and the enlarged and overgrown dispensary in Casablanca was commissioned as Base Hospital No. 5 in May 1943. A 500-bed quonset hut hospital was built at Oran and commissioned Base Hospital No. 9 in November 1943. These two hospitals served as the hospitalization centers for U. S. Navy personnel throughout the campaigns. Base Hospital No. 9 was particularly well located because of the lines of air, sea, and rail communications connecting Oran with advanced areas to the east and oversea communication for the evacuation of patients to the United States.

Base Hospital No. 5 was used principally for the hospitalization of personnel from the bases and naval groups in French Morocco. Its location permitted easy evacuation of patients by air to the United States by the Naval Air Transport Service and by the Air Transport Command, from Port Lyautey and Casablanca, respectively.

The dispensaries established at the Naval Air Station, Port Lyautey, and at the Naval Base, Palermo, Sicily, were of adequate size and had sufficient personnel and equipment to enable them to furnish hospital care of all types. Both performed valuable and satisfactory work. The Port Lyautey dispensary was set up in one wing of the civilian Municipal Hospital. When a 100-bed quonset hut dispensary, with complete hospital facilities, was constructed on the base in January 1945, the dispensary in the Municipal Hospital was closed. The Palermo dispensary was the only American military hospital in Sicily during the last year of its existence. It was disestablished in 1945.

The advanced amphibious training base at Arzew had a 100-bed dispensary set up in quonset huts. As soon as the Allied Forces gained military control of the Bizerte-Ferryville-Tunis triangle the main component of the amphibious force was moved forward into the area. The new site was the French Naval Base at Karouba and La Percherie and the medical department moved into the French naval infirmaries. These had been battered by bombing attacks but were rendered serviceable after repair.

In the forces afloat the smaller ships transferred patients to larger ships or to shore establishments, using U. S. Navy facilities whenever possible, and when these were not present, U. S. Army, British Army, or civilian hospitals. The larger ships, particularly the transports, had excellent sickbays and were able to care for all type of cases; they were of great assistance to the smaller ships and smaller bases.

The procurement of medical supplies was an extremely difficult problem for the U. S. Navy bases during the first few months of their existence. This was due primarily to a misunderstanding on the part of both the medical officers in the field and the Medical Supply Depot in Brooklyn in the matter of shipping priorities for the theater. The Combined Chiefs of Staff had assigned control of all shipping into the theater to the U. S. Army Service of Supply (later the Service Command) and cargoes were loaded on the east coast in accordance with assigned priorities. Except for Navy cargoes loaded into U. S. Navy ships destined for assignment in the theater, no Navy cargoes were loaded at east coast ports unless they were authorized by a priority approved by the Service of Supply. Medical Department requisitions were sent in regularly by the bases and were filled by the Naval Medical Supply Depot, but nothing happened beyond that stage. When stocks in the naval medical activities became dangerously low it was discovered that nonshipment was due to a failure to establish shipping priorities and this difficulty was quickly resolved by obtaining the necessary priorities.

Navy Medical Storehouse No. 9 was set up in Casablanca and continued to operate until it was transferred to Oran in the spring of 1944. Most of the medical supplies and equipment were obtained directly from the storehouse after its establishment. A very appreciable amount of stores and equipment was obtained from the U. S. Army, especially immediately preceding operations, because of the better availability of numerous Army Medical Supply Depots.

Cooperation between the Medical Departments of the Army and Navy was very satisfactory and improved steadily throughout the Mediterranean campaigns. U. S. Army hospitals rendered a great deal of medical care and treatment to the U. S. Navy personnel. This was in keeping with the plans made by the Combined Chiefs of Staff before the invasion of North Africa. Later, the original plans were supplemented and these arrangements were combined, thereby avoiding duplication of logistical efforts. This arrangement was satisfactory and workable in its broader aspects but it presented problems in execution requiring adjustment. These arose from the differences in the administrative procedures of the two services.

The Army employs a centralized system of its medical records. The person's health record is retained in The Office of the Surgeon General, in Washington, and pertinent additions to it are added by forwarding them from the field. Thus, the activities in the field never have more than the current records with which to be concerned. The Navy, on the other hand, used a partly decentralized system wherein the health record is retained by the individual's medical officer, and clinical record sheets are forwarded to the Bureau of Medicine and Surgery at specified times for inclusion in the individual's jacket. The descriptive sheet, the medical abstract, the immunization record, and the dental record are retained in the health record. Navy regulations places responsibility for the custody of Health Records with the individual's commanding officer and medical officer, and provides for records of transfer when health records are transferred with individuals from one command to another.

When Navy personnel were transferred to Army hospitals, the Army assumed responsibility for their medical care and treatment. However, the Navy retained full jurisdiction over them. They were not "lost" from Navy records and rolls. Great confusion existed during the first 6 months of the North African campaign in the matter of Navy patients sent to Army hospitals. Naval medical officers and commanding officers followed Navy Regulations when they transferred patients and sent all the records with them to the Army hospitals. The Army medical administrative staffs, not being familiar with Navy records, usually let them get adrift. No distinction was made for Navy patients in the matter of evacuation to the rear, or to the zone of the interior, and health records, pay accounts, and service records of Navy patients were scattered all the way from Tunisia to the United States without anyone (Army or Navy) knowing where they were. The Army was not in a position to do much about preventing the confusion. They were busy handling the sick and wounded of an expanding force engaged in active combat operations and had no time to reeducate their medical personnel in a system that was applicable only to Navy personnel. The problem was solved satisfactorily by local agreement; certain Army hospitals in each area were designated to which Navy personnel would be transferred, and Navy medical personnel were assigned to those hospitals to assume custody of and maintain personnel records of Navy patients, to monitor their transfers to other hospitals, and to report such transfers to the cognizant Navy commands. In the spring of 1944, the whole matter was clarified on a service-wide basis by a joint Army-Navy directive.

The Naval Medical Corps in Amphibious Operations

In the three major amphibious operations in the Mediterranean and the several amphibious landings that were made in support of these operations, including those at Anzio and the capture of the islands in the Tyrrhenian Sea, the Navy Medical Department's responsibilities included:

1. Furnishing medical care for the personnel of all services while embarked in U. S. Navy ships.
2. Furnishing seaward evacuation of all casualties from the assault areas until the Army became sufficiently established to treat, hold, and evacuate in a routine manner.

The chain in casualty evacuation included the medical section of the Navy Beach Battalion on the invasion beaches; the ambulance boats running between the beaches and the transports and hospital ships lying offshore, and the landing craft running in close enough to the beaches to receive casualties directly aboard.

The duties of Navy Beach Battalions, including the medical sections, are difficult and arduous. They land in one of the first waves and perform their duties frequently under fire during the difficult and confusing period of overlapping Army and Navy jurisdiction. A clear-cut assignment of the division of responsibilities and adequate training of the Army and Navy medical sections in their duties are essential for efficiency. The Army must assume responsibility for the care of casualties landward of the high watermark and for their transportation to the Navy Beach Battalion evacuation stations. The Navy must care for casualties in the evacuation stations and for their evacuation seaward. An evacuation record is very important. The system found to be most satisfactory in the Mediterranean Theater was for the Army to furnish the Navy with a list of all personnel brought by them to the Navy evacuation stations and for the Navy to use this as a check-off list for all seaward evacuations, adding the names of those for whom they initiated treatment and whom they later evacuated. The check-off lists were then forwarded to the Army Medical Section for their permanent records.

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No attempt was made to evacuate casualties until after assault troops and equipment were landed, except personnel wounded in landing craft en route to the beaches. Personnel so wounded were never landed, except in the event the landing craft was disabled, because ineffectives on an assault beach are of no military value and their presence increases the tasks of the beach parties. They were given first aid in the small boats, retained aboard, and returned to the mother ship.

Small craft returning to the transports or hospital ships with casualties transferred their patients either by litter hoist or by hoisting the ambulance boats to the rail and transferring the patients directly to the deck. The most expeditious method from a military standpoint was to keep one boat, usually a disabled one, permanently rigged for hoisting and to have the ambulance boats come alongside to transfer their patients.

Landing ships, tank (LST's) were available as evacuation ships. An operating room was set up on the forward part of the tank deck. They are acceptable evacuation ships and meet the requirements for emergency evacuations when other facilities are not available. The Mediterranean is peculiar in that distances between friendly shores and target areas are short enough to permit quick turn-around time for hospital ships of moderate speed but are too long for making use of LST's for casualty evacuation. LST's being combat ships and unprotected by the Geneva Conventions sailed in convoy and were legitimate targets for enemy planes. Medical planning in the Mediterranean included the use of LST's equipped for casualty evacuation. Their routine use was limited to the evacuation of ambulatory patients. Transports acted as hospital ships as long as they remained in the target areas. There were sufficient U. S. Army and British hospital ships to take over evacuation duties when the transports left.

In all three operations the commander of the U. S. Naval Forces Northwest African Waters (later the Eighth Fleet) was the Allied Naval Task Force commander, but the Royal Navy, under the Commander in Chief, Mediterranean Fleet, exercised operational control of all naval craft in the theater, except those actually in the combat area. This arrangement was found to be unsatisfactory during the Sicilian campaign, insofar as it affected hospital ships. It required the Army commander, ashore in Sicily, to request hospital ships from CinC, Mediterranean, by radio dispatch. The request was relayed to the Principal Sea Transportation Officer who issued the sailing orders. The plan was awkward and cumbersome and delayed casualty evacuation. In later operations all hospital ships, regardless of service or nationality, were put in a pool under the direct operational control of AFHQ.

Hospital ships were not taken into the combat areas on D-day. They were not needed because there were sufficient hospital and evacuation facilities aboard the ships of the invasion fleets and there was nothing to be gained in having them exposed to enemy attack in the confusion of D-day battles. Their protected status was respected for the most part by the enemy, except for three attacks, one of which was probably accidental but the other two definitely deliberate.

Evacuation ships delivered casualties to military hospitals in the rear medical echelon in accordance with plans agreed upon by the various services before the operations. Prior to reaching debarkation ports the ship's medical officers prepared casualty reports in triplicate, giving the full name and rank or rate of each casualty aboard, his service number and organization, the time and date received aboard and the date disembarked, the diagnosis and treatment received while aboard, and his condition at time of debarkation (favorable, unfavorable, serious, or critical). Upon reaching the debarkation port the originals of these reports were mailed to the Detachment of Patients, U. S. Army. One copy was sent to the Commander Eighth Fleet and one copy retained in the ship's files. U. S. Army casualties were not reported to the War or Navy Departments. Navy casualties, including deaths, were reported to the cognizant Navy Department divisions in accordance with article 908, Navy Regulations. Dead in ships in combat area were taken ashore as soon as possible for burial by the Graves Registration

Service. Dead in ships at sea were retained aboard, if practicable, for burial ashore; if this was not practicable, they were buried at sea, an accurate report of complete identification, and time and place of burial being forwarded to the commander of the Eighth Fleet.

Medical and Epidemiological Considerations

The experience of the U. S. S. *Thomas Stone* (APA) was unique in the North African invasions. Early in the engagement this transport was beached approximately 100 yards from the exposed sandy beach at Algiers. Deprived of flotation and means of propulsion because of torpedo and bomb action before and after the invasion, the ship was in other respects in perfect condition. Her excellent sickbay proved to be a helpful supplement to the U. S. Naval Dispensary established shortly after the capitulation of Algiers, particularly for surgery, dentistry, laboratory work, and roentgenology. From all evidence, the medical department of the ship functioned during battle in accordance with the best tradition of the Navy.

In the Casablanca area, the first Navy medical personnel destined to establish permanent shore establishments debarked at Fedala on 10 November 1942. They established a temporary barracks and a small sickbay in a camel barn on the dock.

A first-aid station was established in the port area of Safi on 9 November and a sickbay at Casablanca on 12 November. On 18 November a group of medical and dental officers arrived to establish the first dispensary at Casablanca. A permanent dispensary was established on 7 December 1942 in a clinic formerly operated by a French physician. To meet increasing needs, neighboring villas were occupied until there was room for 210 beds.

There was a certain amount of misconception, particularly among the American forces, about the climate, the living conditions, and the diseases in French North Africa. The larger cities were found to have excellently administered Pasteur Institutes, and organized Departments of Health were found in all communities where Europeans form an appreciable part of the population. Sewage was disposed of in a sanitary manner, the public water supply was safe to drink, food distribution was under sanitary regulations, and contagious diseases were isolated or quarantined. The Arabs, however, except for a very small wealthy minority, lived in poverty and squalor, and infestation by lice was almost universal. Malaria, tuberculosis, and the venereal diseases were widespread, infant mortality was high, and the gastrointestinal infections were endemic.

In Sicily and Southern Italy, typhoid fever, the dysenteries, and other waterborne infections were endemic. Malaria was widespread in the rural areas. The incidence of malnutrition, tuberculosis, skin disease, infant mortality, and venereal disease was appallingly high. Typhus appeared in Naples in November 1943 and an alarming sharp upswing in the incidence of the disease was immediately apparent. Had it not been for the heroic and previously untried use of DDT in a program in which approximately 2 million persons were dusted one or more times within the space of a few weeks, a major public health catastrophe would have resulted.

Marseilles was notorious for its high venereal rate and its thousands of registered prostitutes. Typhoid fever was prevalent the year round, about 60 new cases being reported each month during the summer season and somewhat less that number during the winter months. The Public Health officials found that the infections resulted from eating shellfish taken from beds contaminated by raw sewage. Malta fever is sporadic along the Durance River north and west of the city. Fievre boutonneuse is also prevalent and is transmitted by the Ornithodoros tick. The soil of Southern France is heavily contaminated with tetanus spores and human cases of the disease are not uncommon. Marseilles reported the following communicable diseases for the period from 1 June to 15 September 1944:

	Cases
Typhoid fever	165
Diphtheria	69
Scarlet fever	23
Measles	13
Undulant fever	7
Tetanus	6
Cerebral meningitis	2
Tracoma	2
Leprosy	1

Malaria is endemic in the islands of Sardinia and Corsica. These islands were occupied after the capture of Sicily and were used as bases in support of both the Italian and Southern France campaigns. In both Sardinia and Corsica malaria, typhoid fever, and dysentery constituted the main hazards to health.

MALARIA

The first objective for the U. S. Navy in North Africa, after the landings, was the establishment of suitable port facilities through which men and equipment could be funneled into the new theater of operations. One of the first bits of epidemiological information gained from the French was that the area surrounding the city of Port Lyautey and the air base had the reputation of being the most malarious spot in all French North Africa. Forty percent of the French personnel at the base had the disease during the year immediately preceding American occupation.

A survey conducted by a U. S. Navy Malaria Control Unit found that all the Arab huts within 5 miles of the base and many of the dwellings of the Europeans living near the base were infested with adult *Anopheles maculipennis freeborni* and culiciform mosquitoes. Spleen rates among the Arabs were 90 percent for the children and 50 percent for the adults. Blood smears made on both Arabs and Europeans living in the area showed a high rate of parasitization, predominantly benign tertian, but with a significantly high estivo-autumnal number. Case histories of persons who had had the disease showed a high percentage of recurring attacks.

The French had attempted to control the disease with an extensive system of drainage ditches and a start had been made in a program to dust the lagoon with Paris green from low-flying planes. Antimalarial drugs had been made available to the Arab and European civilian population in an attempt to reduce the reservoir of infection. This part of the program met with the least success because the Arabs who constituted the principal danger from infection could not be made to cooperate when the program conflicted with their racial customs and religious beliefs.

At the time of American occupation malaria constituted a real threat to the mission of the newly established naval air base. Positive and vigorous control measures were necessary. A rather complicated condition of overlapping spheres of influence existed. The U. S. Navy operated and administered the base under the United States naval commander in the theater, who in turn was subordinate to the Commander in Chief of the British Mediterranean Fleet. It was an Army theater under the command of the Supreme Allied Commander. The French Army and Navy were also a factor to be considered because every effort was being made to rehabilitate their forces and this was being done in the garrisons and bases which they had controlled before the invasion. Cooperation was required between these different groups, but the important thing was to inaugurate a control program with a minimum of delay. The U. S. Navy indicated its desire and ability to assume full responsibility for protecting all personnel stationed on the base.

Fortunately, time was a factor that operated on the side of the control program. The occupation of the base occurred shortly after the end of the 1942 malaria season and several months would elapse before the 1943 season would begin. A malaria control team, composed of a malaria control unit and a group of approximately 50 construction battalion officers and men, was organized and given the task of rendering the base reasonably safe from malaria. Drainage ditches were cleared of vegetation and all collections of water that could not be drained immediately were oiled at regular intervals. Screens were installed on the windows and doors of all living spaces and the use of mosquito nets was made mandatory for all hands. Officers and men were thoroughly indoctrinated in malaria discipline, and carelessness and deliberate breaches were immediately punished. Liberty expired for all hands at sundown; everyone working in the open or in unscreened buildings after dark was required to use mosquito repellents. Freon pyrethrum was sprayed in all living and sleeping quarters daily to kill adult mosquitoes.

Attention was given to the dangers that existed in the town and surrounding countryside. An extensive system of new drainage ditches was constructed in the swampy area at a distance from the base. The lagoon was dusted regularly with Paris green from low-flying planes and later with DDT when this agent became available. The French and Arab inhabitants living nearby objected to this on the grounds that it was injurious to their livestock, but their objections were overruled in the interest of the war effort.

The reservoir of infection that existed in the civilian population was not ignored. Atabrine was made available for use by both Europeans and Arabs, but difficulties were encountered immediately with the latter. They could not be depended upon to treat themselves and they would not cooperate by coming to a central dispensing point, or with the medical officers and corpsmen who attempted to prescribe the drug for them in their huts. They would not permit members of the control team to enter their homes for mosquito eradication. Eventually, the Arabs were relocated in new huts beyond the probable flying range of mosquitoes and the old huts destroyed.

The United States and British Armies made the suppressive use of atabrine mandatory for all their forces in the North African Theater from mid-April to mid-November. The U. S. Navy did not adopt this policy but elected to depend upon mosquito control measures. The Port Lyautey area offered an excellent opportunity to determine the efficiency of control measures alone when such measures were vigorously and intelligently administered and the group rigidly controlled. The test was successful. The incidence of malaria during the first year of American occupancy of the air base was less than one-half of 1 percent and the cases that did occur included men newly arrived from other theaters in whom recurrences, rather than new infections, were possible. The incidence of the disease showed a slight but steady decline during the remaining years of American occupancy.

Malaria presented no problem in the other United States naval bases in French North Africa. This was due to the low incidence of the disease in the area where those bases were located and the antimalaria regulations promulgated by the United States naval commander in the theater.

It did not prove necessary to resort to the use of atabrine in any U. S. Navy base or for any U. S. Navy personnel operating under their commands. Army forces in camps and staging areas in all parts of the country, many of which were unsanitated, and those engaged in combat operations were compelled to rely upon suppressive treatment.

Malaria is endemic in French North Africa and will always be a factor to be considered in military operations. The insect vector is found in all parts of the country and the human reservoir of infection is constantly present in the Arab population, a race that is normally nomadic and whose movements are unpredictable and practically impossible to regulate. There is probably no part of the country where mosquito control measures will not be successful if sufficient time is allowed to place them in effect and if the required men, equipment, and materials are made available. The fact that the disease proved no serious handicap in this campaign indicates that present methods of malaria control are adequate in this particular region.

DYSENTERY

Bacillary dysentery is endemic in the entire Mediterranean area, including French North Africa. The French Public Health authorities reported that mild diarrheal disturbances occurred in the spring, summer, and autumn seasons and that cases could be found in practically every community. Flies are unusually prevalent during these seasons and undoubtedly are an important contributing factor, as is the unsanitary manner in which the Arabs live. Every city, town, and village became war conscious immediately following the invasion, and in anticipation of heavy air raids, constructed numerous slit trenches for their protection in parks, gardens, and fields. The ubiquitous Arab very quickly discovered that they made excellent latrines and by the spring of 1943 it was most unusual to find one that had not been repeatedly fouled with human feces, unless it had been kept under the strict and constant surveillance of guards.

Bacillary dysentery made its appearance early among the invasion forces in North Africa and continued to be a threat as long as they remained in the Mediterranean Theater. Fortunately, the disease occurred in a relatively mild form, but this was due entirely to luck and could not be attributed to any control measures. The fact that it occurred in any form was indicative of inefficient control. The principal offending organism was *Shigella sonnei* but at various times and in numerous places 70 enteric pathogens were isolated from active cases. Numerous cases of acute gastroenteritis were studied in which *Pseudomonas aeruginosa* was found in overwhelming numbers and occasionally in pure culture.

The disease appeared in all the newly established bases during the spring of 1943. The outbreaks were explosive in character and affected most of the personnel within a few days. Most patients were well after about 1 week under a regime of diet, sulfaguanidine or sulfathiazole, and rest. The commands were seriously handicapped by the attendant loss of manpower and urgently needed work was delayed.

A definite pattern of unsanitary conditions was found to exist in all of the outbreaks. Flyproofing of latrines was frequently incomplete and most haphazard. Galleys and mess halls were too frequently left unscreened. Fortunately, there was a universal distrust of the water supply at the new bases and Lister bags were used by all hands until the local supply was demonstrated to be safe.

Sanitary control over the preparation and handling of food, sewage and garbage disposal, and water supply for drinking purposes was gradually established. Administrative officers were indoctrinated in the basic facts of dysentery control and medical officers and hospital corpsmen were reeducated in the same principles and in their responsibilities in the matter. All galleys and mess halls were tightly screened against the entrance of flies, and double swinging screen doors were installed at all entrances and exits. Mess gear was washed in hot soapy water and rinsed in boiling water and, whenever practicable, it was stowed between meals in flyproof compartments. When this was not possible it was dipped in boiling water immediately before food was served. Existing toilet facilities were improved and enlarged as materials became available. Latrines were abandoned as quickly as possible, and when this was not possible, they were rendered flyproof and frequently inspected to insure that they were kept so. The factor of carriers in food handlers was investigated. The potability of the local water supply was determined. An intelligent system of garbage disposal was placed in operation and fly-breeding places in the immediate vicinity of bases were eliminated with the cooperation of the local civil authorities. All personnel were indoctrinated in preventive methods. Sporadic cases continued to occur all through the period that American forces were in the theater, but the infection in these later cases resulted from carelessness in choosing places to eat and drink on liberty.

Bacillary dysentery is preventable and prevention should be a responsibility of the planning staff before new bases are established. Prospective medical officers should enter into the planning phase to the extent that they are made conversant with the problems they are likely to meet, and should be given the requisite authority to compel the cooperation necessary to insure complete protection from the very first day.

SAND FLY FEVER

Sand fly fever is endemic in the coastal areas of practically all the Mediterranean countries. *Phlebotomus papatasii* is indigenous and was found to be particularly prone to occur in large numbers in areas that had been heavily bombed. The rubble of the ruins apparently provided a desirable breeding ground as did underground caves and caverns. The incidence of the disease was unusually heavy at Malta where repeated bombings had destroyed many structures in the inhabited areas and all important military offices were located in caves and underground tunnels. The disease occurred so regularly in the U. S. Navy personnel sent there on temporary duty that a bout with the disease was considered standard operating procedure.

The ordinary wire screening and bed nets used for protection against flies and mosquitoes offered no protection against the sand fly. These insects are small enough to pass through the mesh. *P. papatasii* is a weak flier and rarely travels any appreciable distance from the place of its origin unless transported artificially or by wind currents. Control measures consist of eradicating breeding areas in and about the living and sleeping spaces. Rubble and refuse must be cleared away. Living spaces should be regularly and thoroughly sprayed with an insecticide. DDT proved to be most effective. Particular attention should be paid to the cracks and crevices in the floors and walls of buildings and to dark musty basements and subbasements. These simple precautions will do much to lessen the chances of infection from the insects carrying the virus.

TYPHUS

Typhus has always been a threat in the eastern Mediterranean. Repeated epidemics have occurred in the Balkans, in Asia Minor, and in Egypt, where the disease has been endemic. No difficulty was experienced with typhus by the Armed Forces operating in the Mediterranean Theater, however, until December 1943 when an epidemic of major proportions was threatening in Naples.

TABLE 25.—*Typhus cases and deaths in Naples*

Month	Cases	Cumulative frequency	Deaths	Percent mortality
March 1943	1	1	0	0
April	3	4	1	33
May	6	10	2	33
June	0	10	0	0
July	2	12	1	50
August	12	24	2	17
September	19	43	4	21
October	27	70	10	37
November	50	120	13	26
December	341	461	66	19
January 1944	1,014	1,475	145	14
Total	1,475		244	

The exact origin of the Naples epidemic was never ascertained, but it was believed that a few cases occurred in March 1943 among some Serbian prisoners in an Italian prison camp near the city. Statistics made available by the Italians and from Allied records after the capture of the city portray the course of the epidemic (table 25).

The opportunities for an epidemic were abundantly present:

1. There was an original seeding of the population from infected persons arriving from the Balkans as prisoners of war.

2. There was an extensive rise in the louse population of the community due to a disruption of the water supply system, an absence of soap, and a lack of desire for personal cleanliness. Added to this was the onset of colder weather and the corresponding use of more clothing. Then there was the overcrowding of the terrified population into the air raid shelters, where many lived for weeks at a time amid surroundings of indescribable filth.

3. Food supplies were very short and actual famine existed among the poorer classes.

4. Medical care was practically nonexistent and no attempt was made to isolate or quarantine early cases.

The epidemic remained confined to Naples for the first 10 months, but at the end of that period it began spreading southward, although the fighting moved northward out of Naples. The mortality rate was 16.5 percent which is surprisingly low in a nonimmune population (35 percent could have been expected). The case incidence was highest in the 10 to 24 age group and there was no apparent difference noted between males and females.

The initial phase of the control was started on 15 December 1943 by members of the Rockefeller Foundation Typhus Commission. The U. S. A. Typhus Commission assumed responsibility for the control measures on 3 January 1944. All suspected cases were investigated by Italian-speaking officers. The patients were deloused and all clothing and coverings with which they had come in contact were steam sterilized. All contacts with patients were dusted with DDT. All buildings were dusted with DDT once a week as long as they were occupied. Stations for a mass delousing of the entire population were set up in 42 locations in the city. The average station deloused 1,000 persons a day but as many as 5,000 were treated in a day during the height of the program. The maximum number deloused in 1 day in the city was 66,476, on 12 January 1944. A grand total of 1,633,134 were deloused between 15 December 1943 and 12 February 1944.

Refugees returning to Naples, southern Italy, or Sicily presented a problem in the control of the spread of the disease. They were deloused before being permitted to enter and all persons were required to present a certificate of a recent delousing before being permitted to leave the city. Vaccination played a very minor role in the control program among the civilians; only about 45,000 of the first of the series of three injections were given. Later all civilians were inoculated; 2½ cc. of the vaccine being given in 1 dose.

Only two cases occurred in United States military personnel: one was a vaccinated man from the Fifth U. S. Army and one was an unvaccinated man. Credit for the low incidence was due in part to the vaccination program of the U. S. Armed Forces and to the higher standards of personal cleanliness among the Americans.

RELAPSING FEVER

Louse-borne relapsing fever occurred in an Italian prisoner of war in July 1943 in a prisoner of war camp in Tunisia. For the next few months a few sporadic cases were reported by the French among both European and Arabian civilians, but there was no indication of serious epidemic tendencies. Eight cases were reported in January 1944, 51 in February, 250 in March, and from then on there was a monthly rise until a peak of 6,536 new cases were reported in March 1945, after which the incidence receded. A total of 41,755 cases were reported during 15 months in Tunisia and this was considered to be approximately one-fifth the actual number, taking into account the unknown cases among the Arabs.

A U. S. Navy epidemiological unit was afforded the opportunity of studying the epidemic at close quarters and to assist the French health authorities in their efforts to control the disease. They closely observed the cases that occurred in two small Arab villages near a United States naval station. The mean age of the inhabitants of these villages was 24.7 years and the mean age of the patients was 22.6 years. The signs and symptoms of the disease were quite uniform in all patients, consisting of fever, headache, generalized malaise, chills, nosebleed, abdominal pain, and occassionally, vomiting. The majority of the patients showed a generalized petechial rash on the arms, chest, and abdomen and an enlarged spleen. The rash appeared early in the disease as small, bright red areas that faded to brown after 2 days and disappeared in about 5 days. Leukocyte counts were inconclusive. Twenty percent of the patients showed a slight neutrophilic leukocytosis, 20 percent had leukopenia with a relative lymphocytosis and, 60 percent had normal white blood cell counts throughout the course of the disease. Blood in all cases was positive for spirochetes in stained smears as well as in darkfield examinations. Agglutination tests with *Proteus OX–19* antigen was negative in all cases, both during the course of the disease and after convalescence, thus ruling out a concurrent typhus fever infection.

No cases occurred among United States military personnel. The effectiveness of DDT against the insect vectors and the therapeutic value of penicillin was also studied. Fifty out of fifty-six persons examined during a preliminary louse survey had body lice and nits. The entire population was dusted with 10 percent DDT in talc. Following this, 9 new cases occurred within the next 9 days (the normal incubation period of the disease). No further cases occurred in these villages after that time. A second louse survey held at the end of the incubation period revealed no lice or nits. Twenty-seven patients with the disease were treated with penicillin. Adults were given 30,000 units intramuscularly every 3 hours for

48 hours. Children were given 20,000 units at the same intervals and for the same period of time. All positive blood smears became negative within 48 hours following which there was a rapid clinical recovery and no relapses.

PLAGUE

Bubonic plague is sporadic throughout the Mediterranean but major outbreaks of the disease have been very rare. The exact incidence and the mortality rate were not reported to the Navy, but unconfirmed reports were that about 30 cases occurred and that the mortality rate was 40 percent. Ferryville was the site of a U. S. Navy LCT base and, at the time of an outbreak of plague there, had a complement of 80 officers and men. They were promptly vaccinated with formalin-killed vaccine containing 2,000 million organisms per cc., by two injections at 5-day intervals, the first, one-half cc., and the second 1 cc. During the 4 months immediately preceding the appearance of the disease, 190 rats were trapped by the Navy medical staff beneath the quonset huts of the base, in the galley, under tent floors, and along the sea wall. All were autopsied and none were found to be infected.

A U. S. Navy team assisted the French health authorities in rat extermination in Ferryville after the outbreak of plague. A total of 37 rats were taken by trap or by poisoned baits during this period. They were of two types, the black house rat, *Rattus rattus*, and the wharf rat, *Rattus alexandrinus*. The black rat predominated. Fleas found on live trapped rats were of three genera, the common rat flea, *Xenopsylla cheopsis*, the human flea, *Pulex irritans*, and the dog and cat fleas, *Ctenocephalides canis* and *Ctenocephalides felis*. The greatest number of fleas found on one rat was 100, predominantly *X. cheopsis*. Three of the dead rats taken were positive for *Pasteurella pestis*.

The Advanced Amphibious Training Base, Bizerte, was located about 10 miles from Ferryville. At the time of the plague outbreak in the latter place there were in excess of 10,000 U. S. Navy personnel stationed there. All were given plague vaccine in the same manner as those in Ferryville. A strict quarantine against entry into Ferryville, except on official business, was enforced on all United States military personnel. Rat extermination was intensified at the Bizerte base and 66 rats were caught. None was found to be infected. Traps and poisoned baits were used. The poisons used were barium carbonate, red squill, and thallium sulfate on ground beef, bacon, salmon, rolled oats, and whole wheat. Barium carbonate and red squill were found to be more effective than thallium sulfate.

An attempt was made to employ the insecticidal effect of DDT in the campaign againt the disease by the U. S. Navy team assisting the French. A 5 percent solution of DDT in kerosene was thoroughly sprayed by motor-driven apparatus over all vegetation, refuse, and rat infested areas in the hope of destroying fleas in that area. Unfortunately this phase of the work could not be followed through because of the exigencies of the service but it was believed promising and to warrant use in similar circumstances.

An outbreak of human plague occurred in Dakar, Senegal, French West Africa in April 1944 and continued into the following November. A total of 567 cases were recorded with 514 deaths–a mortality rate of 91 percent. A total of 10,500 rats were taken during the course of the epidemic. Three thousand five hundred and one were examined for plague and 65 were found to be infected. The rats taken consisted of the Norwegian rat *(Rattus norvegicus)*, the Alexandrine rat *(Rattus alexandrinus)*, the common black rat *(Rattus rattus)*, and the Camtchouli rat *(Crycetomys gambianus)*. The first three were common, the fourth somewhat less so. With a few excep-

TABLE 26.—*Types of plague cases seen in Dakar, and percent mortality*

	Bubonic	Pulmonic	Septicemic	Bubo-septicemic
Number in native hospital	96	15	16	0
Number in military hospital	5	0	7	5
Percent mortality—native hospital	61	100	100	----------
Percent mortality—military hospital	0	----------	100	20

tions the infections were found to be limited to the Norwegian and Alexandrian rats.

Statistical data are available on 127 cases treated in the Native Hospital and on 17 cases treated in the French Military Hospital (table 26).

Both hospitals employed the same treatment and therapeutic agents but in a slightly different manner, as shown in table 27.

TABLE 27.—*Methods of treatment of plague cases*

Therapeutic agent	Native hospital	Military hospital
Sulfapyridine	4–6 gm. daily as long as fever continued.	8 gm. daily for 3–4 days orally and intravenously then 3 gm. daily as long as fever continued.
Sulfadiazine	Initial dose, 2 gm., then 1 gm. every 4 hours for duration of fever.	6 gm. daily as long as fever persisted.
Plague bacteriophage	1 cc. intravenously as long as fever persisted.	2–3 c.c. first day then 1 cc. daily as long as fever persisted. Given intrabubo in bubonic type and subcutaneously in septicemic cases.
Plague antiserum (Madagascar strain).	100 cc. daily during fever.	60–80 cc. daily intravenously during fever.

Sulfapyridine was considered ineffective and was discontinued as soon as a sufficient supply of sulfadiazine became available. The results of treatment are shown in table 28. Those cases at the Native Hospital which were treated with sulfapyridine are omitted because data on them is not available.

It was the opinion of the medical officers in both hospitals that bacteriophage was indispensable and that the best results were obtained from the combined use of bacteriophage and sulfadiazine. There was a 100 percent mortality among the septicemic and pneumonic cases, regardless of the therapy used. The patient with the bubonic type of case had very little chance of survival unless treatment was started before the fourth or fifth day of the disease.

An extensive program of flea eradication was undertaken in an effort to destroy the insect vectors. The inhabitants of the flea-infested area and their habitations were treated with DDT. The effort was 90 to 95 percent effective in killing the insects.

TABLE 28.—*Results of treatment of plague cases*

NATIVE HOSPITAL

	Bubonic		Septicemic		Pulmonic	
	Cases	Deaths	Cases	Deaths	Cases	Deaths
Sulfadiazine	11	7	3	3	5	5
Sulfadiazine and bacteriophage	44	23	8	8	12	12

MILITARY HOSPITAL

	Bubonic		Septicemic		Bubo-septicemic	
	Cases	Deaths	Cases	Deaths	Cases	Deaths
Serum and sulfapyridine	1	0	4	4	1	0
Serum and sulfapyridine and bacteriophage	1	0	1	1	2	1
Sulfapyridine and bacteriophage	1	0	0	0	0	0
Serum and bacteriophage	0	0	1	1	1	0
Serum and sulfadiazine and bacteriophage	0	0	1	1	1	0
Sulfadiazine and bacteriophage	2	0	0	0	0	0
Total	5	0	7	7	5	1

YELLOW FEVER

Yellow fever is not found in French North Africa, nor in any of the countries or islands of the western Mediterranean region. No cases were reported among United States military personnel and no measures, except routine vaccination, were necessary.

SCHISTOSOMIASIS

Schistosomiasis is not prevalent in North Africa. One case of the disease was reported among United States naval personnel in the theater. The source of his infection could not be determined. A survey of all the fresh water streams in the vicinity of his ship failed to reveal any evidence of cercariae. Surveys were conducted at the other Navy bases with similar negative results.

AMEBIC DYSENTERY

Amebic dysentery was endemic in the Mediterranean countries but did not constitute a serious health menace.

INFECTIOUS HEPATITIS

Infectious hepatitis was the most troublesome disease condition throughout the entire theater. The local health authorities in all areas were in agreement that the disease did not exist in the Mediterranean region before 1943, hence it cannot be attributed to any local condition, but was a by-product of the war. A few sporadic cases of what was diagnosed and treated as simple infectious jaundice occurred during the first months of the campaign, although in no greater number than was experienced among the Armed Forces in the United States and Great Britain, and they responded to the usual treatment in a normal time. A more severe type of the disease appeared among the forces in Tunisia in June 1943 and gradually increased to epidemic proportions during the summer and autumn. When cooler weather began the incidence declined but the disease did not disappear. It appeared among the forces in Italy and during the winter of 1944–45 became so widespread that the problem was considered serious.

In the earlier cases in Tunisia the onset was usually insidious with malaise, fever, and anorexia. In a few days nausea, vomiting, right upper quadrant discomfort, liver enlargement, and usually a mild diarrhea appeared. The amount of fever bore no relationship to the severity of the disease. Some degree of jaundice was usually apparent after the fifth day, although some patients never became icteric. Others had an icterus index as high as 200. The degree of jaundice had little or no relationship to the severity of the disease or to the length of convalescence. Liver tenderness and liver enlargement were constant physical findings. Slight leukopenia was the rule although in many patients the white and differential blood cell counts were normal. Red blood cell counts and hemoglobin showed no alteration. About 10 percent of the patients had an acute stormy onset with fever, chills, nausea, vomiting, and mild prostration.

Relapses after apparent recovery became more frequent during the latter part of the Tunisian outbreak. This appeared to indicate that the etiological agent was increasing in virulence as time went on. The mortality rate was 0.05 percent. At necropsy acute yellow atrophy of the liver was noted.

The fact that the disease made its appearance in the early summer and continued during the warm months, to decline in incidence with the advent of cooler weather led to the belief that it was associated with the acute gastrointestinal infections that were also prevalent during that period. All attempts, however, to identify and isolate the exact etiological agent were futile. Blood studies were negative for *Leptospira icterohaemorrhagiae* and other spirillae. All attempts to cultivate a virus from blood, urine, and feces of patients with the disease were failures.

Chapter IX

Air Evacuation and Transportation of Sick and Wounded

Leon D. Carson, *Captain (MC) USN*
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Before the beginning of World War II the Bureau of Medicine and Surgery, in conjunction with the Bureau of Aeronautics, made provisions for procuring specially fitted and constructed ambulance planes to evacuate the sick and wounded. Until well after the war began, aerial transportation of the sick and injured was a function of local commands, but the early experiences in the Guadalcanal campaign highlighted the need for an aerial evacuation service that could be coordinated by one central agency. At Guadalcanal, it was again indicated that three cardinal factors operated to reduce the mortality from wounds. These were:

1. Immediate first-aid treatment.
2. Prompt treatment of shock by the administration of plasma and morphine, the control of hemorrhage, and the use of chemotherapy as prophylaxis against infection.
3. The earliest possible evacuation of the wounded to hospital ships or advanced base hospitals for definitive treatment.

The United States was not alone in developing facilities for the transportation of casualties by air. In the first years of the European phase of World War II, the armies of Britain, Russia, and Germany developed and employed air transportation for the sick and wounded. In Russia and particularly in Germany, this service developed rapidly. These developments were closely observed by the air medical services of our Army and Navy, who began to plan methods of evacuation and devise medical equipment transport aircraft.

Air evacuation of the sick and wounded on a large scale had its inception in the Pacific during the Battle of Guadalcanal, when the advance echelon of Marine Air Group 25, consisting of 14 R4D2 aircraft, arrived in the South Pacific on 1 September 1942. They made the first flight into the combat zone 2 days later. Evacuation of the wounded was started immediately, although no medical personnel were available for the planes. The planes were equipped with supports for 18 stretchers, but the auxiliary gas tanks in the cabin, needed for long trips over water, prevented the installation of more than 10 stretchers. During the first 6 weeks, there was no medical supervision of loading of casualties, or facilities for the handling of patients at unloading terminals. Medical personnel were added to crews of planes carrying the more seriously wounded early in 1942. By 1 November 1942, a sufficient number of medical personnel were available to permit medical officers to accompany planes carrying the seriously wounded. Hospital corpsmen were assigned to air transports carrying the less seriously wounded and the sick.

Responsibility for air evacuation of combat casualties during these operations was divided between task force commanders in assault areas and the Commander, Forward Area, invariably resulting in delays in getting the wounded to hospitals. This division of responsibility was continued during the Pacific operations, until the Air Evacuation Service was established under the administrative control of the Chief of the Bureau of Medicine and Surgery.

The foundation for a joint transportation service was laid in October 1942, when Army transport planes began joint operations with Marine Air Group 25 in the South Pacific. They provided transport service to Sydney in Australia, Auckland in New Zealand, Espiritu Santo, and Guadalcanal (by November 1942) and evacuated 4,595 casualties during the 4-month period ending December 1942. Patients were flown out of the combat area, usually loading under cover of darkness and often under enemy shell fire and bombing.

At first no medical officer or Hospital Corps personnel were available for the screening of patients at the target area or to accompany the injured. Before long, however, a General Order issued by the wing commander required that (*a*) the hospital receiving units establish facilities and assign medical personnel for the reception of patients at airports, (*b*) medical officers and hospital corpsmen accompany patients on aircraft whenever such personnel could be made available, and (*c*) receiving units provide transportation from the airports to the hospitals concerned. This order required that an air evacuation flight log be kept, and that liaison Hospital Corps personnel at each receiving airport insure the exchange of medical equipment. In order to maintain contact between the operations office and receiving hospital, records were to be kept of all patients received at unloading terminals. A flight surgeon was detailed as loading officer at pickup points within the combat zone. By March 1943 the South Pacific Combat Air Transport, composed of Army, Navy, and Marine air evacuation groups, was an efficient and effective organization. It transported 12,017 patients from Guadalcanal during the period from September 1942 through June 1943.

The following conclusions were reached regarding the safety of transporting casualties by aircraft: (*a*) Any patient may be evacuated by air if he is in condition to travel at all. (*b*) Patients suffering from chest, abdominal, or other severe wounds should be free from shock. (*c*) Patients who have undergone an abdominal or other serious operation should have recovered from postoperative shock. (*d*) Patients with acute chest and abdominal injuries should be flown at low altitudes. (*e*) The three most valuable therapeutic aids for use on planes are morphine, plasma, and oxygen. (*f*) The general condition of the patient is more important than the exact nature of his disease or injury.

Experience of medical personnel associated with these operations indicated the need for a medical officer to be in charge of the selection and loading of patients for air evacuation, and for a trained nurse and Hospital Corps personnel to accompany patients in flight.

In most campaigns, the operations plan assigned no responsibility to any organized transport squadrons for the evacuation of combat wounded and sick; this task was assigned to hospital ships and surface craft. On those occasions when air transport was called upon to clear a combat area of wounded, it was done as an emergency measure and without profiting from the lessons learned in the earlier days in the Solomons. An example of unplanned air transport evacuation of casualties occurred at Saipan, where it is estimated that aircraft provided 15 percent of the lift for the wounded and sick. No provision for proper medical screening of patients was made and the Air Transport called in to lift patients had no medical or nursing personnel or necessary equipment. As a result, a number of wounded died en route to hospitals in Hawaii, or arrived in poor condition. This is in contrast with the planned air evacuation program at Iwo Jima, where about 2,500 wounded were evacuated by air to hospitals in Guam and Saipan without the loss of a single patient aboard the air transports; or with Okinawa where 16,100 were carried by hospital ships, 4,900 by other ships, and 15,700 by Air Transport. Of the 15,700 transported by NATS or ATC hospital planes to Guam or Saipan, only 3 patients died en route.

The geographical distribution of anticipated areas of operation indicated the need for an even broader organization to cover the air evacuation program. On 24 November 1942 the Division of Aviation Medicine and the Chief of Plans and Training Division, Air Surgeon's Office, discussed plans to develop a coordinated evacuation of patients by air, but the lack of facilities, including airplanes and personnel, prohibited the development of a completely adequate plan at that time. Coordination and control of the Air Evacuation Service remained a function of task force and area commanders until October 1944. At that time, on the basis of a study made by the Division of Aviation Medicine, recommendations were made for the establishment of an air evacuation command whose primary mission would be evacuation of casualties and to which would be assigned experienced flight surgeons, specially trained nurses and flight hospital corpsmen. Planes of the latest type were to be so modified as to equip them for proper handling of casualties. This command, established under ComAirPac, was designated as Air-Sea Rescue and Air Evacuation Squadrons. It was intended that it should function in the dual capacity of rescue and air transportation. Later it became known as the Dumbo Squadron. Its activities were limited to air-sea rescue, principally because of the range of the planes that were used. Combat operations were developing rapidly in the Pacific at increasing distances from established hospital facilities. The problem of moving large numbers of casualties from target areas to advanced hospitals was becoming immediate and pressing. Although hospital ships and other types of hospital transportation were constantly being placed in commission, they still were not capable of carrying the peak loads that occurred.

Because of a lack of four-engine long-range aircraft, the function of air evacuation was transferred at the request of Division of Aviation Medicine to the Naval Air Transport Service. The VE squadrons organized under this plan were first used in combat in the battle of Saipan.

Reports of the work of Air Evacuation Group One in the Central Pacific Theater during the bitter struggles for the capture of the two final objectives in Japanese home waters attest the effectiveness of that command's operations. The extensive use made of air evacuation at Okinawa has no parallel in previous amphibious operations. Air evacuation was regarded as remarkably successful and was uninterrupted on all but 2 days of the operation. The heavier load was carried by planes of NATS Air Evacuation Group One, ATC planes lifting roughly a third of total patients carried by air. The success of this transport operation can be attributed largely to the highly trained personnel of both organizations and to careful medical screening of patients at the target area.

From experience gained in the South and Central Pacific, as well as in the European Theater, an operational plan for air evacuation and a training schedule for medical, nursing, and Hospital Corps personnel were formulated and placed in operation within the Pacific Theater. Flight nurses and flight hospital corpsmen were placed under instruction at a newly established school for Air Evacuation at Naval Air Station, Alameda, Calif. The course consisted of didactic lectures and demonstrations in techniques employed, survival training, minor surgery, and first aid. Emphasis was placed on recognition and treatment of shock, splinting and redressing of wounds, and chemotherapy. Graduates of this school were made available to the Air Evacuation Wing.

Air Transport Evacuation Group 94.12 was supplied with trained flight nurses, flight hospital corpsmen, and medical officers in sufficient number to provide not only adequate medical and nursing supervision of casualties, but also a medical screening team at target area to insure proper selection of patients for air evacuation.

After the conclusion of the Iwo Jima operation, the total responsibility for air evacuation of noneffective sick and wounded, Pacific Ocean Areas, was assumed as a function of ComNATSPac, and Air Evacuation Group One was set up at Guam.

Air Evacuation Group One included the following personnel: 1 captain MC, USN, staff medical officer; 5 flight surgeons, lieutenant commander MC, USN and USNR; 1 flight surgeon, lieutenant MC, USNR; 4 Hospital Corps officers; 85 flight nurses; 5 chief nurses, lieutenant NC, lieutenant (jg) NC, and ensign NC; 156 flight hospital corpsmen.

PLANES AND EQUIPMENT

During the Okinawa operations, R5D–1's, 2's, and 3's—the Douglas Skymasters—were employed. These are four-engine land planes employed by both ATC and NATS for long-distance cargo and passenger hauling. Those assigned to the air evacuation schedules were equipped with standard webbing strap litter supports for carrying 28 litter-borne patients. Additional seats for four ambulatory patients were also provided. In addition to the regular crew, a flight nurse and a flight hospital corpsman accompanied each trip. Medical equipment and supplies comprised the following items:

1. One airborne medical chest, weighing about 70 pounds and containing dressings, instruments, medicines, bedpans, urinals, and catheters.

2. One refrigerated whole blood shipping container modified to contain two units each of whole blood, plasma, serum albumin, and a supply of distilled water and penicillin.

3. Boxed evacuation flight rations, which were placed aboard each plane just before departure to target, and consisted of canned fruit juices, soups and boullions, crackers, candy, tomato juices, tinned boned chicken, turkey, tuna, chewing gum, cigarettes, and other miscellany. In addition, a carton containing bread, paper cups and feeding tubes, and thermos jugs containing hot coffee and water were carried. The fresh water tanks of the plane were also filled before each trip. Two electric hot cups (12–24 volt) were carried in the medical chest.

4. Twenty-eight steel pole or aluminum pole litters, as well as three blankets per patient. These were off-loaded at target in exchange for loaded litters and blankets.

OPERATING POLICIES CONTROLLING FLOW OF PATIENT TRAFFIC

All patients at target area were routed through an air evacuation hospital situated about a mile and three-quarters from loading point on air strip. Emergency surgical treatment and redressings were accomplished there. At the air strip, all patients were screened by a combined Army and Navy screening team prior to departure. This team issued treatment orders to flight nurses in charge of each plane load regarding chemotherapy and blood substitutes for care of the patients en route to the Marianas. Patients were loaded aboard airplanes within a half hour after they landed at target air strip. Loading was accomplished by two-stage loading platforms on wheels, or by finger-lift trucks. Planes arrived and departed on half-hour schedules beginning at 0700.

After a 1,500-mile return flight of about 7½ hours' duration, patients were disembarked at the Air Evacuation Center in Guam. Unloading of ambulatory cases was by roll-away two-stage loading platform, or by finger-lift truck. Planes taxied to a paved area immediately outside the entrance to the Air Evacuation Center at Agana.

All litter patients were carried into the Air Evacuation Center and litters placed on slightly inclined racks so that the head of each litter was elevated about 6 inches. Patients were examined by medical officers and nurses, and displaced dressings were secured or replaced. Those in shock were given plasma or whole blood, and emergency transfer to nearest Navy or Army hospital was arranged. All other stretcher patients were loaded into ambulances for dispatch to hospitals. Ambulatory patients were sent in busses.

Most of the rearward movement of patients was performed by surface ships, but a large number of patients were returned via Naval Transport Service and ATC. Between 2,400 and 2,500 patients per month, noneffective sick and casualties were transported by air from Guam to Honolulu, and about 15,000 patients per month were moved from Honolulu to Oakland.

SCREENING OF PATIENTS

In evacuation of casualties from combat to target areas, military necessity required the transfer by air of almost every conceivable type of casualty. Patients having chest wounds with pneumothorax, severe abdominal wounds with extensive visceral damage, spinal injuries with partial paralysis affecting accessory muscles of respiration, severe head wounds with exposure of brain tissue, and many other serious wounds have been transported by air. The only criterion as to acceptance by medical screening officers at the target has been the question, "Is the patient sufficiently recovered from primary or postoperative shock or has hemorrhage been so combated, as to permit travel by *any* means of transportation?" Special flights at low level were arranged for patients whenever requested by the flight nurse, and as a consequence patients required administration of oxygen only infrequently. Each plane carried three portable oxygen supply systems. Very few patients had delayed shock while in transit. Nurses were instructed in the treatment of shock in its incipient stages and the routine use of plasma and serum albumin was directed.

SCREENING OF PATIENTS FOR AIR TRANSPORT TO HOSPITALS IN REAR AREA AND ON THE MAINLAND

Selection of patients for evacuation from hospitals in the Marianas to Honolulu or the mainland was made, in collaboration with the medical, surgical, and neuropsychiatric services of those hospitals, by two flight surgeon screening officers attached to Air Evacuation Group One.

Patients with peripheral nerve injuries and those with brain or severe head injury were given top priority for evacuation to the States. Psychotics were carefully prepared and sedated prior to departure.

At first, due to lack of a holding center at Honolulu, all patients arriving there were readmitted to hospitals in that area. Later, provision was made for a holding center where patients scheduled for transportation to the States could rest for 24 hours or overnight, before continuing flight. This permitted an opportunity for careful changing of dressings, bathing, and other hospital care of patients.

ADVANTAGES OF AIR TRANSPORT OF SICK AND WOUNDED

1. *Morale.*—The improved spirits and outlook of patients brought in by air was remarkable. The usual comment of patients was either: "How long has this been going on?" or "Why hasn't the Navy done this before?" This morale effect extended to combat troops who knew that, if wounded, they had a chance of speedy removal from combat to quiet areas.

2. *Flexibility.*—As compared with the hospital ship, air transport can adapt its schedules from day to day to adjust to increased or decreased casualty loads in combat areas. Further, patients arrive at forward area hospitals on an hourly or half-hourly schedule in small increments, and this prevents the sudden overloading of all available ambulances and busses, which occurs when hospital ships arrive.

3. *Economy of Medical Personnel.*—An equivalent number of patients can be handled from point of loading to destination with one-tenth the medical, nurse, and Hospital Corps personnel required for evacuation by hospital ship. As an example, one hospital ship could make a round trip between Okinawa and Guam in 8 to 10 days, bringing about 600 patients. Two R5D planes could evacuate 640 patients in 10 days and employ only 6 flight nurses and 6 hospital corpsmen, allowing each nurse and hospital corpsman 2 days' rest between trips. If aircraft were designed to carry a passenger load equivalent to maximum cargo carrying tonnage, well over 60 passengers could be carried per plane.

DISADVANTAGES OF AIR EVACUATION

1. Patients cannot be evacuated from a target area until an air strip has been captured and made ready. This period is variable; experience showed that from 7 to 10 days are usually required. During this time hospital ships and auxiliaries, such as LST(H)'s, must carry on whatever evacuation is possible from the beachhead.

2. Transport aircraft cannot use air fields while they are under enemy air attack. However, hospital ships and LST's are similarly handicapped when the fleet lying off shore is under such attack.

3. Transport aircraft have not been designed for carrying wounded. All have to undergo modification before being assigned to this task. Space for litters does not permit the carrying of enough patients to even approach weight-load capacity.

Maximum use should be made of air transport to transfer sick and wounded personnel. Plans for all future operations should specify a task for Air Evacuation Service commensu-

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rate with its capacity. Under no circumstances should air evacuation be considered as an auxiliary or secondary service.

Military transport aircraft should be designed to permit maximum litter capacity. A lighter weight, stronger medical chest should be developed which, when opened, can be supported at a convenient working level. Instruction in the techniques and methods of evacuating patients by air should be included in the curriculum at Schools of Aviation Medicine. Cognizant Bureaus should jointly develop plans and specifications for transport aircraft for air evacuation. Food systems should be investigated to determine which are the best types of diets for sick and wounded that can be prepared and served on evacuation aircraft in combat areas.

Chapter X

Aviation Medicine

A. Developments in Aviation Medicine

John C. Adams, *Rear Admiral (MC) USN (Retired)*

To appreciate the significance of aviation medicine and its value in World War II, its record of accomplishment must be viewed against the background of meager facilities and scarcity of personnel that existed prior to the national emergency. Such a perspective reveals the degree of our unpreparedness. These deficiencies, however, were largely a reflection of the general situation that then confronted naval aviation as a whole. Regardless of the valiant efforts for progress in the naval air arm, and the many noteworthy achievements, the fact remains that naval aviation then lacked the green light for healthy growth and development.

It was not until the Germans had demonstrated the importance of aviation in the war in Europe that a new perspective in aviation was forced upon us. These revelations, though much belated, were profound and decisive, and cleared the way for a modern and gigantic Army and Navy air force with the attendant development of aviation medicine.

Prior to the declaration of the national emergency, the Division of Aviation Medicine in the Bureau of Medicine and Surgery consisted of one medical officer and one clerk. Approximately 49 flight surgeons were on duty with aviation commands ashore and afloat. Their principal function was to determine the physical qualifications for flying of some 3,000 aviation personnel. There was no Navy school to train flight surgeons. Funds or facilities for aviation medical research did not exist, nor were flight surgeons engaged in research.

The program necessary for a healthy aviation medical service required, among many other things, improvement of the low morale and service standing of flight surgeons. A school of aviation medicine was required, and a program for aviation medical research and facilities for its accomplishment were urgently needed. Later there would arise the need for scientists allied to medicine; the psychologists, the physiologists, and others.

With these objectives in mind, this small organization of flight surgeons in 1938–39 was progressively expanded until, at the close of the war, the aviation medical service had over 1,200 medical officers. It staffed an aircraft carrier program that involved over 100 ships, and provided the medical service for all Marine Corps aviation units in the Pacific. It rendered service from Guadalcanal to the Aleutians. The record of the heroic service of the flight surgeon is attested by the fact that the death rate of flight surgeons was 2½ times greater than that of any other group of naval medical officers in the combat area.

In 1939 a limited number of flight surgeons were assigned to flying duty. This proved to be a great factor in increasing the proficiency and effectiveness with which they performed their duties. After the declaration of war, increasing numbers of aviation medical examiners and flight surgeons were given flight orders, until at the close of the war the majority of such officers were flying regularly.

To improve further the efficiency of flight surgeons, authority was obtained from the Bureau of Aeronautics in 1938–39 to give flight training to 4 flight surgeons each year and to give them the designation of naval aviator. Medical officers selected for this training were those with resourcefulness and motivation. These flight surgeons who became naval aviators were destined to fill the most important assignments on the staffs of aviation fleet commands and to exert a profound and wholesome influence in the development of aviation medicine.

As a further support to morale, authority was obtained in July 1942, for an insignia for flight surgeons. These "wings" were included in the official uniform regulations and became a symbol of prideful distinction.

On 29 November 1939, a school for Navy flight surgeons was organized at the Naval Air Station, Pensacola, Fla. Prior to this, training in aviation medicine for naval medical officers had been conducted at the Army School at Randolph Field, Tex. Funds for the school at Pensacola were provided by the Bureau of Aeronautics. Later, after extensive research facilities had been added, the name was changed to "School of Aviation Medicine and Research."

The first step toward providing a research program was taken on 15 November 1939, when the Surgeon General and the Chief of the Bureau of Aeronautics agreed to the assignment of a flight surgeon, Captain John R. Poppen, for research under cognizance of both bureaus. Inasmuch as there were no medical research laboratories in the Navy, Captain Poppen's initial job was to evaluate the research needs, determine what other governmental agencies or facilities were available to do the work, or what civilian institutions could render the services, and at what cost.

Probably one of the most important developments resulting from this humble beginning was the disclosure that few, if any, scientific institutions knew more about aviation or aviation medicine than did the military services. In other words, the country was nationally unprepared to supplement or supply these needs.

Under the guidance and leadership of Captain Poppen, a program was started that led to rapid expansion and a vast ramification of aviation medical research throughout the country. Concurrently, it was necessary to stimulate the interest of civilian scientists. Numerous visits were made to civilian educational and research institutions. Meetings were held on the subject of aviation medical research, and keen interest in these matters was rapidly stimulated.

Partially as a result of the foregoing measures, a subcommittee on aviation medicine of the National Research Council was formed on 19 October 1940, with Dr. Eugene DuBois of Cornell University as Chairman. This group inspected all important aviation activities throughout the country.

Because an extensive expansion in personnel of the aviation medical research organization was indicated, a Division of Medical Research was established in the Bureau of Medicine and Surgery, in 1942, to direct all aspects of a broad medical research program. Rear Admiral Harold Smith was designated as head of the division. Aviation Medical Research, a section of the Bureau of Aeronautics, was incorporated in the new Research Division in the Bureau of Medicine and Surgery and a flight surgeon was assigned to the Bureau of Aeronautics as a technical liaison officer. This arrangement has continued and has been invaluable in facilitating the exchange of information between the aviation medical organization in the Bureau of Medicine and Surgery and the Bureau of Aeronautics.

With the progress of the war, aviation medical research in our country as well as in Great Britain and Canada was tremendously accelerated. The Committee on Aviation Medicine, National Research Council, enlisted the help of our principal universities and scientific institutions. Equipment and money became available and soon extensive research projects in all phases of aviation medicine were underway in many institutions throughout the country, including the new Naval Medical Center at Bethesda, Md., with its splendid research facilities. A close working liaison in aviation research was maintained with Great Britain for standardizing as well as improving oxygen equipment for pilots, and for exchanging information concerning air embolism and combat fatigue.

After the detachment of Captain Poppen from the Research Division, Commander Eric Liljencrantz headed the Division. On 5 November 1942, Commander Liljencrantz was killed when the wings of his plane collapsed while he was making studies in gravity stress encountered in dive bombing. The loss of this brilliant officer was a tragic and heavy blow to the organization.

The Division of Aviation Medicine expanded until its staff exceeded in number the total medical officer personnel employed by the Bureau of Medicine and Surgery prior to the war. Over 50 psychologists and many physiologists and other scientists were added to the organization. They were primarily responsible for the development of the psychological screening tests that were later employed so effectively in the selection of students for flight training.

Naval aviation was never heavily committed in the European theater of war. Its principal activities were concerned with the North Sea patrols, convoys, antisubmarine measures, and coastal patrols. In the Pacific theater the picture was quite the reverse. Here, naval aviation was heavily engaged under the most diversified and trying conditions. Owing to the vast area of operation, there arose the complex problems relating to environmental stress, as well as problems involving climatic conditions varying from the tropical latitudes in the South Sea Islands to the frigid region of the Aleutian peninsula. The possibility of being shot or forced down in the vast reaches of the Pacific Ocean was a continuous threat to aviators and detrimental to their morale. There was an urgent need to improve the means for the survival of downed aviators until they could be rescued. Better flying clothing and gear were required and a program of precise and effective air-sea rescue was an urgent need. To maintain the morale of flying personnel, there was need for a realistic and effective rotation program for the replacement and physical rehabilitation of war-weary pilots.

It became necessary to screen and properly dispose of incompetent as well as physically depleted personnel. New techniques for the psychological screening of applicants were required. Such procedure was developed and became so perfected that predictions for success or failure under flight training were reduced to mathematical precision.

Similarly, an extensive altitude training program for pilots was required. Low-pressure chambers were installed in the principal continental naval air stations. This training program, under flight surgeon administration, led to the establishment of schools for training aviation medical technicians, low-pressure chamber technicians, medical personnel in air-sea rescue programs. Many training aids were devised, including manuals and environmental museums, to aid pilot training and survival.

These programs and developments constituted a vital function of the aviation medical organization. The flight surgeons and aviation medical examiners became an indispensable part of the Navy's aeronautical organization. Their theme was service and their immediate and controlling objective was functional support to aviation, wherever and however possible.

Flight surgeons were assigned to each combat air group and to all carriers and aviation commands, ashore and afloat. Although trained for their technical duties, these medical officers were all volunteers, and only those who demonstrated an aptitude for this duty were retained. This, in part, is the explanation for the superior morale of these officers. Their value is demonstrated by the way in which they gained the confidence of their pilots, enabling them to know the personal attributes of each and, by proper appraisal, to safeguard flying personnel affected by staleness or combat fatigue.

As planes flew higher and faster, and as the techniques in combat progressed, "blackout" in dive bombing and in combat maneuvers became a serious problem. Naval aviation medicine was soon leading in the development of measures to control this problem, and came up with the "antiblackout" suit and equipment.

As the importance of night flying in patrols and combat increased, the need for a program for training pilots in the better use of their eyes at night became urgent. This led to the development of the Navy's night vision training program for pilots, conducted by flight surgeons and trained technicians.

As the fighting became more intense in the Pacific Islands, it became necessary to employ aircraft for the evacuation of sick and wounded. This led, in December 1944, to the creation of a school at the Naval Air Station, Alameda, Calif., for training flight nurses and to the development of facilities for a system of air evacuation. This medical service, organized and manned by Navy flight nurses and aviation medical officers, was a valuable aid in the care of the sick and wounded.

In May 1944, a Physiological Test Section was established at the Naval Air Test Center, Patuxent River, Md. Later, test sections were established at three other stations and in the fleet. This was headed by flight surgeons and physiologists who flew the planes in the conduct of the studies and tests.

On 29 February 1944, formal procedures were established for the disposition of war-weary and other pilots who failed to meet the required standards. In October 1944 measures for the physical reclassification of naval aviators were adopted. These measures, belated as they were, provided a means for a systematic relief of fatigued aviators and for their orderly rehabilitation and reemployment.

That so much could have been accomplished in so short a period, and with such a record of individual resourcefulness, reflects, the character and superior morale of everyone who served on the team. The organization functioned in a spirit of teamwork, and from this it gained strength and effectiveness. Regardless of these facts, final success could not have been attained without the unstinted and forceful support that the Surgeon General, Vice Admiral Ross T McIntire, consistently gave, nor without the sympathetic backing of the Bureau of Aeronautics and the funds it so generously provided.

Much credit is due our allies, Great Britain and Canada, with whom we enjoyed a free exchange of information throughout the war. Lastly, grateful acknowledgment is due our many universities, civilian institutions, and scientists, who joined forces so generously to help in the common cause of victory.

B. High Altitude Training

Norman E. Williams, *Commander (MC) USN*

Norman Lee Barr, *Commander (MC) USN*

Lack of oxygen was always the primary problem in high altitude flights. Much time and effort had been devoted to the development of equipment to supply it, but because of waning interest and the slow advance in aircraft performance, very little progress was made until just prior to World War II.

In February 1940 a recommendation was made by the Medical Research Section of the Bureau of Aeronautics that facilities be procured for the instruction of all aviation personnel in the use of oxygen and of oxygen equipment, and in the physiological and psychological effects of anoxia. Practical demonstrations were to be given to small groups in low-pressure chambers, where the effects of anoxia could be experienced and where the beneficial effects of oxygen could be demonstrated. In July 1940 the Bureau of Aeronautics approved the procurement and installation of four 14-place low-pressure chambers, and in June 1941 the first of these chambers began operating at the Naval Air Station, Pensacola, Fla. A month later indoctrination in the use of oxygen was begun in the naval service for the first time. Later in 1941, plans were made for expansion of the altitude training facilities by the procurement of six 8-place low-pressure chambers. In November 1941 plans were developed for a program of pilot declassification based on each aviator's tolerance to anoxia, chilling, and air embolism, and for the installation of a refrigerated low-pressure chamber at the Naval Air Station, Pensacola, Fla. In 1943 six mobile low-pressure chambers were procured for oxygen training in fleet units. By 1945 facilities for altitude training included 16 altitude training units.

From 1940 until 1945, procurement and installation of altitude training facilities and training directives were functions of the Medical Research Section of the Bureau of Aeronautics. Training of personnel and their assignment was accomplished by the Division of Aviation Medicine, Bureau of Medicine and Surgery. In April 1943 the responsibility for the administration of this program was assumed by the Division of Aviation Medicine, and an Altitude Training Section was established. The Medical Research Section of the Bureau of Aeronautics developed specifications for and arranged for procurement and installation of the first four low-pressure chambers. The procurement and installation of the next six 8-place chambers were handled by the Bureau of Yards and Docks. Procurement, installation, and maintenance of the low-pressure chambers became a function of the Special Devices Division of the Bureau of Aeronautics following its establishment in 1943.

By August 1941 the Altitude Training Unit at Pensacola had written and made available the first training syllabus. A 2-hour lecture on the physiology of respiration was given by a medical officer. This was followed by a 1-hour lecture on the types of oxygen equipment, their operation, and use. Cadets, in groups of 10, received a 45-minute review lecture preceding a 1-hour demonstration in the low-pressure chamber. The simulated flight consisted of ascent to 5,000 feet followed by rapid descent to 2,000 feet to test the ability of the passengers to equalize pressure in the middle ear and to reassure them. An ascent was then made at 5,000 feet per minute to 19,000 feet. This altitude was maintained for 15 minutes to demonstrate the effects of anoxia. The use of oxygen was then begun and ascent to 28,000 feet was made to show the beneficial effects of oxygen. A cancellation test (composed of various combinations of letters of the alphabet) was developed at Pensacola and given to each passenger at sea level, at 19,000 feet, and again at 28,000 feet. This test was designed to be equally difficult in all three tests, but was soon modified to make the test at 19,000 feet more difficult, as the undesirable effects of anoxia were not demonstrated effectively. The 15-minute stay at 19,000 feet was considered too severe because of the high incidence of vasomotor collapse and ascent to 18,000 feet became routine procedure.

Along with the development of plans to select flight students for various types of flying, the Medical Research Section, Bureau of Aeronautics, in August 1941, recommended that measures be established for individual tolerance to anoxia, air embolism, and low temperatures, and that criteria be established as physical qualifications for high altitude flying. This recommendation was the result of anticipated flights to altitudes of 40,000 feet, and information that the R.A.F. and the Luftwaffe were using altitude tolerance tests as a means of selecting aviators for high altitude performance. At Pensacola approximately 10 percent of the aviation cadets showed symptoms of hypoxia at 18,000 feet.

Early in December 1941 the Altitude Training Unit at Pensacola made a few low-pressure chamber flights to 35,000 feet to determine if chamber operation at such simulated altitudes was feasible.

During 1942 the Altitude Training Unit at Pensacola conducted investigations aimed at the establishment of measures of altitude tolerance. Reactions to hypoxia at altitudes of 18,000 and 18,500 feet and factors in the occurrence of air embolism at altitudes of 35,000 and 40,000 feet were studied. These studies indicated that one 1-hour exposure at an altitude of 35,000 feet was not a valid test of susceptibility to air embolism and that a minimum of three 1-hour exposures to an altitude of 35,000 feet on successive days were necessary. Tolerance to anoxia was considered unsatisfactory if supplemental oxygen was required during 15 minutes at an altitude of 18,000 feet. It was generally accepted that persons requiring supplemental oxygen under these conditions were more susceptible to hypoxia. It was believed that they would have a smaller margin of safety should they lose their oxygen supply, but this concept was eventually discredited.

The first altitude training directive, prepared by the Medical Research Section of the Bureau of Aeronautics in April 1942, outlined the instruction to be given and chamber routines to be followed in conducting oxygen indoctrination and altitude classification. This directive established altitude classification as a requirement for assignment to fighter training. All of our allied medical services were conducting high altitude classification low-pressure chamber flights, but each one was using a separate type of test procedure. By summer 1942, the Altitude Training Unit personnel at Pensacola were beginning to question seriously the value of the low-pressure chamber as a selection device. The belief was growing that the real value of the chamber was in teaching. During the latter part of 1942, the School of Aviation Medicine recommended that altitude classification be discontinued and that stress be placed on altitude training. In early 1943 the Intermediate Aviation Selection Board at Pensacola analyzed the effectiveness of altitude classification and found it so ineffective that it too was convinced that the greatest value of the Low-Pressure Chamber Program was educational.

Installation of the first refrigerated low-pressure chamber was completed at Pensacola in December 1942. On 15 December 1942, a Bureau of Aeronautics directive outlined the high altitude low-temperature indoctrination and classification program. This established a third low-pressure chamber flight to be given to all aviation cadets.

By 1943 the rapidly expanding aviation training program began making it difficult for the Altitude Training Units to comply with directives. The shortage of trained medical personnel and a rapid increase in the training load required some of the Altitude Training Units to work in two shifts. The ground training and flight training syllabuses were too crowded to allow sufficient time for conducting the oxygen indoctrination and altitude classification requested by the Bureau of Aeronautics. The lack of equipment was so acute that operations would have ceased had it not been for the ingenuity and enterprise of Altitude Training Unit personnel. It became apparent that the program had developed into a major administrative problem. In April 1943, the Bureau of Aeronautics requested that the Bureau of Medicine and Surgery assume responsibility for the administration of this program.

A directive issued in August 1943 initiated a graduated and well-integrated program. The primary mission became altitude training; classification became secondary. This provided that each aviator have a minimum of three low-pressure chamber flights. The first two were provided during the intermediate state of flight training. The first or "indoctrinational" flight was given to demonstrate the effects of hypoxia at altitudes of 18,000 and 30,000 feet. The second or "high altitude" flight was given to demonstrate decompression illness (air embolism) at altitudes of 35,000 feet. The third was provided at a naval air base shortly after assignment to a fleet unit. This flight was given as a "refresher." It demonstrated the effects of anoxia at altitudes of 18,000 and 30,000 feet and afforded the opportunity of providing all fleet aviation personnel with information on recent developments in biochemistry of oxygen and in oxygen equipment.

A new directive provided more training in the use of oxygen equipment, including its use during flight in training aircraft. The teaching value of the low-pressure chamber flights was greatly enhanced by the adoption of mask removals at altitudes of 30,000 feet.

In December 1943 a directive was issued that outlined the low-temperature flight to be made. This flight included a 15-minute stay at altitudes of 18,000 feet with the temperature lowered to 0° F. Further ascent was made to altitudes of 30,000 feet and the temperature held at 0° F. until mask removal demonstrations were completed. Then the temperature was lowered to −30° F. and held for 15 minutes, followed by descent to sea level. This low-temperature low-pressure chamber flight became routine as the first or "indoctrinational" low-pressure chamber flight for aircrewmen.

By the end of 1944 a close working relationship had been established between the Altitude Training Units in the field and the Oxygen and Low-Pressure Chamber Section in the Division of Aviation Medicine. This resulted primarily from the frequent visits made to the Altitude

Training Units, permitting the Division of Aviation Medicine to be cognizant at all times of the problems and needs peculiar to each unit. They could then evaluate accurately Altitude Training Unit functions, and expedite reports and requests that concerned other Divisions of the Bureau of Medicine and Surgery or other Bureaus of the Navy Department.

Another factor in the development of coordination in the Altitude Training Program was the distribution to each training unit of a continuous stream of current Army and Navy technical orders and notes, circular letters, and research reports concerning oxygen equipment and high altitude physiology. A statistical analysis of monthly reports submitted to the Bureau of Medicine and Surgery by the Altitude Training Units was compiled monthly and distributed to training units, to keep them informed as to their relation to the over-all program.

One of the major accomplishments of the altitude training program during 1941 and 1942 was to dispel misconceptions concerning the use of oxygen. It was commonly believed that breathing 100 percent oxygen was harmful, that strong men did not need supplemental oxygen until they reached comparatively high altitudes, and that only the physically weak needed to use oxygen at the low altitudes. To many, use of oxygen at low altitudes was an admission of weakness and lack of stamina. These misconceptions were so prevalent and firmly ingrained that altitude training personnel soon found themselves selling the use of oxygen to aviation personnel.

EVALUATION OF TRAINING PROCEDURES

In 1944 a survey was made to determine the number of low-pressure chamber flights being made by aviators and aircrewmen. The altitude training program was designed to provide each aviator a minimum of three low-pressure chamber flights and each aircrewman a minimum of two flights. During December 1944 and January and February 1945, 2,499 aviators and 3,416 aircrewmen were given low-pressure chamber refresher flight indoctrination. Of 2,499 aviators, 53 percent had received three or more low-pressure chamber flights. Only 20 percent had received more than three flights. Of 3,416 aircrewmen, 49 percent had received two, and 11 percent more than two low-pressure chamber flights. These figures indicated that at least during December 1944 and January and February 1945, the training program was fairly effective, and that 33 percent had received more than the minimum training prescribed.

A comprehensive analysis of the effectiveness of the altitude training program was completed in November 1945. Performance on an oxygen obstacle course and a high altitude questionnaire were used to evaluate the information on the use of oxygen and oxygen equipment by aviation personnel. The following factors were found to contribute significantly to the knowledge on the use of oxygen: (*a*) Lectures on the use of oxygen; (*b*) flights in the low-pressure chamber; and (*c*) experience with oxygen equipment in aircraft, depending on the type of plane. Of these, experience with oxygen equipment in aircraft was the most influential factor. Personnel who obtained their experience in single engine planes knew more about the use of oxygen. The use of oxygen in aircraft during training appeared to be as effective a teaching agent as use of oxygen during combat. It was also found that one flight in the low-pressure chamber was beneficial, but more than one did not seem to add anything to the person's knowledge.

ADDITIONAL TRAINING ACTIVITIES

1. *Training of Medical Personnel*

It was planned from the beginning that oxygen training would be conducted by flight surgeons and hospital corpsmen assigned to this duty. In 1941 a course of instruction in low-pressure chamber technology, leading to the designation of Low-Pressure Chamber Technician, was established for hospital corpsmen. Altitude training units began operating in 1942 and 1943, to train low-pressure chamber technicians. In December 1943 the first classes of WAVE corpsmen began training to replace male corpsmen who were needed for fleet assignments. Training of corpsmen leading to the designation Low-Pressure Chamber Technician was discontinued in the latter part of 1945. Courses of instruction for Aviation Medicine

Technicians and Low-Pressure Chamber Technicians were combined. Corpsmen who completed this training were designated as Aviation Medicine Technicians. With the expansion of the program, a shortage of medical officers was anticipated and physiologists were procured to assist in low-pressure chamber operations.

2. *Aviation Equipment Officers' School*

Early in 1943 a course of instruction for physiologists leading to the designation "oxygen officer" was inaugurated at the altitude training unit at Jacksonville, Fla. Later the course was modified to include air-sea rescue and survival and the designation "oxygen officer" was changed to "aviation equipment and survival officer." A similar school was established at Naval Air Station, Pensacola, Fla., in 1944. By the end of 1945 these schools had trained over 400 officers.

OBSERVATIONS DURING SIMULATED FLIGHTS

1. *Anoxia*

Observations of the effects of hypoxia made on 47,881 passengers at a simulated altitude of 18,000 feet showed that 1,977 required supplemental oxygen, the most frequent indication being pallor and/or perspiration. Most altitude training units followed the practice of giving oxygen routinely to anyone who had pallor or was nauseated. At some training stations the passengers were given a choice of taking oxygen. Oxygen was given because of fainting in only 0.6 percent and for all causes in 4.1 percent of 47,881 passengers.

The number of passengers given oxygen during 15 minutes at altitudes of 18,000 feet varied among altitude training units. This variation was not due to differences in tolerance of passengers but to variation in reasons for giving oxygen. The altitude training unit at Jacksonville, Fla., gave oxygen to 33 of 10,533 for "fainting," while at Corpus Christi, Tex., 34 out of 7,432 were given oxygen for fainting: an incidence over three times greater than at Jacksonville. Reasons for this variation become apparent when a comparison is made of the number of passengers given oxygen while conscious. At Corpus Christi, only 12 out of 7,432 passengers were given oxygen while conscious, whereas at Jacksonville, 301 out of 10,533 conscious passengers received oxygen. The majority of these requested oxygen or were given oxygen for reasons other than pallor or nausea, such as dizziness, drowsiness, and cyanosis. The average time elapsing before oxygen was given at Corpus Christi was one-half to 1 minute longer than at Jacksonville. Similar variations existed between the other altitude training units but not always to the same degree. These two altitude training units were chosen to represent the two extremes in managing hypoxic passengers.

At Corpus Christi, Tex., during 1943, oxygen was given routinely to passengers who fainted. When pallor or nausea occurred they were not given oxygen. If a passenger asked for oxygen he was given a chance of sticking it out or taking oxygen. Before the run, passengers were not instructed to ask for oxygen. If a passenger insisted on getting oxygen after being given a choice of sticking it out, he was given oxygen even though he appeared normal. Out of 14,076 passengers 232 were given oxygen while at 18,000 feet; 82 were conscious and 150 were unconscious. It will be observed that almost all passengers who required oxygen did so during the first 10 minutes at 18,000 feet. These findings are in general agreement with the experience of others.

Of the 232 passengers who were given oxygen at 18,000 feet during their first low-pressure chamber flight, 128 returned days to weeks later for a second low-pressure chamber flight. Of these, 22 (17 percent) again required oxygen. In 1942 the altitude training unit at Jacksonville, Fla., gave oxygen to 47 out of 1,286 passengers. Forty-one out of forty-seven returned for a second low-pressure chamber flight and 6 required oxygen. This suggests that 18 percent of those who need oxygen during the first flight to 18,000 feet will require it on a second flight. The great decrease in apprehension that attends the second flight explains why such a small percentage require oxygen during their second flight.

There is a definite decrease in the number of passengers requiring oxygen during "chill" flights as compared to normal temperature. One hundred and thirty-four (1.3 percent) out of 10,311 persons were given oxygen during "chill" flights and 1,977 (4.1 percent) of 47,881 were given oxygen during normal temperature flights. The chamber temperature during "chill" flights while at 18,000 feet was 0° F. plus or minus 10° F. In 1944 the altitude training unit at Miami, Fla., compared response to hypoxia at 18,000 feet during "chill" and "heated" low-pressure chamber flights. They found that as the temperature increased there was a parallel increase in the number of persons requiring oxygen, and that at temperatures from 86° to 97° F. the heavier the clothing worn the higher the incidence of the need for oxygen.

The number of persons requiring oxygen during 15 minutes at 19,000 and 20,000 feet rises slowly from that observed at 18,000 feet; from 20,000 to 25,000 feet the percentage rises rapidly to 93 percent at 25,000 feet. At 28,000 feet the average period of consciousness was 3 minutes and 25 seconds; at 30,000 feet, 2 minutes and 30 seconds; and at 35,000 feet, 40 to 70 seconds. At 25,000 feet and above the hypoxic person remains upright, there is a rise in pulse rate and blood pressure, cyanosis occurs, muscular twitchings appear, and the extremities become rigid. Fixation of ideas is often manifested by writing one word over and over. Upon return of consciousness after the administration of oxygen, the first conscious effort is often to continue writing. Memory is lost for the last commands which the subject had tried to obey.

2. *Decompression Illness (Air embolism)*

After August 1943 low-pressure chamber training flights above altitudes of 30,000 feet were made routinely to demonstrate bends. Prior to this date, several special studies had been made (table 29).

In 1942 and 1943 the three altitude training units reported the incidence of symptoms from exposure to altitudes of 35,000 and 40,000 feet. The chamber flight included a stop of from 5 to 25 minutes at 18,000 feet, and 100 percent oxygen was started. Forty minutes were spent at 35,000 feet, followed by 10 minutes at 40,000 feet. The chamber temperature was not reduced. At Pensacola an exercise test was given for 30 seconds every 10 minutes. Joint pain was found more frequently in the right extremities, with a higher incidence in the upper extremities than the lower in Pensacola and Miami. They found no predilection for pain in previously injured joints. The group studied at Jacksonville showed a higher incidence in older age groups. The correlation of symptoms with age was not reported by Miami. Severe symptoms usually occurred after the first 30 minutes at 35,000 feet.

TABLE 29.—*Incidence of decompression illness in low-pressure chamber training flights*

	Number of subjects	Persistent joint pain		Disabling joint pain		Skin sensations		Abdominal discomfort	
		Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Pensacola	1,000	197	19.7	72	7.2	550	55.0	346	34.6
Miami	1,010	182	18.0	78	7.7	-----	-----	-----	-----
Jacksonville	927	77	8.3	16	1.7	37	4.0	-----	-----

A reliability study of high altitude classification was made at Pensacola. The chamber flight included a stay of 10 minutes at 18,000 feet, 40 minutes at 35,000 feet, and 10 minutes at 40,000 feet. This low-pressure chamber flight was given to 105 aviation cadets on 4 consecutive days. Subsequently, 99 aviation cadets, ages 19 to 27, were observed for 1 hour in low-pressure chamber flight as previously described, and the following day were observed in a 4-hour flight at 35,000 feet with no stop at 18,000 feet. Pure oxygen was used from sea level. A man was considered to have failed a flight if he had incapacitating symptoms of air embolism. Seventy of the 105 passed all tests. Thirty-one failed 1 or more tests and 4 failed all 4 tests. Of the 35 who failed 1 or more tests, 34 failed in 1 of the first 3. The fourth test picked up 1 failure not detected in the preceding flights. Fourteen failed the first flight; 10 passed the first and failed the second; 10 passed flights 1 and 2 and failed 3; one passed flights 1, 2, and 3 and failed 4. From this evidence, it appeared that three 1-hour flights will select as efficiently as four 1-hour flights.

The 1-hour test followed by a 4-hour test showed that 13 out of 99 failed the 1-hour test. In the first hour of the 4-hour test, 3 of the men who had passed the 1-hour test failed; in the second hour 3 more failed; in the third hour 4 more; and in the fourth, 1 failed. From the studies of various combinations it appears that three 1-hour tests on successive days is the most efficient method. Approximately 30 percent would be expected to fail this test. In this study the incidence of failures was higher in the older age groups.

The incidence of aero-otitis on descents from 30,000 to 8,000 feet, recorded for each 1,000 foot level during descent, for a 12-month period at 3 altitude training units, indicates that ear block seldom occurs during descent from 30,000 to 20,000 feet, but occurs most frequently during descent from 20,000 to 8,000 feet. The highest incidence occurs when at about 14,000 feet. The variation in incidence noted by these three altitude training units was not more than 3 percent. A difference of only 1 percent between Jacksonville and Corpus Christi is interesting, because over 90 percent of the flight chamber passengers at Jacksonville were enlisted aviation personnel while at Corpus Christi about 90 percent were aviation cadets or officers. A routine test descent at the beginning of low-pressure chamber flights has been practiced to eliminate those who are unable to equalize pressure in their middle ear cavities. Studies by the altitude training units at Jacksonville and Miami and others have shown that this procedure does not alter the incidence of aero-otitis. Routine test descents made at Corpus Christi and Pensacola showed an incidence of 14 percent and 11 percent respectively, whereas at Jacksonville, where no routine test descents were made, the incidence was 13 percent.

3. *Aero-otitis media and aerosinusitis*

Ear or sinus discomfort usually occurs during the period of increasing pressure of simulated descent, with the exception of an occasional passenger who has symptoms during simulated ascent. The altitude training units made normal temperature and refrigerated indoctrination flights to 30,000 feet. The rate of descent from 30,000 to 20,000 feet ranged from 3,000 ft./min. to 10,000 ft./min; from 20,000 feet to sea level descent ranged from 2,000 ft./min. to 5,000 ft./min. For the 15-month period covered, they noted the incidence of aero-otitis and aerosinusitis for refrigerated and normal temperature flights to vary less than 0.5 percent and suggested that a temperature variation of from 78° to 0° F. does not increase or decrease the incidence of ear or sinus blocks. Seasonal variations occur; the lowest incidence during the summer months and the highest in late winter and early spring. The right and left ears were almost equally involved. This was true also of the frontal sinuses. The other sinuses were seldom involved.

The altitude training unit at Miami conducted both refrigerated and normal temperatures indoctrination low-pressure chamber flights through March 1945. Routine test descent was made but descent from 30,000 feet to sea level did not include a stop at any particular altitude. From April through September 1945, low-pressure chamber flights did not include a test descent but did include a 10-minute stop at 19,000 feet, during descent from 30,000 feet. A low incidence of aero-otitis was noted after the routine stop at 19,000 feet; the incidence increases at 14,000 feet. This observation suggests that if routine stops were made at 20,000, 15,000, and 10,000 feet, it might possibly result in a considerable decrease in the aero-otitis that occurs during low-pressure chamber operations.

C. Night Vision Training

Norman Lee Barr, Commander (MC) USN

Before World War II little need or opportunity to use night vision in military flight operations arose, and most flight surgeons and physiologists were not as well informed about scotopic visual physiology as they were about the physiology of day vision. Just prior to the war, however, the increasing tempo of night flight operations stimulated interest and precipitated investigations. Laboratory studies showed that some persons are 15 times better fitted for seeing at night than those with poor night vision, and others are from 5 to 10 times better fitted than the person with average night vision. This suggested the possibility of selecting persons for flight training who are naturally endowed for exacting night visual observations.

Instruments for testing retinal sensitivity were found unsatisfactory for Navy use because of complicated design or low inherent validity and the extensive laboratory investigation required for testing. A need was visualized for a scotometer that was simple in design, simple and rapid in operation, and of sufficient test validity to weed out those with night blindness. To fill this need the Navy radium plaque was developed. This instrument was adopted for Navy use, primarily for its suitability for testing large numbers of personnel rather than for the preciseness of its measurement. Correlation between passing the Navy radium plaque test and the ability to see at night was too low to warrant the use of the test as a selective procedure. Therefore, the only instructions issued relative to those who failed the test were that they should be designated as not qualified to stand night lookout watches.

It was immediately apparent that, from a practical point of view, the ability of naval aviators and aircrewmen to make optimum use of their eyes at night could be attained most quickly through training. Also, the hope was held that the training process might serve additionally to discover personnel who had the least retinal sensitivity. On 27 March 1942, the Chief of the Bureau of Medicine and Surgery appointed a Night Vision Board to study night vision and submit reports as developments warranted. This board drew up the outline for an article summarizing the current knowledge on use of the eyes at night, which was published in the United States Naval Institute Proceedings, June 1942. Reprints were distributed to operating and training units for use in the night vision training program.

In 1942 other aids to the use of the eyes at night were developed, including specifications for the Navy's dark adaptation goggles, which were later supplied to night lookouts as well as to all night operating aviation units. These goggles demonstrated superiority of red lighting over fluorescent lighting. Subsequently, cockpit and instrument panel lighting was redesigned to make use of red light and so interfere as little as possible with rod vision. Red lights were installed in pilot and aircrew waiting rooms as an aid to dark adaptation, and red battle lights were installed on ships for the dual purpose of aiding dark adaptation and restricting the range to which the lights would be visible to the enemy.

In the fall of 1943 the increasing use of night fighters and the development of night fighter squadrons added to the already growing concern regarding night vision. A careful survey of the night training methods in use by the Allied military services established the fact that the most effective and usable night vision training methods were those developed under the direction of Wing Commander K. A. Evelyn, RCAF, and then being used in the training of RCAF pilots and aircrewmen.

Six complete two-dimensional Evelyn night vision trainers and the illuminating lights for 6 three-dimensional trainers were obtained from the Royal Canadian Air Force. The first U. S. Navy night vision training unit was established at the Naval Auxiliary Air Field, Charleston, S.C., as a test of the advisability and practicability of using the Evelyn method in the naval aviation training program. The first demonstrations to U.S. Navy medical and aviation personnel were made by Wing Commander Evelyn at Charlestown, R.I., in the spring of 1944.

This training was enthusiastically received and its usefulness was immediately apparent. It involved the use of a number of training exercises which were conducted in a completely blacked-out room under controlled illumination accurately adjusted to correspond with night illumination outdoors. The basic training device consisted of a projector by means of which animated two-dimensional shadowgraphs of typical outdoor scenes were projected on a screen with the intensity of illumination corresponding to starlight. The silhouettes provided material for a practical demonstration of the various phenomena of dark adaptation and night vision as discussed by the instructor.

The basic instruction was followed by further two-dimensional instruction on silhouettes of various characters and of airplanes, projected by a slide projector. This provided excellent instruction in aircraft and ship identification under night conditions. Three-dimensional scale models of typical ground and water objectives were used in the advanced instruction. These were studied under simulated night conditions, and dramatic illustrations of the effect of the direction of illumination from the moon and flares were made.

The use of these devices involved joint lectures and demonstrations in which students discovered for themselves the fundamental principles of night vision and received an explanation of the phenomena. The combined demonstration and exposition served to fix the basic principles of night vision so that they were not soon forgotten, and emphasized the need for continuing practice in developing proper night vision technique.

This program was recommended to the Director of Aviation Training, and authorization for it was secured. It was immediately undertaken by the Bureau of Medicine and Surgery, which was given the basic responsibility for its direction. The syllabus designed to provide progressive training, beginning at the primary level and continuing through intermediate levels, included two periods of primary training in the primary training command, three periods of intermediate training at the intermediate training commands, three periods of advanced training in the operational training command, and two additional units of advanced training in fleet training commands for personnel assigned to night operating units. In addition, a syllabus consisting of three periods of two- and three-dimensional instructions was provided for aircrewmen.

Copies of the Evelyn training devices were procured and supplied by the Special Devices Division of the Bureau of Aeronautics, and units were established at primary, intermediate, and advanced fleet and Marine Corps training activities. The RCAF Night Vision Manual was modified and adopted as the Naval Aviation Night Vision Instructors' Manual. This was issued to all night vision training instructors. A motion picture, "Night Vision for Airmen," was produced and used at all levels of training as well as in the fleet, and a popularized pamphlet, "Night Vision for Airmen," was printed and distributed to all naval aviation personnel.

The need for night vision training for submarine lookouts had been recognized, and instruction was being given at the U. S. Naval Submarine Base, New London, Conn., on a lookout stage that presented ship models silhouetted against a skyline under low illumination. When the Evelyn method of training became available, its fundamental portions were added to the submarine medicine training program.

A school for the training of instructors for the night vision training program was established at the Naval Air Training Base, Pensacola, Fla., 7 August 1944. About 60 medical officers and physiologists were trained at this school during the war. In all, some 80,000 men-units of night vision training were given during the period between the beginning of the program and the surrender of Japan.

As had been expected, the Evelyn Night Vision Training method served to spot personnel with poor night vision. The retinal sensitivity of personnel failing to advance in ability to see and accurately interpret the visual clues projected at levels of illumination comparable to starlight was studied by means of the radium plaque adaptometer and other laboratory techniques. Assignments to other than night operating units and rejections for night fighter training were recommended only on the basis of an accurate appraisal of the person's inherent visual acuity under low levels of illumination. This system was found to be well suited for processing the large numbers of pilots and aircrew trainees involved.

Postwar reorganization has permitted the placement of the entire night vision training program in the aviation training command so that all student aviators and aircrewmen receive training in the use of the eyes at night as a part of their total aviation training, along with oxygen indoctrination and training in the physiology relating to flying. In addition, the importance of night vision training for deck watch standers has been recognized.

To Wing Commander K. A. Evelyn, who was

the first to conceive this method and who developed and built the prototypes of all the devices used in this training, goes full credit for the development of an important training adjunct that holds the promise of a long life of usefulness.

D. Aviation Psychology

John G. Jenkins, *Captain (HS) USNR (Deceased)*

DEVELOPMENTS FROM 1939 TO 1941

Feeling that an adequate screening procedure could not be based solely on a determination of physical fitness, medical officers of World War I added a neuropsychiatric interview designed to determine whether the applicant was "aeronautically adapted." Navy Flight Surgeons were fairly well satisfied with the physical portions of the Flight Examination in the 1930's, although none of the standards had been validated, but the neuropsychiatric interview soon became a cause of dissatisfaction. Frequently it was reduced to routine questions that elicited perfunctory replies which were entered as "normal," "denies," or "not disqualifying."[7] Eventually a realization of the subjectivity and unreliability of the unstructured, unstandardized interviews provided the motivation to seek aid from psychologists. The first step toward developing an objective and reliable means of predicting performance in flight training was taken at Pensacola in 1935 when two Navy Flight Surgeons applied Strong's Interest Inventory to 150 aviation cadets. They lacked the technical assistance essential to the development of the validity of the test, but the first step in the use of pencil and paper predictors had been taken.

In 1939 a Flight Surgeon with Pan American Airways became interested in Strong's Interest Inventory and enlisted Strong's aid in developing a scoring key for aircraft pilots. In the fall of the same year the Civil Aeronautics Authority invoked the aid of the National Research Council in developing means of selecting candidates for a nationwide light plane training program. Although the training program was concerned entirely with civil aviation, it seemed appropriate to have both the Army and Navy represented on the Committee, and two flight surgeons were designated as Navy representatives.

The basic plan was to allot funds to various universities to support locally conceived research projects that had been approved by the executive subcommittee. The "Harvard Project" was established at the Naval Air Station, Pensacola, with funds allocated to Harvard University. This project used a "shotgun approach" to pilot selection with much more time devoted to physiological than to psychological predictors. Approximately 1,000 cadets were subjected to various combinations of physiological and psychological measurements, of whom 180 failed flight training. Criteria for the validation of the tests were established by assembling pass-fail lists with extensions to include 130 cadets who had appeared before the Advisory Board but had not failed. Four of the psychological tests (intelligence, two-hand coordination, eye-hand coordination, and the Mashburn) were found to satisfy conventional levels of confidence in differentiating failers from passers. Only one of these, however, the intelligence test, was represented in the final battery of naval selection tests. On 15 February 1941 the first official letter regarding the validational program, as sent to the Naval Aviation Cadet Selection Board, stated:

> The items finally selected for validation and use in the selection of student aviators consists of an abridged self-administering intelligence test (the Wonderlic), a compilation of various biological data and personality analysis items (the Biographical Inventory), and a vocational interest test (Strong).

This letter also directed that applicants for flight training be required to fill out these three items following satisfactory completion of the flight physical examination.

The Wonderlic Personnel Test was used as a general intelligence test. The Biographical Inventory, which was developed by E. L. Kelly at Purdue University on a NRC-CAA grant, had been validated on a group of good and poor private pilots. The form in use was the "Green Form" containing three sections including a forced-choice section, which was later dropped. The Strong's Interest Inventory was introduced in the hope that the Stanford project would provide a profile for aircraft pilots. No such profile was ever furnished, and after 4 months the Bennett Mechanical Comprehension Test was substituted for the Interest Inventory.

By 1940 considerable interest was shown by the Naval Flight Surgeons in the use of various psychological tests, and a letter issued 5 April 1940 requested all naval aviators to fill out the Strong's Interest Inventory and pointed out that this test might prove valuable in mass recruiting of applicants for training. In another letter dated 30 August 1940 a suggestion was made to introduce the Wonderlic Personnel Test, which is a modification of the Otis Intelligence Test and a test of mechanical aptitude. The letter ends with the suggestion that we should attempt to test the following aspects of total personality as though they were separate entities:

(a) Intelligence; (b) Vocational interest; (c) Mechanical aptitudes; (d) Stability of temperament; and (e) Physical conditions (as measured by the standard flight physical examination and appropriate laboratory work).

This letter is of special interest in that these suggestions were so closely followed in establishing tests finally adopted. The final battery included an intelligence test, Bennett's Mechanical Comprehension Test, the Biographical Inventory (directly concerned with temperament), and the flight physical examination.

On 1 November 1940 a Naval Reserve Flight Surgeon was called to active duty in the Bureau of Aeronautics, Medical Research Section, and in addition to regular duties concerned with Aviation Medicine, was assigned the direction of work in the use of psychological tests for prospective pilots.

Several changes took place in the program during the period from June 1941 to October 1942, while the validational program was under the cognizance of the Medical Research Section of the Bureau of Aeronautics. In March 1941, a letter from the Medical Research Section to the Selection Boards pointed out the necessity of giving the tests to applicants before acceptance for training, and directed their administration before the use of the cycloplegic visual refraction. The pressure of procurement and the time required to administer the three tests permitted the use of only the Wonderlic Personnel Test at Selection Boards. The Interest Inventory and Mechanical Comprehension Tests were moved to the Elimination Training phase at Reserve Aviation bases. In June 1941 all Naval Reserve Aviation Bases were directed to substitute the Mechanical Comprehension test for the Strong's Interest Inventory in future examinations. The expansion of the test-validation program to include both Selection Boards and Reserve bases brought increased pressure for specialized personnel to handle the testing. Consequently, for the first time commissioned psychologists entered the program. The Bureau of Navigation (later designated the Bureau of Naval Personnel) on 20 December 1939 authorized the limited procurement of psychologists under the classification D–V(S), but no provision was made for psychologists to serve in the aeronautical organization. By July 1941, however, 20 psychologists had been commissioned, and by January 1942 were assigned to Selection Boards. This procurement also permitted the first use of psychologists as regular members of the Medical Research Section, BuAer. On 13 June 1941, a psychologist was placed in charge of the administration of tests and preliminary statistical surveys. In November 1941 another psychologist was assigned to the Medical Research Section to assist with the work on tests. During the fall of 1941 the practice of having all newly commissioned H(S) psychologists report to the Bureau for a period of indoctrination of 2 weeks or more was established.

During the summer and fall of 1941 keys were developed for the Biographical Inventory based on an item analysis of 200 "failers" and 200 "highest passers" as rated from a flight-jacket interpretation. The keys were validated on 100 failers and 100 passers. In November 1941 all Naval Reserve Aviation Bases and Naval Aviation Cadet Selection Boards were instructed to continue to administer the Personnel Test at Selection Boards, with scores to be reported to BuAer, and to administer the Biographical Inventory and the Mechanical Comprehension Test to all student aviators within 2 days after reporting at Reserve Training Bases. The following prediction table for the Biographical Inventory scores was given:

BI SCORE

1. Chances of success are 10 times that of "average" student or greater.
2. Chances of success are 2 to 9 times greater than for "average" student.
3. Chances for success are "average."
4. Chances for failure are 2 to 9 times greater than for "average" student.
5. Chances for failure are 10 times that for "average" student or greater.

No tables of probability were offered on the Wonderlic Personnel Test, but it was noted that scores in the range of 25–35 were desirable and that scores of 20 or below on the first test and 24 or better on the retest indicated that considerable difficulty in instruction might be encountered.

Developments from 1942 to 1946

On 29 October 1942 the Surgeon General directed the establishment of the Aviation Psychology Branch of the Aviation Medicine Division. This directive transferred to the Bureau of Medicine and Surgery the functions that had been performed in the Medical Research Section of BuAer. The directive stated:

> By agreement of the Bureaus concerned, the development and administration of the psychological tests employed in the selection or classification of Naval Aviation personnel, and the development of related studies employing the services of H–V(S) psychologists will be under the cognizance of the Bureau of Medicine and Surgery.

H–V(S) psychologists were commissioned originally to administer, score, and interpret tests, but it soon became apparent that use could be made of their training in statistics, experimental design, and training techniques. Therefore, as the field staff of psychologists increased they were employed in the Aviation Psychology Branch for The Central Research Group, The Selection and Procurement Specialists, The Field Service Specialists, and The Special Services Officers.

The first wartime directive regarding the use of basic tests in selection and training proved to be unsatisfactory, and a revised directive was issued 11 February 1942. The revised directions for the use of the Personnel Test called for the rejection of all applicants who scored below 25 on the first test and 23 on the retest. These standards remained in force until the introduction of the Aviation Classification Test in the fall of 1942. The provisions for labeling men who were dropped from training as flight failures on the basis of records and test scores proved unsatisfactory, and were revised in May 1942 to provide four options in labeling men dropped from training:

1. Failed ground school.
2. Failed flight training.
3. Found psychologically unsuited for advanced training.
4. Found unsuited for commission.

Up to February 1942, only men with 2 years of college or its equivalent had been processed at Selection Boards, but at this time men capable of completing 2 years' college were admitted for training. A "Coarse Screen" was established at the recruiting centers by designating a cutting score on the General Classification Test sufficiently high to eliminate those most likely to fail on the cadet classification battery. The cutting score, rejecting all high school applicants below a score of 80, proved to be too high, and it was lowered to 70. Those qualifying under these conditions were then sent to Selection Boards, where they were required to meet the existing standards on the Personnel Test and the Mechanical Comprehension Test. In October 1942 the Aviation Classification Test was substituted for the Personnel Test and the cutting score on the Mechanical Comprehension Test was raised from D to C.

The most important contribution of the year was the introduction of the Flight Aptitude Rating which permitted the establishment of a single index to represent a combination of test scores. The basic idea of a Flight Aptitude Rating (FAR) had been under discussion before BuAer announced that it desired to "skim the cream" off a large backlog of accepted candidates and expedite their progress through training. BuAer proposed to send the most promising men directly from Civilian Pilot Training to primary training, while the less promising men were to be routed over a longer course in the Flight Preparatory Schools. On 21 October 1942, a twofold table was issued showing for a population of 3,055 the percentage of cases falling under each possible score-combination on the Aviation Classification and the Mechanical Comprehension Test. Finally, on 3 November 1942, the following recommendations were made.

1. To forward directly to Civilian Pilot Training those men in the backlog having A, B, or high C on the Mechanical Comprehension Test.
2. To administer the Biographical Inventory to the remainder of the backlog on arrival at Flight Preparatory Schools.
3. To compute the Flight Aptitude Rating with intent to drop all FAR IV and V men who fail to make average records in training.
4. To raise the cutting score on the Mechanical Comprehension Test to eliminate D's as well as E's at the Selection Boards.
5. To give the Biographical Inventory in the future at the Selection Boards, with all scoring to be done in Washington and the scores to be reported for use as in (3) above.

An accompanying report gave the percentages that would be expected to fall under each FAR score and indicated what this would mean to the Navy in terms of men required to produce 1,000 designated pilots. A basic table showed that 1,000 graduates with Navy wings could be obtained by training 1,220 candidates with FAR scores in Group I, but that 2,273 FAR Group V candidates would be required to produce the same number. It was also shown that by training 1,000 FAR Group I men, 65,000 training hours would be saved over the cost of training 1,000 FAR Group V men.

The FAR remained in use throughout the war, although later adjustments were made as available data demanded. The experience of the first year of the war showed the undesirability of a hard-and-fast application of test scores and indicated that "intelligent flexibility" in their use could be expected to produce better results as well as a higher degree of acceptance. Ultimately a nine-fold table of score combinations was issued, but this occurred late in the war and affected relatively few pilots.

Early in 1942 the psychologists expressed dissatisfaction with the Wonderlic Personnel Test. Its abbreviated form did not permit high reliability and the dichotomizing for statistical analysis demanded maximum spread and reliability in the region of the cutting score. Accordingly the Psychology Branch began work on the development of an intelligence test which would meet these requirements. The Aviation Classification Test was the result and was soon substituted for the Personnel Test in the selection battery. At the same time, surveys were made of the usefulness of the Personnel Test. In general, the findings paralleled those of the AAF, in that the general intelligence test was found to be a good predictor of Ground School performance, but only a small contributor to the prediction of flight training success.

The Central Research Groups

There were four central research groups:

1. The Aviation Psychology Branch at the Naval Air Station in Pensacola, Fla.
2. The Aviation Gunnery Group.
3. The Corpus Christi Group at Corpus Christi, Tex.
4. The Washington Group in the Bureau of Medicine and Surgery, Washington, D. C.

The Pensacola Group

Psychologists came into the Navy when a project of the National Research Council on the selection of Naval Aviators was established at the Naval Air Station, Pensacola, Fla. This project, originating under Civil Aeronautics at the request of the Navy, was staffed by men from psychology and related sciences. It investigated the relationship of more than 30 different physiological and psychological measures of success in flight training. One of the three principal areas in which this group functioned was in the selection and classification of aviation cadets. The group continued the studies of the National Research Council until the validation of tests was taken over by the Washington Branch. In an attempt to obtain adequate criteria for the validation of the tests, the Pensacola group revised flight rating scales, made intensive studies of flight jackets, and correlated grades with test scores.

An early recommendation from the Pensacola group led to the first work on the problem of classification for advanced training. Among those studied were the instructor selection program, studies of attrition figures and reasons for attrition, the adequacy of the low-pressure chamber tests for placement purposes, and the selection of key instructors.

The Pensacola group was also interested in such visual problems as the value of depth preception tests and color vision in the selection of aviators, and did much of the early work on night vision. After the establishment of the program on night vision instruction for all aviators, Pensacola became the school in which instructors were trained and syllabi developed.

Another project studied the effect of autokinesis. Night fliers following the single light of a plane ahead sometimes experienced disorientation which resulted in accidents. This disorientation appears to be related to the autokinetic phenomenon. H(S) officers helped revise lighting systems to lessen the danger from autokinesis and carried out extensive research on the phenomenon itself.

The earliest work on speech and communication done at Pensacola included methods of instruction and trained many of the new speech officers, but it also carried on related research. Although laboratory investigations had been made on the problem of an intelligibility test, the previous findings had to be carefully checked because many of them did not hold. Another project compared the relative intelligibility of alternative words commonly used in communication procedures. H(S) officers went into the low-pressure chambers to study the effects of high altitude and accompanying cold upon speech intelligibility. The communication equipment was also critically reviewed and tested. Investigators sought by research to improve the design of the mouthpiece, the diameter of the tube, and the construction of the helmet.

Aviation Gunnery Group

The first psychological research on gunnery was carried out by means of a civilian contract under the cognizance of the Aviation Psychology Branch. A number of aviation psychologists were included in the score of specialists attached to the Naval Aviation Free Gunnery Standardization Committee which sought, among other things, to establish uniform curriculums for gunnery schools. In developing and maintaining the gunnery aptitude test battery, experience showed that it was possible to locate or devise appropriate tests which would correlate fairly well with course grades, the best available criterion. Hence, the criterion itself presented the chief problem.

A major concern of the Standardization Committee was in the field of training. Problems of selecting and training instructors arose, as well as the task of writing manuals for these instructors. Also, a more effective system of training gunners was designed and, as part of the training aids, the group produced training films and booklets which explained such topics as sighting techniques and observation from the air.

Various gunnery training devices were experimentally evaluated by the group. The instructional value of camera guns was assessed and procedures for using them in training were developed. The relative clarity of several graphic methods for illustrating the cones of fire for aircraft was the problem of showing on paper those directions from which an airplane's armament protected it from attack. The work of this group not only covered problems of design and procedures from the viewpoint of the man firing the guns, but also tested equipment for its efficiency and practicality.

The Corpus Christi Group

The Corpus Christi group, founded considerably later than the Pensacola group, expanded slowly. Basic research projects usually were directed to the older organization. Consequently, the Corpus Christi group concentrated on the many local problems at its huge training base. Many of the research projects here paralleled those reported for Pensacola. Flight jackets were analyzed to determine the predictive value of specific maneuver grades, and a check was made on the validity of the basic cadet selection tests for predicting outcome of the latter phases of training. They worked on classification and training problems. For example they set up a provisional method for selecting flight instructors before the nationwide program was completed, and low-pressure chamber procedures were analyzed to check on the standardization of training from month to month and station to station. They also studied basic emotional and social problems. One product was a psychological discussion of fear, with emphasis on how to counteract it. They made a survey of attitudes, which led to a recommendation for an orientation program to keep cadets well informed on world events. Counseling, communications training, and lectures on instruction were also included in the activities of this group.

The Washington Group

The central aviation psychology group in Washington started with a single billet in the Medical Research Section of the Bureau of Aeronautics. The organization grew from one Ensign serving under a Flight Surgeon to a staff of a dozen commissioned psychologists assigned to a separate Aviation Psychology Branch in the Division of Aviation Medicine, Bureau of Medicine and Surgery. This expansion was partly a consequence of the development of field billets for more than 70 officers. A principal function of the Washington Branch was to help these men and through them to help Naval Aviation.

As the administrative center of the aviation psychology program, the Washington Branch was responsible for recommendations on the procurement and placement of H(S) officers for aviation work. It had cognizance over the administration and interpretation of the aviation cadet selection tests and advised on the minimum standards set for them. In addition, it maintained informal liaison with all aviation psychologists and initiated official actions as required by the needs of the field.

The original and basic function of the Washington group was the analysis of results from the selection tests. In the light of the early findings reported by the NRC Pensacola research project, a number of tests were given an experimental trial on all aviation cadets. After sufficiently large groups had received their wings or had failed, their test scores were correlated with the outcome of their training. The tests were not used for actual selection until they had been cross-validated on several populations whose test scores had been locked up to prevent contamination of the criterion. The Aviation Psychology Branch maintained continuing checks upon the efficacy of these instruments, especially when changes in procurement policy altered the nature of the applying population.

Although the need for validating the selection tests against combat criteria was repeatedly stated in official memoranda, wartime expediency prevented the establishment of this ultimate check during the early years of the war. Arrangements were eventually made, however, for several psychologists to go to the fleet. They faced the familiar problem of developing a satisfactory criterion. Number of planes shot down, decorations, and other alleged measures of proficiency were examined and found inadequate. After considerable preliminary research, a nominating technique was established which yielded dependable results. Aviators with combat experience were asked to name two pilots with whom they would most like to fly in combat and two with whom they would least want to fly. They were also asked to indicate the reasons for their choices on a checklist prepared from the free responses of previous respondents.

Two conditions were responsible for the success of the technique. Wherever possible, the H(S) officers lived with the squadron and got to know its members on an informal basis, so that the actual request for their help, although officially sanctioned, did not come from a total stranger or through impersonal channels. The investigators were also supported by an official guarantee that the pilot's opinions would be treated confidentially and would be used for research alone. Inspection of the preliminary free response materials and analyses of the nominations gathered in the major project left no doubt that the pilots had cooperated in a most satisfactory manner.

There were other developments of this combat criterion project carried on by the Washington group. Representatives tried out the nominating technique at a preflight school to determine whether those characteristics mentioned by combat aviators which did not refer to pilot skill could be indentified early in training. The results suggested that attributes like leadership and teamwork could be judged by fellow cadets, although there was no guarantee that these judgments would agree with those made when these men reached operational flying. In another study, the extreme groups identified by the nominations of combat pilots were compared in terms of their athletic records, as a corollary to the basic research on the validity of test scores, age, and other possible predictors of combat proficiency. These subsidiary investigations, carried out at the request of another Bureau, illustrate the service function of the Aviation Psychology Branch and indicate that administrative boundaries did not restrict its areas of usefulness.

In addition to the validation of field work and the development and standardization of new tests, the Central group had administrative functions. It exchanged information with the Army Air Forces testing program so that each psychological service could benefit from the work of the other. The section checked the accuracy of scoring done in the field and maintained card files for record and research purposes. Statistical breakdowns of attrition data gave the frequency of various reasons for failure as well as the relative ability of the tests to predict each type of failure. The different parts of the selection battery were correlated with age, education, previous flight training, and other relevant factors. It was the responsibility of the Aviation Psychology Branch to make such administrative recommendations as the results of these analyses warranted.

The Selection and Procurement of Specialists

By the summer of 1941 the demand for the procurement of Naval Pilot material had grown to such an extent that the medical examiners sent appeals to the Navy Department for technical help. On 15 July 1941 the Chief of the Bureau of Aerōnautics issued a directive stating that a new class of commissioned specialists was to be procured. In general, the duties of these specialists were to administer research projects under the jurisdiction of the Bureau.

In the initial stage of the program the psychologists were assigned the duty of administering, scoring, and reporting test scores, but their duties steadily increased to include a variety of services. The Selection Board psychologist played a part in the establishment of the procedures of the Selection Board. He took part in the procurement program. He prepared procurement addresses, radio scripts, and publicity materials. In some cases, the psychologist took on the additional task of the terminal interview of those rejected.

These officers also played a role in the instructor-selection projects. After the institution of a selection program based on this research, they carried out studies to check its effectiveness. Attrition figures were compiled and reasons why cadets were dropped or wanted to be dropped from training were studied.

The procedures at the various Selection Boards varied somewhat from time to time and place to place, but essentially were as follows: The applicant for flight training was checked for age, height, weight, and schooling. He was then given the Flight Physical Examination, a medical screening involving rigorous standards of physical fitness. Having passed this he was given the psychological tests. If his score met the standard, he was interviewed by a line officer who appraised his suitability for aviation training.

As the pressure of procurement went up in the early part of 1942, the Bureau began to receive requests from the Selection Boards for the assignment of a second psychologist.

The Field Service Specialist

The Field Service Specialists were psychologists who were assigned to preflight schools, primary air stations, and naval flight preparatory and gunnery schools. Their chief duty was to administer tests and to assist in the development of the training program, but these officers proved to be useful in a variety of ways. One H(S) officer became a member of the Aviation Safety Board, another made contributions to the field of training for aircraft gunners. Many of them became student counselors or advisory officers to the cadets. More important, perhaps, were the contributions of these officers to experimental design and to statistical analysis of Naval Aviation data in the solution of flight training problems.

The Special Services Officers

The Washington group found themselves more and more in demand for help on specific problems outside their regular responsibilities. A battery of tests designed to select flight instructors was established on the basis of research carried out by the central research group with the collaboration of the field service organization. The basic problem was the selection of valid criteria. The number of students completing training with each instructor was selected, but incomplete records and small numbers of cases made it inadequate. The composite criterion finally selected was based primarily on the rating of the instructor's performance by his students, and secondarily on the reports of inspectors who checked the work of each instructor. Using extreme groups, it was possible to derive scoring keys which stood up under cross-validation. The validated measures were not intelligence tests, but rather questionnaires regarding preference for assignments and attitudes towards instruction.

There were other problems in the fields of training. The group was asked to help select Link Trainer instructors, control tower operators, and nonpilot navigators. An evaluation of the Link Synthetic Flight Trainers was made. The experimental design was set up by the Aviation Psychology Branch in conjunction with cognizant Navy Department officers, and one H(S) officer was assigned to the field station where the project was carried out. His responsibility was to set up the experimental and control groups, assist in compiling records, and watch for extraneous influences upon data. In a project requested by the Naval Air Training Command, correlations were run between test scores and grades on specific flight maneuvers. They also were requested to set up and conduct an experiment to determine the relative value of two synthetic gunnery trainers.

The Aviation Psychology Branch was called upon to apply quantitative methods to nonpsychological problems. Thus a Bureau medical officer enlisted help in making a statistical evaluation of the effectiveness of oxygen indoctrination. They were also called upon to review the experimental design and the statistical treatment of data in a wide variety of reports reaching the Division. A member of the Washington group was also assigned to the Office of Research and Inventions of the Navy Department. His function was to review the experimental design for research proposals to be carried out under Navy contract.

E. Naval Aviation Medical Research

Compiled by Aviation Branch, Research Division, Bureau of Medicine and Surgery

Research in naval aviation medicine had been carried on for many years by personnel of the Medical Department, but these studies were not closely correlated with aviation. In November 1939 a Medical Research Section was established in the Bureau of Aeronautics. The earliest problems studied by this activity concerned selection and training of personnel, visual problems, and general problems of physiology in aviation. In December 1941 a group of psychologists and statisticians were added to the research staff to take over the supervision of the studies in selection and training of aviation personnel.

Another major development at this time was the establishment of an altitude training program using low-pressure chambers, first at the Naval Air Station, Pensacola, Fla., and then at other naval air stations. The program entailed indoctrination of aviation personnel in the hazards of high-altitude flying and protection against these hazards.

Research in aviation medicine continued under the jurisdiction of the Bureau of Aeronautics until October 1942. At this time the staff of psychologists was transferred to the Division of Aviation Medicine of the Bureau of Medicine and Surgery. Later the entire unit was incorporated into the Research Division, Bureau of Medicine and Surgery, as the Aviation Medicine Branch. The specific objective of this unit during World War II was to apply the results of research in medical problems in aviation to flight safety, flight efficiency, and to increase the caliber of flight personnel through improved selection and training.

ACTIVITIES ENGAGED IN AVIATION MEDICAL RESEARCH

The following activities conducted aviation medical research in the Navy:

1. School of Aviation Medicine, NAS, Pensacola, Fla.
2. Naval Medical Research Institute, National Naval Medical Center, Bethesda, Md.
3. Aero Medical Department, Naval Air Experimental Station, Naval Air Material Center, Philadelphia, Pa.
4. Medical Field Research Laboratory, Camp Lejeune, N. C.
5. Medical Research Department, U. S. Submarine Base, New London, Conn.
6. Naval Air Training Bases, Corpus Christi, Tex.
7. U. S. Naval Air Stations at San Diego, Calif.; Alameda, Calif.; Seattle, Wash.; Norfolk, Va.; Quonset Point, R. I.; Miami, Fla.; Vero Beach, Fla.; Jacksonville, Fla.; and Anacostia, D. C.
8. U. S. Marine Corps Air Station, Cherry Point, N. C.

In addition, research of interest to the Navy was carried out at other naval activities as well as in Army and civilian laboratories.

ACCELERATION

As early as 1932, Captain Poppen (then Lieutenant Commander) conducted studies on the effects of acceleration and on protective measures against these effects, in collaboration with the Fatigue Laboratory at Harvard. Subsequently, investigations were conducted at the naval aircraft factory in Philadelphia. Through experiments with dogs, a compression belt was devised to provide support to the abdominal area in order to prevent blood from pooling in the splanchnic vessels. In 1939 a complete air suit with provisions for compression of the splanchnic area and lower extremities was developed and flight tested, but was not found practical for service. In 1942 the Moeller-Carson gradient pressure suit and the Ferwerda pulsatile-pressure suit were flight-tested at Anacostia and Cecil Field. These proved to be effective in preventing blackout and grayout in maneuvers, but they required improvements.

In 1943 gradient pressure suits were delivered to combat squadrons for operational testing. Although pilots at first were enthusiastic about the suits, it was later found that the suits were too cumbersome and impractical for general use. In 1944 extensive tests on the gradient pressure suits were conducted in the Pacific. As a result a single-pressure suit was evolved from a modification of the old three-way gradient pressure suit. This suit was again modified by Moeller and Carson, was flight-tested at Eglin Field, Fla., and was adopted by the Army Air Forces, although the Navy still considered it too bulky for universal use.

CLOTHING

During the war it became necessary to develop a great number of items of clothing, particularly electrically heated clothing for the protection of naval aviators against cold. A very satisfactory summer flying suit, made of nylon, was developed. One feature of this suit that required investigation was the "inflammability" of nylon fabric. It was determined at the Naval Medical Research Institute that nylon was a "noninflammable" material that does not support combustion but reacts to heat only by melting.

Fundamental work on body cooling during exposure to water at various temperatures added impetus to the development of a quick-donning antiexposure suit for use by airmen in the event that ditching at sea became necessary. The suit was developed jointly by representatives of the Naval Medical Research Institute; Research Division, Bureau of Medicine and Surgery; Equipment and Materials Branch, Bureau of Aeronautics; and Military Requirements Division, Bureau of Aeronautics.

The disadvantages of attempting to don an exposure suit in the critical moments of ditching led to attempts to develop a suit appropriate for continuous wear, one permeable to water vapor but impermeable to water. Such a suit was designed at the Naval Medical Research Institute but was not issued to the service.

Other items of special protective clothing that were devised included body armor for protection against antiaircraft fragments. The Research Division, Bureau of Medicine and Surgery, designed and developed the aviator's nylon "flak suit," and the "Doron" armored life jacket.

DENTISTRY

In May 1943 the Naval Medical Research Institute reported the effect of environmental conditions in flight on dental pulp and periosteum. In their preliminary work, 115 fillings of various types were inserted into uniform cavities prepared in extracted human teeth and these teeth were placed in a pressure chamber having a simulated altitude of 60,000 feet for 20 periods for 1 hour. No evidence of displacement of the filling following these exposures was noted, but it was believed that during rapid changes in altitude oral fluids might be forced under leaky fillings and so account for the toothaches experienced by flying personnel. In June 1944 rats were exposed at simulated altitudes of from 24,000 to 26,000 feet for twenty-five 3-hour periods. That environment did not affect the rate of growth of the incisor teeth but did disturb the calcification of dentin. Later in 1944 rats were exposed to vibration of 0.05 inches amplitude at 2,600 cycles per minute for twenty-eight 8-hour periods. This neither affected the rate of growth of incisor teeth nor the calcification of dentin.

In March 1943 a study of the relationship of dental malocclusion to ear block showed that of 447 men with normal occlusion, 5.8 percent developed ear block, while in 374 men with some degree of malocclusion, 23.7 percent developed ear block. Overbite, retrusion, and protrusion were the chief types of malocclusion. Of the various methods for clearing ear block, movement of the mandible proved to be the most effective.

The Naval Air Station, Jacksonville, Fla., reported in March 1945 that mechanical pressure from expansion of air trapped under dental fillings was not the usual cause of dental pain occurring at high altitudes, and indicated that the pain in some way resulted from changes in barometric pressure associated with sudden variations in altitude.

In July 1945 an extensive study of aerodontalgia made at the Marine Corps Air Station, Quantico, Va., indicated that the pain of aerodontalgia was often so severe that the person affected was distracted from performing important tasks. They theorized that dental pain occurring during altitude changes resulted from referred pain from the maxillary sinus and could be relieved by techniques similar to those used for relieving aero-otitis media. Since there was a tendency for pain referred from the maxillary sinus to localize in carious teeth, good oral hygiene and regular dental examination for all aviation personnel was considered to be essential.

EAR, NOSE, AND THROAT

The chief ear, nose, and throat problems in aviation medicine were acute aero-otitis media, aerosinusitis, and chronic deafness. Loss of hearing in aviation personnel was prevented with the use of various ear "defenders" and "wardens," particularly the V-51R.

Techniques were evolved to reinflate the middle ear after descent from high altitude. Nose clips to aid dive-bombing pilots in equalizing middle ear pressures were suggested, but experienced pilots rejected these clips because of the necessity of applying them just before the dive and removing the oxygen mask to do this. Inexperienced pilots who had formed no prejudiced conclusions about their equipment accepted these clips more readily, however.

FOOD AND WATER

Food

The study of the problem of feeding personnel in flight resulted in the development of an emergency candy ration to be carried in the aviator's personal gear. This replaced such items as pemmican and high protein foods that were found to increase dehydration because of the resultant excretion of large quantities of water necessary for the dilution of the nitrogen metabolites.

At the University of Chicago and Columbia University altitude tolerance test studies showed the advantages of a high carbohydrate meal. Research was therefore directed chiefly toward the development of adequate in-flight feeding, providing hot food to replace chocolate bars and crackers. During the latter part of the war, some transport planes were equipped with apparatus for the preparation of complete meals.

Water

To provide an adequate supply of emergency drinking water in airplanes was always difficult because of limited storage space and stringent weight requirements. Zeolites for the desalination of sea water were introduced through the efforts of the Naval Medical Research Institute and the Permutit Company. A satisfactory desalination kit was devised and adopted for service use. To some extent the kit replaced canned water in seat packs. Final evaluation of the relative advantages and disadvantages of the desalination kit and canned water had yet to be made. Investigations were also conducted on the physiological action of the crystalloids remaining in sea water after use of the kit, of bacteria in sea water, and of standards for emergency drinking water supplies.

Most naval activities concerned with air-sea rescue problems also carried out tests with solar stills for sources of drinking water.

MOTION SICKNESS

Motion sickness was noted in approximately 13 percent of aviation cadets. In rough air the incidence was 30 percent, while otherwise it was about 6.5 percent. Scopolamine hydrobromide, in doses of 0.6 mg. given 30 to 60 minutes before a flight, was found to be a preventive of air sickness and to have no undesirable side effects. The Naval Medical Research Institute found no undesirable side effects with scopolamine–containing formulas but found them with bulbocapnine. Using a questionnaire technique, they found no evidence to indicate a correlation between general psychosomatic complaints and susceptibility to seasickness, although they considered such a questionnaire useful in screening out persons who would be severely affected by seasickness.

DECOMPRESSION ILLNESS

In 1942 workers at the Experimental Diving Unit, Navy Yard, Washington, D. C., measured gaseous exchange under conditions simulating aviation and deep-sea diving. Inhalation of radioactive krypton was used to determine whether or not the rate of saturation of the tissues in the lower forearm and hand could be employed as an index of susceptibility to decompression sickness. They found that this test could not be used to determine susceptibility to air embolism but that the technique gave a precise physiological index that might be used to estimate physical fitness. In 1943 these workers determined that preoxygenation and exercise substantially reduced the time required for decompression. They confirmed previous studies showing that susceptibility to decompression illness was influenced by alcohol, disease, increasing age, and previous attacks. They noted further that after 1 hour of oxygenation at rest at sea level 88 percent of susceptible individuals when at 35,000 feet were protected from incapacitating symptoms of decompression sickness for 4 hours.

In March 1944 the Naval Medical Research Institute reported that extravascular gas bubbles occur in adipose tissues, in the adrenal cortex, and in nerve fibers, but not in the liver, skeletal muscles, or tendons; and were more numerous in those tissues rich in fat. A significant fall was observed in the specific gravity of the entire animal after decompression, this decrease being greater in fat animals than in lean ones. It was inversely related to the total fat content, but directly related to the water content.

In January 1944 the Naval Medical Research Institute suggested a test for selection of personnel resistant to the effects of decompression. In the first procedure, in order to eliminate the most susceptible, the subject rested 1 hour and exercised 1 hour at simulated altitudes of 38,000 feet. The second procedure provided 2 hours of exercise at 38,000 feet. The most resistant men had no symptoms during this stage.

Pensacola reported in September 1945 that exercise at 26,000, 28,000, and 30,000 feet greatly increased the incidence of decompression illness and that a greater incidence of decompression illness was encountered at higher temperatures than at lower temperatures. At altitudes below 30,000 feet for 20 minutes, the incidence of decompression illness in resting subjects was very low and environmental temperature was not a factor.

ORIENTATION IN FLIGHT

In September 1944 it was found that lights arranged so that at least 3 similar lights, widely separated, were visible from any angle, reduce the incidence of autokinesis. This arrangement was found to be advantageous in giving clues to depth perception.

In February 1945 a group of workers observed that the autokinetic illusion was experienced by persons who could not distinguish real from apparent motion. The recommendation was made that aviators, and operators of other means of transportation, be taught the characteristics of the phenomenon and the practical means by which it may be reduced. In November 1945 this group noted that the oculogyral illusion changes observed following stimulation of the semicircular canals were more easily produced in dim than in bright illumination and were unaffected by the administration of relatively large doses of scopolamine hydrobromide. They considered the illusion to be of considerable importance in night flying.

In March 1946 this same group developed a new device for checking the illusory perception of movement caused by angular acceleration and by centrifugal force during flight. Observations during various flying maneuvers were made in complete darkness, with a collimated "star" installed in the rear cockpit of a training plane, and the observer's and pilot's reports were recorded during flight. They found that forces engendered by various flight maneuvers were sufficient to produce considerable illusory perceptions of movement and displacement of an objectively motionless object observed in the dark. These illusions probably contributed to disorientation and resulted in accidents in night flying.

The Naval Air Station, Anacostia, in a study on disorientation of pilots in night and instrument flying, found that 1,400 hours of flight experience was the dividing line in the indication of "spinners" and "nonspinners." They believed that this degree of experience brought about sufficient familiarity with disorientation problems so that they could be solved in flight.

ANOXIA AND OXYGEN EQUIPMENT

In procedures for the measurement of altitude tolerance, it was noted that the dotting apparatus was useful in obtaining a quantitative distinction between normal and severe anoxia, but that it was unsatisfactory in the detection of moderate degrees of anoxia. No deviation from the base line results were obtained at simulated altitudes of from 8,000 to 12,000 feet, although definite changes were found at 18,000 feet. The Wickes' psychomotor apparatus required too long a training period to make its use practical in routine testing. The flicker fusion apparatus was found to be valuable for experimental purposes but required too much training to make it practical for mass testing. In a direct comparison of flicker fusion and dotting tests under comparative conditions of anoxia, neither method gave a true evaluation of an individual's response to anoxia.

The Naval Air Station, Seattle, developed a card sorting test for use in the low-pressure chamber, to demonstrate the effects of anoxia. In this test, 89 percent of 200 individuals scored better at altitudes of 30,000 feet with oxygen than at 18,000 without oxygen. The test was unsuitable for use, however, because learning greatly influenced the test results, because the results under anoxia were influenced by compensating factors, and because the test was relatively difficult to perform.

In September 1945 the Naval Air Station, Vero Beach, Fla., developed a new ("M–N") device for demonstrating effects of anoxia on night and day vision. This apparatus consisted of monocular and binocular "scopes" constructed to allow the observer to view slides of aircraft silhouettes under illuminations approximating that of starlight and average daylight. With this test 90 to 96 percent of subjects tested in a low-pressure chamber were convinced subjectively and objectively that anoxia impaired night vision. Ninety-eight percent of those tested were also convinced objectively of the anoxic effect on macular vision.

The Altitude Training Unit, Naval Air Station, Miami, reported on the measurement and demonstration of loss of visual function associated with anoxia and concluded that: (*a*) loss in range for targets observed under conditions of low illumination was evident at 5,000 feet; (*b*) the loss in range above 10,000 feet when supplementary oxygen was not used was very great; (*c*) the effect of anoxia on vision at altitudes below 10,000 feet was small and not considered of operational significance. Supplementary oxygen was therefore considered unnecessary below 12,000 feet.

The Naval Air Station, Alameda, Calif. found that at altitudes of from 10,000 to 12,000 feet differences in form perception at low levels of illumination using the Radium Plaque Adaptometer, were not measurable and that form perception of the completely dark adapted eye was not affected by the reduced barometric pressure at an altitude of 10,000 feet.

DEVELOPMENT OF OXYGEN EQUIPMENT

Early in the war, the most pressing problems were those of oxygen supply. The procurement of some type of oxygen equipment suitable for use during long flights in Catalina patrol planes was extremely urgent and the question of oxygen economy was paramount. Partly for these reasons, a rebreather type system, using an oxygen regenerating chemical for both CO_2 absorption and supplementary oxygen production, was adopted. The Medical Research Section and the Division of Aviation Medicine concluded that, in spite of its greater comfort, the lack of a demand feature in the FWB recirculator obviated its general adoption.

Many Navy fighter planes were equipped with a demand-type apparatus which, while having certain features superior to the rebreather, required large supplies of oxygen. Under the sponsorship of the Army Air Forces, various manufacturers were modifying the demand apparatus by incorporating a diluter valve which would admit measured quantities of ambient air at altitudes below 30,000 feet. This type of apparatus offered many advantages over the rebreather type but still required considerably more compressed oxygen than the latter.

OXYGEN EQUIPMENT FOR THERAPEUTIC PURPOSES

The development of resuscitators was greatly stimulated by the problem of toxic gases resulting from shipboard fires. Aviation medical activities cooperated with BuShips and other agencies in attempts to provide adequate personnel protection against smoke from shipboard fires. Instances such as the holocaust aboard the carrier, U. S. S. *Franklin,* greatly stimulated the interest. As a result, in the summer of 1945, for the first time, a resuscitator for general issue was added to the supply table.

DEVELOPMENT OF OXYGEN MASKS

A large number of oxygen masks, including the MRS–1 mask developed by the Aviation

Branch, Research Division, were tested. In general, the earlier efforts aimed toward devising masks that would fit perfectly, not freeze up at temperatures around −65° F., be comfortable to wear for long periods, and be durable under service conditions. During the course of the testing program, it became obvious that some compromise with these factors was necessary. The Type A–14 mask, developed by the Mayo Clinic and the Army Air Forces, was finally adopted as standard for use with the diluter demand regulator.

MASK LEAK TESTING

Suitable methods for determining oxygen mask leakage were devised. In the early phases, tests such as presenting volatile substances in the vicinity of the mask were tried, but the results of these were unsatisfactory. Quantitative test methods included the so-called "spot" tests, which were either gasometric or volumetric, and analysis of expired air collected over a period of several minutes. The Bureau of Aeronautics recommended the simple "spot" test using devices such as the McKesson Spirometer for quick determinations of the adequacy of fit of an airman's mask. This was supplemented by the analysis of expired air when evaluating the fit of experimental masks.

It was found that all of the mechanical testers gave a large number of false failures, chiefly because the subject found it difficult to hold his breath for the required 10 seconds, but also because movement of the subject's head or jaw frequently destroyed the pressure relationship between the mask and the tester regardless of the fit of the mask to the face.

The Royal Canadian Air Force oxygen mask leak tester was evaluated in September 1945 at Pensacola. It was concluded that its greater complexity of design, operation, and maintenance, as compared to collapsible testers (as advocated by the Bureau of Aeronautics) made it undesirable for Navy use.

CHEMICAL OXYGEN GENERATORS

On the basis of convenience and economy of weight, it was considered desirable to have oxygen for breathing purposes in airplanes in the form of a stable chemical compound which could be made to liberate gaseous oxygen when desired. Chemicals as a source of oxygen for use in aviation were first utilized in the Navy rebreather. A substance known as "GOX," a mixture of alkaline peroxides, mainly sodium peroxide, served both to absorb CO_2 and to produce from one-third to one-half of the total oxygen supplied during a run.

For a number of years, the Naval Research Laboratory engaged in experimental work on the development of peroxides of metals other than sodium, and in cooperation with the Du Pont Company developed a material known as "KOK," which consisted chiefly of potassium tetroxide. "KOK" supplied a much larger amount of oxygen than the earlier chemicals, so that a suitable canister filled with this material produced oxygen in excess of the user's demand and the excess could be employed to flush nitrogen from the rebreather system.

In the early part of the war, the British utilized an "oxygen candle" for supplying oxygen in small submarines. This device was adapted to aviation use through the cooperative efforts of the Naval Research Laboratory, the University of Pennsylvania, the National Defense Research Committee, and the Mine Safety Appliances Company under contract with the Bureau of Aeronautics. In one form, it was incorporated in an apparatus with a continuous flow of approximately 20 minutes' duration; in another form, it was combined with the "KOK" described previously, in a 2-hour rebreather apparatus designated the "C–K" unit. Neither unit was available in time for operational use during the war.

Liquid oxygen

On a volume basis, liquid oxygen was the most economical form in which to transport large quantities of oxygen for use in breathing equipment. During the war numerous methods to adapt this source to use in aircraft were tried. Two types of apparatus were most commonly used. One employed electrical energy to convert the liquid to a gas; the other device utilized the environmental temperature to effect the transformation. Physiological problems were concerned chiefly with the establishment of peak rates of flow required from a converter designed for multi-place aircraft, and the possible inhalation of oxygen at very low temperatures. Owing to a number of engineering difficulties, liquid oxygen was never installed in naval aircraft.

In November 1945 the Naval Medical Research Institute evaluated the chlorate candles devised by the Naval Research Laboratory as a source of oxygen supply for aircraft use. These candles gave oxygen percentages of from 95.6 to 97.2 percent, plus insignificant amounts of CO and CO_2. The initial smoke, however, was frequently unpleasant and was sometimes irritating enough to necessitate removal of the mask.

LOW-PRESSURE CHAMBER INDOCTRINATION AND TRAINING

In November 1945 the Altitude Training Unit at the Naval Air Station, Norfolk, on checking aviation personnel to determine their knowledge of oxygen equipment, found that the ability to use this equipment deteriorates very rapidly, especially when instructions were not given periodically. Lectures, low-pressure chamber "flights," and actual aircraft flights were all valuable in contributing to knowledge of the use of oxygen equipment, but experience with the actual equipment in aircraft was the most important.

A method was devised for the direct estimation of the gas tensions in blood samples which were obtained by the use of an indwelling arterial needle. It was noted that great variations occurred in the arterial oxygen tension when exercise was done at high altitude.

In February 1944 the microgasometric method of Roughton and Scholander for the determination of oxygen saturations of "capillary" blood was adopted. The oxygen saturations of "capillary" blood obtained from the heated earlobe were compared with those of samples of arterial blood obtained simultaneously from the brachial artery and found to correspond under a variety of conditions and levels of anoxemia. This method furnished a simple and accurate means of determining arterial oxygen saturations without recourse to arterial puncture.

A study of the arterial oxyhemoglobin saturations in men breathing various oxygen-nitrogen mixtures at critical pressure altitudes in the decompression chamber was made. In 43 observations on 24 subjects at 20,000, 35,000, and 40,000 feet, the following facts were noted: (*a*) the oxyhemoglobin saturation may be predicted with an accuracy of plus or minus 3 percent for a given oxygen-nitrogen mixture at these pressures; and (*b*) the arterial oxyhemoglobin saturation may fall appreciably during a short period of medium to heavy work (in states of mild anoxia), during which time certain undetermined factors operate to make the saturation unpredictable.

In January 1945 a direct method for the determination of oxygen and carbon dioxide tensions in blood was reported. This method involved the equilibration of a bubble of gas with blood at 37° C., and the analysis of this bubble for CO_2 and O_2. The Roughton-Scholander syringe was used both as an equilibration chamber and a bubble analyzer, thus eliminating any transfer of the bubble. The results of this technique agreed very closely with those obtained using a tonometer at sea level, for both CO_2 and O_2. Comparing the results at altitude in the low-pressure chamber, the method was also found accurate enough for practical purposes, and this technique was sufficiently simple, quick, and accurate for application to problems in respiratory physiology.

In July 1944 the individual variation in respiratory responses to CO_2 at altitude were studied and it was concluded that the response of a group of subjects to CO_2 was the same at 15,000 feet pressure altitude as at sea level, when the same tension of CO_2 in the inspired air was used.

The altitude training unit at the Naval Station, Miami, studied the effect of temperature on anoxic failure in altitude chambers and noted that the average incidence for failure at 18,000 feet approximated 3 percent in ordinary low-pressure chamber runs, whereas only 0.3 percent of men given chilled runs showed anoxic failure at this altitude. The accumulation of oxygen was no different in the warm or cold runs. The findings suggested that improved vascular tone due to cold and shivering increases resistance to vasomotor collapse, despite the increase in oxygen consumption.

The Naval Medical Research Institute studied the urea clearance of men at simulated altitudes of 18,000 feet for 1 hour (in a low-pressure chamber) and found no significant variations. In February 1943, with the use of the "pneumolotar" of the General Electric X-ray Corporation, subjects were able to undergo flights to 45,000 and 50,000 feet in low-pressure chamber without any other equipment. Intermittent pressure breathing of air enabled men to remain at 22,000 feet for 30 minutes without distress and at 25,000 feet for 15 minutes with some distress, when the pressure was of the order of 8 inches H_2O. This increase in "ceiling" of about 6,000 feet indicated greatly increased safety of oxygen administration for the aviator.

The Altitude Training Unit at Pensacola conducted studies on the rate of fall of blood oxygen saturation at high altitudes following mask removals. At altitudes of 28,000 feet and above, a subject's mask was removed and he performed a simple card-sorting task while his reactions were noted and recorded. When unconsciousness was imminent, the mask was replaced and 100 percent oxygen administered. Blood oxygen saturations were estimated throughout the procedures with a Millikan oximeter, and ambient oxygen pressure was determined with a continuous oxygen analyzer.

Blood oxygen saturations averaged 64 percent at the appearance of the first error and 56 percent at the time unconsciousness became imminent. This procedure was repeated on 25 men at 28,000, 30,000, 35,000, and 38,000 feet. It was found that unconsciousness was imminent after 141 seconds at 28,000 feet, 98 seconds at 30,000 feet, 72 seconds at 35,000 feet, and 47 seconds at 38,000 feet, while average time of useful consciousness as determined by the appearance of the first error in card sorting was 110 seconds at 28,000 feet, 73 seconds at 30,000 feet, 46 seconds at 35,000 feet, and 35 seconds at 38,000 feet. Thus, the period of useful consciousness was found to be approximately three-fourths of the total period of consciousness.

In August 1945 workers reported the effect on the blood cells in man of acute hypoxia, with and without added CO_2. They found that exposure of 29 men to lowered oxygen tension (10 percent oxygen in nitrogen) for 20 minutes produced no immediate significant alteration in the white blood cell count, red blood cell count, hematocrit, hemoglobin concentration, or red blood cell volume. Addition of carbon dioxide (2 to 5 percent) did not alter these measurements.

The Naval Medical Research Institute studied the transfusion of human erythrocytes as a means of increasing tolerance to hypoxia. A total of 1,300 ml. of 55 percent fresh erythrocyte suspension in saline was administered intravenously to each of two subjects over a period of 3 days. The transfusions were well tolerated, causing only mild symptoms. The hematocrit reading was increased from 45.8 percent to 52.7 percent in one subject and from 50.0 percent to 56.1 percent in the other subject—an increase of approximately 12 percent in the total cell volume. The increased hematocrit readings returned to normal over a period of about 1 month. After 12 days, the increase was still greater than half the peak value attained. Analysis of arterial blood samples taken at altitudes indicated that the percentage saturation of hemoglobin with oxygen was within the normal range for the ambient oxygen partial pressure. Thus, the oxygen content of the blood, as well as the oxygen capacity, was greater than normal at this altitude. In tests made at simulated altitude of 18,000 feet to determine any deviation from normal reaction, the subjects who had had previous experience in low-pressure work noted an improved tolerance to hypoxia during the several days of polycythemia.

The Altitude Training Unit at the Naval Air Station, Norfolk, tested aviation personnel to obtain their reaction to inspiratory obstruction at simulated high altitudes. Exposing 50 naval aviators, without warning, to inspiratory obstruction resulting from an induced failure of the oxygen supply at 30,000 feet simulated altitude, they found that all of the subjects within 17 seconds, plus or minus 2 seconds, were certain of the time when the obstruction took place. This response was considered tantamount to an immediate warning of oxygen failure. All subjects showed anxiety at the sudden increased resistance to breathing. Trained subjects were able to handle the situation adequately while untrained subjects showed signs of varying degrees of mental confusion. On the basis of this study, the Norfolk group suggested that an oxygen regulator equipped with an automatic device to warn aviators of the loss of oxygen should be developed.

Development of pressure breathing

Pressure-breathing oxygen regulator and bail-out equipment were developed by Gressly. A limited number of these devices were in use for high altitude flight. One phase of pressure breathing almost exclusively a Navy innovation was the development of an emergency breathing procedure (EBP). This "voluntary pressure breathing" was designed as an emergency maneuver for use in the event of failure of the oxygen supply. At altitudes up to 25,000 feet, it was considered advantageous to exert pressure by contracting the respiratory muscles while holding a deep breath.

In October 1943 it was found that EBP of air increased an aviator's ceiling by approximately 10,000 feet and thus enabled an aviator, without equipment of any kind, to remain alert and conscious at altitudes of 25,000 to 26,000 feet for periods of as long as 30 minutes. This procedure could successfully be taught to aviators by means of a supervised training run in a low-pressure chamber. It appeared to have usefulness in sustaining aviators at high altitudes in emergencies, during parachute falls from high altitudes, and as an emergency procedure in aircraft pressurized cabins.

In actual flight tests at simulated altitudes of 25,000 feet for 10, 18, 21, 24, and 26 minutes, copilots were able to maintain the aircraft on instruments, and the radioman functioned successfully—all without oxygen. One man was able to recover from anoxia after its onset. Hyperventilation, on the contrary, was not considered to be an adequate means of survival without oxygen at 25,000 feet because an arterial oxygen saturation of only 65 to 70 percent was achieved and most subjects collapsed from anoxia, acapnia, or both within 8 minutes. Using EBP of 100 percent oxygen, an altitude of 40,000 feet could be reached with ordinary oxygen equipment, and the physiological ceiling could possibly be raised to approximately 50,000 feet.

Several dangers inherent in the use of EBP included: (*a*) The development in some instances of severe degrees of acapnia (even tetany) due to hyperventilation; (*b*) the inadequate respiratory coordination in some men, with resultant impairment of "altitude tolerance;" (*c*) the difficulties involved in indoctrinating large groups of men in performing the technique efficiently; and (*d*) the possible development of overconfidence in an emergency maneuver which might encourage attempts to fly at hazardous altitudes without oxygen. The Naval Medical Research Institute found in tests at 25,000 feet that no advantage was gained by "pressure breathing" during hyperventilation and that EBP and voluntary hyperventilation were equally effective in increasing the oxygen saturation of arterial blood when breathing ambient air at simulated altitudes of from 18,000 to 20,000 feet. They concluded that EBP was impractical for aviation personnel, hyperventilation at the rate of 12 to 15 breaths per minute being easier and less fatiguing than EBP at the same rate, and equally effective.

PHARMACOLOGY

At Camp Lejeune the effects of scopolamine on marksmanship were studied and it was found that men given this drug performed with equal efficiency before and after its administration. In February 1943 the effects of benzedrine on "fire power" (hits per minute) under conditions of extreme fatigue were observed. It was found that 10 mg. doses at 8-hour intervals significantly increased fire power of personnel subjected to arduous tasks, although a slight degree of euphoria and diminished judgment was evident.

Safety Devices and Survival

HUMAN FACTORS IN ENGINEERING AND DESIGN

Naval aviation medical personnel played an active part in the development of airborne equipment to aid in the handling of survivors. Improved litters, hoists, droppable rafts, first-aid kits, and methods of packaging medical supplies for dropping to survivors were perfected by the cooperative efforts of engineering and medical personnel. In 1944 the Air-Sea Rescue Agency designated a committee to study the medical and physiological aspects of air-sea rescue, and representatives of the Army, Navy, Coast Guard, and Public Health Service met at frequent intervals to coordinate their efforts in this study.

Subjects investigated at naval aviation activities included sunburn protective ointments, life preservers (with regard to the optimal flotation position in the event of unconsciousness), prevention and alleviation of immersion foot, shark repellents, optimal position to be taken by personnel during ditching, protection against underwater blast, testing of various signaling devices, and the use of oxygen equipment for emergency escape from submerged or sinking aircraft. In May 1944 the Naval Medical Research Institute designed an individual personal first-aid kit for aviation personnel. This was a compact shock and moisture resistant plastic container holding a sufficient quantity of essential first-aid materials for one man until he could obtain help. Shelesnyak, in April 1945, devised a compact first-aid kit for use in aeronautic pneumatic liferafts.

TOXIC GASES

The problems of toxic gas centered around the entrance of exhaust gases into the cockpits of naval aircraft. Certain structural characteristics of carrier-based aircraft made this problem more serious in naval planes than in Army type planes. In the early part of the war, very little was known about the effects of carbon monoxide on the body when exposure occurred at altitudes involving moderate degrees of anoxia. There was a tendency toward ultraconservatism, and the limits of CO concentration set by some branches of the service were almost infinitesimal. For these reasons, two main lines of development were emphasized: (*a*) study of the effects of carbon monoxide during periods of altitude anoxia and (*b*) the development of instruments for measuring CO concentrations in air and blood. In these studies, it was necessary to determine whether or not there were any other substances in the exhaust from airplane engines which would add to the toxicity of the carbon monoxide. It was concluded that while certain aldehydes might be a source of irritation the toxicity of exhaust gases could be suitably evaluated on the basis of their carbon monoxide content alone. The policy of determining blood level, rather than the air concentration of CO was adopted as a standard by the Bureau of Aeronautics. Using the changes in the critical frequency of flicker, it was established that 8 to 10 percent carbon monoxide hemoglobin depressed altitude tolerance by 4,000 to 6,000 feet at altitudes around 10,000 feet.

In August 1945 a study of the in vivo equilibrium between oxy-, carboxy-, and reduced hemoglobin in the blood of human subjects breathing gas mixtures containing from 0.005 to 0.015 percent carbon monoxide indicated that the amount of COH_b could be determined from the Haldane equation, knowing only the percentage of CO in the inspired air and the air pressure. Furthermore the symptoms produced by CO were proportional not only to the blood concentration of COH_b but also to the duration of exposure to given concentrations of CO.

The MSA portable Hopcalite carbon monoxide indicator was compared with the bulb type colorimeter. The colorimeter had a possible error as great as 0.007 percent, especially when estimating small concentrations of carbon monoxide (below 0.005 percent).

Investigation of the toxic gases resulting from jet-assisted take-offs (JATO) showed that hydrochloric acid and carbon monoxide constitute the worst hazards to personnel exposed to JATO on carrier flight decks.

Vision

AIRCRAFT AND INSTRUMENT LIGHTING

In September 1942 the National Institute of Health demonstrated the superiority of red lighting over fluorescent lighting for reading aeronautical charts and for preserving dark adaptation.

As a result of a questionnaire submitted to 400 pilots, it was determined that the greatest difficulties in night flying were confusion of lights, inability to judge speed and distance, and disorientation or vertigo. It was found that the accident rate greatly increased as the evening advanced. This was shown to be primarily due not to increasing darkness but to sleepiness and fatigue which significantly increased in the later night hours. Taxiing accidents occurred equally under moon and moonless conditions, but landing accidents attributed to leveling off too high occurred more frequently in moonlight.

Ultraviolet and indirect red systems of illumination for aircraft instrument panels were compared. When the brightness level was greater than that required for minimum legibility, ultraviolet illumination caused a sharp decrease in the efficiency of spotting faint targets against the sky background, while red had very little effect.

Early in the war the source of supply for the Ishihara color plates was cut off from the Navy and a new color test became imperative. The effect of tinted lenses on color vision was checked and it was found that neutral and greenish lenses produced little effect on color perception. Reddish-orange lenses caused an effect equivalent to that of moderate color blindness and yellow lenses produced the effect of extreme color blindness. The aftereffects of wearing any colored lenses diminished rapidly.

VISION, MISCELLANEOUS

Reduction in size of permetric field was observed in subjects exposed to prolonged physiologic stress, other than anoxia, but this was probably no greater than that observed under nonstress conditions.

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Test firing under low illumination showed that practical advantage is to be gained through the wearing of dark adapter goggles.

NIGHT VISION

The dark adaptation threshold of officers as compared with enlisted men was studied on the U.S.S. *Enterprise*, using the Hecht-Schlaer adaptometer, and no significant difference was found. All subjects who were deficient in original testing, improved on vitamin A administration.

The optimal lighting level in ready rooms for cone function of personnel wearing dark adaptation goggles was found to be between 20 and 30 foot-candles. At this level, the optimal time for dark adaptation, wearing the red goggles, was 45 minutes followed by 2 minutes of complete darkness. After exposure to light levels above 30 foot-candles, an excessive amount of time was required to fully dark-adapt, while levels below 20 foot-candles gave insufficient illumination for cone function. If all-red lighting was used instead of the goggles, the intensity required was between 2.5 and 3.8 foot-candles. It was concluded that any night vision training device should be binocular rather than monocular, because at low illuminations the perceptual threshold was lower for binocular than for monocular viewing.

A study of dark adaptation while wearing orange dark adapter goggles indicated that standard red goggles were superior to 5 percent orange goggles and to 5 and 10 percent neutral goggles under conditions demanding quick recovery of complete dark adaptation. Where somewhat less complete recovery was required, the 5 percent orange goggles were almost as efficient as the standard red ones.

Sunlight produced temporary and cumulative effects on night vision. A single exposure of 2 to 3 hours delayed the onset of dark adaptation by 10 minutes or more, and night vision threshold was not reached for several hours. With repeated daily exposure to sunlight, the delay in reaching the normal threshold persisted overnight. This threshold, after complete dark adaptation, was higher each day for about 10 days and then remained at the highest level. This elevated threshold corresponded to an average deterioration of about 50 percent in visual acuity, range of visibility, contrast discrimination, and in the frequency of picking up a barely visible target. This chronic effect did not disappear even after 10 days of protection from sunlight and was approximately equivalent to the loss in night vision experienced at altitudes of 12,000 feet without oxygen. These workers concluded that adequate sunglasses should be worn by all persons exposed to bright sunlight during the day, if they expect to perform critical night duties.

LIST OF APPARATUS AND PROCEDURES ADOPTED AS A RESULT OF AVIATION MEDICAL RESEARCH

1. Development and testing of Anti-G protection devices.

2. Study of physiological effects of rapid ascent to high altitudes for establishment of criteria for advanced type aircraft.

3. Development of new micro techniques for visualization of air embolism in living tissues.

4. Development of preoxygenation techniques for prevention of divers' bends and air embolism in aviators.

5. Establishment of human breathing patterns at sea level and altitude for use in design of aviators' oxygen breathing equipment.

6. Flight testing and evaluation of Navy aircraft oxygen regulators.

7. Establishment of criteria for design of Bureau of Aeronautics oxygen equipment.

8. Development of a simple flowmeter type apparatus for testing oxygen regulators in aircraft.

9. Establishment of standards for size distribution of A–14 oxygen mask for use by naval personnel.

10. Comparative tests of devices for testing of high altitude oxygen mask leakage leading to modification of existing equipment.

11. Development of procedure for instruction and indoctrination of key aviators in problems of high altitude flight and pressure oxygen breathing equipment.

12. Evaluation of techniques employed in oxygen indoctrination of aviation personnel.

13. Development and evaluation of voluntary pressure breathing methods and techniques.

14. Development of new simple methods for blood gas analysis.

15. Investigation and recommendations regarding dental pain occurring in flight.

16. Evaluation of visual standards for use in selection of naval aviators.

17. Development of aptitude tests for selection of naval aviators, flight instructors, and aircraft gunners.

18. Development of improved techniques in aircraft intercommunication systems and in speech intelligibility of communication in aircraft.

19. Development for liferafts of an emergency ration and of headgear protective against the sun.

20. Evaluation of motion sickness preventives for use in liferaft first-aid kits, leading to recommendations for adoption of scopolamine.

21. Development of individual first-aid kit for flying personnel.

22. Development of techniques for dropping of medical supplies from aircraft.

23. Development of improved naval in-flight rations.

24. Development of special methods for interior and exterior lighting of aircraft.

25. Establishment of method of illuminating submarine conning towers.

26. Determination of and recommendation of methods for elimination of factors causing disorientation in pilots during flight at night.

27. Establishment of criteria based on human factors for the design, placement, and operation of instruments and controls in aircraft, and for pilot comfort, efficiency, and escape.

28. Development of nylon aviator's flak suit.

29. Evaluation of crash injuries, leading to establishment of methods for prevention.

30. Development of harness for protection against crash deceleration and parachute opening shock.

31. Testing of and recommendations for improvement of ventilation on naval aircraft and aircraft carriers.

32. Recommendations based on the investigation of toxic gases produced by JATO units.

33. Development of single aperture goggle for uninterrupted, wide-angle vision.

34. Development of red goggles for dark adaptation.

35. Development of radium plaque adaptometer for night vision testing.

36. Development of brow-rest all-purpose Navy sunglasses.

37. Development of sun-scanning visor for ground, ship, and flying personnel.

38. Research leading to the establishment of specifications for aviator's neutral sunglasses.

39. Development of equipment for indoctrination of naval personnel in techniques to aid in night vision.

40. Recommendation for methods of prevention of deleterious effects of exposure to intense sunlight on subsequent night vision.

41. Development of antifluorescent goggle to prevent dazzling of landing signal officer.

42. Development of new color vision test book.

43. Development of new Navy color vision testing lantern.

44. Development of a field method for the measurement of the central scotoma under dim illumination.

45. Development and evaluation of test targets for measuring visual acuity.

46. Evaluation of the Orthorater, Sight-Screener, and Telebinocular as compared to standard methods of visual testing.

Chapter XI

Burns

Lamont Pugh, *Rear Admiral (MC) USN*

The stimulus for medical and surgical advancement occasioned by World War II was very great. This was particularly applicable to the management of burns. In the Navy and Marine Corps the case fatality rate for burns was only 8.7 percent as compared with 22.9 percent in World War I. The difference of 14.2 percent was indicative of improvement in the methods of burn management. Perhaps not all of this improvement was attributable to measures or principles born of the war's stimulus; to some extent it was ascribable to progress made during the interval between World War I and World War II. Of significance, however, was the fatality rate for burns of 17.4 percent in 1942 which dropped to about 6 percent in 1944 and 1945, definitely indicating improvement in treatment ascribable to the war's stimulus. Figures provided by the Army closely paralleled those of the Navy.

Whatever change the concept of burn management may have undergone during World War II, that change was wrought, in an appreciable measure, by what was unlearned rather than by what was learned. We were still short of an ideal regimen in the treatment of burns and there remained differences of opinion among various groups as to what constituted the best regimen, save that practically all were in agreement that simplicity was a prime requisite. Certain principles became fairly well standardized. These resolved themselves into three categories, namely, general and local treatment and rehabilitation.

GENERAL

1. A more intelligent appraisal of the value of blood plasma and a more general realization of its limitations were developed. While the sheet anchor in the management of shock was blood plasma, it alone was not sufficient in severely shocked patients. Certain other elements were essential as a complement to plasma in order that the most effective means to combat or treat shock could be provided and conditions most favorable to healing maintained. Supplementary use of an extract of whole adrenal cortex made it possible to successfully cope with shock in stages beyond the reach of plasma alone. At least that was my conviction. Concentrated albumin had its indications and advantages in the management of burn shock. Based upon sound reasoning, the use of an amino acid solution or casein hydrolyzate as a means of maintaining the blood protein balance gained favor and stood to supplant plasma completely. Buffers to maintain a proper acid-base balance were also taken into account.

2. The importance of maintaining a positive nitrogen balance by either oral or parenteral administration of protein was generally recognized. A high protein diet and an adequate vitamin intake, particularly of thiamine and ascorbic acid, was deemed essential.

3. The essentiality of whole blood transfusions in certain patients received general recognition. In severely burned patients, cachexia often supervened despite the most careful treatment, and death, sometimes months after the original burn and regardless of what was done, was the rule. Repeated whole blood transfusions were necessary—nothing sufficed in their stead and nothing contributed more to the patient's chances of living.

4. A better understanding was developed of the proneness of certain complications such as pneumonia to supervene.

5. A more intelligent appraisal of or realization of the merits and demerits of the sulfa

drugs, penicillin, and other antibiotics came to exist.

LOCAL TREATMENT

The most notable advancements in local treatment of burns included:

1. The virtual abandonment of tannic acid and other coagulants, including silver nitrate, the dyes, picric acid, and the proprietary formulas.

2. A return to the old emollients such as vaseline, vaseline and paraffin (parawax), and boric acid ointment.

3. A fuller appreciation of the importance of protection of the burned area from infection, and the prevention of further damage that resulted when burned surfaces were in apposition.

4. The popularization of the pressure dressing. The rationale of the pressure dressing was based upon three important principles: (*a*) The prevention of circulatory stagnation and of fluid loss, along with the support of the part; (*b*) the reduction of the risk of introducing secondary infection by leaving the part alone; and (*c*) the elimination of the painful ordeal of repeated changing of the dressings, which was gratifying to the patient.

5. The pronounced trend toward early skin grafting and the popularization of the patch graft. Skin grafting was generally done within about 3 weeks. Early skin grafting was instituted more and more freely, not primarily as a plastic procedure but as a conservation measure to preserve the deeper structures, prevent further fluid loss, prevent infection, and conserve the general health of the patient. The type of graft used was governed largely by what the particular surgeon had found would be most likely to grow. Patch grafts were very popular. This method involved removing a split thickness sheet of skin and cutting it up into small pieces. Infection was not nearly so likely to prevent a take when the patch graft was used.

REHABILITATION

The importance, from both a sociologic and economic standpoint, of rehabilitation of burned patients was more and more fully realized, but too frequently was neglected. This phase of therapy often presented a challenge of the first magnitude, which in the well-ordered hospital was satisfactorily met, at least in cases of burns involving the hand, through the medium of a "hand" board comprised of an orthopedic surgeon, plastic surgeon, and neurosurgeon. These specialists collaborated upon the matter of the salvage and restoration of function of burned hands.

PROPHYLAXIS

The development and provision of prophylactic measures in the form of special clothing and local applications to meet the needs of a rapidly changing world were born of and given impetus by the war. Efforts toward prevention of burns and improvement in their treatment were continued. Great advances were made in devising protective covering and local applications as prophylactic measures against burns, for military and naval as well as for industrial personnel.

Chapter XII

Program for the Deaf

Ross T McIntire, *Vice Admiral (MC) USN (Retired)*

The treatment of deafness has given the otologist great concern for decades. The causes of deafness have been reasonably well understood, but a sound approach in prophylaxis had never been achieved and the results of research in this disability were disappointing.

Three types of deafness have been recognized: (*a*) The chronic progressive type; (*b*) the nerve type; and (*c*) the type following chronic otitis media. In chronic, progressive deafness the predominant findings are: (1) Reasonably normal tympanic membranes; (2) a negative Rinné test; and (3) a gradually increasing profundity of hearing impairment. The patient often has a familial history of deafness, and audiometric tests show a mixed loss of hearing tones.

The nerve type of deafness, as seen in the Navy, was often traceable to damage from heavy gunfire. It was reasonable to expect that damage to the acoustic mechanism might cause immediate deafness. This was not true. Due to the inflammation of the end organ an immediate loss occurred, but usually there was some improvement in a few days. We observed that there was a slow loss of hearing over a period of from 1 to 2 years, until the deafness became severe enough to be incapacitating.

One of the most common complaints of patients suffering from nerve involvements was tinnitus associated with headache; some complained of vertigo. Unfortunately, the patient frequently failed to consult a medical officer until his hearing reached such a low level that the deafness was very difficult to treat.

One of the conditions that was always considered was malingering. In fact, the man who had nerve deafness was likely to give one the impression that he was malingering. Situational deafness occurred in some men following gunfire, blast, or the noise of heavy machinery. This condition was supported by functional and audiometric tests, and usually the disabiltiy was of relatively short duration. Men who had this condition were often psychologically unstable and were often classified as malingerers.

One of the great troubles we experienced was to get the patient under treatment in a reasonably short time; our average was 6 to 18 months. In other words, the patient with nerve deafness went through the cycle of typical gunfire hearing loss before he was seen. This was something that civilian specialists should consider in those patients who have been subjected to blast and noise in industrial occupations.

We believed that the upper respiratory tract played a most important role in the causation of infections of the eustacian tube, middle ear, and mastoid process, and that nerve deafness often resulted from foci of infection.

The fenestration operation developed by Lempert offered hope for the patient with true otosclerosis. After operation, over 65 percent of the patients showed recovery to normal hearing levels. Because of this fact, the Navy trained a number of its specialists in the technique of this operation.

Rehabilitation of the deaf was carried on in the Acoustic Clinic set up at the Naval Hospital, Philadelphia. The program was designed for the patient who had permanently lost some or all of his hearing. The discovery of this loss and its implications represented for him a major crisis in adjustment and he had to learn to live as successfully and happily as possible despite his loss.

The first task in rehabilitation was to select, train, and supervise a staff of specialists, so that the psycho-physio-social problems of the deaf could be attacked intelligently. We found that the psychological upset that occurred in the deafened man was greater than that in the blinded man. The lack of proper hearing disturbs speech, and when a man misses a key word in a sentence because of his hearing defect his reply is based on an erroneous assumption. After a number of false answers his personality suffers.

To measure the actual hearing deficit by decibels was necessary, because many patients who suffered only slight loss in hearing acuity were more seriously handicapped than those who had a very great defect. Such differences could only be explained in terms of the individual personality. It was considered imperative, therefore, that the rehabilitation processes be individualized. It was essential that a sincere effort be made to understand the man who had a hearing loss. The patient was prepared psychologically to accept the fact that his chances of improvement in hearing were too small to run the risk of waiting for it to occur, and to accept the practical course of developing effective structures of compensation that would be as permanent as the disorder itself.

A sudden loss of hearing often had a heavy impact upon the personality of the man. Those who had lost hearing over a period of years were often unconscious of the steady downgrade and had already made adjustments. This type of patient was difficult to treat, for they became eccentric and antisocial. The most positive deterrent to the growth of these attitudes was the development of practical skill in communication by the employment of other sensory channels and by the effective use of residual capacities. The patient was made to realize that it was necessary to compete in a highly competitive world, and that he could be equipped to meet the competition with new abilities and skills. He was made aware that he was not a deafened man who must find ways to appear normal, but rather that he could become a successful deafened man, if the residual hearing he possessed was put to its maximum use.

Our experience justified the principle of treating the whole personality and of considering the limitation of hearing as a significant but not disproportionately important part of the man. The over-all principle which unified our various methods defined order and direction for the specialists who might otherwise have attacked the problems in different ways.

The method of the treatment of deafness was predicted on functional testing procedures for diagnosis and an accurate evaluation of the results of treatment. In addition to the usual history and physical examination, fork tests, audiograms, whispered and conversational voice tests, and speech reception tests, both monaural and in a free field, were employed. These aided greatly in the accurate measurement of residual function. An apparatus was developed under the auspices of the National Research Council for the Army and Navy Aural Rehabilitation Services. This consisted essentially of an electronic device to transmit high fidelity recorded or free speech at any level of intensity. It was calibrated in decibels of from 1 to 100 and noise masking could also be added in measured amounts. It was anticipated that use of this instrument before and after the fenestration operation, or other methods of treatment, would greatly facilitate evaluation of results.

A careful search for factors that were operative in the existing deafness was first made. Thus otitis media, if present, was treated either by medical or surgical means. Personnel who showed evidence of high susceptibility to acoustic trauma were cautioned to avoid future exposure. The use of ear wardens by persons necessarily exposed to loud noises, either of the continuous type such as those caused by airplane engines, or the explosive type, did much to reduce the incidence of traumatic deafness. Many young men had symptoms of persistent or recurrent eustacian salpingitis with peritubal lymphoid hyperplasia. These patients were treated with radium, using two 50-mg. nasal applicators. Aero-otitis media in flying and diving personnel was similarly treated. Associated infection such as sinusitis was also treated intensively.

Patients that were suitable for the fenestration operation, that is, those with noncatarrhal conductive deafness (otosclerosis) showing at least 40 decibels (db.) loss in the better ear for speech frequency, were offered the advantages of this operation. Because hearing aids were most effective in this type of deafness, many preferred wearing an aid to undergoing an operation. In a successful operation, the patient usually obtained a gain in hearing of from 25 to 30 db. Patients showing no middle ear disease or tympanic scarring, no appreciable loss of hearing for high frequencies, and a decibel loss no greater than 60 in the speech frequencies were considered to be suitable for operation. Even with good results from the operation, a hearing aid was necessary if the gain failed to raise the threshold to 30 db.

The mental attitude of the patient was considered to be most important in both diagnosis and treatment. Recently deafened persons minimize or hide their defect. They become sensitive or irritable or introspective and detached. Some patients developed psychogenic overlays, thus exaggerating an existing organic deafness; others manifested typical hysterical deafness. While the latter was rare, the former was not uncommonly engendered by worry, anxiety, and insecurity.

Patients with mild forms of overlay usually required no treatment and the condition disappeared as the hearing improved; patients with severe types were treated by narcosynthesis or hypnosis.

The recognition of a psychogenic component in deafness was important not only from the standpoint of prognosis, but also in the evaluation of therapy. Since it was not unusual to ascribe curative value to a treatment that acted largely by power of suggestion, the power of suggestion was utilized in inducing acceptance of a hearing handicap and of the urge to persist in a retraining program until the handicap became minimal. This retraining program consisted essentially of speech (lip) reading, auditory training, speech correction, and vocational training. Speech reading stressed not only the observation of lip movements but also included training in the interpretation of all cues such as facial expressions and gestures. This training was particularly valuable in the type of nerve deafness where consonants were poorly heard. Since the intelligibility of speech was largely dependent on consonants, speech reading restored communication to those who previously had only heard unintelligible vowels. Patients with mild deafness obtained practically normal reception by the use of a hearing aid alone; for those, lip reading was cultivated against the time when the deafness would become worse. In case of marked deafness of the mixed or nerve type, hearing aids usually did not give sufficient amplification of the higher frequencies for complete intelligibility, and lip reading was used to supplement the hearing aid. In complete deafness, speech reading was the main substitute for the hearing loss. Some persons with marked hearing loss benefited from a hearing aid by obtaining auditory cues to augment their lip reading ability.

It was found necessary to match the hearing aid to the audiogram on the theory of selective amplification. In nerve deafness a slightly better performance was often obtained by the use of an aid with a 6 db. per octave "tilt," but such factors as amplification, quality of tone, and body baffle required careful consideration. Carefully fitted, individually molded ear pieces were provided for all patients at the outset of the retraining program.

Hearing aids did not substitute for atrophied nerves and the patient with nerve deafness had to go through an orderly and prolonged training process in order to get the maximum benefit from his aid, as well as to learn the limitations he had to accept. Many patients with nerve deafness could be successfully fitted with aids because precision instruments of high fidelity were available.

Auditory training in World War II was a relatively new concept. The failure of many individuals to adapt themselves to a hearing aid in the past was largely due to intolerance of amplified sound. The patient with conductive deafness presents no great problem, because as soon as sound penetrates the barrier, it is appreciated as a threshold sound. In nerve deafness on the other hand, as soon as the sound becomes audible, it is perceived as a loud sound and so may cause acute distress. The greater the hearing loss, the louder the sound seems to be when it becomes audible, because the patient was accustomed to a pathologically quiet world.

Part of auditory rehabilitation consisted in teaching men how best to wear and care for the aid, as well as in defining its limitations. It was found useful to instruct patients in the elementary anatomy, physiology, and pathology of hearing, with particular emphasis on the type of disability the patient had. With this knowledge, the element of mystery was removed and the patient regained confidence.

One of the factors that required thought was the care of the residual hearing of the deafened man. This required a central diagnostic clinic where the patient could be checked from time to time. It is the hope that in the field of social rehabilitation the experience gained in the handling of the many thousands of individuals who suffered hearing defects during World War II will be put to use for the deafened men, women, and children in civil life.

Chapter XIII

Blindness[1]

Clifford A. Swanson, *Rear Admiral (MC) USN*

Roy A. Stewart, *Lieutenant (MC) USNR*

The medical and surgical care given to the injured fighting man in World War II was superb. It was characterized by better care of eye injuries, not so much because of improved surgical techniques as because of chemotherapy. The use of sulfonamides and penicillin soon after injuries occurred undoubtedly decreased the incidence and severity of eye complications. Although eye injuries during World War II provided an interesting aspect of military medicine, they comprised only a small percentage of the total number of injuries.

Eye surgery during the war differed from that in civilian life in that often a wound of the eye was virulently infected for some days before surgical interference was possible. In addition, the tissue injury was far more severe than that noted in industrial accidents. The general surgeon followed a plan of early and extensive débridement of gunshot wounds, but such a course was not possible in wounds of the eyelids where primary suture was indicated. Infection following primary suture was rare and when it did occur it could be controlled easily. A feature of plastic surgery of the eyelids that varied from that in civil life was the frequent occurrence of extensive injuries of the orbital bony structures.

Iritis, corneal ulcers, refractive errors, and similar conditions often caused more loss in military manpower than did gunshot wounds of the eye.[2] In one naval base hospital during a 1-year period, 10 times as many patients were admitted because of errors in refraction and disease of the eye than because of eye injury. When men with hyperopia were subjected to battle conditions they frequently had eye symptoms; apparently the intraocular muscles can overcome a moderate hyperopia under normal conditions but not under the stress of war.

In war wounds, the eye injury frequently was of secondary importance. The attendant major wound had to be cared for first and treatment of the eye injury was postponed until shock or serious body injury was treated. In order that injuries to the eyes should not be overlooked, a close liaison between the ophthalmologist and the general surgeon was essential.

Bullets rarely entered the eye anteriorly. Orbital injuries from secondary bony missiles often caused more damage to the eyeball than did the bullet. The eyeball sometimes literally "exploded" in the orbit.

Shell-fragment wounds of the tissues around the eye were often attended with powder-incrusted areas of the face and eyelids and embedded grains of sand, gravel, mud, and metal. This gave the extra-ocular regions as well as the cornea and conjunctiva a tattooed appearance. Such wounds were irrigated with boric acid solution, the skin cleansed with soap and water, and each bit of embedded material was painstakingly removed. The administration of penicillin and sulfadiazine greatly decreased the incidence of secondary infection in these wounds.

Bomb explosions produced such great air compression that retrobulbar hemorrhage with

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[1] Adapted from: Causes of Uniocular and Binocular Blindness in the U. S. Navy and U. S. Marine Corps in World War II. U. S. Nav. M. Bull. 46: 520-527, Apr. 1946.

[2] The eye injuries during the American Revolution of 1776 and the War of 1812 were predominantly burns of the eyelids and eyes from the powder flash of the flintlock muskets or from bits of flint. The Civil War was noted for the frequent occurrence of sympathetic ophthalmia. World War I was noted not only for severe eye injuries caused by gunfire but also for ocular injuries caused by poisonous gases.

proptosis, blindness, and subsequent optic atrophy occurred. Iridodialysis and rupture of the choroid with secondary glaucoma were also prone to occur.

Burns of the face were noted frequently, but as a rule these did not produce blindness because the eyelids were principally involved. It was sometimes necessary to suture the eyelids together as an adjuvant to treatment.

Benkwith wrote an excellent description of injuries and diseases of the eye in war. In some of his patients with eye injuries, he irrigated the anterior chamber with a freshly prepared solution of calcium penicillin, 10,000 units per cc., and made subconjunctival injections using 2 cc. of this solution.

In the statistics that follow (table 30) we have defined blindness as a visual acuity of 20/200 or less, not correctible by any type of lens, or a permanent visual field of 15 degrees or less in its widest diameter. The records studied did not in every case include a definite statement as to visual acuity; therefore, these figures may understate the actual number of cases of blindness.

TABLE 30.—*Blindness, Navy and Marine Corps World War II*

	Caused by disease	Caused by injury		Total
		Combat	Non-combat	
Cases:				
Binocular blindness	42	85	14	141
Uniocular blindness	202	755	417	1,374
Total	244	840	431	1,515
Percent distribution:				
Binocular blindness	30	60	10	100
Uniocular blindness	15	55	30	100
All blindness	16	56	28	100

There were approximately 10 cases of uniocular blindness to 1 of binocular blindness. More than half of the cases of blindness resulted from injuries incurred in combat. Some of the war wounds causing bilateral blindness were almost freakish. One Marine was blinded by a bullet which penetrated the left temple and destroyed both eyes and the bridge of the nose. Bullet wounds accounted for only about 15 percent of combat-incurred blindness, whereas wounds from shell fragments caused nearly 60 percent.

Noncombat injuries were responsible for over one-fourth of the total number of cases of blindness. In about 40 percent, blindness resulted from lacerated or punctured wounds of the globe; in 20 percent, blindness was caused by foreign bodies.

Disease and poisoning accounted for one-sixth of the total number of cases of blindness, and these were more often binocular than uniocular. Seventeen percent of all cases of binocular blindness was due to methyl alcohol poisoning. Of uniocular blindness due to disease, neoplasms caused 8 percent and vascular diseases 4 percent, but in the majority of cases the cause was less precise. The distribution by site of uniocular blindness due to disease was as follows:

	Percent
Eyeball, generally	26
Cornea	12
Iris	6
Lens	10
Chorid and retina	33
Optic nerve, tracts, and centers	13

Enucleation was performed on slightly more than one-third of the patients with blindness due to medical causes, and on 21 patients with panophthalmitis. Neoplasms, principally malignant melanoma, were a frequent indication for enucleations.

Intraocular foreign bodies were of particular importance. In 67 percent the intraocular foreign bodies were classified as magnetic and in 33 percent nonmagnetic. In 50 percent of patients with intraocular foreign bodies, enucleation was necessary. While identical methods of handling intraocular foreign bodies were not used at all naval medical facilities, the diagnostic and therapeutic measures cited were generally applicable.

Frequently the injury was so extensive that the eye could not be saved, even though the intraocular foreign body was removed. Because the equipment necessary for the removal of an intraocular foreign body was large and cumbersome, evacuation to a base hospital was often necessary and therefore valuable time was lost. Many of these foreign bodies were removed successfully, however, with the aid of a portable x-ray machine and a silver wire sutured around the limbus to act as a locator.

The history of the type of eye injury was most important. Any evidence of a perforating injury to the eyeball or a bloody vitreous made one suspect an intraocular foreign body. A small conjunctival laceration with a subconjunctival hemorrhage was often the point of entrance of an intraocular foreign body. A careful examination with the loupe, slit lamp, and ophthalmoscope was the first step. A slit-lamp ophthalmoscope offered a valuable aid when the vitreous was cloudy. The point of entrance of an intraocular foreign body offered no definite clue as to its location.

Roentgenography offered the best diagnostic aid for the presence and localization of an intraocular foreign body. A film taken in one or two positions did not always rule out an intraocular foreign body and it was often necessary to resort to Vogt's skeleton-free or bone-free method for foreign bodies in the anterior part of the eyeball. With the retrobulbar injection of 2 or 4 cc. of physiological saline solution or 1 percent procaine hydrochloride, an artificial proptosis was produced and this frequently aided in roentgenographic diagnosis.

For successful removal of an intraocular foreign body accurate localization was most important. For magnetic intraocular foreign bodies the Berman locator offered much help and because of its portability it was used when an x-ray machine was not available.

The question of a double perforation of the eyeball was frequently answered by injecting air into Tenon's capsule to produce proptosis, thus creating an area with a density different from that of the tissues surrounding the eyeball and increasing the diagnostic effectiveness of roentgenography.

Localization of the intraocular foreign body could be accomplished by the modified Sweet method or by the Comberg contact lens. Thorpe devised a plastic contact lens with suture holes in it so that the lens could be sutured to the episcleral tissue. Stereoscopic roentgenograms were necessary.

If the anterior segment of the eyeball was intact and the foreign body was in the vitreous, it was removed by posterior sclerotomy. It was obvious that removal by the anterior route would result in damage to the lens, suspensory ligament, and ciliary body in such cases. The posterior route was preferable as a rule, in that it offered the minimum risk except for small foreign bodies not lying against the ciliary body.

When x-ray localization was impossible, tiny foreign bodies were often removed by the anterior route without material damage. Intraocular foreign bodies as large as 4 mm. in diameter could usually be removed without enucleation, leaving a fairly good-looking although sightless eye. Intraocular foreign bodies 0.5 to 2 mm. in size generally left a useful eye after their removal. Is was the practice to make diathermy punctures prior to the scleral incision when the posterior route was chosen. Foreign bodies in the anterior chamber and iris were removed through a keratome incision at the limbus. Some surgeons used a spinal puncture needle attached to a syringe; on producing suction a small foreign body in a traumatic cataract could thus be removed.

Nonmagnetic intraocular foreign bodies in the vitreous offered greater difficulty in removal. If the vitreous was clear, the Thorpe ophthalmic endoscope or the biplane fluoroscope was used. Special grasping instruments were devised by Thorpe and Cross.

Nonmagnetic foreign bodies anterior to the vitreous were removed by forceps through a corneal incision. If embedded in the iris, an associated iridectomy was done. Those in the lens were removed if and when the cataractous lens was extracted. If a nonmagnetic body in the eye was not easily accessible, it was left in situ.

Sympathetic ophthalmia following intraocular foreign body injury occurred in 5 patients. Penicillin was used in two of these without avail. The injured eye was removed in all cases and useful vision was preserved in the sympathetic eye.

In contrast to the experience in World War II, no case of blindness from sympathetic ophthalmia was recorded in the American Expeditionary Forces in 1917–18. Greenwood accounted for this in three ways:

1. Enucleations were performed of eyes so badly injured that a useful eye could not be expected.

2. Less devasting injuries were treated expectantly; often the wounds were sealed by a conjuctival flap with the result that healing took place without subsequent iridocyclitis.

3. Enucleation was done in all cases of persistent iridocyclitis.

The incidence of all types of eye diseases and injuries during World War II [3] was as follows:

Total	[3] 72,347
Diseases	58,972
Injuries:	
Battle casualties	979
Nonbattle	12,396

The number of eye injuries in battle casualties was not much greater than the number of cases of blindness resulting from war injuries. A war wound affecting the eye alone was relatively rare. Further, in reporting a casualty who had multiple wounds only the major wound was recorded. Therefore figures reported for battle wounds excluded minor eye injuries associated with more serious wounds of other parts of the body. Of all battle casualties, 1.07 percent were carried on the sick list with the eye injury as the diagnosis of primary importance. It must be assumed that other eye injuries occurred and required treatment but were considered, for reporting purposes, to be of secondary importance.

In a study of 901 nonfatal cases of heavier-than-air naval aircraft accidents it was found that 40 patients had minor injuries to one eye and 15 had minor injuries to both eyes. Four had major eye injuries to one eye and one had major injuries to both eyes.

Out of every 35 nonbattle injuries, one was an injury to the eye. Of these injuries to the eyes, 2.9 percent resulted in blindness in one or both eyes.

Diseases of the eye accounted for over four times as many admissions to the sick list as did eye injuries, but the admissions for eye disease included a considerable proportion of common conditions of slight severity. The ratio of blindness caused by disease to the total number of cases of eye disease was about 1 to 240; in other words, 0.4 percent of the patients with eye disease became blind.

[3] In World War I, out of 48,290 patients with war injuries, 1.54 percent had eye injury. Of these, 0.8 percent were serious.

Chapter XIV

Neurosurgery

Winchell McK. Craig, *Rear Admiral (MC) USNR*

The Bureau of Medicine and Surgery recognized neurologic surgery as a specialty long before the beginning of World War II. In fact, on 7 December 1941, the first medical specialist unit[1] to be activated was Neurosurgical Unit Number 54, which was immediately ordered to the U. S. Naval Hospital, Corona, Calif. The staff of this unit included 3 neurosurgeons.

Neurologic surgeons were ordered to duty in continental and extracontinental naval hospitals wherever they would be of most value. Realizing, however, that some naval hospitals were better equipped than others to cope with neurosurgical problems, the Bureau designated certain naval medical centers as neurosurgical centers. Such centers were established as the naval hospitals at Chelsea, Mass.; St. Albans, N. Y.; San Diego, Calif.; Philadelphia, Pa.; and Oakland, Calif., and at the National Naval Medical Center, Bethesda, Md. At these centers, to which patients needing combined specialized treatment were transferred, there were available consultants in orthopedic surgery, plastic surgery, maxillofacial surgery, orthodontia, and other specialties.

The neurosurgeons closely cooperated with these consultants, and with the general surgeons, in an attempt to rehabilitate the wounded.

CRANIOCEREBRAL INJURIES

In the years between World War I and World War II, it was recognized that the brain and meninges could resist infection to a remarkable degree. Harvey Cushing, in World War I, reported that the mortality rate of 36.6 percent in craniocerebral injuries was principally due to infections such as meningitis, abscess, and encephalitis. Geoffrey Jefferson, then neurosurgical consultant in the British Emergency Medical Service, estimated the mortality to be 20 percent. The introduction of the sulfonamides and penicillin changed the prognosis for all types of wounds in World War II. Much of the information concerning the treatment of wounds of the central nervous system stemmed from the early experiences of the British. Brigadier Sir Hugh Cairns, R.A.M.C., and his colleagues advocated the use of sulfadiazine on the first day in the treatment of craniocerebral injuries and meningitis and as a prophylactic measure. The British also initiated the use of penicillin intrathecally in the treatment of meningitis caused by susceptible micro-organisms. They showed that in cellulitis of the scalp, osteomyelitis of the skull, and infected brain fungus, the systemic administration of penicillin was of great value.

Early in the war it was established that the use of sulfonamides and penicillin was in no way a substitute for meticulous surgical procedure, although in craniocerebral wounds, pathogenic organisms gained access to the subarachnoid spaces or ventricular system regardless of the care used. It was found, however, that with the aid of the sulfonamides and penicillin complete débridement could be done and the craniocerebral wounds closed without drainage, the majority of them subsequently showing no evidence of infection.

The use of antibiotics reduced the incidence of intracranial abscess to a very low percentage. Advances in the treatment of those abscesses which did occur included the demonstration of the safety with which one could

[1] The medical specialist units, of which there were 110, were made up of U. S. Naval Reserve officers who were medical and surgical specialists.

wait until the abscess wall was well established, after which the abscess could be removed in its entirety without the occurrence of widespread encephalitis.

Penetrating wounds of the head and retained missiles received a great deal of thought and were thoroughly investigated. It was found that removal of a foreign body from the brain within 12 hours reduced the incidence of fatal infection. Failure of the foreign body to reach the ventricle greatly reduced the likelihood of death from a fulminating infection. At first it was believed that an unsterile foreign body deeply embedded but not communicating with either the skin or ventricle would not cause a fatal infection unless the ventricle at some time was penetrated. Early in the war, retained bone chips, rather than retained missiles, were believed to be the cause of abscess of the brain. Later, the occurrence of an abscess of the brain about a missile, even though the bone chips had been completely removed, was frequent enough to direct closer attention to removal of the missile. Electromagnets previously used to remove steel fragments were replaced, for the most part, by the simple procedure of using a piece of magnetized steel held in a pituitary rongeur. Intracranial hematoma was uncommon in missile wounds of the brain.

It was found that with the use of antibiotics, extensive reparative operations on the head for craniocerebral wounds could be delayed until the patient was transported to hospitals staffed and equipped for the treatment of such injuries.

Early in the war, the use of tantalum and acrylic resin was recommended for repairing skull defects. Prior to this, cranial defects had been repaired with sheets of celloidin or various metallic substances, including silver, and by flaps from the outer table of the skull. The lack of tissue reaction made tantalum a safe metal for use in making repairs.

It was recognized that the insertion of a tantalum plate would not relieve convulsive seizures. On the other hand, in patients in whom encephalography did not disclose evidence of a cystic or degenerating lesion, the insertion of a plate frequently relieved the posttraumatic headache. The frequent occurrence of convulsive seizures following craniocerebral injuries was the source of a great deal of concern in the Navy, and in determining the prognosis of penetrating wounds of the head, the fact was not forgotten that such seizures could appear weeks, months, or even years following the head injury.

The British found that all kinds of war wounds of the skull were followed by convulsions in 24 percent of patients, probably because the underlying injury to the brain was more severe than that which occurs in injuries of the skull in civilian life. The British also found that, although convulsions were more certain to follow direct injury to the sensorimotor cortex than damage to some region at a distance from the rolandic area, the exact site of cortical trauma did not seem to have an important bearing on the occurrence of convulsions. The first seizure might take place within a few hours or as late as 20 years after the original injury, although the initial onset was usually noted during the first 2 weeks.

For the prevention of craniocerebral injuries, Cairns perfected the protective helmet worn by motorcyclists in the British Army. The steel helmet worn by the American soldier and Marine furnished excellent protection against such injuries, but it had not been designed with aircraft and tank personnel in mind and could not be used to advantage by them, mainly because of its size, shape, and weight. Colonel Loyal Davis (MC) AUS, consulting neurological surgeon in the European Theater of Operations, designed a close-fitting helmet that was made by molding pieces of acrylic resin to conform to the frontal, temporal, occipital, and vertex portion of the skull; this was then covered with leather and lined with chamois and fleece. Such a helmet permitted movement of the head in all directions, provided complete protection over the frontal and occipital areas, and weighed only 18 ounces. Designed for the Army and adopted by Marine and Navy fliers early in the war, this helmet significantly reduced the incidence of craniocerebral injuries.

Blast injuries occurring in the water were of great concern, and much experimental work was done at the National Naval Medical Center in analyzing these wounds and determining whether some means of protection could be provided. In these injuries, cerebral lesions without any wounds of the head were noted.

Cairns, of the British Army, believed that the possibility of cerebral fat emboli had to be considered, although they were not always found at necropsy. Another mechanism that undoubtedly produced brain injury was the change in velocity of the head following a blow. It was shown experimentally that the velocity behind the blow and the restricted motion of the brain within the skull were important factors in cerebral trauma in closed head injury, because a type of shearing strain results when the brain lags behind the rotational acceleration forces. At the National Naval Medical Center this was demonstrated by experimental work wherein lucite plates were substituted for the calvaria in monkeys, permitting direct observation of the brain as the skull was subjected to blows of measured intensity. Motion pictures made at the rate of 2,000 frames per second showed a very definite rotational movement of the brain.

The brain could also be observed through this lucite cap when certain gases were injected into the subarachnoid space. The effect of hypoxia, of oxygen, and of vasodilating chemicals could also be noted through the transparent acrylic resin. Some of these monkeys were sent to Princeton University where research on ballistics was in progress, so that the explosive effect of the bullet within the brain could be observed. This experimental work was probably the greatest contribution to neurosurgery during the war because it showed without question the effect upon the underlying brain of force directed against the intact skull, and also the effect of penetrating missiles of different velocity.

SPINAL CORD INJURIES

One of the great problems of war surgery has been the treatment of patients with injuries to the spinal cord. The incidence of vertebral fractures involving the cord was high on shipboard and in landing operations. Another type of injury was the disintegration of the spinal cord that followed concussion due to the passage of projectiles, not through the cord itself, but in its neighborhood. This lesion of the spinal cord did not respond to any type of surgical treatment, but early in the war it was established that laminectomy should be done to insure that no fragments of bone were compressing the cord and producing disability. This was indicated because preservation of even a small amount of motion or sensation in the lower extremities permitted easier and more complete rehabilitation of the patient.

In closed wounds, such as fracture-dislocation of the spine, the application of traction was frequently followed by improvement. In fracture-dislocation of cervical segments of the spinal cord, it became standard practice to apply traction early with Crutchfield tongs attached to the skull, or with a head harness to extend the neck. Decompressive laminectomy performed weeks or months after spinal cord injuries rarely benefitted the patient when there was evidence of a complete transverse lesion without subarachnoid block; nevertheless its use should be considered.

Open wounds always required the most careful débridement. It was common practice in World War II to remove all bone fragments and foreign bodies and cleanse the wound, without opening the dura in the potentially infected field. Dural rents were closed by suture or by the application of living fascial grafts, in order to stop the leakage of cerebrospinal fluid. Chemotherapy was of great assistance in dealing with the wounds of the spinal cord.

The nursing of patients with injury of the spinal cord proved to be complicated. The use of indwelling catheters and regulated enemas aided in the prevention of decubitus ulcers. Tidal drainage was successfully used in some neurosurgical centers, while, in others, cystostomy was employed to empty the bladder. Drainage with an indwelling catheter, the development of an automatic bladder, and transurethral section of the hypertrophied sphincter contributed to rehabilitation.

The prevention of decubitus ulcers was found to depend on good nursing care. When they occurred in spite of adequate nursing

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care and nutrition, they were treated with the attention necessary to prevent further infection. Excision of the ulcer and the use of free skin grafts or pedicle skin grafts hastened healing.

In the nutrition of patients the value of maintaining serum proteins and the albumin-globulin ratio at normal values was demonstrated repeatedly. A high protein diet provided an average daily intake of about 2,800 calories.

The establishment of efficient urinary function was one of the primary goals in the care of these patients. Tidal drainage was used extensively, although it required the attention of a medical officer, a nurse, and a hospital corpsman and was not a simple, self-regulating mechanism. It did, however, afford a means of continuing cystometric study and assisted in minimizing bladder infections. In spite of its drawbacks, it seemed to be the only certain and safe means of training the bladder for automatic function. Various methods of urinary drainage which were used in the early days by both the Army and Navy included (*a*) permitting the bladder to distend and overflow, (*b*) manual expression of urine, (*c*) perineal urethrostomy, (*d*) suprapubic cystostomy, (*e*) repeated urethral catheterization, and (*f*) an indwelling urethral catheter.

Under favorable conditions, automatic micturition developed after complete transection at any level within the cord or cauda equina, appearing earlier when the lesion was located between the seventh cervical and fifth thoracic segments. It did not develop in incomplete lesions of the cord, although the effect of extravesical stimuli on the initiation of micturition may be quite similar in either a complete or partial transection. It occurred with remarkable regularity at intervals as long as 3 hours, but with very low efficiency as evidenced by a large amount of residual urine. Automatic micturition will develop only when there is no mechanical obstruction of the bladder and when the sphincter is capable of reflex relaxation. Automaticity will not develop when sepsis or calculi are present, or in patients with severe debilitation.

Another complication encountered in the rehabilitation of patients with injuries of the spinal cord was the persistence of pain in the extremities. This was treated in a number of ways, including chordotomy, rhizotomy, and the intrathecal injection of alcohol. The release of abnormal reflex activity was treated by the injection of alcohol and by resection of the motor root. Because each patient was an individual problem, no general rules could be applied regarding the treatment of this complication.

PROTRUDED INTERVERTEBRAL DISKS

One of the perplexing problems was ruptured nucleus pulposus with its associated syndrome of low back pain and sciatica. It soon became apparent that operations for the relief of such pain were unsuccessful in the majority of patients, and that they had to be returned to hospitals in the United States.

A statistical study carried out at the U. S. Naval Hospital, Bethesda, Md., disclosed that only 62 percent of enlisted personnel returned to duty after operations for the relief of pain due to ruptured nucleus pulposus, whereas almost 100 percent of officers returned to duty after the same operation. The procedure of choice was a limited type of hemilaminectomy which was introduced before the war. It was found that a certain percentage of patients who had low back and sciatic pain also had changes in the bony structures or other definite lesions such as spondylolisthesis.

INJURIES OF PERIPHERAL NERVES

The treatment of peripheral nerve injuries during World War II was aided by experimental investigation, planned and implemented through the Office of Scientific Research and Development of the National Research Council. Among the advances were: (1) Tarlov's work on the use of plasma glue to facilitate the union of nerve ends that could be approximated without tension, (2) the study of the traumatic degeneration produced by the concussive effect of gunshot wounds in which the nerve trunks were not severed, (3) the development of new staining methods to demonstrate the different patterns of nerve regeneration after end-to-end suture, (4) the use of autogenous and homogenous grafts, and (5) the evolution of electromyographic methods for the study of denervated and reinnervated muscles.

One of the most important contributions made during the war in the treatment of injuries of peripheral nerves was the observation that a second operation should be performed on patients in whom the injured nerves did not show any evidence of regeneration within 3 months after primary suture. In a large number of patients the second operation disclosed that the ends of the sutured nerves had become separated because of motion or tension. To determine whether or not regeneration was taking place, certain electrodiagnostic procedures were developed. The changes in response to galvanic stimulation which characterize the complete reaction of degeneration are hyperirritability of the muscle to galvanic stimuli, sluggishness of relaxation following the contraction wave, lessening of the ratio between the amperage necessary to produce tetanic contractions and the rheobase almost to unity, and increase in the efficacy of anodal closing stimuli to equality with cathodal closure. The practical application of electrodiagnostic methods permitted evaluation of regeneration at an earlier date than could be done by clinical observation. If, after sufficient time had elapsed following injury, the characteristics of denervation were not found by electrodiagnosis, the nerve was considered to be spontaneously recovering and operation was not required. If, after a severed nerve had been sutured, the characteristics of the denervated state were not found, it was assumed that recovery was taking place. When a sufficient time had elapsed after nerve injury for regeneration to have occurred, and the characteristics of denervation were found, operative intervention was necessary.

One of the great problems in the treatment of nerve injuries was the fact that they were frequently associated with damage to bone, muscle, or skin. Thus it was apparent early in the war that the combined efforts of the plastic surgeon, the orthopedist, and the neurosurgeon were essential in treating peripheral nerve injuries, in order that any associated injuries might be treated simultaneously. This eliminated a great deal of controversy with regard to the use of splints, the application of braces, and the delayed treatment of fractures. Results of treatment of injuries of peripheral nerves were more satisfactory in the neurosurgical centers where there was complete cooperation between the different departments. Physical medicine also played its part in the treatment of these injuries, the use of passive motion and massage of the extremities contributing much to the preservation of function of joints and muscles.

The use of new staining compounds developed during the war years revealed that after any nerve injury the mesodermal tissues are the first to react by proliferation. This proliferation occurs at the site of the lesion, and extends into the gap between the severed nerve segments, into the degenerated distal nerve segment, and into the perineurium and epineurium of the central segment. Regenerating nerve fibers follow the path of proliferating histiocytes and collagenous fibers. This observation appeared to be evidence against the generally accepted theory that the regenerating distal segment of the end of a cut nerve exerts a chemotropic influence on regenerating nerve fibers growing out of the end of the central stump. Mesodermal tissue plays a primary role in the organization of autogenous and homogenous grafts in laying down a scaffolding that is followed by regenerating nerve fibers. Depending on the degree of survival of the mesodermal elements in the graft and the degree of necrosis that occurs, this scaffolding follows the original nerve structure or becomes irregular, deviating, and confused in its course and thus influences the course and the efficacy of the regenerating nerve fibers.

One of the most difficult problems in the treatment of peripheral nerve injuries occurred in patients with gunshot wounds in which the continuity of the nerve had not been interrupted. Extensive injury was found in a nerve near the site of trauma caused by a missile that had passed through the adjacent tissues without penetrating the nerve. It was difficult to realize that degeneration of long segments of a nerve could take place, both centrally and peripherally, as a result of this type of injury.

Young and Medewar in England, and Tarlov in this country carried out a series of experiments by using concentrated blood plasma gel to unite the ends of divided nerves. This method of repairing nerves was given a clinical trial in the U. S. Naval Hospital, St. Albans, N. Y., where it was employed in one series of cases while in a parallel series suture with silk, nylon, or tantalum wire was used.

Experiments on the use of different types of sutures were carried out at the National Naval Medical Center. It was found that those sutures which caused the least reaction in peripheral nerves were human hair, nylon, silk, and tantalum wire. The use of catgut was not advised because of the marked reaction of the nerve cells about the suture.

The syndrome known as "causalgia" was one of the great problems in the treatment of injuries to the extremities. Operations on the sympathetic nervous system with denervation of the affected limb were followed by relief of pain in a high percentage of patients.

Among the advances in neurosurgery was the introduction of hemostatic agents such as "fibrin foam," a fractionation product of blood plasma, and "gelfoam" made from ordinary gelatin.

A NEUROSURGICAL HEADREST

Certain neurosurgical operations have been greatly facilitated by placing the patient in a sitting or upright position. In some clinics, dental chairs were converted for use in these procedures; in others, elaborate appliances were made that could be attached to the operating tables, or various special tables were constructed for this purpose.

Shortly after the beginning of the war, it became apparent that the hospitals of the Armed Forces needed an appliance that could be attached to an ordinary operating table. From a practical standpoint, this attachment had to be inexpensive and of relatively small size, and had to combine certain essential features so that it could be used by the Army as well as the Navy. Such an apparatus, known as the Craig headrest, was constructed at the National Naval Medical Center. This headrest could be attached to the ordinary operating table in use in the Army and Navy hospitals and could be easily stowed away when not in use. It proved valuable in performing operations on the brain and cervical portion of the spinal cord.

One of the great objections to the use of the upright position for neurosurgical operations had been the variations which occur in blood pressure during the operations, necessitating lowering of the patient's head from time to time in the course of the procedure. The headrest in question obviated this drawback, as the patient could be placed in the sitting position with the feet and legs elevated to the level of the head. As a further precaution, it was found that splinting the vascular bed of the lower extremities had a stabilizing effect on the blood pressure. It was noted that if the legs were wrapped in ordinary bandage of one thickness from the ankle to the groin, the blood pressure would not vary even when the operation was carried out under general anesthesia, unless there was an extraordinary loss of blood.

A NEUROSURGICAL FLYING UNIT

The limited number of adequately trained neurosurgeons in the Navy made it important that they be used wisely. The Surgeon General, Vice Admiral Ross T McIntire, was cognizant of this fact and suggested the formation of a flying neurosurgical unit to be stationed at the National Naval Medical Center. This unit, authorized by the Bureau in July 1942, was to be ready to answer emergency calls up and down the East Coast in the event of bombing by the enemy. Admiral McIntire realized that adequate operations on the brain, peripheral nerves, and spinal cord required special equipment not available in all service hospitals and also realized the importance of a trained surgical team.

Experience had shown that in the management of injuries of the brain and spinal cord, transportation of the wounded to the nearest hospital where adequate care was available resulted in a lower mortality rate and a more satisfactory convalescence. Because it was realized that bombing of the Atlantic coast might result in a great number of central nervous system injuries at a place where adequate neurosurgical care was not obtainable, the flying neurosurgical unit was maintained throughout the war to augment the staff and equipment of any hospital along the coast in an emergency. It not only assured specialized surgical care in widely separated areas, but greatly reduced the need for a neurosurgical team in every hospital.

The neurosurgical flying unit consisted of a neurosurgeon, an assistant neurosurgeon, an anesthetist, and a hospital corpsman. The entire equipment was so assembled that the four men comprising the team could transport it from the hospital to the flying field in a station wagon or ambulance, carry it to the plane, and arrange for transferring it to the hospital where needed. It consisted of a small portable electrosurgical unit, a fiber case for neurosurgical instruments, a small portable suction unit, and a portable operating table. The carrying cases for supplies of necessity had to be light and easily handled, so Marine sea bags with handles were used. These contained towels, linens, gloves, pans, gowns, and gauze. A list of the contents was typed on linen, which was sewn on the flaps. Operating room supplies such as gowns, drapes, and towels were packed in three sea bags. Necessary solutions such as plasma, serum albumin, saline solution, and pentothal sodium and equipment for intravenous administration were packed in similar bags. Four other medical kits containing all necessary incidental items for proper surgical care were also included. The total weight of these items is shown below.

	Weight of equipment (pounds)
1 first-aid kit	12½
1 suction apparatus	23
1 fiber case of instruments	73
1 operating table	87
1 electrosurgical unit	70
1 first pack	50
1 second pack	52
Total	367½

The supplies in the Marine sea bags, the electrosurgical unit, the suction apparatus, the fiber case of neurosurgical instruments, and the portable operating table were sufficient to carry out emergency neurosurgical procedures whether in an emergency room, in a schoolhouse, or in temporary hospital quarters. Forty minutes after the unit was alerted, the instruments could be sterilized, the supplies assembled, and the unit underway to the airport.

No history of any period is complete without comment on the mistakes that have been made. Among the outstanding errors made during World War II, were lack of cooperation and immobility of the surgical specialists. During peacetime, the number of surgical specialists needed to care for civilians is not so great as it is in time of war. In the tables of organization of naval hospitals other than neurosurgical centers and hospital ships, some surgical specialties, particularly the specialty of neurosurgery, should be eliminated. Neurosurgical teams and consultants should be mobile. Reports have indicated that the incidence of injuries to the central nervous system during World War II was about 10 percent of all casualties, and it is a waste of time and talent to immobilize a neurosurgeon to take care of 10 percent of the wounds which come to a naval hospital. It might be well to create neurosurgical teams that could go wherever needed and be available as indicated. In another war the neurosurgical consultant in a given area should be responsible for the neurosurgical activity in the naval hospitals of that entire region. Only in this way will it be possible to take care of the neurosurgical wounds satisfactorily and supervise the rehabilitation of patients who have sustained injuries to the central nervous system.

Chapter XV

Peripheral Neurosurgery

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Most of what is known about the treatment of nerve injuries was learned during a war. It is only then that a sufficient number of these injuries can be grouped together for the investigations necessary to establish criteria for more accurate diagnosis and better surgical techniques. The first effort in this direction was made during the Civil War when the Surgeon General of the U. S. Army set aside Turner's Lane Hospital in Philadelphia for the study of treatment of nerve injuries.

No adequate analysis of the nerve injuries that occurred in World War I has ever been made, yet the evidence has clearly indicated that this group of casualties was of considerable medical and economic importance. Long before World War II began, it was known that approximately 10 percent of all war wounds were complicated by serious injury to one or more major peripheral nerves, and that the proper care of these patients required specialized training in diagnostic and prognostic methods, in addition to the most careful surgical technique.

In World War I, nearly 45 percent of the nerves sutured failed to recover any function. Nerve injuries have always required long periods of observation and an inordinate amount of attention. These facts indicated that the economic importance of nerve injuries resulting from war wounds is much greater than the number of such injuries would suggest.

The story of the development of peripheral neurosurgery at the U. S. Naval Hospital, Oakland, Calif., which follows, is illustrative of much that was learned. The first group of patients with nerve injury reached the hospital from the fighting front on an average of 5 months after they had been wounded. The principal reason for this delay was the critical shortage of transports in the first year of the war. It was impossible to bring the patients directly to the mainland, so they were transferred from one naval hospital to another in the Pacific Area until transportation to the United States became available.

An example of the problems presented by the patients with nerve injuries is one who had an ischemic paralysis with severe causalgia in his left arm and hand. He had been wounded when his ship received a direct hit, sustaining wounds of his back and the posterior aspect of his left shoulder. When received for treatment at this hospital, his left hand was cold, cyanotic, functionless, hyperesthetic, and the source of deep, burning pain. There was evidence of an arteriovenous aneurysm and a large, firm swelling just above the inner condyle of the humerus. The hard mass was thought to be an organized hematoma, but the roentgenogram and subsequent exploration revealed it to be an 11-ounce rivet. Apparently the rivet had been driven through the man's shoulder and down the inner side of the upper arm, to lodge near the humeral condyle. Surgical excision of the arteriovenous aneurysm and removal of the rivet did not relieve the patient's pain. It was months before this could be brought under control. Three exploratory operations were done before the injury was finally demonstrated to involve the nerve, from the elbow region to high in the axilla. The median nerve was the last nerve trunk to be sutured. When the patient was finally discharged from the service 2 years after being wounded, it was still too early to be sure that the last nerve anastomosis would be successful because considerable disability still remained in his hand.

At this hospital many patients with nerve injuries were not examined by a neurosurgeon. Nerve lesions that complicated fractures were usually treated by the orthopedic surgeon, and the same situation held true on other specialty wards. Some of these nerve lesions were very skillfully handled, others received the same casual treatment they usually received in civil practice. The intern or surgeon who first exposed the lesion would suture the nerve; the suture material and technic depending upon what was at hand. Often nerve injuries were unrecognized, or were neglected for long intervals because the specialist was primarily interested in some other phase of wound healing.

An orthopedic surgeon whom I encountered one day on the hospital ramp, said to me: "I'm sorry you weren't in the surgery this morning when I changed the cast on a fractured femur of one of my patients. I think his sciatic nerve has been severed, and I wanted to consult with you about it."

I asked when the man had been wounded and was told that he had been struck by a bullet during the early fighting on Guadalcanal, more than 6 months previously. I then asked how long it had been suspected that a nerve lesion existed, and whether or not anything had been done about it.

"Well," he replied, "I've suspected that the nerve was gone because of the paralysis of his foot, but I wanted to get a solid union of the fracture before investigating the nerve lesion. The bone is quite solid now, and I believe this man will have a fine result after a very serious type of fracture."

Fortunately, this casual attitude toward a nerve lesion was not the usual one. Most of the medical officers were alert for evidence of nerve involvement in their patients, and were glad to share the responsibility of care with some one interested in this type of lesion.

Progress in peripheral neurosurgery began when the members of the staff realized the desirability of segregating patients with nerve injury for study and treatment. When some other complication such as a fracture was present, the patient was often left on that specialty ward, and the neurosurgeon shared the responsibility for treating the nerve disability.

The major difficulty in treating patients with nerve injury was that it was often impossible to retain them on the ward long enough to complete the diagnostic procedures and the necessary surgical explorations, to say nothing of the follow-up studies they required. There was an enormous pressure for more beds to receive the increasingly large numbers of patients arriving from the Pacific. To meet this demand, the patients were moved to nearby convalescent hospitals at Santa Cruz and Yosemite, or to the more distant hospitals in Glenwood Springs, Colo., and Sun Valley, Idaho, or to naval hospitals in other parts of the United States. Ward medical officers were expected to transfer any patient fit for travel. The fact that the patient might be in the midst of prognostic studies or just recovering from a surgical exploration made no difference; if moving the patient would not jeopardize his life, he went. The majority of our patients sent elsewhere were rarely seen again by the original physician. Regrettable incidents that occurred among the patients who returned might have been averted if there had not been so much pressure to clear patients from the wards.

During the development of a Peripheral Nerve Service at this hospital, there were two principal factors that made it difficult to provide adequate care for the patient with a nerve injury. The first of these was the rapid turnover of patients and the second was the lack of continuity of service among staff personnel. By using double-decked bunks for half of our ward, we could accommodate approximately 70 patients in the neurologic department. The remainder of the patients with nerve injury were scattered over the hospital.

The routine tasks of the ward represented only a small part of the real work of the clinic; in addition to the maintenance of the records, there were detailed histories to record, examination and mapping of sensory and sweat patterns to carry out, diagnostic and prognostic testing to be done, and periodic re-examinations for each patient. All of these activities, except the most routine, required special skill and training on the part of the examiner; otherwise the findings were not worth recording in the patient's clinical record. Whenever possible, a medical officer was assigned to the Peripheral Nerve Clinic to assist with the ward work. About the time this assistant had acquired sufficient training to make his observations reliable, however, "orders" would arrive transferring him to some other hospital. There were also interns in training at Oak Knoll, and one was assigned to our ward for a period of 2 weeks. The continuity of service among the nurses and corpsmen assigned to the ward rarely extended beyond a month or two. A nurse who had evinced an aptitude and interest in the work might be called away to do night duty or work in the hospital laundry, or a corpsman just completing his training in mapping sensory or sweat patterns would be transferred to another ward or to work in the galley.

Yet, in spite of the rapid turnover of patients and staff, we discovered some interesting facts. The first of these was that plaster casts, used to support paralyzed muscles in the uncomplicated case of nerve injury, did more harm than good. Of course, there were other complications such as a fracture that required rigid fixation of the limb, or a patient with extensive wounds of the soft parts might require a plaster cast for comfort and safety during transfer to another hospital. Plaster casts were applied routinely to patients with uncomplicated nerve paralysis. Physicians had been taught that paralyzed muscles must be supported because otherwise the opposing muscles would develop a contracture, or the paralyzed muscle would be hopelessly stretched. There is an element of truth in both of these claims, although not enough to justify the routine employment of plaster-cast fixation for long periods. Because of this teaching, however, and because they lacked more suitable splints, the medical officers in the Pacific area were using plaster casts to support paralyzed muscles. During the months our patients had been shifted from one Pacific area hospital to another, the patients never stayed long enough in one hospital to permit thorough investigation of the need for cast fixation. If the cast became soiled, it was removed and a new one applied. By the time some of the patients reached a hospital in the United States their limbs were wasted and their joints stiffened. Sometimes, the tissue damage caused by the cast was more serious than the nerve injury and required months of physical therapy treatment.

One of the first routine orders on our service was to bivalve all plaster casts as soon as the patient was admitted to the ward. This permitted an adequate examination of the limb. In most instances cast fixation could be discarded at once or physical therapy treatments started while the patient was still supported in the bivalved cast. Our reaction to cast fixation extended to all forms of splinting. We questioned whether even the lightest splint was justified and ultimately rejected all splint support in every uncomplicated nerve paralysis except that of the peroneal nerve. The bed patient with foot-drop was protected from the pressure of bed covers, and passive motion of the foot was encouraged. The ambulatory patient with foot-drop was provided with a light spring support attached to his shoe that he could wear or not as he chose. If he thought that it prevented his stumbling, and concealed his disability better, he was permitted to wear the splint. If he didn't mind "slapping the deck" with his foot as he walked, or if he wore a Marine shoe which lessened the drop of the foot by its support of the ankle, he was not required to wear a splint (patients with peroneal and radial nerve paralysis were excepted). We taught patients with wrist-drop to carry their hands at their sides and use the hand in the supinated position. These men undoubtedly made much more use of the affected hand, and a casual visitor seldom noticed the defect. Evidence that the lack of splint support to paralyzed muscles was harmful was rarely noted. We were convinced that the absence of splints favored a greater activity and a better morale, at the same time maintaining the tissues of the limb in a more normal state than with a splint.

The second observation of interest was that many patients whose history and health records indicated that their nerve paralysis had been complete for weeks or months, while they were in the South Pacific, were showing signs of spontaneous recovery by the time they reached Oak Knoll. One of the firm convictions I had had when I entered active service in the Navy was that all nerve lesions should be surgically repaired as early as possible after injury. When a complete loss of function of a nerve exists in conjunction with an incisional wound, one is justified in assuming that the nerve trunk has been severed and that immediate surgical intervention is indicated. However, wounds caused by high-velocity missiles are capable of paralyzing nerve function in many ways other than by complete transection of the nerve trunk.

A high-velocity missile releases an enormous amount of kinetic energy as it passes through human tissues, and produces in its wake a large pulsating cavity. Nerves at some distance from the path of the projectile may sustain injury by the combination of the effects of impact and the stretching and tearing of the tissues during the phase of cavitation. The damage inflicted may be sufficient to paralyze all function and interrupt the nerve fibers and yet leave the nerve trunk in anatomic continuity. A fusiform neuroma usually develops at the site of the damage and this offers varying degrees of obstruction during the regeneration of fibers. Many injuries of this type fail to produce as serious a distortion of the intraneural fiber patterns as that caused by the most painstaking nerve suture. In some patients who had begun to regain function, the degree of recovery promised to be more rapid and complete than we could have hoped for after resection of the local neuroma and an end-to-end anastomosis of the nerve trunk.

Without this war experience of spontaneous recovery in damaged nerves, many lesions would have been resected that might better have been left alone. Because of this experience a very conservative attitude regarding these local lesions was assumed. This led us into error at times. Not infrequently surgical exploration was delayed in the belief that spontaneous regeneration was taking place, only to be required later when it was found that the damage to the nerve trunk had been more serious than we had realized. Such errors, however, usually meant no more than a delay in the surgical resection and suture, while an early resection of the lesion might have meant a less satisfactory end result. It will be impossible to evaluate the results of this conservative policy until follow-up studies can be completed, but the impressions gained from our observations suggest that the policy is a sound one.

The question of what to do with lesions in continuity imposed a heavy responsibility on the surgeon. Should the lesion in continuity be resected or not? It might be too early for regenerating fibers to have reached their terminal distribution even if they had been successful in passing the damaged nerve segment. For this reason clinical examinations and electrical tests of the paralyzed muscles would not help the surgeon in making his decision. Was there any other method by which nerve fibers growing through a neuroma could be demonstrated? It was thought that an oscillograph might aid in the surgery. If nerve fibers were growing through the neuroma it might be feasible to demonstrate action potentials set up by electrical stimulation passing across the damaged segment.

Lt. Comdr. Henry Newman was assigned to carry out all the electrical testing. His knowledge of electronics enabled him to successfully record action potentials in the surgery and to construct a testing instrument to determine strength-duration curves, chronaxie, and "tetanus-twitch ratios" as well as the usual RD reactions.

The Peripheral Nerve Clinic at Oak Knoll reached its maximum efficiency about the time the war ended. At that time the operative schedule was full, and each of the many activities of the clinic was at its best. Detailed case records had been collected on more than 1,200 major nerve lesions, the great majority of which were caused by high-velocity missile injury.

One of the most promising of our clinical investigations concerned changes in the sensory pattern after the permanent loss of function in a mixed nerve. It is a well-known fact that the anesthetic zone appearing immediately after such a nerve has been cut begins to shrink in size long before regeneration could take place. The accepted interpretation was that sensory fibers supplying adjacent areas normally overlap one another, and that when one nerve is cut the overlapping fibers of the neighboring nerve gradually recover their ability to transmit sensory impulses. According to this interpretation, there is no active in-growth of new fibers from the neighboring nerve. The "isolated" supply of the cut nerve, that zone exclusively supplied by it, was supposed never to recover sensibility unless that nerve regenerates. For instance, the distal part of the index finger is believed to represent the "isolated" supply of the median nerve, so that recovery of sensibility at the tip of the index finger was interpreted as incontrovertable evidence that the median nerve is regenerating. On the other hand, animal experimentation carried on in England has shown that in a rabbit's leg there occurred an active ingrowth of new sensory fibers from neighboring nerves to provide a denervated zone with sensation. Our clinical observations seemed to show that in human subjects as well as in the rabbit the factor of "invasion" contributed to the gradual shrinking of anesthetic zones in exactly the same way that skin grafts become innervated. Because this observation is of some clinical significance, the following brief summary of a case is recorded:

A marine wounded at Vella Lavella on 24 August 1943, sustained extensive damage to his right median nerve when a large piece of shrapnel plowed obliquely up through his forearm. The usual pattern of sensory and motor loss characteristic of median nerve paralysis supervened. Three attempts were made to secure an end-to-end anastomosis of this damaged nerve, and when these attempts had failed a frozen-dried graft of human nerve was used to bridge the remaining gap. During 2 years of observation, the zone of complete anesthesia steadily diminished in size until at the end of the time there was quite a satisfactory recovery of sensibility, even at the tip of the index finger. If this man had had a simple suture of his median nerve we would have rated his sensory recovery as "satisfactory" and would never have questioned the evidence that the median nerve had regenerated. Yet, because we were inclined to question the efficacy of any nerve graft, this man was subjected to further investigation. An infiltration of 2-percent novocaine into the median nerve, both above and below the graft, failed to alter in the slightest degree the sensory status of the hand, while novocaine block of the ulnar nerve rendered the fingers completely anesthetic.

It should be clear that this fact of active "invasion" of sensory fibers into denervated areas has a clinical significance. The one great task remaining to be done in relation to peripheral nerve casualties is to carry out a follow-up study of the results of nerve surgery. It is important for us to know the capacity to regenerate of each major nerve, and the influence that the level of the interruption and the technique of anastomosis may exert on the recovery of function. The success of a nerve suture will be judged by the degree to which motor and sensory function is restored. In order to avoid erroneous conclusions based on these studies of end results, the examiner must make a careful distinction between true regeneration of the nerve under question and the invasion of sensory fibers from neighboring nerves.

Several obvious lessons can be drawn from this discussion. Insufficient importance was given to peripheral neurosurgery in preliminary planning, and valuable time was lost before special clinics were established. Even then there was at first little continuity of service, so that clinic personnel were continually being transferred. There was a general lack of appreciation of the importance of early attention to nerve injuries by specialists, of the danger of transferring certain patients, of the need of a long follow-up study of each case, and of the great value of research and investigations based on the abundant material available.

To make this criticism constructive, one should show how preliminary planning might improve the status of peripheral neurosurgery in any future war. No better method for this suggests itself than outlining the program for the care and study of nerve casualties which was carried out by the British.

In England, during World War II, a central body was made responsible for the treatment of all nerve casualties, instead of having each branch of the military handle the problem as it saw fit. This Peripheral Nerve Injuries Committee of the Medical Research Council was composed of experts from various parts of England. Its members formulated policies, authorized research investigations, and supervised follow-up study of all nerve injuries, whether they occurred among civilians or military personnel.

In June 1941, this Committee adopted a comprehensive program whereby it was possible to follow each patient throughout his period of active treatment, and for at least 3 years thereafter. They provided a system of uniform report forms for recording histories, evaluating nerve recovery, and describing the findings of surgical exploration of nerve lesions. The Committee encouraged many research projects and saw that contributions relating to nerve surgery or the more fundamental aspects of nerve physiology were made available to every worker in this field.

Three great centers for the special care and study of nerve injuries were developed, one at Winwick, another at Pyrford and Botleys Park, and the largest one at Oxford in the Wingfield-Morris Orthopedic Hospital. Two additional centers were established later. Because of the location of these centers in various parts of the country, nerve casualties could be sent to a hospital near their home. This made it possible to shorten the period of hospitalization for many of the ambulatory patients who could be sent home between operations or special investigations, thus freeing a hospital bed until it became time to recall the case for further observation.

Even after a man was discharged from service and his pension rate established, he was required to report at definite intervals to a member of the Peripheral Nerve Injuries Committee. His ability to draw his pension was made dependent upon his reporting. This arrangement ensured an adequate follow-up study of each case and enabled the Committee member to send any man back to the hospital if further treatment or investigation was indicated. At each of the centers, the essential nerve surgery was performed by men with special training in this work. The work of the surgeon was supplemented by that of a trained corps of physicians who made the diagnostic and prognostic examinations which served to guide the surgeon in his operative decisions. To complete the program, the Peripheral Nerve Injuries Committee fostered research at the centers. The investigations in the clinics were supplemented by laboratory research into the fundamental problems of nerve physiology and pathology.

The details of the beautifully coordinated British program were reported to the National Research Council in 1943. Most of this information had, however, been available to the military authorities in this country since 1941, and it is hard to understand why the Navy should not have incorporated into their own program the best features of the British plan, particularly after it was called to their attention in 1943. In its special planning for nerve casualties, the Army apparently did better than the Navy. At least, they set up a good program for the training of young surgeons in peripheral neurosurgery, established 20 centers for the treatment of nerve injuries, and developed a "Peripheral Nerve Registry" with uniform records for all the nerve anastomoses performed by Army surgeons, long before the Navy showed any active interest in adopting similar measures. Yet, as far as I can judge, neither the Army nor the Navy even approximated the coordinated activities of the Peripheral Nerve Injuries Committee in England in handling this important group of war casualties, or in fully utilizing the available clinical material in the advancement of scientific knowledge.

If the United States ever again becomes involved in a war, more adequate preparations should be made for the care of patients with nerve injuries.

Chapter XVI

Thoracic Injuries

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The opportunities presented during World War II for the treatment of thoracic injuries were without parallel in medical history. Many of the barriers that stayed the hand of the surgeons in World War I had been surmounted. Infection, which killed more men in the Civil War than did bullets, was no longer the principal cause of death. Wounds of the thorax comprised approximately 6 percent of all war wounds. The total mortality rate for wounds averaged about 8 percent, but those of the thorax accounted for 32 percent of this mortality rate. Thus, although there was a relatively low incidence of thoracic wounds there was an extremely high mortality rate in this group of injuries.

Table 31 shows the mortality rate in patients with thoracic wounds in wars prior to World War II. The exact rate for thoracic injury is not known, because the nature and extent of the wounds of many men killed in combat could not be determined.

TABLE 31.—*Mortality rate from thoracic wounds in wars prior to World War II*

War	Mortality rate (percent)
Crimean War	79.2
American Civil War	62.6
Franco-Prussian War	56.7
Spanish-American War	24.5
Boer War	14.9
World War I	27.5
Sino-Japanese War	14.8

In World War II, chemotherapy, a clearer concept of the abnormal physiologic processes associated with thoracic injury, and adroit and audacious surgical treatment served not only to preserve life but also to restore physiologic function to normal or near normal in what had previously been a fatal injury. The interval between injury and treatment, which, when prolonged, made surgical correction impotent, was greatly shortened by having skilled corpsmen and medical officers in the forward areas. Immediate transfusion of blood or plasma, accurate evaluation by frontline medical officers of the type of treatment indicated, and rapid transportation to a well-equipped hospital in which every known method of treatment could be prescribed were factors that contributed greatly to the lowered mortality rate and the shortened period of morbidity. Much credit should be given to the Bureau of Medicine and Surgery administrative plan of segregating thoracic injuries, in order that the exacting care and the diagnostic and therapeutic measures needed to achieve the best results would be available.

Primarily, we were concerned with three questions: (*a*) What conditions must we be prepared to treat? (*b*) When do we treat them? and (*c*) How do we treat them? The answers to all three questions in an individual patient were modified by the location of the patient and by the availability of personnel and equipment. All units were prepared to treat shock, control hemorrhage, and institute measures to combat infection and support respiratory function.

Infection.—For practical purposes, all wounds of the chest were considered to be potentially infected. Penetrating wounds usually had been contaminated by foreign bodies, such as bullets, metallic fragments, clothing, dirt, or skin. Blast or crush injuries without penetration often resulted in infection of the pleural space because of the establishment of a communication with a traumatized lung, bronchus, or esophagus. The empiric use of sulfonamides and antibiotics, applied locally and administered parenterally to ensure a protective level in the blood, proved effective.

No single organism appeared to be responsible for the infectious processes usually observed. Those most commonly obtained on culture, especially in chronic infection, were alpha, beta, and gamma strains of hemolytic streptococci, *Staphylococcus aureus*, and *Pseudomonas aeruginosa*. Less frequently found were *Escherichia coli*, *Aerobacter aerogenes*, and *Proteus vulgaris*. Infections that went on to suppuration commonly contained anaerobic streptococci, fusiform bacilli, and spirochetes (*Borrelia vincentii*). The presence of such virulent pathogens plus the contamination of the wound by an endless variety of local organisms made the institution of measures to combat infection mandatory at the earliest moment. The value of the sulfonamides and antibiotics in acute surgical infections is now well established, and adequate dosage at the onset often thwarted the development of the more complicated mixed chronic infections that demanded more specific therapy.

When treatment was to be given.—The question of when to treat thoracic injuries was of the utmost importance. This management could not be reduced to a simple formula but was governed by the presence or absence of various factors in the individual patient. Each member of the "team" treating these injuries was made aware of the facilities and his capabilities. The "team" consisted of all personnel who aided the patient from the time of injury until his final discharge from medical care.

Corpsmen who first saw the patient were taught that sucking wounds should be closed immediately with a dressing large enough to stop the sucking noise; that a "stove-in" chest should be bandaged snugly; that the wounded man should be urged to cough if he had mucus in his throat, and that he should be transported in a sitting position if he had difficulty in breathing when lying down.

When the patient was seen at the aid clearing station, immediate appraisal of the extent of the injury was made. The medical officer's first concern in the seriously ill thoracic casualty was how best to prepare the patient for safe evacuation to a forward hospital or ship.

Early therapy in advanced areas.—Morphine was administered for the relief of pain, and fluid replacement therapy was begun to ensure adequate volume of circulating fluid. Nothing was as effective as whole blood when loss of blood had occurred, but plasma was often the only substance available. The first-aid measures instituted by corpsmen were checked. Open chest wounds were sealed securely with petrolatum dressings, the stability of the chest wall was ensured by strapping, and if a suction apparatus could be improvised an adequate airway was obtained by cleansing the mouth and throat, including the laryngeal area and upper part of the trachea. Early and rapid evacuation of these patients was given high priority. Evacuation by air was contraindicated for some because patients with respiratory embarrassment did not tolerate the rarified atmosphere or the increase in volume of a pneumothorax that occurred when high altitude was attained.

Definitive therapy.—Upon arrival at a hospital, the patient's status was re-evaluated without delay. The physical examination included roentgenograms, if the patient's condition permitted, and an accurate estimation of the features of the thoracic wound. Immediate attention was given to those patients who, in spite of treatment, instituted in the forward areas, had shock, sucking wounds, pain in the chest wall, anoxia, or mechanical difficulties in breathing. To determine those patients for whom immediate surgical treatment was mandatory, accurate diagnosis was essential.

The large majority of wounds were of two types: those resulting from penetrating fragments and those resulting from concussion or blast injuries. In the latter group, unless signs of continual blood loss, perforation of a viscus, or tamponade were present, surgical treatment was delayed. Patients with pulmonary and cardiac contusion tolerated poorly either anesthesia or surgical measures.

In penetrating wounds, the extent of the injury was most important. It was essential to plot as accurately as possible the course of the missile. Possible deflection from bony surfaces, presence or absence of a wound of exit, and the position of the patient when struck were considered. It was necessary to determine if the injury was limited to the thorax, or if structures within the abdomen or neck were also involved. In view of the frequency of multiple wounds, a complete examination had to be done so that secondary wounds would not be overlooked while concentrating on the thoracic injury.

General notes relating to diagnosis.—Concomitant injuries of the abdomen or neck were sought for diligently. When abdominal rigidity was associated with a wound which was *limited to the thorax,* it was usually found only on the *side* of the injury, and was less marked on inspiration than when an intra-abdominal injury was present. The simple expedient of blocking the thoracic nerves, thereby enervating this portion of the abdominal wall, was often of diagnostic aid. An abdomen that was silent on auscultation, or the persistence of spasm of the abdominal muscles *after* nerve block, indicated an intra-abdominal injury. Injury to structures in the neck was usually evident, but a careful examination for emphysema of the mediastinum, neck, and chest wall, audible bruit, and signs of caval obstruction was essential. The importance of accurately plotting the tract of the missile cannot be overemphasized; the evidence obtained was often the deciding factor for or against immediate surgical intervention. If the patient's condition permitted the taking of roentgenograms, upright posteroanterior, upright lateral, and dorsal decubitus views of the chest, plus a flat plate of the abdomen, sufficed for the primary examination.

Therapy in the initial or resuscitative phase.—The resuscitative triad included: (*a*) The restoration of cardiorespiratory balance by the stabilization of the thoracic cage, elimination of pain in the chest by blocking the appropriate intercostal nerves, tracheal aspiration of the "wet" lung, aspiration of blood when hemothorax was present, water-seal drainage of tension pneumothorax, and the administration of oxygen for anoxia; (*b*) replacement of fluids; and (*c*) early control of infection.

The immediate correction of the cardiorespiratory imbalance was the most important single factor in aiding these patients. Although other resuscitative measures were often started simultaneously, the sealing of a sucking wound, permitting the return of the mediastinum to the midline by aspiration of pleural contents (air or fluid or both), the establishment of an unobstructed airway, and the relief of pain were the first considerations. The restoration of fluid balance was considered to be the second, and the prevention of infection, the third factor in early treatment.

The extremely restless, apprehensive, and dyspneic patient was usually anoxic due to loss of blood (either external or into the pleural space), decreased vital capacity caused by compression of the lung by fluid or air, and atelectasis from blockage of the pulmonary radicles by excessive bronchopulmonary secretions. His efforts to rid himself of these burdens to normal breathing were further hindered by the intense pain that accompanied every voluntary effort. Therefore, his cough was feeble and ineffectual and the anoxia increased.

Oxygen, 7 to 8 liters per minute, was administered with a 12 to 18 F. nasal catherer attached to a portable oxygen tank. The apprehensive patient tolerated a catheter much better than a mask.

In our experience, aspiration of the trachea was best accomplished by use of a flexible woven catheter with a thumb suction release. The catheter was passed under the directing forefinger into the larynx. This was done without anesthesia and the maneuver was facilitated if the patient's tongue could be pulled out with a gauze square. If an ordinary rubber catheter was used, it was best to clamp the tubing with a hemostat, preventing suction until the tip had been introduced into the trachea. While the initial aspiration brought relief by the removal of blood and mucus, repeated aspirations were also of value, especially after nerve block when the uninhibited cough of the patient proved to be of great assistance.

The pulmonary edema seen after blast and concussion injuries often persisted for a number of days. With subsidence of the shock syndrome, bronchoscopic examination was made as frequently as twice a day, if needed. Oxygen delivered at the rate of 4 to 6 liters per minute under positive pressure by means of a close-fitting mask was valuable, but unless the tracheobronchial tree was free of secretions, the administration of oxygen was of little benefit.

Regional nerve block.—This procedure was accomplished by the intradermal injection of 1 percent procaine solution at the angle of the involved rib or ribs, including the two rib segments above and the two below the injury. Through these skin wheals, a 2-inch 20 to 22 gage needle was introduced to the body of the rib. The lower edge of the rib was found and 5 to 8 cc. of 1 percent solution of procaine was injected. The relief of pain was immediate and amazing. The patient was able to cough more effectively and to aerate the lung more efficiently. Regional block was preferred to injection into the site of the open wound because of the possible contamination. In nonpenetrating fractures of the ribs, injection of the resultant hematoma gave some relief. Strapping of fractured ribs, as a means of affording relief from pain, was inferior to the blocking of the appropriate nerve or nerves, but was frequently used as an adjunct after blocking of the nerves had been accomplished.

The use of morphine.—While this drug deserved its title of "the doctor's best friend and pain's worst enemy," it was found that it must be administered cautiously to patients with thoracic injury. The recently wounded patient, when admitted to a hospital, usually had already received one or two injections of morphine. This dose (the exact amount was determined, if possible), coupled with the inadequate circulation of shock, was apt to show a cumulative effect during resuscitation. Depression of the cough and respiratory function, the actuation of which one was attempting to achieve, would then occur.

"Stove-in" chest and sternal fractures.—Treatment during the resuscitative phase was aimed at "fixing" the collapsed chest wall in a stable position. If the injury was unilateral, this was best accomplished by wide adhesive strapping, beginning at the bottom and working up. The patient was directed to lie on the affected side and sand bags were used to maintain this "fixed" state.

If the condition was bilateral, or if there was sternal separation or fracture, the chest wall was suspended by traction on towel clips attached to the costal cartilages or by traction through sternal screws. The position was maintained with 2- to 4-pound traction over a pulley on an upright Balkan frame. If it was necessary to transport a patient under treatment with some form of traction, the apparatus was incorporated in a plaster cast applied around the thorax from the level of the suprasternal notch to the lowest portion of the thoracic cage.

Hemothorax (reduction in vital capacity).—The management of hemothorax, pneumothorax, or a combination of the two was the most common problem confronting the surgeon. It had been estimated that blood or air would be present in the pleural space in approximately 70 percent of these patients. A hemothorax was not regarded as a simple hematoma but as a foreign body in a vital space. The pleural cavity responded to this irritation by "weeping" of serous fluid, resulting in additional increase of the pleural mass.

The treatment was removal of the fluid and air. In the dyspneic patient with mediastinal shift, aspiration of the pleural contents was imperative. As much as 1,000 cc. of the contents could be removed safely at one time. When the patient complained of "tightness in the chest," it was wise to stop, as this symptom indicated that too rapid restoration of the negative pressure had been accomplished. An orderly plan of regular aspirations was followed, beginning within the first 24 hours after injury and continuing daily until the pleural space was dry and the lung was completely re-expanded.

Hemorrhage.—A question to be answered in the initial phase of treatment was, "has the bleeding stopped?" If the injury was solely of the lung parenchyma, the compression of the lung by the fluid within the pleural space, the elevation of the diaphragm, and the low pressure within the pulmonary arteries combined to limit the hemorrhage. More than 1,500 cc. of blood from parenchymal injury alone was unusual, and secondary hemorrhage from parenchymal injury was very rare. Bleeding from hilar vessels was usually fatal, however, the patient usually dying before receiving hospital care. Bleeding from the mammary or intercostal vessels was usually progressive.

Besides the roentgenologic changes and the physical signs of the reaccumulation of blood within the pleural space, the following criteria were used as a guide to diagnosing continuous hemorrhage: (*a*) A blood pressure that failed to rise after adequate transfusion of blood (up to 2,000 cc.) or which, having risen to normal levels, fell again. (*b*) Reaccumulation of 1,500 to 2,000 cc. of blood in the pleural space within 24 hours after the initial aspiration of a similar amount. (*c*) Persistent severe anemia in spite of replacement of blood; degree of anemia determined by serial hematocrit readings.

When the diagnosis of persistent serious hemorrhage was made, surgical intervention to control the bleeding was indicated. During surgical intervention, there was an opportunity to remove all foreign material within the pleural space and to perform a decortication of the clot, which was adherent to both pleural surfaces, particularly the visceral surface.

There was no evidence that early aspiration prolonged or brought about a recurrence of hemorrhage, nor was there evidence that air replacement was helpful.

Sucking wounds that had been occluded temporarily by sealed dressings or by approximation of the edges of the wound were repaired with the same precautions as those observed in an intrapleural operation. Control of pulmonary pressure by intratracheal intubation was instituted, even though the procedure was done under local infiltration. With this safeguard to guarantee an adequate airway, care could be taken to débride all devitalized tissues.

The wound of entrance of the missile was usually small and at times insignificant in appearance, but occasionally a huge jagged wound was present. The wound of exit was usually larger and more ragged. The tissues between the two wounds were disrupted because of the sudden release of the kinetic energy of the missile. The destruction of tissue depended directly on the velocity of the missile at the moment of impact and the density of the tissue through which it passed. A missile could pass through parenchymal lung tissue with comparatively little damage, whereas the same missile traveling with the same velocity would produce extensive destruction when it struck a substance with greater density, such as a bone. In addition to the original missile, fragments of bone often acted as secondary missiles and produced additional damage.

Traumatic wounds of the costal cartilage required surgical excision to prevent serious infection. If there was parenchymal damage within the chest that required extensive surgical treatment, the site of trauma was enlarged. It was found unwise to work at a disadvantage, however, and frequently it was more expedient to complete the airtight closure of the sucking wound and do a secondary thoracotomy and resection of a rib through a separate wound. Débridement and suture or resection of the damaged lung, removal of foreign bodies and splinters of bone, repair of the diaphragm, evacuation of blood and clots, and irrigation of the pleural space could then be accomplished with maximal efficiency. Injury to a pulmonary vein made it mandatory to remove the lobe or lobes that it drained. Extensive hematoma of a lobe was viewed with suspicion as to the future usefulness of that lobe. The lobe is vulnerable to infection and the possibility of traumatic arteriovenous fistula was recognized.

The several points deserving attention were: (*a*) The surgical closure of a sucking wound must be airtight. (*b*) If the defect of the chest wall involved a large loss of bony structure, the insertion of a muscle flap to close this defect was done at the initial operation. (*c*) Because of its elasticity, parenchyma of the lung was closed by interrupted sutures rather than by a single continuous suture. (*d*) Positive pressure was used to determine adequate expansion of the lung before closing. (*e*) Closed water-trap drainage or suction with mild negative pressure was instituted to aid in re-expansion of the underlying lung.

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Continued bleeding.—If bleeding was progressive, thoracotomy was performed. The source of the hemorrhage might be the intercostal vessels, the azygos vein, the internal mammary artery, hilar vessels, the diaphragm, the viscera immediately beneath, or extensive pulmonary lacerations.

The management of sequelae of hemothorax, empyema or fibrinous pleuritis or both, was a major problem. Extensive tissue damage plus bleeding combined to form fibrin clots. Thus the three immediate harmful effects (*a*) blood loss, (*b*) pleural irritation, and (*c*) space occupancy in the chest, were manifest. Some surgeons advocated early thoracotomy and evacuation of blood clots and fibrin. They believed that the simple removal of the foreign substance would produce a cessation of the bleeding by hastening re-expansion of the lung. The good results of repeated aspiration did not justify such radical surgical procedures in the acutely ill patient. Some surgeons practiced irrigation of the pleural space through simple perforating wounds with an apparent reduction in the number of posttraumatic aspirations.

Injuries to the mammary and intercostal arteries were of two general types: (*a*) False aneurysms with subpleural hematoma and infiltration, and delayed secondary hemorrhage, and (*b*) those associated with intrapleural laceration and continued intrapleural hemorrhage. In the first type, isolation and ligation of the intercostal artery at points proximal and distal to the injury were necessary for control of the hemorrhage, as arterial pressure was exerted in both directions. If the bleeding was thought to be caused by injury to the internal mammary vessels, an anterior parasternal incision was made at the desired level to expose these vessels. Disarticulation of the costocartilages was done if the primary exposure was inadequate. Open thoracotomy was necessary to correct bleeding from other sources.

Thoracico-abdominal injuries.—In combined thoracico-abdominal wounds, the wound in the chest was explored first. Two fundamental reasons dictated this action. Intensive abdominal exploration was poorly tolerated by the patient with cardiorespiratory imbalance, and it was often possible to explore and repair the abdominal viscera through the diaphragm.

Wounds of the superior surface of the liver were best repaired from the diaphragmatic side. The application of free muscle or fat grafts, suture, or packing was often necessary to control hemorrhage from the liver. Extensive laceration required abdominal exploration and drainage to avoid bile peritonitis. Fibrin foam was available in small quantities toward the end of the war and proved to be of great usefulness.

Lacerations of the spleen through a rent in the left hemidiaphragm were satisfactorily managed from the thoracic approach. Enlargement of the diaphragmatic opening through its membranous portion and in a direction toward the esophageal hiatus furnished adequate exposure for inspection and repair of the stomach or for resection of the spleen. By palpation through this opening, the entire abdominal cavity including the pelvis could be explored manually, but for obvious reasons this examination might have proved to be inadequate. Because of the possibility of multiple injuries to hollow viscera by concussion or by direct trauma from high velocity missiles, a more complete visual examination through an abdominal incision was essential.

The diaphragm was sutured edge to edge with interrupted silk sutures or slightly overlapped. If there was a loss of substance of the diaphragm, the phrenic nerve was crushed where it courses over the pericardium, the posterior lateral attachment of the diaphragm was detached, the central defect of the diaphragm closed, and the posterior lateral edge of the diaphragm reattached to the intercostal muscles at a higher level. On the right side, if a large defect was present, a similar procedure was carried out, or else suture of the cut edges of the diaphragm to the capsule of the liver served as a temporary seal until the threat of infection was past. Then, if needed, a plastic repair with a fascial graft could be attempted.

Hemothorax and infected hemothorax.—Prior to World War II, despite the teachings of some surgeons, the accepted therapy was indicated in the statement that "the mere presence of a hemothorax warrants neither operation nor aspiration." This was soon regarded as untenable, because with the bloody effusion acting as a retained foreign body, a series of pathologic changes occur. The fluid is pocketed by fibrin partitions, and organization of the fibrin deposits on the pleural surfaces begins. This layer of organizing fibrin binds down the lung and prevents re-expansion, so that the only manner in which the space originally occupied by effusion can be healed is by contracture of the chest wall, elevation of the diaphragm, and retraction of the mediastinum. These deformities, which are the usual end result of untreated hemothorax, produce all grades of disability from slight to crippling limitations of the cardiorespiratory function. The early occurrence of fibroblasts in the investing layer of fibrin is the cardinal point in the pathologic changes that occur in hemothorax. The term "thickened pleura" was a misnomer. The density seen radiographically is the investing layer of clotted blood and fibrin, the serosal surface of which is loosely adherent to the pleura.

Treatment by aspiration should start within 24 hours. A delay of 5 or 6 days means increased difficulty in evacuating the cavity. Air replacement should not be used. The patient should be given a sedative, and adequate local infiltration should be made. If daily aspirations are needed, care should be taken to cause as little pain as possible, as the cooperation of the patient is necessary. Aspiration should be high in the chest. Some surgeons preferred aspiration in the ninth interspace in the posterior axillary line, the seventh interspace in the midaxillary line, or the fifth interspace if aspiration was done anteriorly. Others preferred the second or third interspace anteriorly. The rationale for the latter concept is that the diaphragm is frequently elevated in hemothorax and most of the fluid is in the upper parts. A large-bore needle (13 to 15 gage) was needed for some of the jellylike clots. Persistence and patience were the watchwords, for repeated aspirations were done until the pleural space was dry, until re-expansion of the lung was complete, or until it was not possible to remove fluid even with the large-bore needle.

Decortication.—Until World War II decortication never was widely used. It was indicated in patients in whom there was at least 30 percent persistent compression of the lung, in spite of repeated aspirations, especially if the apex was compressed, and in patients in whom primary aspiration had been unsuccessful.

The optimal time for decortication was 3 to 5 weeks after injury. If performed less than 2 weeks after injury, the peel was thin and friable. The operation was tedious, as the poorly defined membrane had to be removed piecemeal or carefully wiped from the pleural surfaces. When performed 10 to 14 weeks after injury, the fibrous union between the peel and pleura was often so firm that a proper cleavage plane could not be established. The visceral pleura was frequently torn and the lung did not expand readily, because of fibrous ingrowths along the septa.

The operation was performed under intratracheal anesthesia through a thoracotomy wound. The parietal pleura and thickened peel were incised so that an opening was made into the "hollow" of the hemothorax. The liquified contents, clots, pus, and debris were evacuated. The peel covering the visceral pleura was incised, and by careful dissection the cleavage plane between these two structures was entered. Finding this line of cleavage was essential to the success of the operation. Two general methods were used: (*a*) The visceral peel was "crosshatched" and positive pressure applied to the lung by the anesthetist, thus expanding the crosshatched segments and causing their edges to curl at their junction with the visceral pleura. The patches then could be dissected away bluntly. (*b*) A single incision down to the visceral pleura was made and by the use of gauze "pushers" or dissectors, the peel was freed in one piece.

Regardless of the method used to initiate the operation, the salient feature to be accomplished was the complete release of the incarcerated lung from the enveloping fibrinous membrane, in order that complete re-expansion could occur. Particular attention was directed to the costophrenic sulcus and the fissures of the lung, as fixation at these sites prevented total expansion. The most difficult portion to free was the apex of the upper lobe. The dissection was carried well down to the mediastinal hilar attachments.

The visceral pleura beneath the peel was usually of normal consistency and was expansible when decortication was done at the optimal time. Areas of atelectatic lung were gently teased by the surgeon's hand as positive pressure through the intratracheal tube was gradually increased. Ballooning up of compressed lung to fill the thoracic cage completely so as to insure a satisfactory functional result was ample reward for exacting dissection. Unless unusual adherence of the peel to the visceral pleura had occurred, tearing of or bleeding from the pleural surfaces was minimal. Closed water drainage with gentle negative pressure was instituted after decortication.

THERAPY IN THE RECONSTRUCTIVE PHASE

Three hundred and nine patients with wounds of the chest wall and lungs were admitted to a hospital on the mainland. They were received 2 months or more after the date of the injury. On admission they were grouped into three classes; class 1—those requiring only simple or no treatment upon arrival; class 2 (the largest number)—those requiring definitive treatment upon admission; and class 3—those requiring elective treatment.

The immediate first-aid treatment they had received was not always the same, and for the most part not ideal. Some had had excellent first-aid treatment, but owing to the distance between place of injury and a fleet or base hospital, and to the time required for the move to our mainland hospital, their clinical condition had been forgotten or overlooked along the way. Considerable credit, however, was due to the medical officers who first attended these men, for it was apparent that they had been handled competently. These medical officers were in no way responsible for the changes or complications that occurred in these patients as a result of their transfer from one medical activity to another.

General considerations.—The types of thoracic lesions requiring operation included hemothorax, hemopneumothorax, simple effusion, empyema, foreign bodies in the chest wall, lung, or mediastinum, bronchopleural fistulas, fibrothorax, diaphragmatic hernia, arteriovenous aneurysm, injuries to the brachial plexus, sinuses of the chest wall, and pneumothorax. Some of the patients had a combination of thoracic and abdominal injuries with orthopedic, skin, and neurosurgical lesions. In a few instances hemothorax and even fracture of the ribs had been sustained after blast injury. All those men had received benefit from the use of sulfonamides or from the combined use of sulfonamides and penicillin. These two agents used in conjunction with therapy for shock were valuable prophylactic weapons that prevented complications and sequelae, and saved lives. The previous generous use of these agents may, however, have misled medical officers who saw the patient for only a short time, the clinical condition appearing satisfactory in spite of the existence of a large hemothorax, sterile abscess, or even empyema, which remained unnoticed.

Preliminary examinations.—All the patients included in this study were examined roentgenographically and fluoroscopically after admission. Because some weeks had elapsed since the date of injury, a few patients showed almost complete clearing of previously treated hemothorax, pneumothorax, or pneumonitis induced by "concussion," and had practically normal-appearing chests with clear pulmonary fields. Many patients with class 1 lesions but with normal lung findings showed single or multiple fractures of the ribs, or the presence of metallic fragments. Very few instances of infection of the ribs were noted, perhaps due to administration of sulfonamides and penicillin.

Class 1 patients.—These patients required very little attention. Their treatment was almost completed during the early phase, when treatment of shock, arrest of hemorrhage, correction of disturbed cardiorespiratory function, and prevention of infection were inaugurated. Many patients were evacuated because of a small hemothorax or effusion, which cleared up en route. Some had been evacuated after suture of a "sucking" wound or removal of a foreign body. A few had small effusions which appeared to be subsiding, and several had moist granulations that filled old chest-wall sinuses. These soon healed. Forty-nine had sustained through-and-through bullet or shell fragment wounds associated with hemothorax. On admission, the pulmonary fields were practically normal and roentgenograms showed very little evidence of the hemothorax recorded in their health records. Several patients with abdominothoracic wounds involving the liver, diaphragm, spleen, stomach, colon, or lung were operated on aboard ship immediately after their injury and were no problem on arrival at our hospital.

Class 2 patients.—In these, most of the problems stemmed from the various sequelae of hemothorax. Practically all patients with wounds of the chest, either penetrating or nonpenetrating, had hemothorax of varying degree which collapsed and compressed the lung. In time the blood became clotted. In the interim an excellent culture medium for bacterial growth was afforded. Replacing air after aspiration was a poor practice and only invited complications. The injected air maintained collapse of the apex, and when infection intervened the empyema was very large or even total, instead of small and limited to the base as it was when the upper lobe was allowed to re-expand and become adherent to the chest wall. Most wounds that penetrated the pleural cavity, even those causing parenchymal damage, resulted in pneumothorax; this set up the clotting mechanism even before the hemothorax became advanced. Therefore injected air only enhanced clotting.

Of the 309 patients, 276 (89 percent) had hemothorax either upon evacuation or on arrival at our hospital. In all instances, patients with hemothorax were immediately submitted to aspiration, using a large (15 or 16 gage) needle. The procedure was repeated every 36 hours or oftener. Aspiration alone without surgical intervention achieved a cure in 121, or 39 percent, of the patients; in several patients aspiration was done only once. The smallest amount of fluid obtained was 30 cc. Penicillin was always instilled after aspiration. A large number of the 121 patients had repeated thoracentesis because the pleural cavity was small. The clotted material interfered with aspiration only to a minor degree. While the finally dried-out pleura remained thick, the benefit gained by thoracotomy would not have been sufficient to warrant the surgical risk. In many instances, the hemothorax was called "effusion" because the fluid obtained appeared to have the typical straw color. A majority of these class 2 patients were returned to duty. In this group of 121 patients, the number who previously had not undergone aspiration and the number who had undergone aspiration prior to admission were about equal. Just why, in such a large number of instances, the hemothorax should clear up without the complications of clotting and serious infection cannot be explained. At first we noticed that a few of the patients who had through-and-through bullet wounds had only a minor hemothorax. It was thought that the high speed of the bullet in passing through the body caused no injury to intercostal vessels and only minimal injury to the parenchyma of the lung. Later, patients with identical injuries came to us with almost total empyema, so this theory was abandoned.

The same technique for aspiration and local anesthesia was used in every case. As a rule, a site in the midaxillary line was chosen without any attempt to place the needle in the most dependent interspace. When fluid was difficult to obtain, the use of a 2 cc. or 5 cc. syringe often brought success. Bacterial study of the specimen aspirated was made, and if it was found to be infected, examination for penicillin-resistant and penicillin-sensitive organisms completed the initial investigation. Much effort was necessary to rid the pleural cavity of fluid, debris, and clots. Sodium citrate, physiologic saline, azochloramid, and tyrothricin solutions were used for pleural lavage, depending upon the nature of the aspirated material. In many instances, when the long-standing hemothorax was evacuated the lungs re-expanded. Even in patients with a small empyema, large amounts of penicillin were instilled after the lavage. Eighteen of sixty-eight instances of empyema were thus cleared up without surgical measures.

The treatment of late or "old" thoracic injuries did not differ from that of recent hemothorax, because the treatment of choice was rapid re-expansion of the lung, which could be accomplished only by repeated aspiration without replacement of air. Early in the war, such a concept seemed to be rather dogmatic, because in prewar civilian practice treatment of hemothorax had been conservative in the hope that the blood would be absorbed.

Our statistics compare favorably with those of others in regard to results in patients with hemothorax, when considered from the standpoint of whether or not they had undergone aspiration previously. One writer found that 17 percent of 200 patients who had undergone aspiration prior to admission to a base hospital had empyema, while 46 percent of 74 patients who had not had aspiration had empyema. Our figures showed that empyema developed in only 13 percent of 200 cases in which aspiration was carried out prior to admission, but in 54 percent of 80 cases in which aspiration had not been done previously.

Chronic hemothorax and decortication.—In the patients with chronic, clotted hemothorax only a small amount of prune-juice-colored fluid was obtained on aspiration, even though physical and roentgenologic examination of the chest indicated flatness and a massive opaque density. Many of these lesions were not infected, as determined by smear and culture. After repeated aspiration, the roentgenogram showed multilocular pockets and many fluid levels. A thoracotomy was performed, opening the pleural cavity very wide to remove the fibrin and fibrous pockets that contained prune-juice-colored fluid and also yellow, custardlike clumps of old clotted blood. Nine patients required decortication because of a very tough, thick, fibrous layer deposited on the parietal and visceral pleurae that kept the lung compressed in a corsetlike vise.

For decortication, the thorax was opened widely. A curvilinear incision like that for pulmonary resection was made, under intratracheal anesthesia. Fluid and the custardlike clotted material were scooped up and wiped out. Dissection of the organized, fibrous peel on the lung was then carried out. Closed suction with a Stedman pump or underwater seal, if the area of decortication was small, was always employed postoperatively.

Fluid and pus developed in four of these patients, but cleared up with aspiration and without further surgical treatment. One patient with sterile chronic, clotted hemothorax in whom decortication was done, had empyema in spite of closed, suction drainage, and further surgical intervention was necessary. In three patients with infected, chronic hemothorax, empyema occurred and rib resection was required. Two of the 4 patients in whom decortications were done 12 and 14 weeks after injury respectively had poor results; when the thick peel was dissected much serum and blood oozed from the thin visceral pleura of the lung. The peel formed a tight union with the lung and fibrous adhesive bands extended through the visceral pleura and even into pulmonary tissue. None of the patients with hemothorax reached our service less than 6 weeks after injury; most came after longer periods. Usually aspiration was tried first for about 2 weeks. This delayed the decortication operation for more than 8 weeks after injury—certainly not an ideal period. The dissections were very long and tedious and although we were enthusiastic in regard to a procedure which would eliminate a deforming thoracoplasty, the time that had elapsed since injury was a factor in determining the relatively small number of decortications that were performed.

Empyema was the great problem in 68 of the 309 patients (22 percent). In many of the patients in class 2, empyema occurred soon after injury. They had been variously treated prior to admission to our hospital; some by closed intercostal drainage with a catheter, some by flap operations, and some by open thoractomy or by multiple thoracenteses with injection of penicillin.

Hemothorax or thoracic injury often resulted in empyema no matter how ideal and diligent the treatment. In some instances empyema occurred because of poorly treated hemothorax, improperly timed open or closed drainage, sucking wounds which sloughed after repair, persistent bronchopleural fistulas, or foreign-body reaction. Just as we were amazed to learn from the health records of some of the injured that a large hemothorax cleared up without ever being aspirated, we likewise had difficulty in understanding why purulent fluid appeared a week or two after injury in some patients. What else besides bullets and shell fragments was carried into these injured chests can only be guessed. Chemotherapy and penicillin shared in reducing sequelae and morbidity. On the other hand, these agents gave a false clinical impression of improvement while an unattended hemothorax was turning into sterile pus and was in need of drainage.

Classic methods of drainage were effectual in 29 patients with empyema, in none of whom did the residual cavity have a capacity of more than 150 cc. All operations were performed in one stage. A long thoracotomy incision was made and segments of one to three ribs were removed. Convalescence lasted from 2 to 10 weeks. There was no remaining thoracic deformity in any of these patients. This was also true of the previously mentioned 18 patients with empyema, in whom the condition was cured by aspiration and instillation of penicillin.

Twelve patients had thoracoplasty in stages, and 9 had one-stage procedures in which ribs and the thick pleural roof of the empyema cavity were removed and muscle transplants were used to fill in the defect. Of these 21 patients, 12 had thoracic deformity. There was 1 lobectomy for lung abscess that followed pneumonitis and atelectasis complicating a hemothorax.

Class 3 patients (elective surgical treatment).—Class 3 patients included those for whom surgical treatment was elective. For the most part the operation consisted of removal of foreign bodies in the chest wall or the pulmonary parenchyma. In addition, three foreign bodies were removed from the diaphragm and two from the mediastinum, three diaphragmatic hernias were repaired, and three arteriovenous or false aneurysms were treated. In class 3 patients, surgical treatment was not undertaken prior to 2 to 4 months after the date of injury, in order that the patient might gain weight and strength and that all possibilities of intrathoracic infection and pleural reaction might be eliminated.

The only fatality in the 309 patients occurred in one with a false aneurysm. This man had been returned to duty overseas after sustaining a through-and-through bullet wound of the right upper part of the thorax, which had healed quickly and without hemothorax. Some weeks later he was readmitted to the sick list because of hemoptysis. Upon the patient's admission to our hospital, the roentgenogram revealed a shadow in the extreme apex of the right lung. During his preoperative period, he experienced an almost fatal hemoptysis. Transfusion of a large amount of blood permitted an operation, at which a large aneurysmal sac connecting the subclavian artery with the apex of the right lung was found. The fibrous sac was being closed to be removed later, when the man died.

Foreign bodies.—Removal of metallic foreign bodies from the lung did not present much of a problem. For the surgical approach much the same technique as for pulmonary resection was used. Postoperative suction drainage was used, followed by early ambulation.

Bullets and large shell fragments in the lung were removed after consideration of the size, proximity to important structures, and the likelihood of future inflammatory reaction. The minimal size for removal was set at 1 by 2 cm. Many of the patients had metal fragments the size of a pinhead; in others the size ranged up to 5 by 10 by 15 mm. Three patients had a salt-and-pepper effect, and, although the possibility of pulmonary resection was considered because of the extremely large number of tiny fragments, they were discharged from the sick list without surgical intervention.

Tissue response.—It was surprising to note the small amount of reaction around many of the retained foreign bodies, just a few months after the injury. The missile tracts usually healed early and the hemothorax and effusion cleared up. The patient's course was characterized by clinical improvement and progressive healing of the lesions, as determined by successive roentgenologic examinations. A metallic foreign body could, of course, carry clothing or other debris with it into the lung and be the source of future infection. One 2 by 2.5 cm. shell fragment removed from the lung was well encased in fibrous tissue, but upon examination shreds of cloth on the metal were demonstrated. Another 1 by 1 cm. fragment shattered a lead pencil while passing through a pocket of the injured man. The fragment lodged in the lung and caused no reaction, although later suppuration of the tract and the discharge of bits of lead and wood occurred. The tract was excised but the fragment was not removed. Another fragment removed from an intercostal space contained a small amount of serous fluid in the fibrous capsule surrounding the metal. In a patient with a large empyema that responded well to aspiration and treatment with penicillin, re-expansion of the lung caused movement of a foreign body, so that it ultimately sloughed through the visceral pleura and dropped into the small remaining empyema cavity, producing a large bronchopleural fistula. Immediate rib resection was necessary and extensive surgical treatment was later required to eliminate the fistula.

Localization technique.—Exact preoperative localization of large fragments was most important. The method employed by our roentgenologist was simple and accurate. By fluoroscopic examination, the position of the fragments was marked on the skin with a pencil. Metallic markers "A" and "P" were placed on the skin of the anterior and posterior chest walls near the fragment site and stereograms of the chest made. A true lateral roentgenogram of the chest also was made. The stereogram established the position of the foreign body in relation to the rib cage and the lateral view determined its position in relation to the anterior and posterior chest walls. This technique was supplemented later, following a suggestion of several authors, by taking a roentgenogram in the lateral decubitus position, duplicating the position of the patient on the operating table.

Postoperative regimen.—The usual postsurgical procedures necessary for patients with thoracic injury were followed for the first 24 to 36 hours, after which early ambulation was encouraged and exercises were started. Even patients too ill to be out of bed for weeks were given exercises supervised by the athletic instructors of the physical education and rehabilitation department and the technicians from the physiotherapy section. As soon as the man could sit up in bed and/or become ambulatory his exercises were increased to the point of tolerance.

A common finding in all patients with hemothorax or wounds of the thorax was atrophy of the pectoral and other muscles of the rib cage. In some, the atrophy was striking, the patient presenting a visible deformity on admission, only a few weeks after injury. Exercise was therefore an important part of the immediate treatment. The instructors and technicians stepped up the tempo of the physical activity as the clinical condition permitted, until such strenuous games as volleyball, basketball, and tennis became part of the treatment.

Many a patient was admitted with a large hemothorax and one-half of his chest immobilized and apparently "stove-in," only to become a robust man on the road to recovery after one or two thoracenteses and a regimen of exercises. The reason for this was just as obscure as that for the patient with total hemothorax that cleared without aspiration.

THE SURGICAL TREATMENT OF TRAUMATIC LESIONS OF THE INTRATHORACIC CARDIOVASCULAR STRUCTURES

Either major or minor wounds of the thorax, whether due to fragments, bullets, bayonets, or knives, have the potentiality of injury to one of the superficial or deep vascular structures. It was difficult to estimate the incidence of this type of war injury, because most of these wounds were immediately fatal due to the impossibility of tourniquet or pressure control. Some men so injured survived, however, and reached distant base hospitals for definitive treatment. The hemorrhage was at least temporarily controlled by certain limiting anatomic structures and by the hematoma and infiltration of the surrounding muscles and tissues. The diagnosis was frequently missed because of the insignificance of the external wound or because of the lack of obvious extensive infiltration, hematoma, visible or palpable pulsation, or other significant physical finding. In many patients a diagnosis was not made until a serious secondary hemorrhage occurred. It became essential that every wound in this region be examined for evidence of arterial or vascular injury, especially by auscultation for the presence of a bruit and by roentgenologic examination for evidence of intrathoracic injury of vascular structures.

Because of the serious nature of the operation necessary to treat this type of injury, surgical treatment was withheld long enough to ensure a reasonably certain diagnosis. It was essential to rule out functional bruits and those resulting from extrinsic infiltration or pressure on vascular structures. Operation was carried out as promptly as possible, however, in order to avoid secondary hemorrhage, pressure on adjacent structures, or a serious disturbance of the intrathoracic dynamics.

Since no specific first-aid measures were effective in this type of injury, supportive measures were necessary to maintain the patient long enough to reach hospital facilities equipped to carry out major thoracic surgical procedures. It was apparent, therefore, that these injuries required priority above all other types.

Cardiac injury.—Penetrating wounds of the thorax with laceration of the heart often resulted in massive intrapericardial hemorrhage and associated tamponade. In a very small percentage of these cases, especially when there was only a laceration of the cardiac wall without actual penetration into the cardiac chambers, the intrapericardial hemorrhage did not produce an immediate lethal tamponade and the increasing intrapericardial pressure tended to control to some extent the hemorrhage from the cardiac musculature. Likewise, a small missile passing into or through one of the chambers could, at least temporarily, produce a balanced tamponade without immediate complete cardiac embarrassment. Under these conditions, a small percentage of patients with this type of injury reached adequate operative facilities where the pericardium could be opened widely, the lacerations of the heart sutured and the pericardium drained. It was not feasible to do a temporary decompression of the pericardium in this type of injury, as it was in cases of tension hemothorax or pneumothorax.

Because patients with tension hemopericardium can survive only a very few hours at the most, the diagnosis had to be made at once and established by the clinical picture of cardiac tamponade. This was characterized by profound cardiovascular and respiratory disturbance, as evidenced by dyspnea, ashen cyanosis, and shock accompanied by an extremely weak, thready pulse, greatly lowered pulse pressure, increased venous pressure, and very distant muffled, weak cardiac sounds. These patients did not tolerate even a moderate degree of cardiac compression for long, and it was imperative that they be operated on through a left peristernal approach, the pericardium opened, and the hemorrhage from the cardiac wall or cardiac chamber controlled by carefully placed silk or cotton sutures. It was important to avoid the pleura, because pulmonary collapse often proved to be a very serious factor in an already critical cardiorespiratory balance. If the pleura was inadvertently opened, closed drainage, or preferably suction drainage of the pleural space, was imperative to facilitate as rapid reexpansion of the lung as possible. Likewise, the pericardium was always drained. In all of these injuries massive doses of penicillin were given intramuscularly.

Intracardiac foreign bodies.—Intracardiac fragments lying free within a cardiac chamber, whether washed there via the blood stream after entering the vascular system at some distance from the heart, or introduced by direct penetration through the cardiac wall, were removed as soon as the condition of the patient permitted. Because there was usually severe shock, the added manipulation and loss of blood entailed in the removal of a fragment from a cardiac chamber was delayed until the patient had recovered from his initial loss of blood and cardiac tamponade.

Blood was given by transfusion through at least two large-caliber needles to every patient with major cardiovascular injury undergoing any type of surgical treatment for relief of the injury. A purse-string suture was laid in the wall of the chamber and a circle of mattress sutures taken into the wall to control that particular area during the probing for the fragment and the final closure of the opening. An incision was then quickly made through the wall in the center of these controlling sutures. A pair of heavy forceps was passed into the cardiac chamber, simultaneously tightening up on the purse-string suture and applying tension to the surrounding mattress sutures to control to some extent the blood loss around the probing instrument. The fragment was located by a bimanual maneuver and removed. The cardiac wall was then sutured and the pericardium drained. As soon as the patient's condition permitted, it was also advisable to remove fragments embedded in the pericardium, free in the pericardium, or in contact with the wall of a great vessel, because of the danger of erosion and serious secondary hemorrhage or the development of an aneurysm.

Injury to mammary and intercostal vessels.—Although it was a well-established fact that in its early phases hemothorax should be handled by aspiration, it was necessary constantly to keep in mind that such an intrapleural hemorrhage could come from a laceration of a mammary, intercostal, or hilar artery. In this case, early operation was required to prevent death.

Injuries to the mammary and intercostal arteries were of two general types: (*a*) False aneurysms with subpleural hematoma and infiltration and delayed external secondary hemorrhage, and (*b*) injuries associated with intrapleural laceration and continued intrapleural hemorrhage. The latter type produced symptoms and signs of an increasing intrapleural pressure and mediastinal shift which progressed until death ensued. Oxygen therapy and thoracentesis were useless unless the bleeding artery was ligated. This was in direct contrast to hemothorax resulting from injury to the lung, which was usually controlled by the pulmonary tamponade from the associated hemothorax.

Physical signs of uncontrollable, progressive, intrapleural tension hemothorax demanded immediate exploration of the wound and a careful search for a lacerated mammary or intercostal artery. If this was found not to be the source of hemothorax, the thorax was opened widely and the hilar structures exposed and inspected for a laceration of a major hilar pulmonary artery or vein. Such a vessel would necessarily require ligation irrespective of the possibility of subsequent pulmonary damage, although permanent pulmonary damage would be unlikely. Whenever a thorax was opened widely, it was necessary that it be drained by a closed method, suction preferred, in order to re-establish quickly normal dynamics and re-expansion of the lung.

Injury to vascular structures in the mediastinum.—Injuries to the mediastinal vascular structures were quite common. In most instances, if death did not take place at once from massive hemorrhage, the hemorrhage was at least temporarily controlled by infiltration of the surrounding tissues, with a resulting pulsating hematoma or false aneurysm.

Injury to subclavian vessels.—Injuries to the subclavian arteries were quite similar in many ways to injuries to other systemic arteries. Being more deeply situated, the external infiltration and hematoma were much less obvious, however, and the diagnosis was made chiefly by the presence of a bruit and a widened mediastinum as evidenced by the roentgenogram. (This was a rough bruit heard through systole, or during the entire cardiac cycle if an arteriovenous aneurysm was present.)

It was a common finding to have not only a false aneurysm but also an arteriovenous aneurysm. This added complication of the arterial injury could often be diagnosed by an increased venous pressure in the arm involved and venograms showing a distortion or block of the vein at the level of the injury.

Functional bruits were fairly common in this region and had to be distinguished carefully. This could be done by repeatedly examining the patient. The functional bruit varied considerably from examination to examination and in relation to the position of the patient and the position of the upper extremity. Likewise, simple compression from external pressure and infiltration about the artery often produced a bruit. It was again essential to distinguish, if possible, between compression and true laceration of a vessel with a false sac, for which surgical treatment was essential to effect a cure. If there was any question regarding the diagnosis of the type of bruit heard it was usually safe to keep the patient in bed under observation. As long as there were no signs or symptoms of further infiltration or cardiac damage, a careful period of observation could be carried out. The functional bruits could be ruled out by their inconstant nature; the bruits due to pressure gradually decreased in intensity as the roentgenologic signs of infiltration diminished and the patient improved.

Although false aneurysms and arteriovenous aneurysms of the subclavian artery were most hazardous surgical problems, the same general principles of management for all of the major vascular injuries were carried out. In order to do this type of operation it was essential to have a fully equipped operating room, a trained anesthetist, adequate assistance, and continuous infusions during the procedure. It was found best to start the operation by tying large cannulas in the ankle veins of both legs so that if one cannula should become plugged at a crucial time in the operation the other could carry on satisfactorily; if a very severe hemorrhage was encountered, blood could be run through both as rapidly as possible.

The general principle of approach to this type of injury was to avoid entering the false aneurysm at any point before the major artery and vein, both proximal and distal to the injury, and all significant branches of this section of the injured vessels were fully controlled. This was accomplished by accurate exposure of these vessels proximal and distal to the infiltrated site of the false aneurysm, and by control of the flow through these vessels by tension on small, soft catheters placed around them. The vessels were then further exposed until the false aneurysmal sac was finally entered and the actual injury to the artery visualized. Even with full control of the injured major artery and vein there was still a rapid flow of blood from the injured part into the sac. The vessels were then ligated, both distal and proximal to the injury, and the injured part was excised, carefully preserving for collateral circulation all branches that did not immediately enter into the tissue to be excised.

In general, quadruple ligation and excision of the injured section of artery and vein was the procedure of choice from the standpoint of the greatest safety and curability. This radical management was usually necessary owing to the extensive damage to the vessels and surrounding tissues, making repair of anastomosis of the artery hazardous because of potential secondary hemorrhage or recurrence of the false aneurysm. In early cases and those in which reasonably normal tissues were encountered, arterial reconstruction or exision and end-to-end anastomosis, if accomplished without undue tension, were, however, the best methods of management.

To approach the subclavian vessels, a low cervical incision was made above the medial end of the clavicle. The lateral clavicular insertions of the sternocleidomastoid muscle were cut and the carotid sheath and its contents retracted medially. The scalenus anticus muscle was exposed, the phrenic nerve freed and retracted medially, and the muscle cut across. The subclavian artery was then exposed and a catheter passed around it for tourniquet action. Connecting with the original incision, a diagonal incision was made across the pectoral region (similar to that for axillary exposure except that the pectoral muscles were split for the exposure of the axillary vessels immediately below the clavicle). The clavicle was then cut across and the ends retracted, widely exposing the injured part of the subclavian vessels. Dissection of these vessels was carefully carried out in both directions until the neck of the sac and false aneurysm were isolated and entered. Here again, considerable bleeding was accepted as the final identification of the actual opening in the artery. The artery and vein were ligated proximal and distal to the laceration and the injured part excised.

Because the brachial cords were closely associated with the aneurysmal sac, the missile had often done direct damage to these nerves. Further damage could be demonstrated from the pressure on and infiltration of the nerve trunks from the dissecting hematoma and false aneurysmal sac. It was necessary to isolate them carefully and produce no operative trauma, but no attempt was made to suture any of the cords that were found injured at this time. The clavicle was then wired together and the wound closed, with simple Penrose drains.

Injury to the innominate artery.—False aneurysms and arteriovenous aneurysms involving the innominate, left subclavian, and left common carotid vessels within the superior mediastinum were diagnosed primarily on the basis of a bruit, roentgenologic findings of infiltration of the superior mediastinum, and induration extending into the suprasternal notch and the back of the neck. Submanubrial and cervical pain were the outstanding symptoms. Again, because of the grave nature of the operation, it was absolutely necessary to be certain that this bruit was not due to some external infiltration and pressure on the artery. As long as the patient was kept in bed under close observation and there were no signs of cardiac hypertrophy or change, the surgical procedure could be delayed to establish beyond question of doubt the presence of a false aneurysm. Several patients were observed in whom the roentgenologic signs of mediastinal infiltration and the bruit disappeared after weeks of observation. Continued pain, however, especially with exacerbations of pain, increasing or undiminished bruit, or any signs of cardiac effects, were considered a demand for surgical intervention. The same general approach was essential for this type of operation. Because of the close relationship of the vessels in the superior mediastinum and the base of the neck it was much more difficult to avoid entering the false aneurysmal sac before adequate exposure and complete control of the injured vessel were obtained.

A transverse incision was made across the midpart of the neck above the clavicles and the suprasternal notch. This was then joined with a vertical incision over the midmanubrium. The suprasternal notch was exposed and the soft tissues retracted to expose the entire manubrium and upper part of the sternum down to the level of the third interspace. The mediastinal tissues were very carefully freed from the undersurface of the manubrium and a short section of the sternum down to the third interspace. The mediastinal structures were protected with a thin spatula and the manubrium split in the midline, carrying the division downward into the sternum to the level of the third interspace and laterally, connecting these interspaces on either side. The manubrium and sternum were then retracted widely by rib spreader retractor. This gave good exposure of the entire superior mediastinum and the arch of the aorta. The vessel involved was then isolated at its origin from the arch of the aorta and a catheter passed around it for tourniquet action. The vein was also isolated and controlled in a similar way. Just beyond the bifurcation of the innominate vessels the subclavian and common carotid arteries and their associated veins were isolated and likewise controlled with catheters. Finally, with full control both proximally and distally by means of traction on the catheters or rubber-covered arterial clamps, the aneurysmal sac was isolated and the injured section of the artery excised after ligation both proximal and distal to the laceration. The manubrium was then wired together and the superior mediastinum drained with a simple Penrose drain.

When these general principles were exercised, the mortality and complications were minimal, with only an occasional swelling and weakness of the upper extremity. No amputations were necessary and no treatment was required for any unusual circulatory disturbance in this respect. The extremity concerned should, however, be carefully watched and kept exposed at room temperature, every effort being made to avoid constriction from clothing or position. Should significant circulatory disturbance develop, antispasmotic drugs and sympathetic blocks should be used. The patients recovered rapidly, but the function of the upper extremity was variable, depending on the degree of the original associated damage to the nerves and muscles. The lack of circulatory complications was undoubtedly the result of the youth of these patients, and probably this procedure could not be done in an older group of patients without serious circulatory complications.

Chapter XVII

Orthopedic Casualties Aboard a Hospital Ship

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Some 70 percent of all combat casualties admitted suffered from one or more orthopedic injuries involving chiefly the back and extremities. Large ragged wounds and compound comminuted fractures were the rule. Sometimes hundreds of shell fragments were found within the wound, with bits of clothing and pieces of bone embedded in soft tissues elsewhere in the body.

During the period when large numbers of casualties were being admitted, the task of the medical officers would have been an almost impossible one had it not been for the skill and cooperation of Hospital Corps personnel. They had received many hours of training in first aid and were therefore competent in arresting hemorrhage, treating shock, administering plasma, and applying splints, as well as thoroughly indoctrinated in proper methods of transporting the injured. Above all, the corpsmen were impressed with the importance of their part in treatment and took pride in a job well done. It is no exaggeration to state that their efforts frequently were determining factors in the ultimate result.

To receive patients via gangways and cargo doors, or hoists, davits, and ladders was tedious and difficult. During hostilities, when as many as 700 casualties were waiting to be taken aboard, the delay, in spite of the utmost effort, was often appalling. The use of movable escalators, each large enough to hold an Army stretcher, would have greatly facilitated the reception of patients. With four escalators in service, fore, aft, starboard, and port, the ship could have been fully loaded within a comparatively few hours.

In combat areas, large numbers of casualties had to be brought aboard as quickly as possible. Often they came directly from the beaches, many of them in shock. Some had no dressings at all and others had not been dressed for days. Some were in casts, but others had free-swinging traction devices that aggravated pain. Many had Thomas splints with traction, which caused pressure across the dorsum of the foot and above the heel. As each casualty came aboard, he was examined by a medical officer who assigned him to a ward or operating room according to the severity of the injury. Corpsmen administered plasma and tetanus toxoid or antitoxin, and when indicated applied temporary splints or pressure dressings. Morphine was given to relieve pain.

FACTORS INFLUENCING CHOICE OF TECHNIQUES

Every operating room on the ship was adequately equipped to treat any orthopedic problem. The rolling, pitching, and yawing of the ship limited the choice of therapeutic measures, however, excluding, for example, those requiring traction by free-swinging weights, which would swing with the ship's motion, aggravating pain and sometimes displacing the fragments. Moreover, every patient had to be in a condition permitting immediate evacuation in case of fire or other emergency, and as most patients were transferred after 10 days, a fixed type of traction apparatus was used to permit their transfer from ship to ship or ship to shore. The limitations of space also precluded any form of prolonged traction as well as the time factor. The bunks were too close together, and there was little space between tiers or the fore and aft sections.

In view of the large number of casualties taken aboard after every engagement, it was inadvisable to rely on external fixation methods such as the Roger-Anderson, Haines, or Stader splints, because the first boatload of wounded would exhaust the supply. Thus it was necessary to rely on techniques employing pins and plaster casts. Fractures of the humerus did well with casts and 1½ or 2½ pins; fractures of the tibia with casts and 2 pins; femoral fractures with single spica and 1½ pins. Fractures of the neck of the femur were not nailed aboard ship, but were immobilized in well-leg traction casts pending further treatment at a base hospital.

EMERGENCY TREATMENT OF WOUNDS

In the operating room, after careful inspection, wounds were washed with soap and water, and easily accessible foreign bodies, such as bits of clothing or metal, were removed. In the débridement which followed, no attempt was made to reach every piece of metal, which would have been impossible in most instances. Foreign bodies in a joint, however, were always removed.

Fractures were brought into alignment following débridement, using both the fluoroscope and roentgenograms as guides. Normal length of limb was maintained whenever possible, even in the presence of large bone defects.

Since most combat wounds were extensive and the associated fractures comminuted, it was difficult to achieve immobilization with plaster casts alone, so pins incorporated in a cast were usually used. To permit dressings without disturbing the cast or limb, a large removable flap was cut in the plaster and then replaced to prevent the development of edema in the fenestrated area. If pressure was likely to develop, the cast was split to the skin.

Once adequate immobilization was attained and the wound lightly packed with vaseline gauze, frequent dressing was unnecessary. Light packing with gauze was essential to prevent it acting as a plug and obstructing drainage. With this type of immobilization, the patient could be debarked from the vessel at a moment's notice, without need for special apparatus. Periodic roentgenograms showed the position of the fragments. Occasionally, when foreign bodies left in the tissues set up a reaction, they were removed through small incisions. Otherwise they were left alone.

FRACTURES OF SHAFT OF FEMUR

With the patient in traction on an orthopedic table, the wound was cleansed, débrided, and packed. Adequate traction usually corrected lateral displacement, unless the proximal fragment was very short. The distal fragment was often flexed at the knee, but by suspending both fragments in slings, they could be lined up with the aid of the fluoroscope. Slings and traction maintained the corrected position.

A combination of full and half pins of the Steinman type was used, the full pins passing entirely through the bone, the half pins just into or through the inner cortex. With the fracture reduced and temporarily immobilized, it was then a simple matter to incorporate the pins in a plaster of paris spica extending from the lower ribs to the lower third of the leg.

The site for the pins had to be chosen carefully. Ideally the upper pin was placed just below the trochanters, penetrating the inner cortex of the femur but not extending through the bone. The lower pin was passed through the bone just above the condyles. In large wounds with extensive comminution, these optimum sites frequently had to be abandoned. Occasionally the upper pin had to be passed obliquely through the greater trochanter into the lesser, or the lower through the upper tibia.

The thickness of the pins used was determined by the size of the bone and the amount of traction necessary. The length was also important; the lower pins had to extend 2 inches beyond the skin on either side of the leg—the upper, 3 to 4 inches on the side of insertion. If they were not long enough, they were likely to slip into the cast when the patient moved, for atrophy of the thigh was often rapid and severe.

As soon as the cast was firmly set, traction was released and the foot and lower part of the leg included in the plaster. To prevent motion of the fragments, the cast was always extended from the toes to the mid-chest. When the slings were removed the holes in the cast were covered over.

Once the half pin was in place, even a short upper fragment could be manipulated and brought into proper alignment without having to abduct the leg more than 20°. Immobilization was secure. The fragments could not slip and length was maintained. The patient could easily be turned within the confines of even the middle bunk of a tier of three. If necessary, he could be evacuated on short notice, without need of elaborate equipment or loss of apparatus that could not readily be replaced.

The fluoroscope proved invaluable in the reduction of fractures of the femur, obviating the need for subsequent trips to the operating room for the correction of malalignments. Because of its frequent use, some protection had to be devised for patients and operator. Lt. Richard Hoffman improvised an effective apparatus for this purpose. Essentially it consisted of a portable fluoroscope with a long, narrow metal cone limiting the field and preventing scattering of the rays. An ordinary leaded apron, suspended between the patient's thighs, had a 5- by 6-inch window through which the cone of the fluoroscope was directed at the surgical field. With the aid of a head screen held just above or below the patient's sound leg, the roentgenologist could direct the surgeon in the exertion of traction or the manipulation of the slings supporting the fragments.

Secondary atrophy of the thigh, which was frequent and severe, was compensated for by applying felt to the inner aspect of the leg or narrowing the plaster cast (without removing it). This last was done in one of several ways. Either a section of the cast was cut away on the inner side of the thigh, above the lower pin, and replaced with fresh plaster closer to the skin, or wedges were cut in front and back and the spica narrowed at those points, or the entire front of the cast was removed and replaced.

During the summer of 1944, about 45 patients were treated by these methods with gratifying results. Even when further measures were required after evacuation to a base hospital, the procedure as performed conserved time, position, and length of limb.

INTERTROCHANTERIC FRACTURES OF FEMUR

To understand the special problems presented by the intertrochanteric type of fracture, it is necessary to consider the mechanics of the hip. The glutei, tensor fasciae latae, adductors, rectus femoris, long head of the biceps, and inner hamstring muscles exert a steady pull on the shaft of the femur, mainly in their own direction. Since the neck of the femur forms an angle of 135° with the shaft, it is subject to a constant shearing force. The intertrochanteric area, which is almost at right angles to the neck, is not parallel to the shaft of the femur but inclined toward its long axis. Thus a fracture at this point does not cause the shaft to slip past the neck, as in intracapsular fracture, but rather, the upward thrust is transferred to the lower end of the neck, the proximal fragment is pushed upward at the site of the fracture, and coxa vara occurs. Numerous methods have been tried to counteract this tendency, with varying degrees of success.

The ordinary plaster of paris spica is ineffective. As it rides up on the body, it carries the femur with it, causing a recurrence of the deformity. The double spica also overrides an inch or two, after atrophy takes place or if much padding is used. Sometimes good results are obtained by the application of a plaster of paris spica with the limb in extreme abduction, so as to cause the greater trochanter to impinge upon the ilium, maintaining an angle of 135° between neck and shaft. The trochanteric impingement on the ilium prevents the shaft from riding up. The position is awkward and painful, however, and transportation is difficult. In addition, the Navy bunk is too narrow to contain the abducted limb.

Similar considerations contraindicated several other procedures in common and successful use in hospitals, notably Russell skin traction and skeletal traction through pin or wire. With these techniques a regular hospital bed is needed, to which a special Balkan frame or its equivalent can be attached. Also, the traction apparatus must be detached for transportation of the patient, and Thomas splints must then be applied. Pain and loss of position results.

Transfixion by the Smith-Peterson nail, multiple pins, or wires is not feasible in the trochanter because the area does not afford sufficient space for a good bony purchase. The meager grip obtainable is easily vitiated by the muscular pull on the limb, and coxa vara recurs. A combination of nail and plate effectively overcomes this weakness, but is not applicable to the compound and comminuted fractures that are the rule in combat casualties.

With well-leg traction using the Roger-Anderson apparatus, it is possible to maintain a constant pull on the injured limb, as in Russel and skeletal traction, and transportation presents no difficulties. Moreover, no special bed is required and the method is effective in simple, comminuted, or compound fractures. By utilizing the sound leg both as a fulcrum and a site for the application of countertraction, the injured limb can be held in proper position at all times. The drawback to this procedure is that the apparatus leaves with the patient on transfer and the supply of this equipment is soon depleted.

It was necessary to devise a procedure that would secure the advantages of the techniques cited without their drawbacks. A combination of three methods—well-leg traction, skeletal traction, and the double spica plaster of paris cast—solved the problem. With the patient on an orthopedic table, a Steinman pin was passed through each femur just above the condyles. Traction was applied to the injured limb, and pressure to the well leg, until the coxa vara was corrected. A double plaster of paris spica was then applied from just above the iliac crests to the toes, with the pins incorporated in the cast. Also incorporated were reinforcing crossed bars, to prevent the limbs of the cast from breaking and disrupting the traction maintained through the pins.

In fractures involving both legs, each extremity was pinned individually and individually encased in plaster. It was then possible to apply well-leg traction when necessary, because the pins, fixed in the plaster, prevented disturbance of the fragments on either traction or compression.

TETANUS

An experience with about 80 wounded Japanese prisoners forcibly demonstrated the value of immunization against tetanus and early administration of antitoxin. Within a week after their admission to the ship, about 25 percent of the prisoners had tetanus in spite of the antitoxin administered when they came aboard. Heroic measures failed to save them for they apparently had not been immunized prior to injury. In happy contrast, not one of the thousands of our casualties developed tetanus.

Chapter XVIII

Cardiology

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During the years 1942 through 1945, there were more deaths among Navy and Marine Corps personnel from cardiovascular diseases than from any other cause except trauma. In a war of unprecedented violence, 4,477,886 sick days were lost because of simple fractures, a very common injury, while 3,411,722 sick days were lost because of heart disease.

The Medical Statistics Division of the Bureau of Medicine and Surgery reported in 1945 that out of 5,346 medical deaths, as compared with 22,197 surgical deaths in a similar period, about one-seventh of the deaths from medical conditions were due to heart disease. Of these, 797 patients died from coronary artery disease and thrombosis, and 53 died from various forms of rheumatic heart involvement. The sick days lost by the former group totaled only 213,232, while 3,198,490 sick days were lost by personnel with acute rheumatic fever and its cardiac complications. Further, of 11,734 men in whom a diagnosis of heart disease was made, 6,928, or about 59 percent, were invalided from the service. Mitral valvular insufficiency was noted in 3,961 patients, mitral stenosis in 1,584, coronary heart disease in 1,372, chronic myocarditis in 1,194, and acute dilation of the heart in 116. Only 667 patients were found to have hypertensive heart disease, although many hundreds were noted to have high blood pressure.

In spite of the apparent high incidence of cardiovascular disease in the Navy during World War II, the rate was no greater than that occurring in comparable groups in the general population. No other medical disability presented greater problems in preventive medicine. In the younger age group rheumatic fever accounted for a huge toll of sick days; in the older age group, coronary artery disease killed about 200 officers and enlisted men.

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CARDIOVASCULAR PROBLEMS IN THE ENLISTMENT EXAMINATION

The objective signs and symptoms of heart disease were usually not difficult to evaluate, but early or potential cardiovascular disability presented a most difficult diagnostic problem.

In the list of causes for rejection for enlistment, diseases of the heart and blood vessels ranked third. During 1942, about 15 percent of Selective Service candidates were disqualified because of organic heart disease, but during 1943 only about 7 percent were found to have disqualifying heart disorders. It was the older group of personnel that was primarily responsible for the high incidence of heart disease in the services.

Diagnostic cardiac clinics were established in the various naval districts to cope with enlistees and inductees who presented borderline findings. The first Cardiac Consultation Service was set up at the U.S. Naval Hospital, Brooklyn, N. Y., on 15 December 1941. To this clinic were referred all men with doubtful cardiovascular conditions discovered at recruiting offices within the Third Naval District. Later, similar diagnostic clinics were established in Philadelphia, Boston, Baltimore, San Francisco, and other large cities.

It was soon recognized by all examining physicians that criteria for the identication of early or potential heart disease required codification. The Committee on Cardiac Examinations disseminated factual information relating to this problem in diagnosis. The number of "missed" cardiac cases in a sample survey taken in the New York area showed a drop of nearly 60 percent within 3 months after the introduction of these diagnostic criteria.

The functional systolic murmur.—The largest number of doubtful cardiac conditions referred for special examination were in men who had systolic murmurs. Using the modification of the point scoring system suggested by Hyman, a systolic murmur, especially when localized at the apex, was considered as functional regardless of the loudness or pitch of the murmur when no other cardiac abnormalities were noted. Phonocardiographic studies made at the U. S. Naval Hospital, Brooklyn, showed that both functional and organic systolic murmurs had the same graphic pattern and the sounds were identical in both types of murmurs.

A history of two or more attacks of rheumatic fever during childhood or adolescence and the presence of a systolic murmur was sufficient evidence to disqualify the applicant for enlistment. Various combinations of cardiac abnormalities were noted; the most common was slight enlargement of the heart and a poor exercise tolerance test. Another combination was a slight delay in the P-R interval to 0.24 second, associated with enlargement of the heart, lowered vital capacity, and a poor pulse rate response. In the presence of systolic murmurs, all of these men were considered to have mitral valvular disease.

Correlation unit scoring studies were made on 1,986 men referred for cardiac investigation; of these, 1,144 or 57 percent had systolic murmurs. After evaluation 421, or about one-third of those with murmurs, were finally considered to have organic heart disease.

Paroxysmal hypertension.—Systolic blood pressure levels of 140 to 160 mm. Hg or higher in young men, constituted the second largest group referred for consultation. In most of these patients this finding was caused by psychosomatic factors—nervousness and an unstable vasomotor mechanism. After a resting period, the blood pressure often returned to normal limits, although some were required to reappear on several successive days before acceptable levels were obtained. Of 46 young men with initial systolic readings above 140 mm., 17 were found to have normal blood pressure on the second examination, 12 on the third, 8 on the fourth, and 6 on the fifth examination. Two had evidence of renal disease, and one had essential hypertension.

No applicant was accepted until one reading below 140 mm. was obtained. This was in contrast to the recommendation of the New York Medical Advisory Draft Board that persons with pressures as high as 170 mm. were acceptable for service, provided the diastolic level was below 95 mm. There was evidence to indicate that the so-called tendency to high blood pressure in young persons may be followed later by permanent hypertension. After World War I, Brooks, Friedman, Libman, and others investigated a number of juvenile hypertensive patients over a period of several years, most of whom eventually succumbed to a variety of conditions secondary to high blood pressure.

Labile blood pressure levels were considered to be nondisqualifying provided one normal reading was obtained. This decision of the Committee was frankly a compromise between the military demands of the time and the available medical opinion concerning paroxysmal hypertension.

High diastolic blood pressure alone was an infrequent finding. Out of 21 men with a diastolic pressure over 100 mm., 16 had evidence of associated kidney involvement. Only in rare instances was the diastolic blood pressure elevated in the psychosomatic group, and it was largely upon this dissociation of the systolic and diastolic levels that a diagnosis of juvenile or paroxysmal hypertension was made. When both levels were elevated, the applicant was considered unacceptable. In the New York area the upper normal qualifying levels were systolic 140 mm. and diastolic 94 mm. These figures were higher than the acceptable normals in other parts of the nation; in the Southern States, for example, 132/80 was considered to be the upper limit of normal. This was in keeping with life insurance surveys which indicated that blood pressure levels were generally higher in urban than in rural areas.

Functional cardiac irregularities.—Premature contractions or extrasystoles were found in 64 percent of the men referred for cardiac study. The diagnosis was ordinarily made without verification by electrocardiogram. The ectopic focus responsible for the premature beat was in the ventricles in about 82 percent of the patients. Auricular extrasystoles occurred in 7 percent, nodal premature contractions were seen in 4 percent, and extrasystoles from two or more ectopic foci were noted in 6 percent. A wandering pacemaker was a rare finding.

In the absence of any other evidence of heart disease, estrasystoles per se were not considered to be disqualifying. No attempt was made to classify the ectopic contractions into the effective or ineffective types; after a brief period of observation the Wolffe-Digilio index was abandoned.

Simple sinus tachycardia with rates as high as 160 was discovered in many applicants. Unless the condition was associated with signs of thyroid dysfunction or other evidence of cardiac disability the candidate was not disqualified. Most young men with rapid pulse rates also showed the syndrome formerly called neurocirculatory asthenia, and in the light of psychosomatic medicine, these patients could now be classified under the various groups of anxiety neuroses. Usually there was a recurrence after exposure to any hostile environment. Further large scale study of these persons is important in a final determination of their eligibility for future military duty, experience in the combat areas having shown most of them to be unreliable manpower.

In certain instances the change in the pulse rate was so abrupt or so irregular that a diagnosis of premature contractions was considered. In 3 cases, auricular fibrillation was mistaken for sinus arrhythmia.

A group of 84 applicants were referred for irregularities which were subsequently demonstrated to be exaggerated types of sinus arrhythmia, and in many of these an electrocardiogram was necessary to establish the diagnosis. Regardless of the degree of irregularity, however, the condition was not considered by the Committee to be disqualifying.

Paroxysmal tachycardia was discovered in 11 applicants and a presumptive history of one or more attacks was obtained from 9 others. In the absence of any other cardiac abnormality and with a negative history of rheumatic fever, the candidate with only one episode was accepted for enlistment. Where there was a history of two or more episodes, however, the condition was considered to be disqualifying. Subsequent follow-up of four of these young men disclosed that each of the four had a number of episodes in the succeeding years. In seven other men, rheumatic heart disease was discovered, while three applicants had evidence of essential hypertension.

Paroxysmal tachycardia in the older age groups (40 to 55) was considered to be serious. It is doubtful whether men in this age group with a history of previous attacks of paroxysmal tachycardia should be accepted for service, even if there is no other evidence of cardiovascular disability.

Paroxysmal auricular flutter and fibrillation were seen occasionally. In young men who had no demonstrable heart disease, the occurrence of a single attack was not considered to be disqualifying, but where there was a history of two or more episodes the applicant was rejected. In men beyond the age of 30, however, the condition carried a more guarded prognosis and was considered to be disqualifying. A follow-up of two men for about 3 years showed that neither had recurrence, although both saw sea duty. This tends to confirm the opinion of authors who believe that paroxysmal fibrillation may occur in an otherwise normal heart. Some consider the syndrome psychosomatic in origin.

FUNCTIONAL OR IDIOPATHIC ABNORMALITIES IN THE ELECTROCARDIOGRAM

Probably a million electrocardiographic tracings were taken during the war years, most of them on normal persons. Nearly all electrocardiographic studies made in civil life prior to World War II were carried out on patients with heart disease. Normal series were usually secured from medical students, school children, and insurance applicants, from which small group of controls, the so-called normal standards, were developed. As the number of tracings began to accumulate, many observers noted that the previously accepted standards had been too limited. Wide variations in the electrodynamic cycle were discovered in healthy athletic young men and correlation studies revealed no cardiac abnormalities. In nearly all, there was no history of rheumatic infection or previous cardiac disability. Under the conventional electrocardiographic standards defining what were then considered to be the limits of normal these young men would have been disqualified for service in the Armed Forces.

Prolongation of the P–R interval.—Most authorities accepted 0.20 second as the upper physiologic limit of this period. There were, however, a large number of candidates with much longer P–R intervals, some as high as 0.26 second. More common was the group with 0.22 second. In the absence of a history of rheumatic fever and with no objective evidence of heart disease, they were considered qualified for enlistment or commissions. A few men with P–R interval of 0.24 second were also accepted.

While a fixed or permanent delay in conduction to 0.26 second may be "normal" for a given individual, a changing P–R interval was regarded with suspicion. For example, in one applicant, age 21, the electrocardiographic tracing showed a P–R interval of 0.24 second; an ECG made 10 days later disclosed an increase to 0.28 second. He had no physical or laboratory signs of rheumatic fever and gave no history of having had the disease. In a third tracing about 2 weeks later, the P–R interval had returned to 0.22 second and a faint systolic murmur over the mitral area was then heard for the first time. He was rejected with a diagnosis of subacute rheumatic heart disease.

When time permitted, all applicants in whom the P–R interval was found to exceed 0.22 second were observed for several weeks, tracings being taken every 10 days. If there was no demonstrable change during the period of observation, they were accepted for enlistment.

Left axis deviation.—In boys and young men, left axis deviation was ordinarily considered to be evidence of cardiac involvement, in the absence of a mediastinal shift secondary to pulmonary disease or other lesion of the chest. The condition was frequently associated with left ventricular hypertrophy and was seen in patients with relatively long-standing aortic or mitral valvular disease. Less common were the various types of idiopathic hypertrophy of the heart. In certain persons with wide thoracic measurements and narrow pelvic brims (hypersthenic classification of Draper) the anatomic axis of the heart may be greater than 45°. This may be sufficient to shift the electrodynamic axis toward the left during shallow breathing. When, however, the diaphragm is dropped during deep inspiration, the heart becomes more vertical and the original left axis deviation may disappear.

In all cases where left axis deviation was discovered in men under 25, the third lead was repeated during deep inspiration. Applicants were accepted if the left axis deviation disappeared. If the deviation was only slightly reduced or unchanged, the condition was considered to have clinical significance.

QRS delay.—The upper limit of normal for the duration of the QRS complex was generally agreed to be 0.10 second. Many otherwise acceptable applicants showed a delay in conduction time to 0.12 second, and a few values were as high as 0.16 second. The problems previously considered in the prolonged P–R period were equally applicable to the lengthened QRS complex. A QRS of 0.12 second, if constant, was considered as normal. Under certain circumstances, even 0.14 or 0.16 second was acceptable, but an increasing QRS was considered to be suggestive of rheumatic infection.

Q–waves.—In the older age groups (35 to 55), the discovery of Q–waves, particularly in leads I and II and in chest leads CF_4, CF_5, and CF_6, offered a challenging diagnostic problem. In many men a "small" Q–wave was accepted as normal, although most authorities agreed that such Q-waves should not exceed 0.2 mv. Many applicants in this age group showed Q–waves as deep as 0.6 mv., and where a history of coronary insufficiency or anginal pain was secured, such deep Q–waves were regarded as diagnostically significant and the applicant was ordinarily rejected. In the absence of a history of stenocardia and with no objective findings of coronary artery disease, Q–waves of 0.4 mv. were not considered to be disqualifying.

ST segmental changes.—A surprisingly large number of young men were found with ST segments elevated above the isoelectric line, in some instances as high as 0.6 mv. Repeated examinations over a period of months showed no change in a selected series of 44 cases, and where there was no evidence of rheumatic heart disease, this finding per se was not considered to be disqualifying. In the older age groups, however, a depression of the ST segment below the isoelectric line was considered to be more important than a deep Q–wave in the presumptive diagnosis of coronary insufficiency or disease. After careful examination and repeated exercise tolerance tests, most of these men were found physically unfit for military service.

T–waves.—Most authorities believe that in leads I and II, the T–waves should normally be upright and of relatively high voltage. Isoelectric and negative T–waves in the older group were usually associated with serious myocardial and coronary changes, while in the younger group, rheumatic infection was the most common cause of the abnormality. Many men in their 50's may have a low T_1 without necessarily showing signs of coronary disease, and evaluation of the degree of lessened voltage that should be considered significant in any given case may depend on careful study and the application of knowledge gained only from personal experience. In general, T_1 should have an amplitude of at least 0.1 mv. Men with isoelectric or inverted T_1 and/or T_2 were not accepted for enlistment.

T–waves in the chest leads.—In most adults the T–waves are upright in leads CF_4, CF_5, and CF_6, while in children, some or all may be inverted. Some young men may retain the inverted CF_4 T–wave pattern, but when it is discovered after the age of 25 it should be regarded with suspicion. A number of deaths from coronary artery disease were reported in servicemen under the age of 30, some of whom were known to have had negative CF_4 T–waves prior to enlistment.

Q–T interval.—While the Q–T interval is of much less importance than either the P–R or QRS, lengthening of the interval may have some clinical significance. The generally accepted upper limit is 0.40 second or twice the P–R in any given case. In younger persons it may be prolonged as the result of rheumatic disease. In the older groups, it may represent an old coronary episode and may remain long after the T–waves have returned to normal. Delay in the Q–T interval beyond 0.44 second is ordinarily seen only in association with other signs of cardiac involvement.

Multiple abnormalities.—In considering the electrocardiogram as a whole, any one of the abnormalities previously noted might, in certain instances, be accepted as normal for a given individual. When there were two or more such changes present, however, the condition was regarded as evidence of cardiac involvement. As an example, one applicant for the Air Corps showing a P–R of 0.22 second, a QRS of 0.12 second, and ST_1 elevated to 0.4 mv. and a Q–T of 0.42 second was considered to be disqualified because of presumptive rheumatic heart disease, although he had no murmurs and denied rheumatic episodes. He succeeded in joining another service, however, and 4 months later was hospitalized with valvular heart disease.

The same rule held for the older age groups. A 46-year-old officer was found to have persistent left axis deviation, a QRS of 0.12 second, a slightly depressed ST_1, and a Q–T of 0.44 second. Physical examination was otherwise negative and he denied symptoms of any kind. While on sea duty about 3 weeks later, he had a myocardial infarction requiring transfer to a hospital.

NONDISQUALIFYING ABNORMALITIES OF THE HEART AND AORTA DISCOVERED BY ROENTGENOGRAM

No cardiovascular examination was considered adequate without roentgen visualization of the heart and aorta. As with the hitherto accepted standards employed in electrocardiography, studies of a large number of roentgenograms of normal young men made possible the accumulation of new statistical data not previously available. Most military medical boards considered that these new data proved that the previous upper limits of heart size, as set forth in the Hodges-Eyster tables, were too small. The Selective Service Medical Board, for example, permitted 1 cm. to be added to all cardiac and aortic measurements.

Simple left ventricular enlargement.—Many well-built and vigorous young men were found to have prominent left ventricular borders of the heart. Investigation of this problem indicated that simple enlargement of the left ventricle alone was a benign process, and applicants presenting a prominent left cardiac border were accepted. When the entire heart was enlarged, however, and measurements were more than 10 percent above the Hodges-Eyster tables, the applicant was disqualified. Of considerable interest was the discovery in young Negro men of left ventricular enlargement, in many instances a part of the syndrome of sickle cell anemia.

Prominent conus arteriosus.—A definite increase in the shadow of the conus arteriosus is ordinarily associated with mitral valvular disease or lung lesions such as bronchial asthma and emphysema. Its presence is usually presumptive evidence of a disqualifying condition. In many tall hyposthenic youths, however, the conus may be especially conspicuous, and when there was no obvious organic cause for this, the condition was regarded as normal.

Simple right ventricular enlargement.—Such enlargement without other signs of cardiac disease, an extremely rare finding, was reported only 3 times. In each case there was a scoliosis of the thoracic spine with convexity toward the right, without apparent shift of the mediastinum. The border of the right ventricle was especially prominent both on fluoroscopy and on roentgenograms. The condition was not considered to be disqualifying.

Widening of the aorta.—Increased width of the aorta is not uncommon in the older age groups, and a moderate degree of uncoiling of the aorta is a normal finding. The differentiation between widening of the aortic shadow as the result of such uncoiling and true enlargement or dilatation of the aorta may sometimes be difficult. The diagnosis of simple uncoiling can be made by examination in the three positions. The aorta is actually lengthened rather than widened. The apparent widening is due to a change in position of the arch as it passes diagonally backward. The Hodges-Eyster tables could be used satisfactorily here in the determination of the size of the aortic shadow. A 10 percent variation was permissable, and applicants of the 45- to 55-year age group were accepted if there were no other cardiovascular abnormalities. Widening of the aortic shadow in young men was always considered to be suggestive of organic disease, disqualifying for military duty.

Cardiothoracic ratio.—The ratio of the width of the heart to the width of the thorax is normally from 0.5 to 0.6, depending upon the constitutional habitus of the individual. Selective Service Medical Boards applied the lower figure, although 0.55 was perhaps more accurate.

Surface area of the heart.—This procedure was perhaps the most accurate in determining relative and absolute changes in the size of the heart shadow. Using either the orthodiagram or 6-foot film, the exact area was measured with a planimeter and compared with the predicted tables. A 5 percent variation was permissible. In every instance where cardiac size is important in diagnosis, measurements of the surface area of the heart should be more widely employed, for by this means it was possible to detect small changes in the size of the heart occurring during an episode of acute rheumatic fever or following a myocardial infarction. It was likewise valuable in correlating the findings in cases presenting questionable murmurs or borderline hypertensive syndromes.

Dextrocardia.—The diagnosis was readily confirmed by roentgenogram; many instances were noted on routine photofluorographic films. These men were disqualified only for the special services such as the Air Corps or submarines. Two general types of dextrocardia were noted, the more benign showing complete transposition of the chambers and great vessels (situs inversus). When there were no other cardiac anomalies, these men were considered to be qualified for limited service. The other general group had rotation of the heart without transposition, usually in association with one or more additional congenital cardiac defects. These men were rejected for military service.

Congenital configurations.—A group of about 36 young applicants showed unusual configurations of the heart or aorta or both, in the absence of murmurs or other evidence of heart disease. The most common abnormal configuration suggested coarctation of the aorta, while others resembled intraventricular septal defects or patent ductus arteriosus. In the absence of other objective evidence of congenital heart disease nearly all of the men were accepted.

Undiagnosed mediastinal changes.—A few men, none of whom had symptoms of any kind, showed unusual and unexplained mediastinal shadows. Changes in hilar shadows without apparent cause also presented diagnostic problems in the examination of the cardiac silhouette. Most of these men were accepted. Unfortunately, the cases were not followed.

THE EXERCISE TOLERANCE TEST

The exercise tolerance test was used routinely in the examination of all men suspected of having hypertensive or coronary artery disease. It was also widely employed in doubtful cardiac conditions in order to intensify a murmur or cardiac irregularity, and permit study of the heart under strain. Actually, it was necessary to complete any cardiovascular examination inasmuch as it was not only a measure of myocardial reserve but also permitted a study of the heart under conditions of stress. The applicant was required to perform 10,000 foot-pounds of work, any convenient stairs being used after the height of the steps had been measured to obtain the numerical constant. Blood pressure, pulse, and respiratory rate were taken before the test, immediately afterward, and following 3 minutes' rest.

In the older age groups, the exercise tolerance test was probably one of the most important examination procedures in determining potential or actual coronary artery disease. In addition to the measurement of blood pressure, pulse rate, and dyspneic index, electrocardiograms were taken before and directly after the test. It was noted that depression of the ST segments in leads I and II could be seen after exercise in subclinical types of coronary insufficiency. At the Army and Navy General Hospital, Hot Springs, Ark., it was observed that the tests of the anoxia gave graphic evidence of early coronary and myocardial insufficiency even when all other studies were normal. Precordial pain, with or without anginal radiation, that was promptly relieved by nitroglycerin, was evidence of coronary artery disease.

HEART DISEASES SEEN IN SERVICE PERSONNEL

Rheumatic heart disease.—The combined statistical data from various naval facilities showed that of 21,210 patients with rheumatic fever who were treated in the period from 1942 to 1945, 2,014, or about 10 percent, had heart disease. This compared with 36 percent in a Philadelphia population series and 47 percent in a New York study. The latter series included children, who constitute a group not seen in naval statistics. Nearly 3,200,000 days were lost because of rheumatic heart disease. Acute myocarditis without valvular lesions was noted in 73 patients; in 30 there was evidence of pericarditis. A diagnosis of pulmonic valvular disease was made 3 times and of ulcerative endocarditis 23 times. Three patients with mitral valvular disease died, out of a group of 1,436. Griffith and Huntington reported the deaths of three patients from acute anaphylactic coronary angiitis superimposed upon a low-grade rheumatic carditis.

In recognition of the important role played by rheumatic fever in the development of heart diseases, the Navy set up a special hospital at Corona, Calif., for its study and control. Beginning in 1943, a well-organized program was developed for treatment and rehabilitation of rheumatic cardiac patients.

A study made of acute rheumatic fever at Brooklyn Naval Hosiptal during the winter of 1941–42 showed that in an unselected group of 100 patients, 82 had a history of one or more previous episodes, 11 had a primary attack, and the remaining 7 offered a doubtful history. In 32 patients heart murmurs were noted on admission to the hospital. Of the remaining 68 patients, 41 developed murmurs during the period of observation. Many patients were admitted with pain in one or more joints, slight rise in temperature, and a moderately elevated white count. Often no cardiac signs were noted until the fourth or fifth week, when a soft systolic murmur could be identified for the first time. In some there was no electrocardiographic evidence of myocardial involvement, but more frequently the diagnosis was confirmed by changes in the P–R interval, which often varied from day to day.

Hypertension.—The group with high blood pressure was second in frequency to the rheumatic heart patients seen in the cardiac wards of naval hospitals. These were divided into two general classifications: paroxysmal or psychosomatic hypertension; and essential, organic, or malignant hypertension. As a rule, the former was observed in the younger age groups and the latter in patients from 35 to 60 years of age. There were many instances, however, where paroxysmal hypertension was found in the older age groups. Malignant hypertension was infrequently found in young men because this condition would have been noted at the enlistment examination.

Paroxysmal (functional or psychosomatic) hypertension comes into prominence during every war and was considered an integral component of the "soldier's heart." Together with tachycardia, precordial pain, and sweating hands, it was a familiar picture, masquerading under a variety of names such as neurocirculatory asthenia, effort syndrome, or psychic cardiopathy. Patients with this condition were classified as having a psychosomatic disturbance of the cardiovascular system.

This type of hypertension occurred in emotionally unstable individuals. The systolic pressure was noted in some cases to be as high as 190 mm. but the usual range was from 150 to 170 mm. Only occasionally was the diastolic level involved. A diagnostic finding of considerable importance was the great liability of the systolic levels, which might vary by as much as 30 mm. on repeated readings taken within an hour's time.

In a study of 312 such cases observed at St. Albans Naval Hospital, most of the patients were admitted with a diagnosis of arterial hypertension. During the observation period of 10 days to 2 weeks, the blood pressure fell to normal limits and most of the subjective complaints cleared up, but after the patients were discharged, the entire syndrome, in many instances, recurred within a few days or weeks. In a test series of 50 such patients, 31 were readmitted to the hospital once, 11 were readmitted twice, and 7 had 4 admissions for hypertension. One patient was readmitted 5 times.

The disposition of patients diagnosed as psychosomatic or functional hypertension presented a serious problem. Not all had personality defects but a definitive psychiatric aberration was common to most. In addition, evidence accumulated to indicate that such individuals subsequently had sustained hypertension as a result of secondary changes in the kidney and peripheral vascular tree.

Coronary artery disease.—In one form or another, coronary disease made up the third largest category of cardiac disorders seen in naval hospitals. While most of these patients were in the older age groups, a number of relatively young patients were also noted. Coronary artery disease, confirmed at autopsy, was reported in 11 patients ranging in age from 22 to 38.

Myocardial infarction following anoxia was not usually fatal. In many instances the infarcted areas were subendothelial, and electrocardiographic changes were not always present. Constitutional reactions such as increased white blood cell count, elevated sedimentation rate, and fever were usually absent or minimal.

In acute coronary occlusion, with actual blocking of a major artery resulting in myocardial infarction, the familiar clinical picture was noted of pain, profound shock, elevated temperature, increased white blood cell count, and elevated sedimentation rate, in addition to characteristic electrocardiographic changes. Some patients with coronary insufficiency had no pain. In the determination of myocardial reserve, electrocardiographic changes were observed in patients who only had dyspnea or a sense of weakness after the test. Ordinarily these changes, such as ST_1 depression, returned to normal within a short while.

HEART DISEASE IN THE TROPICS

Oppressive and continuous heat, high humidity, and inadequate water and food supplies plagued the first of the Navy and Marine Corps personnel to reach the Solomon Islands. As the tropical acclimatization process became better understood, the effects of sun exposure and water loss were more easily controlled.

Insofar as cardiovascular disease was concerned, experience soon demonstrated that persons with heart involvement fared poorly in the Tropics. The factors of heat, humidity, inadequate nutrition, and disturbed water metabolism, together with the physical and mental hardships associated with combat duty, aggravated pre-existing cardiovascular disease and in many instances initiated it. The findings of a study of 100 patients with cardiac symptoms seen during the early Guadalcanal period are shown in table 32.

TABLE 32.—*Cardiovascular diseases observed during early Guadalcanal period*

		Percent
1. Neurocirculatory asthenia		34
2. Irregularities of the heart:	*Percent*	
A. Extrasystoles	17.0	
B. Paroxysmal auricular fibrillation	3.5	
C. Persistent auricular fibrillation	2.5	
D. Paroxysmal tachycardia	2.0	
E. Heart block	.5	
F. Miscellaneous	.5	26
3. Valvular heart disease		20
4. Arteriosclerotic heart disease		11
5. Hypertensive heart disease		6
6. Peripheral vascular disease		3
Total		100

Neurocirculatory asthenia was the greatest single cause of cardiac disability in the Tropics. The syndrome was easily recognized by the three outstanding symptoms of persistent tachycardia with rates as high as 140, palpitation, and some degree of breathlessness even at rest.

Sinus tachycardia was not an uncommon finding in personnel in the Tropics. Heat, physical exhaustion, and tropical diseases, all played a role in the development and continuance of high pulse rates. The tachycardia in neurocirculatory asthenia, however, was usually out of proportion to the extracardiac stimulus, and carotid sinus pressure was ineffective in reducing the heart rate. Nearly all these patients at one time or another presented a systolic murmur of varying intensity and duration; the cause of this murmur was not clear. The character of the murmur changed with alterations in posture as well as during the respiratory cycle, and was regarded as functional.

A group of 21 men with moderately severe neurocirculatory asthenia, all of whom had seen action in the Guadalcanal campaign, were studied to determine their fitness for further combat duty. The standard work test estimated in foot-pounds performed in a given unit of time was employed with interesting results. After the equivalent of 5,000 ft./lb., two of these patients were forced to drop out because of breathlessness. After 10,000 ft./lb., six others complained of extreme dyspnea and palpitation. Eleven reached their tolerance between 12,000 and 15,000 ft./lb., one-half of them showing signs of early pulmonary edema. The remaining 2 men finally stopped after 16,000 ft./lb., both with severe precordial pain and extreme dyspnea. In contrast, a group of 10 normal young men were studied using the same tests, all of them reaching the 20,000 ft./lb. standard without unusual cardiovascular symptoms. The pulse rate response in the two groups was characteristic and striking. In the patients with neurocirculatory asthenia, the average pulse rate before the tests was 122 and after the tests 154. In the normal group the pulse rate was 74 before exercise and 96 afterwards.

Irregularities of the heart such as premature contractions, paroxysmal auricular fibrillation, persistent auricular fibrillation, paroxysmal tachycardia, and heart block were seen in about one-fourth of the patients admitted with a diagnosis of cardiac disease. In a number of instances a previously undiscovered cardiac abnormality was found to be responsible for the development of these disturbances of rhythm. Under the stress of tropical combat duty the underlying disease process had become accelerated. A large psychosomatic factor was present in nearly all of the patients who had extrasystoles and paroxysmal auricular fibrillation.

There was a need here for a well-planned program to investigate the temporary and long-term effects of tropical environment upon the aging cardiovascular system. This type of climate in time of peace, freed of the various infections and infestations of the jungle, should be theoretically beneficial for the coronary group of heart diseases. There was considerable clinical evidence to support this opinion. In a superficial survey, a number of military and civilian personnel with a previous history of angina volunteered the information that while in the Tropics they had been more or less free from cardiac pain, notwithstanding the increased physical effort demanded by their jungle assignments. Early in the war the incidence of coronary artery disease in the Tropics was as high as 11 percent, but later statistics showed a drop to 2.2 percent, concomitant with improved living conditions in the combat zone.

Hypertension was found in 6 percent of the patients with cardiovascular abnormalities. This group was about equally divided between the juvenile types of high blood pressure and those hypertensive individuals with associated heart and kidney disease.

Because of the pronounced emotional strain of combat duty, there were many instances where the systolic levels were initially high. In a series of 18 young patients seen after battle, 1 had a pressure of 220/104, another had 212/110, a third had 204/98, 6 were in the 190–200/96–98 group, 4 were in the 180–188/94–96 group, and the remaining 5 had pressures in the range of 160–178/90–94. On leaving the line, they all showed a marked reduction in systolic levels, sometimes as much as 50 mm. within the first 24 hours of observation.

Tachycardia was present in nearly all of the patients with psychosomatic hypertension, but the pulse rate usually fell to within normal limits after a day or two of rest. No extracardiac cause for the rapid rate could be determined, and there was no obvious correlation between the pulse rate and the blood pressure levels. Electrocardiograms taken on 7 patients with psychosomatic hypertension and an elevated pulse rate showed only a simple sinus tachycardia.

Of 11 members of this group on whom exercise tolerance tests were carried out at the end of a 10-day observation period, 8 revealed a rather typical delayed return to a normal pulse rate and blood pressure after exercise. Ten showed exaggerated blood pressure response after 20,000 ft./lb. of work, compared to 5 normal individuals of the same age, height, and weight in whom the response was an average elevation of only 20 percent.

An opportunity was thus presented to test under combat conditions the general conclusions drawn during the enlistment study of juvenile hypertension. Experience proved that such men were poor military personnel who fared badly under the emotional and physical stress of battleline duty, and that they should be rejected for service regardless of the more or less normal interim blood pressure levels. In selecting young men for service in the Navy or Marine Corps, the highest rather than the lowest blood pressure determinations should be the basis upon which acceptance is made.

Hypertension in the older age groups was noted in about 3 percent of cardiac admissions. In a group of 11 selected for special study, the average age was 52; the oldest was 59 and the youngest 46. The highest blood pressure was 210/114 and the lowest was 162/98.

In contrast to the young hypertensive patient, few of the older men complained of symptoms directly related to the higher blood pressure levels. In several instances the discovery of the hypertension was unexpected, admission diagnosis in all 11 patients having been related to abnormalities of the heart, kidney, or lungs, or to combinations of these. Four patients had increasing edema of the ankles and lower legs, two had substernal distress after effort, two had severe dyspnea, and one each had palpitation, asthma, and lumbar pain as the predominant disabling symptom. Headaches, dizzy spells, visual disturbances, insomnia, and other complaints which played such a conspicuous role in the juvenile group were absent here.

No vascular accidents from hypertension were seen in the combat area, but two men had hemiplegia. No conclusions could be drawn regarding tropical combat duty as a predisposing factor to hypertension. Insofar as the older patients were concerned the incidence of hypertension (3 percent) appeared to be less than in similar age groups reported within the continental United States (6 percent at the Brooklyn Naval Hospital). It is possible, however, that there were many undiscovered cases of asymptomatic hypertension among combat personnel.

Tropical infections and cardiovascular disease.—The most frequent tropical disease was malaria. During the early phase of the Pacific war almost 75 percent of all personnel had single or multiple infestations. Improved malaria control measures and the use of atabrine as a suppressive drug eventually reduced the incidence of malaria to insignificant levels, although more than 100,000 cases were reported from 1942 to 1945. Nearly all of the deaths from cerebral and myocardial involvement were due to *Plasmodium falciparum.*

In a study of 100 men with malaria admitted to the hospital in the Guadalcanal area, the diagnosis in 26 percent was abdominal disease, in 21 percent a cardiac lesion, in 21 percent bone and joint conditions, and in the remainder chest, cerebral, and kidney diseases. In a series of 21 patients with malarial involvement of the heart, 7 had angina pectoris, 4 had coronary occlusion, 2 had paroxysmal tachycardia, and 1 had auricular fibrillation. Five patients had premature contractions and 2 had heart block. In each instance, the disease responded dramatically to antimalarial treatment, and there were no deaths.

In a cardiovascular study of 680 patients with dengue, the most common disturbance was bradycardia with rates as low as 48. Conduction defects noted in a number of ECG's were prolongation of the P–R interval and widening of the QRS complex. Arrhythmias were chiefly caused by premature contractions, which were mostly ventricular in origin. Previous observations on patients with postinfluenzal heart disease suggest that the cardiovascular symptoms occurring in dengue may be caused by an excessive vagal response to virus infection.

CARDIOVASCULAR CONDITIONS IN THE SUBARCTIC AREA

The cardiovascular system was profoundly affected by exposure to continuous cold and high humidity. Experimental data secured from studies under simulated subarctic conditions showed that the work of the heart in a cold, damp atmosphere was increased by as much as 110 percent over that required by the same exercise tolerance test performed under ordinary conditions of temperature and humidity. The increase in cardiac work demanded by a given test was dependent primarily upon relative humidity, rather than upon temperature, until –10° F. was reached. Further reduction of temperature below that point produced physiologic changes that were unrelated to the saturation coefficient of the air.

Cardiovascular disabilities noted in the subarctic zones include valvular heart disease in the young and coronary artery disease in the older age group. Acute rheumatic fever was a frequent disability, while hypertension was noted in only a few cases. Peripheral vascular disease aggravated by the cold or secondary to frostbite was a common occurrence.

Hypertension as a separate and distinct clinical entity was not common, which was surprising inasmuch as the initial physiologic response to cold and humidity is one of blood pressure elevation. Persons with moderately elevated blood pressure as high as 170/100 appeared to fare about as well as other personnel. Only two cerebrovascular accidents were observed and both patients were safely evacuated. Paroxysmal hypertension in the younger men was less frequent than in similar groups in tropical areas.

Peripheral vascular disease was of special interest not only in the frigid zones but on all fronts where cold and dampness prevailed and personnel had to work in water because of military exigency. So-called trench foot was a disabling problem as it had been in previous wars.

During the early part of the North Atlantic campaign, the condition appeared among a large group of men who were survivors from sunken ships. They had been exposed to extreme cold, in most cases with their lower extremities wet with sea water for hours or days. Severe reactions had occurred in their feet, and subsequent amputation was found to be necessary in many instances. For this condition, the more appropriate name "immersion foot" was substituted for "trench foot."

In immersion foot, the primary injury was the result of cold, but interference with venous return by dependency, immobility, or tight clothing was a contributing factor. Feet so affected were at first swollen, waxy white (except for scattered cyanotic areas), anesthetic, and pulseless. After warming they became hyperemic and painful. The first or *prehyperemic stage* lasted from a few hours to several days, during which time the feet were cold, dry, swollen, numb, and discolored. The second or *hyperemic stage* lasted from 6 to 10 weeks. In this stage, the feet were swollen, anesthetic, red, and warm, and sweating was usually absent. The third or *posthyperemic stage* lasted from weeks to months, frequently with Raynaud-like phenomena and pain and swelling on exercise. Tissue damage at times was extensive, even with good dorsalis pedis pulsation, and amputation often became necessary. Because the disability was amenable to prophylaxis, serious attention was directed toward the prevention of the syndromes; special stockings, boots, and water-repellent clothing were devised by the Navy Department.

Chapter XIX

Dermatology

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From the medical point of view, World War II might be called the "War of Dermatoses and Skin Reactions." In no previous war had skin diseases, their causes, and the measures for their prevention and treatment played so significant a role. Those who have neither seen the patients nor examined the statistical records may find it difficult to grasp the fact that in many theaters of war from 60 to 80 percent of men who reported to sick call did so because of skin diseases, and that in the Pacific theater one-fourth of all medical casualties were evacuated because of some form of skin damage. It may be imagined that these staggering figures for skin diseases represented unusually high proportions, and were peculiar to particular areas. This notion has some slight justification; but even in times of peace, skin diseases in both Army and Navy accounted for about 10 percent of all patients hospitalized and caused approximately 10 percent of all disability and ineffectiveness.

Recognizing, long before the beginning of hostilities, the importance and growing threat that dermatoses represented, the Medical Department and its Research Divisions proceeded to inaugurate and to foster investigations that were designed to shed light on the causes, prevention, and management of those diseases which fall within the specialty of dermatology and syphilology. It is not possible to describe or list all the dermatologic and syphilologic developments within the Navy during the war, but this account gives some idea of the vast number, the great diversity, and the significance of the dermatologic problems, as well as of the steps that were taken toward their solution.

VESICANT AGENTS OF CHEMICAL WARFARE

From the beginning to the end of the war there could be no certainty that the enemy would not at any moment start to use poison gases on a large scale. It was up to the Armed Forces and combat agencies to develop and maintain the highest degree of preparedness, including every possible means of offense and defense.

Dr. Milton C. Winternitz of Yale University Medical School was appointed Chairman of the Committee on the Treatment of Gas Casualties, and later of Division 5 of the Committee on Medical Research of the Office of Scientific Research and Development. This committee, enlisting the aid of many eminent scientists, organized what was one of the war's great examples of coordinated efforts of civilian and military agencies all striving toward a common goal.

Among the investigators working on the problems of chemical warfare, were dermatologists as well as biochemists, physicists, and other scientists, all concentrating on the scientific and practical studies of the effects of war poisons on the skin. The groups participating in these coordinated studies were composed of representatives of the following agencies: the Naval Research Laboratories of the Bureau of Medicine and Surgery; the National Defense Research Committee, Committees of the Offices of Scientific Research and Development, and the Committee on Medical Research of the Office of Scientific Research and Development; the Chemical Warfare Service and the Medical Department of the U. S. Army; the United States Public Health Service, including the Office of Dermatoses Investigation; a large number of civilian institutions, including Cornell University Medical College, Memorial Hospital, New York University Medical College, Johns Hopkins Medical School, Columbia University College of Physicians and Surgeons, the Rockefeller Institute of Medical Research, University of Chicago Medical School, University of Wisconsin Medical School, and Harvard University Medical School. In addition, a number of leading pharmaceutical firms participated. All these agencies cooperated, not only with each other, but with corresponding agencies and groups of Great Britain and other of our allies.

Chlorine-containing gas protective ointments.—The positive results of these studies included the following: Before the war, a chlorine-containing protective ointment (M4) was issued to the Army for use against mustard gas. The studies by the groups named proved that this preparation was unstable and corroded and destroyed its metal containers, and also that it was extremely irritating to human skin. The protective ointment (S461) issued by the Navy at that time was shown to be less irritating than the Army issue, but it too produced some skin irritations. In addition, it was dead white and therefore had poor camouflage properties, as well as being somewhat unstable and tending to corrode its containers. The development of a new ointment required extensive and methodical laboratory research on antigas chemicals, on ointment, gel, and paste vehicles, on containers and packages, and on camouflage colors. Many thousands of trials were required, first on laboratory animals and then on human volunteers under laboratory and simulated field conditions. Eventually these investigations resulted in a substantial improvement in the protective and decontaminating ointments issued to Army and Navy personnel.

The new chloroamide-containing ointments (Army M5 and Navy S330), while still far from perfect, embodied the following advantages over all former preparations: (*a*) Their proved effectiveness as a protective and as a decontaminating agent against most of the blister gases, including mustard gas and lewisite; (*b*) their relative stability under wide ranges of heat, cold, or humidity; (*c*) their relative lack of damage to containers under all conditions (tropical, arctic, humid, or dry); (*d*) their good camouflage properties and color; and (*e*) most important, the tremendous reduction of their irritating properties to human skin, even when applied repeatedly at short intervals and under tropical conditions.

In the development of these greatly improved antigas ointments, all groups and the Bureau of Medicine and Surgery were active participants. Indeed, a substantial portion of the fundamental work and, in particular, of the practical assays of the many agents and vehicles investigated was carried out under the direction of dermatologists with naval personnel on naval volunteers.

In addition to assisting in the development of new chloroamide ointments for protection against and early treatment of mustard gas and lewisite poisoning the groups listed soon turned their attention to the use against arsenical vesicants of the more specific antidote BAL.

When Peters, Thompson, and Stocken of England transmitted to the American investigators their fundamental discovery of the dithiol, BAL, the "Chlorinating Ointment Program" was already well on its way. The experimental machinery and facilities and the technical knowledge which had been gained was of great advantage in the study of the new thiol antigas chemicals. Through extensive studies by the cooperating groups, the most advantageous ointment vehicles were ascertained and the present stable and remarkably effective 5-percent BAL-containing ointments for local applications to skin and eyes were rapidly perfected and made available.

The groups which had been organized for the development of antigas ointments were able to assist in many other projects. Included among these were notably the toxicologic, pharmacologic, and clinical studies that led to the preparations of BAL for systemic use and intramuscular injections. As a result of this, there was made available to the Armed Forces and eventually to civilian medicine the 10-percent solutions of BAL in peanut oil and benzyl benzoate that have proved so valuable in poisoning and side-effects from such agents as arsenicals, mercurials, and gold salts.

Within these cooperative studies were included many problems, the solution of which led to the development of gas protective clothing and equipment, nonsensitizing and non-skin-irritating respirator masks, and many other practical results. Among the studies, which may some day be of value to civilian medicine, was the demonstration by the Naval Medical Research Unit at Cornell Medical School and at Harts Island that the new, relatively nonirritating chloroamide gas-protective ointments were also efficacious against experimental poison ivy dermatitis, and that these ointments might prove to have practical usefulness against clinical plant dermatitis as well as against important industrial and other allergens (dyes, et cetera) causing contact dermatitis.

Moreover, the nitrogen mustards and their effects, and the fluorophosphates with their most interesting pharmacologic and toxicologic properties, were subjected to intensive study. In addition, much knowledge was gained regarding the skin and its reactions, including new observations on the process of blister formation; the many enzyme systems of the skin and their responses; the laws governing skin penetration by gases and liquids and the influences of heat, cold, sweat, and wetness upon the rates of penetration; and the other factors determining the varying permeabilities of the skin to extrinsic and intrinsic agents.

BURNS AND WOUNDS

It was found that even the best therapeutic measures against vesicant agents of chemical warfare were effective only if applied within 2 to 5 minutes after the exposure of the skin to the vesicant. Otherwise, exposures of the skin to vesicants such as mustard gas or lewisite in liquid form ordinarily led to damage closely analogous to that produced by thermal injuries—the resulting lesions closely resembled so-called mixed second- and third-degree burns. Therefore, Division 5, the Committee on the Treatment of Gas Casualties and the Committee on the Treatment of Infected Wounds and Burns, together with the Bureau of Medicine and Surgery and other agencies, devoted a great deal of time not only to systemic management but also to development and selection of the best external treatment of both chemical and thermal "burns."

For the first time in the history of medicine, many hundreds of different types of local remedies were subjected to controlled studies, first on laboratory animals, then on human volunteers. It was in greatest measure due to naval medical research using naval volunteers that for the first time in the modern study of burns it became possible to elicit standard, equal, and essentially identical burns simultaneously produced on symmetrically situated sites, and to thus study in comparative fashion the natural course of the lesions and to directly compare the effects and effectiveness of two or more external remedies. (Method of "Paired Comparisons" on symmetrically situated sites.)

A wide range of agents was studied, including local applications of many forms of sulfonamides, penicillin, tyrothricin, silver nitrate, balsam of Peru, vioform, and almost all known topical antibacterial agents and vitamins, each separately in a variety of different vehicles and many in various combinations with other agents. Many previously vaunted agents and indeed many vehicles including plain petrolatum and boric acid ointment did not stand the test of scientific, objective evaluation, appearing to favor infection and retard healing.

Only one type of treatment consistently showed a significant beneficial effect in a large series of controlled experiments in which the healing times and course were compared with those of untreated lesions protected by dressings under moderate pressure (a form of "control treatment" which regularly gave among the best results). This beneficial type of treatment included all those measures which had in common the factors of removal of nonviable and necrotic tissue elements, and at the same time were bland enough to spare the maximum amount of still viable epithelium and other tissue constituents. Wet compresses and starch poultices would do this, provided the areas could be kept constantly wet.

The best and most practical way in which the standard second- to third-degree burn could be gently "debrided" and healing accelerated, however, was by the use of a method developed in animal experiments performed under a National Research Council grant at Yale University Medical College. This method consisted of the daily application of pyruvic acid in 0.1 molar concentration in a freshly prepared cornstarch paste, or rather, "Gel." In many hundreds of comparisons, the naval research groups were able to demonstrate on human volunteers that these applications rapidly removed slough, were relatively harmless to viable epithelium, and markedly accelerated healing of the standard burns.

In further development, the Naval Medical Research Unit at Cornell Medical College, New York City, and at the U. S. Naval Disciplinary Barracks, Harts Island, N. Y., screened dozens of different gels and organic acids as unsuitable, but finally demonstrated that the following were among the more convenient preparations that could be used as substitutes for the somewhat impractical pyruvic acid starch gel.

1. Phosphoric acid:

85 percent—1.71 sp. gr.	6.74	cc.
Methyl cellulose (25 CPS.)	170.0	gm.
Water (distilled)	818.5	cc.

2. Phosphoric acid:

(85 percent—1.71 sp. gr.)	27.2	cc.
KY Jelly (Johnson & Johnson)	1,000.0	gm.

Further studies of the Cornell Naval Medical Research Unit together with the Southern Research Institute then succeeded in developing the even more practical powders, which on the addition of water rapidly formed effective acid-containing gels:

Formula I

Pyruvic acid	36.8	gm.
Methyl cellulose	300.0	gm.
Sorbitol	60.0	cc.

(Mix one part of this powder with 10 parts of water.)

Formula II

Phosphoric acid	30.0	cc.
Methyl cellulose	300.0	gm.
Sorbitol	60.0	cc.

(Mix one part of this powder with 10 parts of water.)

The preliminary studies on the healing of standard experimental burns already have received confirmation in clinical trials, but the final evaluation of these preparations in the local treatment of burns and necrotic wounds still requires their use on large series of suitable cases.

Although the further study and careful use of these local measures appears to be clearly indicated, it is to be emphasized that the use of local "chemical" débridement does *not* do away with the *necessity of other standard measures in the treatment of burns and wounds.* Thus grafting and surgical repair should be carried out as early as possible and as extensively as indicated (one great value of the method of chemical débridement lies in the speed and efficacy with which wounds and defects can be prepared for the reception of grafts). In addition, it is obvious that measures to prevent infection, anti-shock and supportive measures, and systemic measures to aid repair and recovery must be taken according to indications, in conjunction with the local chemical débridement.

CONTACT-TYPE ECZEMATOUS DERMATITIS (DERMATITIS VENENATA)

Contact dermatitis, one of the most common of human ills, plagued the Armed Forces both before and during the war. Not only dermatitis from plants such as poison ivy, but also dermatitis from a large number and variety of other external agents had to be studied. As would be expected, these forms of contact dermatitis were particularly likely to occur when the skin was damaged by heat, humidity, and friction, or other irritating conditions prevailing in military service in hot climates.

Poison ivy dermatitis was controlled by eradication of the plant in the vicinity of camps and training stations, and by instruction of personnel in avoiding contact. Unfortunately, it was not until after the end of the war that the two new effective "weed killers" 2–4 D and ammonium sulfamate became available.

The following facts were ascertained concerning poison ivy and plant dermatitis:

1. Treatment of acute plant dermatitis by means of injection of specific extracts is unsatisfactory—more cases were made worse than were helped.
2. Prevention by injection or other administration of specific extracts is not generally feasible.
3. Protective ointments are not generally useful but can be of some value for a short time and under special circumstances, i. e., when large groups of men are forced to go through or work in areas heavily overgrown with the plants.
4. The newly developed and issued chloroamide-containing ointments (M5 and S330) were proved experimentally to be relatively nonirritating to human skin and effective poison ivy protective ointments. It would therefore, seem logical to recommend these ointments for extensive clinical trial whenever it is known in advance that large numbers of persons will be exposed to poison ivy and related plants for long periods of time.
5. Immunologic relationships and cross sensitizations and reactions probably occur between many members of the Anacardiaceae. These include variants of rhus such as Japanese lacquer, poison ivy, and also mango, cashew nut, *Semecarpus anacardium* nut, and other commonly encountered plants and their derivatives. These agents are often encountered in the form of exposures seemingly unrelated to plants, for example the huge incidence of cashew-nutshell-oil dermatitis in those handling electrical insulation, and the dhobie (laundry mark) dermatitis seen in India.

In addition to contact dermatitis from plants, the causes of contact dermatitis in the service included almost every imaginable agent —antimold preparations, insect repellents, clothing materials, dyes and finishes, medicaments (sulfonamide- and penicillin-containing creams), antifungus powders, respirator masks, rubber accelerators, anti-oxidants, and even toilet preparations sold in the Ship's Service Stores. It is likely that the incidence of contact dermatitis among personnel was materially reduced by the studies of many of these items for their skin irritancy and skin sensitization before their general issue, with the resultant elimination of the worst offenders and selection of those which proved least harmful in the pilot and screening studies. These studies, which had to be performed on the skin of large numbers of volunteers, were carried out extensively under the Research Division of the Bureau of Medicine and Surgery, principally at Camp Lejeune in North Carolina and by the Cornell Naval Medical Research Unit at Hart's Island, New York.

Once the techniques and facilities for such screening studies of contact agents had been set up, a method was available for ranging, in order of their relative irritating or sensitizing potentials, a great number of issue substances such as clothing dyes, clothing finishes, impregnating materials, insecticides, and repellents, topical medicaments, and many articles of gear and equipment. On one occasion, at least, this method was called upon to demonstrate that Japanese shells which had been dropped into the hold of one of our ships did not contain vesicant poison gas as had been suspected, but contained an explosive which was also a very strong skin sensitizer with a high potential for producing contact dermatitis in animals and in man.

Contact dermatitis was of itself a major problem and affected large numbers of men, occurring on all parts of the body, due to all manner of causes. This was inevitable when one considers that in a very short period of time the skins of some 20 million persons were suddenly exposed for the first time to a large number of new potential allergens and irritants.

All efforts to prevent skin sensitizers or irritants from being issued or distributed were therefore indicated and worthwhile. Moreover, contact dermatitis was not only a menace per se, but the skin lesions produced by contact agents often irritated, complicated, or maintained many other forms of dermatoses, and acted as portals of entry for a large variety of infections.

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INSECT REPELLENTS AND INSECTICIDES

When one considers the importance of malaria in relation to mosquito bites, of scrub typhus (Tsutsugamushi fever) in relation to bites of mites, of yellow fever in relation to bites of flies, and of typhus in relation to lice, it is easy to realize why so much time and effort was spent on developing means of protecting the skin from biting insects. In these studies, the Naval Medical Research Institute and the dermatologists of the Navy participated with the Division of Entomology of the U. S. Department of Agriculture and with the other groups previously mentioned, under the coordination of Division 5 of the Committee on Medical Research.

As a result of the combined studies and notably those of the Naval Medical Research Institute, the following insect repellents became available before the end of the war: Rutgers 612; Dimethylpthalate; and Indalone.

Some of the newly developed preparations gave protection against mosquito bites for from 6 to 12 hours—as contrasted with protection times of from 1 to 4 hours provided by preparations available at the beginning of the war. This result was based on (*a*) extensive chemical and laboratory studies, (*b*) large scale assays against biting insects on tremendous numbers of human skins, (*c*) carefully planned field trips and field trials in many areas of the Pacific Islands and the tropical Americas, and (*d*) studies of the habits of numerous species of biting insects. The packages and vehicles proved acceptable to the men of Marine Divisions stationed on Guam.

Included among the other investigations to which the U. S. Navy's dermatologists contributed their share, were studies of tick-repellent clothing; of methods for using new insecticides, notably DDT; and of improvement of preparations against scabies, mites, and lice, in particular the clinical assays of NBIN formula consisting of benzocain, 2 percent; benzyl benzoate, 10 percent; DDT, 1 percent; Tween 80, 2 percent; and water q.s.a.d.

Many fundamental facts were learned, not only about the anatomy, physiology, and habits of insects but also about the reactions of the human skin. Among these were proof of individual variations in susceptibility to insect bites; variations in the attraction or repellency of the skin to different species of insects; variations in the skin's capacity to be protected by a given repellent; and the effects of heat, moisture, evaporation, and penetration into or through the skin in altering the persistence of the repellent powers of different odors, colors, and emanations of the skins of different animals and persons.

FUNGUS INFECTIONS

In the Navy, just as in civilian practice, the diagnosis "fungus infection of the skin" was made too often, both by dermatologists and physicians. In analyzing the figures, it must be remembered that many other dermatoses look much like fungus infections and that medical officers were rarely in the position to attempt to confirm their clinical diagnoses by microscopic examinations or cultures. It is undeniable, however, that even if one discounts the high figures for fungus infections a large percentage of dermatoses were either directly caused by fungi or were initiated, aggravated, or maintained by fungus infections.

The Bureau of Medicine and Surgery has long recognized the role that fungus infections played among personnel on all types of duty, particularly among those stationed in hot and humid areas, assigned to submarines or working in galleys or laundries. At an early date during World War II, the dermatologic and other talents of the Navy in cooperation with other services and agencies, such as the National Research Council and several large pharmaceutical firms, were set to work on the problems of combating fungus infection. What is perhaps the most objective scientific study ever planned on the prophylaxis of fungus infections of the feet was carried out by comparative right and left foot assays of various preventive measures on volunteers at the U. S. Naval Disciplinary Barracks, Hart's Island, N. Y. (method of "paired comparisons" as initiated by the Naval Research Unit at Cornell University Medical School). Dozens of preparations, powders, lotions, and ointments were screened by the "paired comparison" method, and selected preparations were tested by supplementary field trials on naval volunteers under the hot, humid conditions prevailing at the Naval Air Stations at Jacksonville and Banana River, Fla. Among the preparations that were superior to the old issue powders in preventing activity of fungus infections of the feet were powders containing the fatty acids. The best preparation was the undecylenic-acid zinc-undecylenate-containing powder. A very close second were the preparations containing propionic acid and sodium propionate.

Other naval studies on the problems of fungus infections included unequivocal verification of the old clinical impression concerning the substantial prophylactic effects of proper aeration of the feet, particularly the wearing of sandals, as first demonstrated in the Army Air Forces at Eglin Field. The prophylactic value of drying the feet thoroughly and keeping them dry, of wearing correctly fitted foot gear, and of meticulous foot hygiene was statistically proved and the general ineffectiveness of medicated foot baths was demonstrated.

In the sphere of treatment, the old dictum that treatment must *above all be mild and non-irritating* was repeatedly confirmed. Bed rest, elevation, and soaks in the acute cases, *mild* antipruritic powders and lotions and tinctures in the subacute ones, and bland softening greases such as undecylenic acid ointments in the dry cases proved to be superior to strong "fungicides" or "antiparasitics" for routine treatment. If generally adopted, the results of the naval dermatologic investigations of World War II will bring about a vast reduction of the superimposed contact dermatitide resulting from too drastic attempts to "kill all those fungi."

PYODERMAS

These diseases, particularly in the Tropics, accounted for a great many more cases than is generally realized. The pyogenic infections were often superimposed upon such diseases as prickly heat, intertrigo, fungus infections, superficial scratches, abrasions, wounds, and burns.

In general, the application of local antiseptics, mercurials, sulfur, iodine, in various forms, resorcinol, quinolines, sulfonamides, or penicillin was, in the Tropics, a two-edged sword; whatever antiseptic effects may have been present were often offset by irritation and sensitization. As a rule, it was preferable to rely on the mildest local measures, such as cleanliness, immobilization of the parts, and soaks or baths. For these, weak solutions of potassium permanganate, boric acid, Burow's solution, very dilute mercurials, resorcin (one-tenth the usual concentration), or vioform ointment was employed. Systemic measures included adequate diets, metabolic regulation, and administration of penicillin or sulfonamides.

SKIN DISEASES DUE PRINCIPALLY TO HEAT AND HUMIDITY

Prickly heat.—This is the scourge of those who are susceptible and are forced to live and work where it is continuously hot and humid. Apparently insignificant, its tortures render many a good man relatively incompetent or entirely ineffective. Moreover, prickly heat in one form or another ushers in a great host of other dermatoses: pyoderma, the impetigos, the furunculoses, the fungus infections, the contact dermatitides, the generalized erythrodermas, and even localization and exacerbations of psoriasis and lichen planus and perhaps also drug eruptions. Studies carried out by the U. S. Naval Medical Research Unit No. 2 on Guam succeeded in uncovering new information about prickly heat and its pathogensis.

On Guam it was found that about 66 percent of personnel became affected within 6 months of their arrival. There was no significant variation of incidence ascribable to sex, complexion, or weight. Sun tanning prevented prickly heat in some skin areas in some persons at some times, but was not universally effective. Furthermore, careful microscopic studies confirmed that the cardinal lesion of prickly heat was probably plugging of the orifice of the sweat ducts by horny plugs, and that vesiculation, irritation, and "internal sweating" occurred in connection with this. Factors that would prevent plugging or remove the plugs were then sought, and several promising methods of prevention and treatment were recommended for further trial. The studies have but begun, however, and the new concepts of pathogenesis must be regarded as opening new avenues of approach rather than as having brought the problem to final solution.

Tropical anhidrotic asthenia.—All studies have shown that in any person's responses to heat and high humidity, the reactions of his skin play a decisive part, because the skin is the organ for the dissipation or conservation of heat and of fluids. However, it was not until the independent studies of workers in the American desert, in Australia, and at the U. S. Naval Medical Research Unit at Guam that a type of "heat shock" was recognized as a systemic syndrome that could be traced directly to a superficial and scarcely noticeable skin lesion.

This disease has been called "tropical anhidrosis" or "tropical anhidrotic asthenia." The plugging of the pores (as in prickly heat) is, in these cases, so extensive that a substantial number of the estimated 2 million sweat glands can no longer function. The fluid is retained in vesicles or forces its way into the interstices of the tissues below the firmly plugged orifices of the ducts. This abnormal disposition of sweat causes papule formation, itching, and periductal inflammation, with sweat resorption by lymphatic channels and into regional nodes. Systemically, whenever elevations of temperature and humidity call upon the individual to make use of emergency mechanism of sensible or secretory perspiration (in addition to the usual constant physical cooling devices, such as insensible perspiration) he is unable to do so adequately and some form of collapse ensues. This collapse may be associated with sweat pouring from the still open glands (usually of the face), accelerated respirations leading to hyperventilation, alkalosis, and sometimes rapid dilatation of the cutaneous vascular bed with a precipitate drop in blood pressure. From this brief composite description of what was observed in cases on Guam and, by others, at the New York Skin and Cancer Unit, it is evident that when a patient is unable to dissipate heat by the usual methods, the body may endeavor to utilize several vicarious cooling mechanisms such as rapid respiraton and rapid peripheral vascular dilatation.

Recognition of the superficial plugs in the sweat glands and of the relationship of the histopathologic changes to those of prickly heat, has improved our comprehension of this disease and its separation from the other heat and sun effects (such as heat strokes, sunstroke, and dehydration). The new understanding of the role of the skin lesion in producing tropical anhidrotic asthenia gives promise of the discovery of prophylactic measures to prevent the plugging and of therapeutic measures to remove the plugs once formed. Correctly adjusted peeling, either with ultraviolet rays or chemical keratolytic lotions (salicylic acid and resorcinol in alcohol) was of therapeutic value not only in prickly heat but also in areas of plugging as found in tropical anhidrotic asthenia. Permitting men to spend several hours of each day in rooms with lowered humidity and temperature aids in preventing both this disease and prickly heat.

The knowledge gained under the "forced draft" of war emergency problems serves as a foundation and stimulus to further medical research. Thus postwar studies undertaken at the New York Skin and Cancer Unit of the New York Post-Graduate Medical School and Hospital make it seem likely that some everyday nontropical skin diseases, which are prone to have exacerbations during periods of high heat and humidity and which rapidly improve on transfer of the patients to places with consistently low effective temperatures, are related to the mechanisms discovered in prickly heat and tropical anhidrotic asthenia. A significant number of such patients with atopic dermatitis, mild ichthyosis, and atypical seborrheic dermatitis were found to have plugged sweat ducts and consequent disturbances in the ability of the skin to dissipate heat.

Many more investigations are required to determine how the repeated abnormal utilization of the accessory circulatory and respiratory mechanisms for heat dissipation may be related to systemic disease, especially to thyroid and metabolic disturbances and to cardiovascular and bronchopulmonary diseases. It is also necessary to study the effects of repeated forcing of sweat into the tissues. It is conceivable that sweat in the tissues may cause a variety of skin lesions, such as the vesicles of dyshidrosis, and lichenoid and scaly dermatoses. And it is not too farfetched to speculate that when, as a result of plugged ducts, millions of intracutaneous injections of sweat and its solutes are made daily, cutaneous sensitization and allergic dermatoses to the substances in solution might occur in susceptible persons. In this way the plugging of sweat glands might favor sensitization to foods, drugs, or other materials secreted with sweat. This may apply to the atabrine eruptions, atabrine being excreted in significant amounts in sweat. If this hypothesis applies, the increased incidence of the lichenoid atabrine dermatoses in the same climates where prickly heat and tropical anhidrosis are most common would be more than coincidence.

DRUG ERUPTIONS

Much knowledge was gained concerning drug eruptions, in particular the new and most destructive form of atabrine lichenoid eruptions. This condition, which has many elements resembling eczema, dyshidrosis, exfoliating erythroderma, lichen planus, discoid lupus erythematosis, Jacobi's poikiloderma, Riehl's melanosis (melanodermatitis bullose toxica of Erich Hoffman), and poikiloderma of Civatte. was intensively studied and clarified in many of its aspects by dermatologists in the Navy. In addition, the drug reactions produced by local and internal administration of sulfonamides and penicillin were observed and new information recorded. Illuminating observations on the localization of penicillin eruptions in areas prone to be affected by primary or secondary lesions of fungus diseases were reported by naval dermatologists. This led to the fundamental concept of possible common antigenic fractions in penicillin molds and in pathogenic fungi, such as trichophytons; and this, in turn, proved a stimulus to research and has already produced important new immunobiologic and mycologic findings.

The studies of sensitization reactions and drug eruptions from penicillin and sulfonamides have led to a much more conservative attitude concerning the use of these drugs as external tropical disinfectants. More intelligent and sharply focused criteria for their application have been developed, with a consequent reduction of disagreeable or dangerous sequelae.

No discussion of the progress made in combating drug reactions can omit the part played by BAL in counteracting the reactions caused by arsenicals, mercurials, and gold. The U. S. Public Health Service, Johns Hopkins Medical College, Cornell University Medical College, naval dermatologists, and naval volunteers all contributed to the studies of toxicity and human tolerance, and in setting up standard dosage schedules for intramuscular administration of solutions of 10 percent BAL in benzyl benzoate and peanut oil.

MISCELLANEOUS ACTIVITIES

The development of more stable and effective sulfonamide and penicillin preparations was largely a matter of the study of vehicles and their effects. The wartime studies, in which the Bureau of Medicine and Surgery participated, succeeded in improving these vehicles and their preparation. Studies were also carried out at the Naval Medical Research Institute at Bethesda, Md., of effects of heat, light, and humidity upon the skin. The development of effective antiflash creams to protect against this most common of all casualties in aerial attacks and explosions; the increased knowledge concerning the effects of sunlight and methods for assaying and compounding better chemical sun screens; and the improvement in buildings, gear, and clothing for use in the Tropics—these were but a few of the important results of studies made.

SYPHILIS AND VENEREAL DISEASES

The Navy fully participated in organized efforts to improve prophylaxis and treatment of venereal disease. Local measures of prophylaxis, methods of rapid treatment, public health investigations with careful reporting and tracing of contacts, improvement in serologic techniques, development of better penicillin preparations, and determination of optimum dosage schedules were actively furthered by the Bureau and by Medical Department personnel throughout the world.

Material progress was made in combating yaws in native populations in the various theaters of war, where mapharsen and penicillin were shown to be effective in treating this disease. Progress was also made in methods of diagnosis, prophylaxis, and treatment of chancroid, lymphogranuloma venereum, and granuloma inguinale.

DEPARTMENTS OF DERMATOLOGY AND SYPHILOLOGY TRAINING ACTIVITIES

Well aware of the significance of dermatoses and of venereal diseases as threats to the health and effectiveness of the Navy, the Bureau of Medicine and Surgery began, long before the war, to develop a well-equipped, efficiently organized, and adequately staffed Department of Dermatology and Syphilology in each of the naval hospitals.

The facilities never were sufficient during the war to meet the huge task, and there were never enough specialists and specially trained hospital corpsmen and nurses to handle all cases, but a tremendous upsurge in the training of physicians, hospital corpsmen, and nurses continued throughout the war. One phase of this effort was represented by the Navy and Army dermatologists collaborating in the preparation of a "Manual of Dermatology" for the National Research Council. This publication, issued to all medical officers and all naval medical activities, contained in concise form the basic information necessary for the diagnosis and management of the most common dermatoses, together with a simple but adequate formulary of useful medicaments. The formulary was designed to eliminate as far as possible unnecessary ingredients, to include only the items immediately procurable in sufficient quantities, and to reduce the bulk and weight of all required medicaments so as to facilitate their transportation and distribution.

As a result of these combined efforts, the Navy's capacity for diagnosis, prevention, and management of dermatoses and venereal diseases substantially improved. While still by no means optimal, the development of facilities for dermatology and syphilology reached a level which was probably higher than that ever before attained during a period of active hostilities in such large and widely disseminated Armed Forces.

DERMATOSES IN RELATION TO THE TROPICS

In patients returned to the United States because of skin diseases, fungus infections made up about 29 percent and acne 28 percent. Other skin conditions with a high incidence were eczema of the lower extremities and atabrine dermatitis.

Dermatoses from tropical infections were extremely rare, if filariasis was excluded. This was surprising because the natives of the Pacific area have many different infectious skin diseases. Of 1,047 natives in New Guinea, 43 percent had cutaneous lesions. There were only a few isolated cases of yaws and most of these occurred among the medical personnel treating natives. Tinea imbricata, so frequently seen in the natives of the Tropics, was not reported in naval personnel.

The effect of the tropical climate on skin diseases was of great importance and the usual dermatoses showed many interesting changes from their course in temperate zones. If a man had a skin disease on arrival in the Tropics, it almost invariably became aggravated. This was particularly true of the fungus infections, which usually spread rapidly and would not respond to ordinary methods of treatment. Seborrheic dermatitis did not do well in heat and high humidity. Severe forms of acne presented many dermatologic problems. Psoriasis, another disease thought to be helped by sunlight, frequently became worse or else was first noted after arrival in the Tropics, while those diseases thought to be aggravated by sunlight, such as lupus erythematosus and cutaneous malignancies, showed no evidence of exacerbation.

It was found that a great deal could be done to decrease the incidence of skin disease by close attention to personal hygiene. This meant at least one or more baths a day with a liberal amount of soap. Following this, the body had to be *thoroughly dried,* so that none of the surfaces retained the slightest trace of water. Particular attention had to be paid to such areas as the ears, axillae, groin, genitalia, and the interdigital spaces. Following this, the liberal use of nonmedicated powder was beneficial in reducing skin maceration. Daily changes of underclothes and socks were necessary. It was found that changing shoes from day to day aided in reducing fungus infection of the feet; this was particularly true if the shoes could be placed where they would dry. A good coat of tan was found to be helpful in resisting superficial infection and in some cases decreased prickly heat. Salt-water bathing was also beneficial if all surfaces, particularly the ears, were dried after bathing.

In general, the treatment of skin diseases in the Tropics was similar to that employed in the Temperate Zone. There were, however, some definite exceptions. Ointments and pastes were not well tolerated and shake lotions or alcoholic tinctures, powders, and mild wet dressings had to be substituted. Also, better results were obtained when the active ingredients were decreased to one-quarter or one-half strength of that commonly used in the cooler climates. In the acute phase of any dermatitis, extremely mild preparations used as compresses, such as boric acid and potassium permanganate, 1:20,000, and plain calamine lotion or other powdery shake lotions gave the best results.

Throughout the war eczematous allergic contact dermatitis was extremely common. The principal cause was overenthusiastic therapy with the mercurial preparations and the sulfonamides. The latter in ointment form were a particularly common source of dermatitis.

Anhidrosis.—Under the title of *thermogenic anhidrosis,* a peculiar and severe form of anhidrosis among the troops training in the desert occurred after long exposure to the hot, dry climate. The face and neck perspired in a normal fashion, but there was a failure to sweat from the neck down. The skin of the affected area showed a dry, papulofollicular, nonerythematous eruption having a "gooseflesh" appearance. In addition to the cutaneous manifestations, there was extreme weakness. Similar cases were observed among the naval personnel in New Guinea, where the climate was hot and very humid. No apparent cause for the anhidrosis was found and the patients recovered on removal to a cooler climate.

Dyshidrosis (pompholyx or cheiropompholyx).—This was frequently observed and in many persons it persisted throughout their stay in the Tropics. It is made up of deep-seated, noninflammatory vesicles involving the palms and soles. It is nearly always associated with hyperhidrosis. These vesicles appear suddenly, last for 24 to 48 hours, and then rupture spontaneously, leaving a collarette of fine scale and a noninflammatory base. There was never any evidence of infection in a true case of dyshidrosis. In differentiating this entity, it is of some help to note that in dyshidrosis there is no inflammatory reaction and no purulent exudate.

Dyshidrosis is probably closely related to prickly heat. On the palms and soles the sweat gland orifices are bridged over or plugged by squamous epithelium and cellular debris so that the gland cannot empty in the normal manner and a small cyst is formed beneath the plug. This is borne out clinically, in that after the vesicles rupture there is no evidence of any underlying infection. Persons suffering from this disease continue to have recurrences throughout their stay in the hot climate. These lesions can become secondarily infected by either bacteria or fungi.

Tropical acne.—This acne differs in many respects from the acne vulgaris in the Temperate Zone. Its onset is more abrupt and the individual lesions are frequently of the cystic type so that many deep-seated pustules develop, resulting in deep scarring. The degree of scarring in many cases at the end of 8 to 10 months correspond to that seen in temperate climates at the end of 5 to 10 years. The disease was important and was noted in 28.5 percent of all patients with skin disease evacuated from overseas. In the older patients, none had had trouble with acne for years until going overseas.

The lesions of acne appeared within 2 months after arrival in the Tropics; in over 90 percent the disease appeared within 6 months. Nearly all the patients had a history of mild acne. Often in tropical acne the face, which showed evidence of previous acne, was not affected, suggesting that areas of old acne vulgaris were resistant to tropical acne.

Sites of involvement of tropical acne were striking as compared with those of adolescent acne vulgaris. By far the commonest sites were the back and chest, but the buttocks and thighs, or the arms and forearms were involved in nearly one-third of the cases. These latter two sites are unusual in adolescent acne vulgaris.

The American Negro appeared to be resistant to this disease, no cases being observed in Negroes.

The most probable cause of this unusual form of acne seems to be an overstimulation of the sebaceous glands because of the heat, somewhat analogous to that which occurs in the sweat gland apparatus in prickly heat. The glands become plugged with sebaceous material and cellular debris, resulting in comedo formation and cysts, which become pustules secondarily.

While these patients remained in the Tropics they became progressively worse. The usual remedies for acne vulgaris were of little or no avail. Many patients improved rapidly on reaching a cooler climate but were usually left with severe and mutilating scarring in the involved areas.

Fungus infections.—Mycotic infections of the skin constituted one of the major problems throughout the war. Diagnosis was usually made on clinical grounds rather than on laboratory findings. The most likely cause for this high incidence of fungus infection was the humidity and sweat that produced constant maceration and thus set up an ideal medium for the growth of the organisms. Many of the patients gave a history of having had a mild infection causing little or no trouble before arriving in the Tropics. On arrival, exacerbation usually occurred and frequently was so severe that it rendered the patient unfit for duty. Lymphangitis and secondary bacterial infection were common, but could usually be controlled by the use of sulfonamides or penicillin. The treatment of ordinary fungus infections of the feet in the Tropics was usually unsatisfactory and in many instances the patient had to be transferred to a cooler climate. Unfortunately, the newer preparations such as undecylenic and propionic acids and their salts were not available in the early part of the war and were not in general use even in the latter part.

Tinea corporis was common among naval personnel, with an incidence much higher than in the United States. Large plaques were frequently noted, some of which were from 10 to 20 cm. in diameter. These had all the clinical characteristics of ordinary tinea corporis seen in temperate countries. The border, however, showed more induration and was erythematous. This condition did not usually respond to ordinary types of fungicidal preparations.

Tinea cruris was also seen frequently. The incidence among naval personnel was higher than that of the Army, possibly due to the type of uniform worn in the Navy. This disease was secondarily infected, and eczematized easily and the entire crural area and inner aspects of the thigh and lower abdomen often became swollen and covered with a weeping crusting mass.

Tinea versicolor with its characteristic yellow or fawn-colored macules and papules was seen in many patients. Many of these patients had extensive lesions covering the greater part of the torso. The achromatic type was common and frequently mistaken for vitiligo. This type is thought to be caused by either a protective action of the fungus against light or the parasite-producing achromia, possibly through the actions of the toxins on pigment or a combination of these two mechanisms.

Tinea imbricata, the spectacular fungus infection of the natives of the South Pacific, was not reported among naval personnel. This is surprising because of the high incidence of the disease among the natives and the fact that the scales are loaded with the organisms, so that it would seem that it could easily be transmitted to Caucasians.

The incidence of deep fungus infection in the Tropics was extremely low.

Pyogenic infections.—These were common following even the most trivial abrasion or trauma. Excoriations from such itching dermatoses as prickly heat commonly became infected, producing extensive pyoderma. Furuncles and carbuncles were frequently noted and became so generalized and ran such a protracted course that the patient in many instances had to be transferred to a cooler climate. Complications of these various forms of pyoderma, such as lymphangitis and sepsis, were frequent but fortunately responded readily to sulfonamides or penicillin.

Tropical impetigo.—The most unusual type of pyoderma seen was so-called "tropical impetigo," in reality a form of bullous impetigo. In temperate countries, bullous impetigo is an extremely rare condition in adults, although common in children. In the Tropics, many adults were infected. It was frequently secondary to prickly heat. Its incidence was extremely high when new bases were being formed or when troops were under combat conditions. As bases became more settled and showers and laundries were installed, the incidence dropped. The organism most frequently isolated from the blebs of this disease was *staphylococcus aureus hemolyticus*.

Tropical impetigo begins as a small, erythematous macule which becomes vesicular in a few hours. The vesicle or bleb covers the entire macule so that there is no surrounding halo of erythema. It is thin-walled, filled with a clear, straw-colored serum, and at this stage is tense. The lesion enlarges further and often reaches a centimeter in diameter. The contents become purulent and the wall of the bleb or bulla becomes flaccid. It is easily ruptured by the slightest trauma, such as the rubbing of clothes, and leaves a raw, superficially denuded surface. The whole process from the appearance of the erythematous macule to the rupture of a bulla may take only 4 to 6 hours. The infection is most contagious and auto-inoculable, so that a large number of new lesions may occur overnight. The axilla, groin, and waistline are the sites most often affected.

Treatment of the individual lesions is satisfactory, but recurrences are common and difficult to prevent while the patient remains in the Tropics. The use of any mild antiseptic preparation will cure the individual lesion. It is important that the patient be seen and treated a number of times a day, so that a lesion does not rupture and auto-inoculate another area. In extensive cases, the injection of 20,000 units of penicillin every 3 hours for a total of 140,000 units was advocated.

Tropical ulcer.—The term tropical ulcer was widely used to cover any type of ulcerative process. Most of these ulcers were not of a specific nature such as those of syphilis, yaws, or leprosy. They were in reality ecthymatous ulcerations of the extremities, usually following some type of trauma or insect bite. They failed to heal because of the climatic conditions and because many of the patients remained in ambulatory status. Another frequently noted factor which delayed healing was dermatitis venenata from too-strong medications. Sulfonamide ointments were the principal offenders. With wet dressings of a concentration of 2,500 units of penicillin per cc., the ulcers healed rapidly.

Before the war, several different types of tropical ulcers were described. They were particularly prevalent throughout the Solomon Islands, New Guinea, and the Philippines. Many of these showed an infection with Vincent's organisms, namely, Spirochaeta and fusiform bacilli. Some harbored pseudodiphtheria bacilli and some were attributable to true diphtheria. A number of authors believed that an inadequate vitamin intake was the underlying factor of many of the ulcers. Other ulcerative eruptions of the Tropics have been described under the titles of desert sore, veld sore, and Barcoo rot. Various bacteria such as staphylococci and streptococci have been isolated by different workers. Others believed that excessive exposure to sunlight was important in the production of the condition. These eruptions begin as vesicles which may rapidly become bullous and soon rupture, leaving a dirty, punched-out ulcer. There is little tendency to heal and they may slowly extend at the margin. There is an associated folliculitis. The ulcers in these categories usually occur on the hands and forearms. Most of these lesions respond readily to cleanliness and weak antiseptic dressings.

Cutaneous diphtheria.—Cutaneous diphtheria, for some still unexplained reason, is frequently encountered among the natives of the Tropics. During the war, only a few cases occurred in Navy personnel. This may have been because most of the men had good living conditions. There were two large series of cases reported from the Army. The first 174 cases were reported from the Solomon Islands, Saipan, and Leyte. The second group of 140 cases were reported from the India-Burma theater. The lesions were noted mostly among combat troops who had been away from adequate bathing facilities for a long time.

Cutaneous diphtheria frequently begins in a pre-existing bite or abrasion, but may start without any definite preceding lesion. It is usually an ulcerative process primarily involving the epidermis and subcutaneous tissues and rarely going deeper. The ulcer is covered with a yellow-brown membrane which can be peeled off, leaving a clean-appearing, hemorrhagic surface. Later a brownish-black slough is found. A wide band of inflammatory reaction usually surrounds the ulcer. In later stages, the ulcers have a punched-out appearance. On spontaneous healing, blebs may develop in the scar tissue which, in turn, break down forming a new ulcer. Most frequently, the lesions, which are usually multiple, are on the legs and feet.

The bullous eczematoid and intertrigolike forms of diphtheria, not unknown in the civilian practice of dermatology, were either extremely rare in the Armed Forces or escaped correct diagnosis.

Complications of cutaneous diphtheria are polyneuritis and myocarditis. In one report 34 percent of the cases had polyneuritis and 2.7 percent had myocarditis. Treatment for this disease includes large doses of antitoxin, to prevent systemic ill effects, and penicillin.

Contact-type allergic eczematous dermatitis, dermatitis venenata.—In the Tropics there are a number of plants that produce an acute dermatitis in susceptible individuals, most of them belonging to the family of *Anacardiaceae.* This dermatitis venenata is similar to that produced by poison ivy or poison oak in this country. Cases of dermatitis caused by the sap of the tree *Semecarpustara,* were reported from the South Pacific as well as others due to the laundry mark (dhobie mark) made from the oil of nuts from the bella gutti (*Semecarpus anacardium*) tree.

In the author's experience, there was only one group of Seabees working in the forest who developed a typical allergic eczematous contact dermatitis from the flora. Some types of military equipment caused many cases of contact dermatitis, however, and dermatitis from external medication, insecticides, clothing, equipment, and cosmetics was of high incidence. Personnel on duty in the Tropics were more susceptible to skin damage and to skin sensitizations than the civilian population in temperate climates.

Schistosoma dermatitis.—This dermatitis is caused by the entry of cercariae or larvae into the skin following bathing in polluted fresh water. It begins a short time after coming out of the water as a tingling sensation on the parts of the body that have been submerged. It is followed by pruritus and the appearance of small red macules. In a few days these may look like chigger bites. Later a severe urticaria may appear and the edema may last several days. The importance of this dermatitis is that it may be the prodromal symptom of schistosomiasis. A number of cases of this dermatitis were observed among men stationed in the Philippines, particularly on the islands of Leyte and Samar.

Dermatitis of the dorsa of the feet and ankles. –This condition has also been referred to as "boot dermatitis" or "bootlike dermatitis" or sometimes "stocking dermatitis." During the war it was extremely common among naval personnel in the Tropics. Unfortunately, its cause could not be discovered. Most observers believed that it was definitely *not* a fungus infection. The process usually started on the dorsa of the feet and the sides of the ankles. This spread and often involved all of the dorsum of the foot and lower leg. It was frequently bilateral. Later there might be an acute, eczematous reaction with marked edema, weeping, and crusting. This was easily infected secondarily and lymphangitis occurred, necessitating hospitalization. After the acute stage was controlled or subsided, lichenification set in, associated with persistent and severe pruritus. Excoriations from this might, in turn, become infected.

These lesions usually were not associated with the ordinary interdigital fungus infection. In fact, the interdigital areas were often peculiarly free. Some believed that this eczematoid reaction began with a fungus infection, but, either through too-vigorous medication or from heat edema of the foot, a secondary dermatitis developed. It appears plausible, however, that heat and moisture plus abrasion from the shoes and socks produced the eruption. Standing for long hours on duty must have also played a part. Some observers found that the men were sensitive to the leather of the Marine type of field boot, but could not be sure that this was the factor in the allergic contact dermatitis group.

Treatment was unsatisfactory. Even the mildest antiseptic solution would aggravate and spread the lesion. These patients frequently had to be returned to a cooler area and even then required a long period of treatment.

ATABRINE (QUINACRINE HYDROCHLORINE) DERMATITIS

The most interesting new dermatosis seen in tropical areas during the war was the unusual and spectacular eruption which has now been proved to be caused by the ingestion of atabrine (quinacrine hydrochloride). It is to the credit of the dermatologists caring for these patients that they realized almost at once that they were seeing a unique eruption and that atabrine was the major factor in its production. This is substantiated by the many different reports that were made.

The first cases were recognized in the early part of 1943. They were noted in widely separated hospitals but the patients all came from the New Guinea, North Solomons area. One report described three cases of exfoliative dermatitis caused by atabrine. They had all had suppressive atabrine treatment for malaria. One patient had an exacerbation of his eruption on retaking the drug, and all had a positive patch test to the drug.

Similar cases were reported among Australian troops coming from New Guinea. They presented an unusual dermatitis and had been taking atabrine. Later in the same summer, cases were observed among Army and Navy personnel who had been evacuated from tropical areas because of skin diseases. Proof that atabrine elicited such eruptions was obtained in 12 patients; in 3, patch tests with atabrine were positive, and in 6 or 8, exacerbations were noted following administration of atabrine by mouth.

These cases were first described as a typical "hypertrophic lichen planus." Because most of them came from New Guinea, it became known as "New Guinea lichen planus" or "New Guinea disease." At first it was believed that the environment in New Guinea had something to do with its development. The role of environment was soon disproved when other cases appeared wherever adequate dosage of atabrine was taken over long periods. Likewise, the theory that the eruption was caused by vitamin deficiency was weakened when the eruption appeared among those receiving well-balanced diets with plenty of fresh foods. Similar cases but in fewer numbers were reported in the Mediterranean and India-Burma theaters. As the war progressed, new cases appeared among the military personnel in the Philippine Islands and later in Okinawa.

Incidence.—Fairly accurate figures on the incidence of this drug eruption have become available. The estimates of maximum occurrence vary from 2 to 10 per 1,000 per annum. It was reported that more than 80 percent of the Army patients evacuated from New Guinea for skin diseases had this lesion.

Incubation period.—One of the most interesting facts concerning atabrine dermatitis was that sometimes there was an extremely long interval before full development of the typical picture. Few cases developed soon after taking the drug; the great majority of the patients did not develop any type of characteristic eruption until they had been taking "suppressive" atabrine for from 3 to 8 months.

Clinical appearance.—Patients developing this type of dermatitis often first noticed scaling areas associated with pruritus, particularly about the eyes, over the knuckles, about the ears, and in the corners of the mouth. At first only one or two lesions appeared and then new areas were slowly involved. The lesions were sharply demarcated papules with dusky red, erythematous bases having a fine scale. About the ears, the early lesions showed diffuse scaling, some edema, and a characteristic purplish-red color.

In many patients, eczematoid eruptions of hands and feet preceded the lichen lesions; in others there were widespread eczematoid and exfoliating erythrodermas which sometimes preceded the lichenois dermatosis and sometimes persisted with few, if any, lichenoid changes. As the lichenoid disease progressed, new areas were likely to appear anywhere on the body. The neck was frequently involved and there was a tendency for the lesions to be oval, with long axes following the lines of cleavage. They were usually about 2 cm. in diameter. In some of the older lesions, the appearance of the scale was that of slightly dirty mortar. Often these oval lesions following the lines of cleavage suggested pityriasis rosea, but the deeper color and type of scale and induration of the papules differentiated the disease.

The disease did not progress rapidly, but after a few weeks the lesions became larger and confluent, forming patches. This was particularly noticeable on the lower legs and the backs of the hands. In more advanced cases showing large patches, there was a tendency to secondary eczematization because of the excessive heat and moisture of the Tropics. In locations such as the axilla and inner aspect of the thighs, there was a great deal of edema, weeping, and crusting. Pyoderma was a frequent complication. On the scalp there was often a thick dry scale, which in many instances suggested psoriasis. Alopecia was associated with this, together with apparent atrophy suggesting lupus erythematosus.

Interspaced between the larger plaques, particularly on the neck, a definite follicular, papular noninflammatory eruption was noted. This had a dry scale and was suggestive of phrynoderma or vitamin A deficiency. The toe and finger nails were frequently involved. In the early stages a purplish-black line occurred at the proximal portion of the nail bed. In some patients this was the only manifestation of atabrine intolerance. The mucous membranes were sometimes affected with purplish-black discolorations and occasionally there were lesions of the mucosae similar to those of lichen planus.

Some authors have attempted to differentiate the types of eruptions caused by atabrine into the eczematoid and hypertrophic lichen planus-like forms. These different types were actually due to the location. The eczematoid were seen in areas such as the axillae, the circumanal area, and about the genitalia where there was secondary maceration from profuse sweating. The hypertrophic form was usually seen on the extremities and the head. Patients nearly always showed both eczematoid and hypertrophic lesions.

Many patients had generalized exfoliative dermatitis with loss of finger and toe nails and generalized alopecia. In this severe form, the absence of sweating was noted in the involved areas. In some instances death resulted from the exfoliative dermatitis. On stopping the drug, most patients gradually improved, however, over a period of months, but in many there was residual apparently permanent atrophy of the skin, pigmentation, and partial alopecia.

In this country, patients with this type of dermatitis who had been returned from overseas were observed. Patch tests with atabrine were of no aid in making a diagnosis, only about 20 percent reacting positively to patch tests, but many dermatologists observed that on readministration of atabrine there was a definite exacerbation of the eruption. It can be regarded as proved beyond reasonable doubt that this cutaneous syndrome is due principally to specific sensitization to atabrine.

Chapter XX

Medical Research

Harold W. Smith, *Rear Admiral (MC) USN (Deceased)*

Notwithstanding all the efforts that preceded "Pearl Harbor," the outbreak of hostilities found us unready. We had no information as to the area of major effort, and little warning as to possible hazards to be encountered. Lack of information was felt particularly in the diversified Pacific Ocean area; the "iron curtain" over the Japanese mandates had resisted penetration, so that, while the diseases in that area were known in general, their exact distribution had not been charted or the local habits of vectors studied. Effective means of control for each locality had to be learned. Even a disease as familiar as malaria was to take enormous toll, in some instances paralyzing a campaign, before efficient suppressive measures came into general use.

The weapons used by the enemy, although known in advance, were used in novel ways or in novel situations, so that medical service had to be adapted to new defensive measures. New tactics, as exemplified in the amphibious assault, required new systems of medical supply, first aid, evacuation, and protection. It was for the protection of assault troops that body armor was developed. The first task devolving on medicine was selection of personnel; its second, to devise practicable means of protecting personnel from the innumerable environmental and occupational hazards to which they would be exposed.

In medicine, as well as in the sciences of combat, advances made in the intervals between wars are so considerable that the implements and procedures employed in one war are superseded in the next. That proved true at the very outset of World War II. New measures had to be selected from among those immediately available, and the manner of their utilization prescribed.

Material for selection was incomplete, however, and much was untried. During the period following World War I, research had been desultory and progress irregular. In only a few instances, had it reached the definitive stage. The exigency did not permit further reference to fundamental research, so there was urgent need for an agency capable of quickly mobilizing the potential of the country to supply authoritative advice and to fill gaps in existing knowledge. Accordingly, by Executive Order No. 8807 of 28 June 1941, there was created within the Office of Emergency Management (the O. E. M.) the Office of Scientific Research and Development (the O. S. R. D.) "for the purpose of assuring adequate provision for reseach on scientific and medical problems . . ."

Under the Director, Dr. Vannevar Bush, there were set up two branches—the lay National Defense Research Committee (the N. D. R. C.), Chairman, Dr. James B. Conant; and the Committee on Medical Research (the C. M. R.), Chairman, Dr. A. Newton Richards. The medical committee, whose function it was to advise and assist the Director in the performance of his medical research duties, consisted of seven members, including one each from the Army, the Navy, and the Public Health Service.

In order that the C.M.R., a small group, should be in position to tap the resources of the whole country, it established organic relations with the Medical Sciences Division of the National Research Council (the N.R.C.). Dr. Lewis H. Weed, chairman of the N.R.C., promptly organized about 50 committees and subcommittees, members of which were selected from universities and other institutions. Representatives of the Armed Forces were present at all meetings, and informational liaison was established with our allies.

The committees furnished opinions, defined problems requiring investigation, formulated attacks, and weighed proposals for research, recommending those advanced by individuals and institutions who were adjudged qualified to undertake the studies proposed. The proposals were next considered by the C.M.R., and those recommended by that body were then, with the approval of the Director, negotiated as contracts by the Administrative Division of the O.S.R.D.

Malaria proved so devastating in the earlier years of the war, at a time when stocks of quinine were dwindling, that the C.M.R. set up a special group—the Board for the Co-ordination of Malarial Studies. This Board furnished an example of the "team" or group research which has been so productive for industry and which proved equally successful in malariology. Drugs of value in the many-sided control of malaria were developed through the joint effort of clinician, chemist, parasitologist, pharmacologist, toxicologist, immunologist, and manufacturer. This concerted form of attack presents a model of the approach indicated in the future for the solution of the many complex problems still crying for elucidation.

Meanwhile, the Navy was active in its own right. The Bureau of Medicine and Surgery established a Research Division charged with maintaining liaison, collecting information, and initiating, implementing, coordinating, and utilizing all medical research. The conviction leading to the creation of this division was that by research as by no other means could the conservation of forces, the mission of the Medical Department, be served. Events justified this belief. Although combat theaters included regions saturated with factors of morbidity, World War II was the first great war in history in which the damage suffered from enemy agents exceeded that from disease.

A collateral function of the Research Division was to acquaint personnel in the field, who were often removed from other sources of information, with new developments pertinent to their varied tasks—often years in advance of publication. This valuable service was adequately performed during the war by a biweekly "news letter."

Combat requirements were studied by special laboratories, suitably located, dealing with the particular problems of aviation, field operations, submarines, biological weapons, and chemical warfare. Special groups for special purposes were organized from time to time. For consultation, reference, and reinforcement, and for basic or other indicated research in the allied sciences, the Naval Medical Research Institute was built at Bethesda, Md.

In rapid succession 11 medical research units were set up. They were primarily concerned with investigation, development, application, and field studies, but turned to basic research when it was the only known approach to the solution of an urgent problem and whenever pursuit of a personal speculative interest was compatible with obligations to implement the war. There were, too, many incidental developments bordering on pioneer research: there was no novelty in the transfusion of blood, but it was trail-blazing to make "fresh" whole blood available throughout the jungles of the Pacific.

In many lines of investigation, the Navy was in a favored position to undertake research, because it had facilities and other enabling resources not available to civilians. For example, the huge aggregations of personnel at training stations under complete control afforded unique opportunity for studies in communicable disease, a fact which suggests practical criteria for allocating tasks to the Armed Forces and to civilian research agencies respectively.

It will be conceded that civilian institutions are usually better equipped and more ably staffed for basic research. They can furnish highly competent specialists, as they did during the war, whose skills can be utilized for special services of one kind or another. For any study within a Navy frame, however, as in the case of an item to be carried through the sequences of development, adaptation, trial, and adoption, the Navy alone has the familiarity with the field of application which from the start must govern the development and also the material resources necessary. In such a case, the military organization concerned should have full direction and control.

While the demands of war limited "pure" research by the Navy, it is gratifying to note that, since the war, the Office of Naval Research has embarked on a policy of supporting "basic research with freedom in its conduct." This course was adopted because of the realization that from the mass of knowledge so accumulated may come the weapons and defenses of the future. Provision was made for medicine by a Medical Science Branch in charge of a medical officer attached to the Bureau of Medicine and Surgery.

Overseas laboratories were commissioned at Guam and at Cairo, Egypt, to cover tropical and subtropical latitudes, thus giving the Navy contact with many diseases for the most part strangers to our homeland but certain to be encountered in the course of a global war and, at all times, possibly pandemic.

Employment of animals for the study of new compounds is a first step, but before the adoption of a new drug is justifiable, data concerning its pharmacology, toxicology, and therapeutic action must be corrected or confirmed on human subjects. Such procedure is not devoid of danger, and commendatory mention should be made of the inmates of naval disciplinary barracks and of civilian institutions, who, although fully informed as to possible hazards, volunteered to serve as subjects for the final studies on new and unproved drugs—particularly antimalarials, fungistatics, and wound dressings. These men, barred from other war service, patriotically viewed the ordeal as their contribution to the war effort.

To make foreign liaison effective, medical officers were attached to the U.S. Embassies in London and Moscow. Various officers served on occasion with the Office of Strategic Services and with Bombing Surveys in Europe and Japan. A British medical officer occupied an office in the Bureau, and Canadian officers were in daily communication.

It has been remarked that during the war there was no research, that what passed for research was, in fact, development and application of products of prior peacetime. That statement is too sweeping; numerous instances to the contrary can be cited, but in large measure it is true. Urgency did not permit resort to so-called fundamental research, the results of which cannot be foretold, much less its duration.

No reproach can attach to such policy, for it is obviously necessary to adopt something of some value that can be used immediately, rather than gamble on the outcome of a program which may yield something of more value at some indeterminate date. The principle, "conservation of forces," must determine the action to be taken, and observance of that principle brooks neither compromise nor delay. For this reason—pressure for research of more immediate promise—the vitally important study of man with reference to his genetic constitution and its highly variable response to environmental influences had to be postponed for the time being.

Nevertheless, in many instances it was possible to carry on basic studies, often simultaneously with use of a product guided by such information as was already available. Penicillin is an example. At the same time that its therapeutic spectrum was being learned by clinical trial, studies bearing on selection of strains, culture methods, constituent substances, and chemical synthesis were being pushed vigorously.

The elaboration of antimalarials is another case in point. Although quinacrine hydrochloride (atabrine) had been proved generally superior to quinine and was in use, investigation continued, some 15,000 compounds being synthesized and their action studied. In the welter of substances isolated, a few with true plasmocidal action were discovered and new light thrown on the life history of the different species of plasmodia within the human host. In fact, attainments in this field tempt one to speculate on the extensions of which war research may be capable: the economic, social, and anthropological effects of virtual extinction of malaria are beyond reckoning.

It may not be amiss to consider what lessons for our future guidance may be derived from our recent experience. One debated question is: to what extent should the Government support the pursuit of knowledge for its own sake in time of war? Although history contains instances of discoveries which at first sight appear to be isolated phenomena, inquiry shows that few if any were made without reference to the sustained interests and occupation of the discoverer. If not the direct issue of planned research, they were incidental to research, investigation, or pursuit of some recognized objective.

Research carried on without reference to a specific objective will, if in sufficient volume, eventually yield results which constitute additions to knowledge and for which, it may be presumed, a use will ultimately be found. But this proceeding is slow, costly, and uncertain; and even if successful, integration or application may be delayed for centuries. Unless research is conditioned by prospective application, it tends to become anchoretic.

During the late war, the fields in which accomplishment was noteworthy were those in which objectives were formulated by directives and research prescribed accordingly. Therefore, in case of urgent need or of a novel development, mastery of which is essential to national security, objectives should be imposed and tasks assigned.

Another lesson learned, although its validity will be heatedly disputed, is that in event of war only "the military" are familiar with all considerations bearing on justification of development and practicability of adoption. Hence, in all organized bodies set up by the Government for the underwriting of research related directly or indirectly to military operations, statements as to needs, determinations of relative importance, judgments on proposals, in fact, all decisions as to action to be taken, should be made by officers of the Armed Forces. They should, however, be sitting in joint session with civilians qualified to advise on matters within their respective areas of cognizance and to set in motion whatever research is deemed desirable. Research in such case has a special purpose and cannot be carried on productively unless subservient to that purpose.

Although in time of war over-all direction of research should be entrusted to the military, that is a policy dictated by time and circumstance. Through the years, both medical and military science will be genuinely advanced almost wholly by the labors of civilians. On the other hand, the Government now accepts the obligation to foster basic research, and appropriates funds to be expended for that purpose in its own laboratories and in civilian institutions. Hence, it is to the mutual advantage of the Government and civilian research workers that close relations be maintained through common membership in Councils, Societies, and National Foundations, by cooperative association with Government agencies, and by personal contract or other form of periodic employment by the Government. In truth, it is not merely a matter of mutual advantage; it is an obligation a group owes its Government and the Government owes to the people.

It now seems a curious fact that prior to the war the engineer, the architect, and the operations officer proceeded with little reference to the human organism. For among the more significant and fruitful developments of the war period was the recognition that came to be accorded to contributions that specialist officers of the Medical Department could make to enhance efficiency—human data as factors in engineering and design.

Broadly speaking, the function of the Medical Department is still to conserve military strength by ensuring that there shall be no avoidable loss in personnel or diminution in its efficiency, but for the accomplishment of that mission new tasks have emerged. Whereas prior to the war the guiding principle, "conservation," found its chief expression in a striving for the mastery of disease, during the war that particular field of activity became relegated to secondary importance, it having been found that the inactivation of personnel by enemy agents exceeded that due to disease or intrinsic disorder.

That outcome was not due to accident or to chance conjunction of circumstances. Knowledge already possessed, research in many quarters, and intelligent application in the field combined to effect the high degree of disease control. The unprecedented achievement is a monument to preventive medicine—to the rerearch teams, to the planners and administrators, to those who applied principles to terrain, to the construction battalions who remade topography to order, and to those in authority who understandingly gave their support.

The very success of preventive medicine led, however, to its partial eclipse, for it gradually became apparent that a greater measure of conservation could be gained by the linkage of medicine to industry and to the combat branches of the Navy in the design, development, production, and employment of the engines, weapons, and devices used in warfare, and by contributing the special knowledge of medicine to the formulation of decisions governing strategy, tactics, campaign planning, and supply. This shift in emphasis has been visibly accelerated by the revolutionary changes in progress.

Because the principle, "conservation and efficiency," demands that the active list be cleared of ineffectives, the retention in a naval hospital of patients who cannot be returned to full duty in a reasonable time can be countenanced only when the vital interests of the patient require it or when other Government facilities are lacking. Hence the conception of a noncombatant branch dedicated solely to the relief of suffering is obsolete, and strictly professional activities become at best a service of first aid, salvage, and morale. Today, then, the Medical Department is to be viewed as an auxiliary corps having positive and direct part in promoting military effectiveness, and its policies are to be formulated accordingly.

As already noted, each war is waged with new developments, and it is upon research that the nation must rely to keep its military ways-and-means modern throughout the years. Indeed, the more the military establishment is reduced, the more imperative it is that purposeful research be supported without stint.

In order to do that, it is necessary that research, owing to its highly specialized and progressively sequential nature, be administratively independent of current operational policies. That principle is embodied in the top organization of both the War and the Navy Departments; a like policy is no less incumbent on the Medical Department.

Further, as a means of self-propagation, the function of training is inseparable from a service as peculiarly specialized and diversified as research. Particularly is it important in the case of a Navy operating from pole to pole that training be carried on in the so-called ancillary sciences which together constitute the science and art of medicine. Fortunately, the necessity of training is now a fixture in Navy practice and is implemented by congressional appropriations. It is a function which cannot be allowed to lapse.

Research is the one instrumentality by means of which we can forecast particular developments of the future and at the same time arrange that the future shall be as we anticipate it in those respects. Witness the atomic bomb. Experience is no acceptable substitute. Granted that experience is the great teacher, it may be so catastrophic as to destroy its victims. In any event, it becomes available only post facto. It is hindsight. Given new conditions such as are met in each successive war, experience is as yet unborn. Research remains the cheapest, quickest, and surest means to industrial progress and military strength.

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Chapter XXI

Clinical Psychology in the Screening Program

William A. Hunt, Commander (MSC) USNR

Both World Wars witnessed significant developments in psychology. World War I saw the coming of age of the *group* testing movement and the development of the now famous Army Alpha and Army Beta group tests of intelligence. World War II saw the maturation of clinical psychology as a specialty, with stress on *individual* testing techniques and supplementation of test scores by the clinical interpretation and judgment of the trained specialist.

The great success of group tests of intelligence in World War I led to their subsequent overevaluation. Many psychologists believed that the problem of measuring intelligence had finally been mastered by a completely objective technique. Here were simple paper-and-pencil exercises which could be administered to large numbers of individuals simultaneously by relatively untrained personnel and scored automatically to yield an accurate measure of intellect. It was a mechanical process that could be handled by anyone, without the intervention of highly trained professional personnel.

As time passed, however, group tests were found to have their limitations. They were reasonably accurate when used on average men of normal intellect and temperament, raised in a common cultural environment with equal educational opportunity and tested under rigidly standard conditions. When applied to the deviant individual, the educationally and culturally handicapped, the mentally deficient, the emotionally unstable, the neurotic and psychotic, and the person suffering from some organic brain condition, group tests proved to be fallible and relatively unenlightening. Yet, it is these persons on which it is vital to have accurate information.

As a result, those psychologists serving in behavior clinics, court clinics, and psychiatric hospitals came to rely upon the *individual* test, a test that is administered in a face-to-face situation to a single subject and is not limited to the use of paper-and-pencil materials. In such a situation, the examiner is able to control the testing conditions more carefully, to introduce any variations demanded by the specific condition of the person being tested, and to complement the resulting test score by his clinical observation of the subject's behavior during the test. Moreover, it is then possible to evaluate the subject's test performance in relation to his personal history and any further clinical data that are available. Such a complete evaluation cannot be rendered by any mechanical testing device, but only by a trained clinician exercising professional judgment.

By the advent of World War II, there had developed a group of clinical psychologists skilled in the use of individual testing techniques and in the clinical interpretation of the test results. Their contribution was recognized by psychiatry and they were experienced in working with the psychiatrist and neurologist as members of a clinical team. It was inevitable that they should be included when the Bureau of Medicine and Surgery began to develop a program of neuropsychiatric screening to obviate those difficult problems of military neuropsychiatry which World War I had demonstrated must be anticipated in the rapidly developing emergency.

Group tests for intelligence and aptitude retain an important place in naval procedure, but are relegated to the Classification Department, where they are used for job selection and placement. When the problem of further refining these rough measures arises, as it does in differentiating mental deficiency from cultural or educational handicap, or in establishing mental deficiency as reason for separation from the service, the case is referred for individual testing by the clinical psychologist.

The original plan for neuropsychiatric screening envisaged a psychiatric unit composed of a psychiatrist, a neuropsychiatrist, and a clinical psychologist who would function as a diagnostic team. It was seldom possible to maintain this exact ratio, but these three complementary disciplines—psychiatry, neurology, and psychology—were always represented.

The duties of the psychologist in this team were delineated in a statement entitled, "Basic procedure for psychologists functioning at training stations and Marine Corps bases in connection with psychiatric units," which was enclosed with a directive on neuropsychiatric screening issued 1 February 1941. This directive assigned to the clinical psychologist the task of evaluating ability and temperament. Certain standard individual tests, such as the Wechsler-Bellevue Adult Intelligence Scale, were suggested as basic procedures, but provision was made for the addition of other tests. The psychologist was further instructed "to collect data on such scales" in order that they might be improved and new ones devised, thus providing a research function in the improvement of current testing techniques and the development of new ones.

It was recognized that in the evaluation of ability and temperament the psychologist should go beyond the mere test scores and utilize his clinical interpretation of the examinee's behavior and history—"The psychologists selected for work in the Medical Corps will have had considerable training and experience in interviewing, counseling, the interpretation of social histories, as well as of strictly psychological tests. Therefore, their findings should prove a valuable supplement to those of the psychiatrists."

The general procedures established for neuropsychiatric screening are dealt with extensively in another chapter. In review, they provided for a brief neuropsychiatric examination of all incoming recruits, an observation ward where those recruits suspected of unfitness could be held for detailed case study, and an Aptitude Board empowered to pass on the findings of the psychiatric unit and to recommend separation from the service to the Commanding Officer. Later directives instructed that a psychologist should serve as one member of this Board, and defined the psychologist as "adjunct" to the psychiatrist, to serve under his direction. This was not meant to minimize the value of the psychologist's work or to limit his initiative; it was a recognition of the fact that in a medical situation responsibility must rest in a medical officer, to be delegated as he sees fit. The psychologist thus worked under and reported to the psychiatrist. In most stations where more than one psychologist was on duty, it became the custom and practice of the senior psychiatrist to recognize psychology as an informal division or department and to hold the senior man responsible, as senior psychologist, for the activities of his group.

These directives established a general framework for the screening program, but wisely allowed great latitude in the working out of details. In part, this was necessary to meet adequately the particular problems of each local command and to allow the flexibility necessary for solving the novel problems that were bound to arise suddenly as the war progressed. In part, it was an attempt to recognize the personal responsibility and to encourage the professional initiative of the psychologist and psychiatrist.

The first time the psychologist was called on to assist the psychiatrist in his diagnostic duties was during the initial screening interview given each recruit upon his arrival at the training station. Here, the stress was on brevity, with the actual interview averaging only 2 or 3 minutes. While men suspected of unfitness could be held for further observation, such facilities were limited and such observation represented a serious interruption of the recruit's training. Thus, the initial interview had to be decisive if possible, and carried great authority. A psychologist was always present for on-the-spot testing whenever this was indicated. With sometimes as many as 40 or 50 men per day being referred to him for testing as they passed down the examination line, it was necessary for him to adapt his procedures to the same pattern of brevity and incisiveness that was demanded of the psychiatric interview.

The extent of the problem becomes apparent when we remember that the classical individual intelligence test as used previously in civilian practice might require 45 minutes or an hour to administer and longer to score and interpret. An hour per man was impossible on the screening line!

Before the war, relatively little work had been done on abbreviating the standard individual testing techniques. The problem of volume in civilian practice, when it arose, was handled by a resort to group tests. Where some abbreviated individual tests had been tried out, the normative material used in developing interpretative standards frequently was based on children and was not suitable for use with adults. One exception was the Kent Emergency Test mentioned by the original directive, but even this received further shortening for military purposes, until it finally emerged as a test of only 10 items.

Faced with the necessity of developing their own short test forms, the naval psychologists solved the problem with alacrity, and many abbreviated intelligence tests were produced. One typical battery consisted of the 10-item Kent Emergency Test, a brief test of verbal opposites, and 2 written tests—a 2-minute arithmetic test and a 2-minute test involving the carrying out of certain easy directions. These 4 tests comprised a battery which could be administered and scored within 10 minutes, and adequately duplicated for screening purposes the performance of the longer, standard tests. In some instances where the pressure of work became too great, it was necessary to resort to mass group testing as a preliminary screening device to select those subjects in need of subsequent individual examination.

The detection of mental deficiency was an important one for the Navy. We must realize that large numbers of the country's feebleminded are never institutionalized and that this is particularly true of the higher grade, borderline cases. Any system of recruiting or drafting large numbers of the population must inevitably draw in a fair share of such incompetents. During 1942 it was estimated at the Newport Naval Training Station that between 2 and 3 percent of the incoming recruit body were mentally deficient. This is about what would be expected in view of what is known of the incidence of mental retardation in the population at large. It is worth noting, however, that only about half of these were being separated from the service. The other half represented high-grade morons of borderline intelligence who seemed suitable for service by reason of particularly stable personality and previous training. Even so, those discharged represented at that time about one-third of all separations from the service by reason of inaptitude.

The psychologist sometimes was thought of as an overzealous individual lurking in the screening line ready to pounce avidly upon any victim who could possibly be called feebleminded. The truth was the exact opposite of this. The presence of the psychologist with his objective testing devices actually saved many more men than it condemned. The diagnosis of mental deficiency is a difficult one to establish quickly, and the harassed psychiatrist working at top speed often mistook educational handicap, physical fatigue, emotional upset, or individual peculiarities of personality for genuine intellectual retardation—a false impression which testing was able to correct on the spot.

Impaired intellectual performance or deficit is a function not only of mental deficiency, but also of the deterioration accompanying mental disorder and many cases of organic brain damage. Intelligence tests are particularly sensitive to such deterioration, which appears in peculiar, atypical test responses not characteristic of ordinary feeblemindedness and often specific to the particular pathosis involved. It is thus possible to use the results of intelligence testing as a diagnostic aid in establishing the presence of psychosis or organic brain condition. Many of the cases referred for testing in the screening line were referred for this reason, and the test results plus the clinical interpretation of the psychologist often resulted in substantiating a difficult diagnosis for the psychiatrist or neurologist. Such diagnostic potentiality in a test was one further requirement that had to be satisfied in developing abbreviated testing techniques for neuropsychiatric screening.

The development of personality tests has notoriously lagged behind that of tests for intelligence. Moreover, the more reliable individual testing instruments used for the analysis of personality, such as the Rorschach, have not yielded successfully to the demands of abbreviation. As a result, few tests of temperament were used on the screening line, being largely reserved for the more leisurely procedure of the observation ward.

An exception to this was the development of the various neurotic inventories used in detecting the presence of psychopathosis of many types. These were paper-and-pencil group tests, most of which in essence called for the subject to check the presence or absence of significant symptoms such as enuresis, sleepwalking, and feelings of depersonalization, as well as clinically significant factors in his personal history such as educational achievement, stability of employment, and a police record.

Tests were developed which were highly successful in detecting the unfit, their efficiency sometimes operating as high as 80 or 90 percent. Their great handicap lay in the fact that most of them had a high false-positive rate, i. e., they incorrectly identified as unfit a number of individuals who were fit. Because of this, they were used only as preliminary screening devices for the selection of those recruits needing further individual examination. The final determination of neuropsychiatric unfitness always issued from an individual psychiatric examination, but such preliminary sorting devices developed by the psychologist lightened the burden of examining for the psychiatrist and permitted him to concentrate his efforts where they were most needed.

Most naval psychologists employed in the selection program experimented at some time with such tests. Among the more popular ones were the Cornell Selectee Index and the various forms of the Shipley Personal Inventory. This last was developed largely under naval auspices, and had wide use in receiving ships, disciplinary barracks, and precommissioning installations, as well as in recruit screening at training stations.

Recruits who were obviously unfit or under strong suspicion of unfitness were referred from the screening line to a neuropsychiatric observation ward for a complete case work-up No recruit was separated from the naval service without such careful, complete study—an important improvement over the less careful Selective Service procedure. The clinical psychologist played an important role on this observation ward. His testing procedures, however, resembled the standard individual testing techniques of civilian clinical practice, and the problems that arose were mostly the universal problems common to all clinical testing and not peculiar to the naval service.

For testing intelligence, the complete Wechsler-Bellevue Scale for adult intelligence was used despite its time-consuming nature. This was supplemented by numerous specialized techniques designed to meet the narrower problems of differentiating educational and cultural handicap, illiteracy, language difficulty, school achievement, and special ability. The testing armamentarium available in the Navy compared satisfactorily with standard clinical practice.

An important aspect of intelligence testing, here as on the screening line, came in the secondary diagnostic cues revealed by intelligence tests when administered to cases of functional mental disorder or the various organic brain conditions. Psychologists were probably called upon for more of such "diagnostic" testing than they were for straight testing of the level of intelligence.

Temperament or "personality" tests occupied a large part of the psychologist's time on the observation ward. The Rorschach ink blots, Thematic Apperception Test, and Minnesota Multiphasic were among the more popular ones used. Because of the time factor—the Rorschach might take an hour to administer—these tests were rarely available on the screening line.

In discussing the psychologist's evaluation of patients on the observation ward, we should stress again that, both by official directive as well as by precedent and practice, such evaluation was not limited to test scores but included case history materials and the results of a clinical interview. It was this general clinical function of the psychologist, based on his long experience in clinical interviewing, that resulted in many essentially psychiatric duties being delegated to him as the war progressed and the shortage of psychiatric personnel became more severe.

There were many special testing duties assigned to the clinical psychologist. Shortly after each recruit began his formal training, he was given a battery of paper-and-pencil tests designed to reveal any special job aptitudes. These included an intelligence test, the Navy General Classification Test, along with tests for aptitude and school achievement. The tests were administered by the Classification Department and formed the basis for assigning the recruit to a specific trade school. By directive, any man receiving a score of less than 50 on the General Classification Test (G.C.T.) was referred to the Psychiatric Unit for individual testing, to assure that mental deficiency was not involved. G. C. T. thus offered a further check on the screening examination in filtering out the feebleminded.

Here again, the rough nature of group tests and the advisability of complementing them with individual testing were revealed. A low G.C.T. score may be obtained for many reasons, only one of which is mental deficiency. Had the low-scoring men been discharged solely upon the evidence of the group test scores, many militarily fit recruits would have been lost to the service. The Naval Training Station at Newport made a periodic survey of all such G.C.T. referrals during the years of 1942 and 1943. One-third of the low-scoring recruits made a poor showing because of difficulties inherent in the testing situation itself—poor testing conditions, failure to understand the instructions, or inadequate motivation. Another third represented marginal cases whose test performance was hindered by educational and cultural handicap (including illiteracy), but who were deemed of potential service to the Navy. The final third were adjudged unfit for service, but of these only one-half were cases of mental deficiency, the others representing various personality disorders. Thus, roughly only one-sixth of the men referred for low G.C.T. scores represented true cases of mental deficiency.

At first, no illiterates were accepted for naval service, but as the war progressed and the manpower shortage became acute, they were accepted and assigned for special training in learning to read and write. Before being so assigned, all illiterate recruits were referred to the clinical psychologist for individual testing, to assure that the recruit had the necessary intellectual ability to benefit from special education. The problem of illiteracy was a serious one. Previous to the outbreak of the war, it accounted for only 2 percent of the inaptitude discharges at the Newport Training Station, but in 1942 this rose to 10 percent. After illiteracy ceased to be a reason for discharge and a special educational program was instituted, it was estimated that between 8 and 12 percent of all incoming recruits fell below the level of fifth grade reading ability that the Navy considered desirable. In some large training stations, such as Great Lakes, the clinical psychologists were given the overwhelming burden of individually examining from 200 to 300 recruits weekly for this reason alone.

Individual examinations for intelligence were given in many other instances. Frequently they were necessary in selecting men for special duty, such as the submarine service. They were utilized in some cases where recruits were accepted with correctable defects, such as hernia. To be acceptable with an operable hernia, the recruit was supposed to have a mental age of at least 11 years, to merit the Navy's investment of time and medical attention necessary to render him fit for general duty.

In addition to their evaluation of intelligence and temperament, clinical psychologists were called on for many other duties in connection with the screening program. We have already mentioned their research in connection with the development of psychological tests. Because of their research training, they were called on to cooperate in other research projects including the improvement of the psychiatric interview, the evaluation of other diagnostic procedures as electroencephalography, and the evaluation of various forms of therapy. In such investigations, the psychologist's graduate training in experimental design, electronics, and statistical techniques was a vital and necessary complement to the psychiatrist's clinical background.

Here, as in other branches of the naval service, the psychologist assumed a large share of the research burden.

Nor can we overlook his functions as a teacher. Many supplementary training courses were developed by the Bureau of Medicine and Surgery, both for officers and enlisted men, in order that they might be acquainted with the various medical specialties and kept abreast of current developments. In many local installations, owing to the psychologist's academic training and background, he was called on to participate extensively in these teaching activities.

His administrative experience also led him to diverse duties in this field. While official directive called on him to participate as a member of the Aptitude Board recommending discharges, he also served as board recorder, was sometimes put in charge of the organization and supervision of psychiatric records, and in some cases assumed the administrative duties of first lieutenant on the observation ward.

In mentioning duties other than testing, we must not overlook the fact that the psychologist was called on in many instances to assume psychiatric duties. As the shortage of trained psychiatric personnel became acute, the psychologist was called upon in the emergency to function as psychiatrist, a role in which his clinical background and close association with psychiatric practice was of inestimable value to him. Clinical psychologists were called on to administer the brief psychiatric interview in the screening line, to conduct psychiatric interviews on the observation ward, to prepare psychiatric case reports, and to carry on therapy, both group and individual. The psychologist also participated in the development of the Navy's electroencephalographic program. In all these functions, he acted under psychiatric supervision.

Criteria are lacking for an objective evaluation of the success of the participation of psychologists in the screening program. They were so intimately connected with all its phases that their contribution must stand or fall on the success of the program as a whole. Considering the inherent difficulties of the selection problem, the conditions under which the program operated in the field, and the constant lack of sufficient trained personnel, one cannot help but consider it successful.

On the pragmatic side, it is significant that the attitude of the average line officer changed from one of grudging acceptance at the beginning of the emergency to one of enthusiastic cooperation as the war progressed. As the value of psychiatry and psychology became recognized and accepted in the naval service, the demand for psychiatric and psychological personnel rapidly outran the available supply. Toward the close of hostilities, it was necessary to reject many requests for the extension of clinical psychological services because personnel were not available. Active commissioning of clinical psychologists continued up to the very end of hostilities, and the top enrollment of 110 was set only by the availability of adequately trained personnel.

Specific criticisms have been raised concerning the screening program. In the first place, no steps had been taken to prepare a manpower pool of clinical psychologists from which personnel could be made immediately available to initiate the selection program. As a result, recruiting was slow and the first psychologists arriving had no specific preparation for the problems they would meet. They had to learn and work at the same time. Supposedly, the Naval Reserve will prevent this situation in the future, and the existence of a Military Division within the American Psychological Association can be of assistance.

Secondly, no techniques were prepared in advance for handling the problems that could have been foreseen. There had been only sporadic interest on the part of psychologists in the abbreviated test techniques necessary to meet military requirements of speed and volume, and equally little attention to such special problems as testing the illiterate, the culturally handicapped, and the foreign language groups. After the war began, all these problems had to be met by psychologists in the service, with little time to spend on the painstaking research necessary for an adequate solution, so that makeshift testing techniques were the rule rather than the exception. The war ended without adequate intelligence tests having been developed for the evaluation of culturally and educationally handicapped persons inducted into service. The Office of Naval Research is at present carrying out such development.

Thirdly, there was failure to prepare the main body of the Navy for the selection program, by any sort of preliminary indoctrination. The specialist not only had to be trained in his duties, but the organization within which he functioned had to be educated to his proper utilization. The psychologist and psychiatrist had to "sell" their services in the field as they worked. This problem will be obviated in part by the Navy's present policy of detailing officer personnel for academic training in numerous specialties. Already, groups of officers are studying modern personnel procedures in various cooperating universities.

Finally, the selection of specialists for commissioning and their subsequent detailing to duty should be handled by someone familiar with the specialty. Not every psychologist is a clinical psychologist or is prepared to be one, nor is there any point in sending a man thoroughly trained in hospital routine with psychotics to duty in a disciplinary activity, while a man skilled in correctional problems and the psychopathic personality is detailed to a naval hospital. A more enlightened personnel policy has fortunately been evolved out of our wartime experience.

Chapter XXII

Medical Aspects of Blast

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Much yet remains to be known about blast and its effects upon the human body, but although intensive research in this field did not begin in the United States until after our entry into World War II, a creditable amount of work was accomplished—at least so far as the solution of our more pressing problems was concerned. With the development of new explosives and other means for the rapid release of energy, related studies were required.

The term "blast" has been used to identify the intense sound wave emanating from a detonated explosive. It has been rather loosely used in the past, and some investigators have even referred to the vibration of a steel deck caused by near-misses as "solid blast." This effect, so productive of os calcis fracture among naval personnel, is no more a blast effect than the transmission of a blow through any solid structure. The effects of ground shock are often attributed to blast, and such loose usage of the term has resulted in widespread misconception. Thus the breaking of windows many miles from the site of an explosion is often attributed to "air blast" in instances where the vibration of buildings due to ground shock was solely responsible. As a result, the term "blast" now encompasses true air blast, underwater concussion, transmitted impact through hulls, ground shock, and the after-vibration of walls and other structures.

It is suggested that the term "explosion pressure" would be more precise. Thus one may refer to "explosion pressure in air" or "explosion pressure in water" while using the expressions "ground shock," "impact transmission through solids," and similar terms wherever they may convey the most precise meaning. Among ballisticians the term "chamber pressure" is in universal use. It connotes the peak pressure in pounds per square inch generated by an explosion confined within the chamber of a gun. Similar physical factors operate when a charge is detonated in the air or under water, except for the absence of confining walls. In the case of explosions within confined spaces, as when a delayed-action bomb is detonated below decks aboard ship, the analogy between blast pressure and chamber pressure is complete, the ship's compartment being comparable to the chamber of a gun in all ways with the exception of size. "Explosion pressure" would therefore appear to be accurate and clearly descriptive.

HISTORY

It seems certain that blast casualties have occurred in battle since the invention of gunpowder. Even before the use of such high explosives as TNT and RDX, this type of fatality undoubtedly was seen, though, as today, but rarely. The death of the soldier without discernible marks on his body was attributed to the "breath of the cannonball," the popular supposition being that the rapid rush of air close to the missile was in some way deadly. It is to be doubted, however, that many of these cases were the result of blast injury, probably having been caused by the entrance of very minute fragments into a vital area. Experience in World War II has taught us to examine casualties with great care in a search for minute entrance wounds, because small fragments only a few milligrams in weight, if traveling at sufficient velocity, may cause fatal wounds. Small stones and debris thrown up by an explosion may have an effect almost as lethal as fragments of the shell casing itself. Hence it appears probable that many deaths attributed to mysterious causes were actually, as now, the result of penetration by minute, high-velocity fragments.

The effects of gun blast on animals was first reported in 1924. Pulmonary tissue was found to be particularly susceptible to injury. The mass bombing of British cities in 1940 marked the beginning of a detailed study of this type of casualty. In the United States, interest in pathologic changes from underwater blast may be said to stem from the sinking of the *Reuben James*. The study of blast injury was initiated by the Navy Department early in 1942.

THE NATURE OF BLAST

Blast may be defined as the compression (and, in air, suction) wave which is set up by the detonation of an explosion. The wave of detonation travels through high explosives at from 15,000 to 30,000 feet per second, the time of detonation varying from 0.0004 to 0.0006 second for small to large bombs. For all practical purposes, therefore, one may consider detonation to be instantaneous. The potential energy of explosion has been calculated as 2.5 million foot-pounds per pound of high explosive employed. One cubic foot of TNT generates about 1,000 cubic feet of gas, but because of the high temperature the gas volume is in the neighborhood of 12,000 cubic feet per cubic foot of explosive. These figures would be much higher (approximately 50 percent) for powerful mixtures such as Torpex.

Because a blast wave is essentially an intense sound wave, its velocity varies with temperature. About 1,100 feet per second may be taken as an average figure in air. In water its velocity approximates 4,800 feet per second, and peak pressures generated are much more severe than in air. As the human body is about 75 percent water, the blast wave will traverse the tissues at over 4,000 feet per second. As in air, the "shock front," or compression wave, is of sufficient thickness to impose uniformly elevated pressures on all parts of the body of swimmers or divers simultaneously. This point is well exemplified by the fact that crusher gages placed back to back will give identical readings following an underwater explosion.

Air blast pressure is profoundly affected by the nature of the surrounding terrain. Thus, its intensity is greatly diminished within depressions such as foxholes, trenches, and ditches, and directly behind trees, bunkers, and walls. On the other hand, the blast wave is reflected from vertical surfaces, theoretically increasing the peak pressure by 100 percent. Actually the pressure caused by "reflectance" falls slightly short of this figure. Reflectance from the ground, cliffs, and walls of buildings; and underwater, from the shoreline, hulls of vessels, and from docks and pilings may produce almost unpredictable variations in pressure. In water, temperature gradients between the surface and the bottom distort the "shock front" and cause it to curve toward the colder strata. Hence, with a surface temperature above that at the bottom of even shallow water, the shock front is very perceptibly "bent" toward the bottom, rather than traveling in a straight, horizontal direction. When these variables are introduced, the "freakish" and almost unpredictable results of a blast may be understood.

Little is known concerning the forces generated very close to the charge, because in this area (the "zone of brisance") recording devices of whatever nature are literally blown to pieces by the disruptive effect of the explosion. Thus the crater may be said to demark this zone of brisance. It will be apparent that medical interest regarding blast effects in this area is nil, as a person within the brisant zone is either disintegrated by the explosion or receives multiple fatal hits from casing fragments.

A blast wave in air is composed of a pressure component followed by a suction component. The suction component is of much longer duration than the compression phase. Thus the duration of the compression phase has been estimated at 0.006 second and the suction phase at 0.03 second. The positive phase may exert pressures measured in hundreds of pounds per square inch (close to the charge), whereas the negative pressure can never exceed 15 pounds per square inch. The velocity and duration of either phase are such that the body of a man would be completely immersed for an instant in a wave of almost uniformly altered pressure.

A blast wave is, physically, simply a very intense sound wave. Thus, although the velocity with which the blast travels close to a charge varies with the "power" of the explosive (volume of gas produced multiplied by heat generated) it is quickly reduced to the speed of sound, and decreases in pressure as the square of the distance. This is true of blast waves generated in either air or water, and indeed of the rate of transmission of a blast wave through any material, including the human body. After the passage of the compression and suction phases, a third "oscillatory" phase follows which gradually decreases in intensity. Pressures produced during this vibratory phase are of such low magnitude that they may be ignored from a medical viewpoint, although their effect may be considered in damage to walls and structures.

MEASUREMENT OF EXPLOSION PRESSURE

Blast is at present best recorded by the use of piezoelectric gages in which the currents generated by the distortion of a suitable crystal deflect the electronic stream in a cathode-ray oscillograph. In such instruments inertia is eliminated, and when calibrated they will accurately record not only peak pressures, but also the duration of the various phases of the blast wave. Photographic records made with the aid of such devices yield a true "picture" of pressure changes throughout the passage of the positive, negative, and oscillatory phases of blast. However, for practical use in the field these gages are seldom employed. This is largely due to the fact that usually a large number of pressure readings are desired at various distances and directions from the charge, and also because the older types of gage are more easily set up and greatly simplify the necessary installations and equipment. Moreover, the loss of or damage to piezoelectric equipment would be a much more serious matter than the accidental destruction of the more simple types.

The Williams gage remains the instrument with which air blast pressures are most commonly measured in the field. This gage is composed of a brass cylinder and aluminum alloy plunger. The distance which this piston is moved by the blast is recorded as the peak positive pressure. The inconsistencies in readings and inaccuracies of blast measurement by means of this instrument are well known, but for the reasons cited it remains the one most commonly used in field experimentation.

Diaphragm gages were experimented with by both the Navy and the Army. Such gages operate on the principle of membrane rupture —the smaller the membrane area, the higher the blast pressure required to rupture it, providing all membranes are of a homogeneous material, unaffected by humidity and other variants. Like the Williams gage, such instruments will record only peak, positive pressure.

In measuring underwater blast pressure, the simple crusher gage remained in common use throughout the war. In this instrument a steel piston is driven against a standardized copper ball, producing an indentation of its surface. Micrometer measurement of the ball then permits an estimation of the peak pressure to be made. As with the Williams gage, several "crushers" are commonly placed together and an average of the readings is taken as the true pressure. From the standpoint of medical research, the principal fault of the crusher gage lies in the fact that it will not operate at "low" pressures, the lower limit being about 300 pounds per square inch. Even here the readings are inaccurate, as the gage is designed to record much higher blast pressures.

Hillier gages may be used in underwater work. Here a series of pistons of varying weight are forced back against a series of springs. With very high peak pressures, it is thus possible to obtain a curve representing the almost instantaneous rise to peak pressure, with more gradual decline to the base line with the passage of the shock front.

None of these more rugged and simpler gages is, of course, comparable in accuracy to piezoelectric equipment, as only the latter can give a true picture of the magnitude and duration of the pressures produced by a blast. The future will doubtless see the employment of piezoelectric gages the rule rather than the exception, multiple installations being placed in mobile carriers to facilitate their use in the field.

AIR BLAST

Animal experiments.—The first investigation of the effects of air blast on animals to be undertaken in the United States was begun by the Navy in September 1942, when rabbits, guinea pigs, and monkeys were exposed, at varying distances, to the blasts from large charges of a high explosive.

The lesion uniformly present was pulmonary damage, either slight or severe, depending upon the magnitude of the blast pressure. Lesions varied from small punctate areas to massive hemorrhage with hemothorax. The cause of this type of injury is the positive phase of the blast, although similar lesions may be caused by explosive decompression. Because the suction wave is present for but a fraction of the time taken for even a very fast expiration, negative pressure cannot be the major causative agent of injury, although it may conceivably add to the damage produced by the compression wave. Furthermore, experience with explosive decompression in man (aviation medicine) indicates that decompression in air, even at rapid rates, is relatively harmless. Although the pulmonary lesions are those most commonly encountered, there is no doubt that sufficiently elevated pressures may produce rupture of portions of the gastrointestinal tract.

That air blast is ineffective at any considerable distance from even large charges was effectively shown in an early Navy experiment in which 1,750 pounds of TNT were detonated. Rabbits and guinea pigs 100 feet distant from the charge were uninjured, as shown by their general condition and roentgenograms, as well as by gross and microscopic examination. This

(Charge: 1,500 lbs. TNT)

Animal	Distance from center of charge (feet)	Conditions of exposure	Result
Guinea pig	32	Behind tree	Killed.
	50	Behind parapet	Killed.
	50	Behind tree	Died within 24 hrs.
	50	Behind tree (in long axis of charge)	Survived.
	73	Behind tree	Died within 24 hrs.
	75	Behind tree	Survived.
	80	Behind tree	Survived.
	100	Behind tree	Survived.
	100	Fully exposed	Survived.
	100	In foxhole	Survived.
	140	In shelter	Survived.
	147	Fully exposed	Survived.
	147	In foxhole	Survived.
	150	Fully exposed	Survived.
	150	In foxhole	Survived.
	200	Fully exposed	Survived.
	220	Fully exposed	Survived.
	220	Behind barricade	Survived.
Rabbit	32	Behind tree	Killed.
	50	Behind parapet	Killed.
	50	Behind tree (in long axis of charge)	Survived.
	58	Behind tree	Killed.
	73	Behind tree	Died within 24 hrs.
	75	Behind tree	Survived.
	80	Behind tree	Survived.
	100	Behind tree	Survived.
	100	In foxhole	Survived.
	140	In shelter	Survived.
	147	Fully exposed	Survived.
	147	In foxhole	Survived.
	150	Fully exposed	Survived.
	150	In foxhole	Survived.
	200	Fully exposed	Survived.
	220	Fully exposed	Survived.
	220	Behind barricade	Survived.
Goat	32	In trench	Killed.
	32	In trench (kapok protected)	Killed.
	50	In trench	Killed.
	50	In trench (kapok protected)	Killed.
	140	In shelter	Survived.
	140	In shelter	Survived.
41 animals	32 to 140	Various	All survived at distances greater than 75 ft.

FIGURE 155.—Tabulation of Navy air blast experiments.

result confirmed the findings of British observers who exposed mice, rats, guinea pigs, rabbits, cats, monkeys, and pigeons to the detonation of 70 pounds of TNT. None of these animals at distances beyond 18 feet was injured in any way. Thus, it appeared in late 1942 that air blast injury, of itself, did not constitute a sufficiently grave military hazard to warrant the adoption of protective measures, frequently recommended, at least until detailed studies of a large number of blast casualties should indicate beyond doubt that such measures were necessary.

These results were further borne out by the Navy experiments of September and October 1942. In these tests, further exposures of animals to large charges were carried out. In still other trials, rabbits and goats were placed within earth and log shelters in close proximity to blasts. The ineffectiveness of shallow-water mines in producing injury to large animals placed within assault craft was also demonstrated. Thus naval medical opinion came to regard air blast as a minor and infrequent hazard (figs. 155 and 156).

The Norfolk blast.—On 17 September 1943, a blast occurred at the Naval Air Station, Norfolk, Va., resulting from the accidental detonation of several Torpex depth charges. The physical damage testified to the intensity of the blast, several buildings being completely demolished and structures damaged at distances of from 300 to 400 yards. A detailed examination of 55 casualties followed. No cases of "blast injury" were encountered, and none of the men exhibited any diagnostic symptoms such as bloody sputum, pulmonary dullness, chest pains, or respiratory embarrassment. Chest roentgenograms were also negative. No injuries to the eyes or ears were reported other than those resulting from missiles, and no eyeground pathosis was noted. Attending surgeons reported no pathologic lung changes uncomplicated by shrapnel penetration, and where intestinal perforation took place, at least one missile had entered the abdominal cavity. There were 94 injuries in the 55 patients. The location and type of wounds are tabulated as follows:

	Percent
Fractures	23.5
Head	14.9
Legs	14.9
Arms	13.8
Abdomen	12.7
Thorax	10.6
Eye	2.2
Burns	7.4

It is not definitely known at what air blast pressure the human tympanum may be ruptured. Available data are based on the accidental detonation of charges in instances where the victim happened to be standing close to a gage of the Williams type. In one such instance the gage reading was 10 pounds per square inch, but in another case, in which a reading

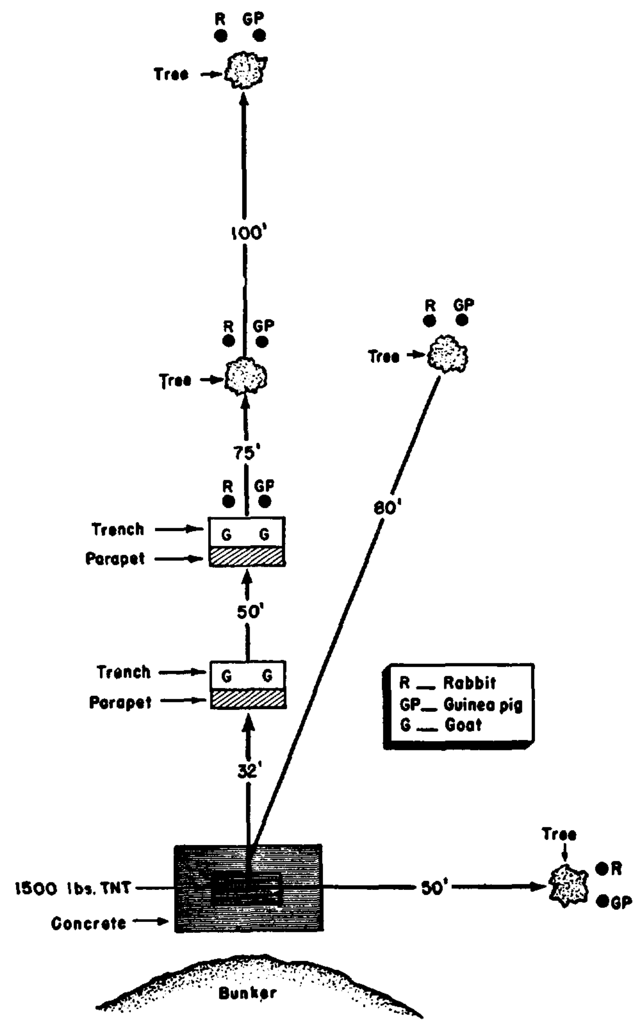

FIGURE 156.—Design of Navy air blast experiments on protection afforded by terrain.

of 12 pounds per square inch was recorded, the tympanum remained intact. The time-honored figure of 7 pounds per square inch as being "about all the pressure a man can stand" would thus appear fairly accurate, at least in regard to blast in air.

All of the Norfolk patients who could be interviewed estimated the distance from the explosion at which they stood at from 25 to 100 feet. Several men were so close to the blast as to receive third-degree burns of the face, without any evidence of injury by blast *per se*. From careful study and tabulation of these cases, it was concluded that: (*a*) "Blast injury" is probably not a major factor in producing injuries from large bomb explosions, inasmuch as no recognizable cases of "blast lung" were observed following the Norfolk disaster. (*b*) Such explosions produce terribly mutilating injuries from missiles as well as burns ranging from first to third degree.

Following this experience the Navy decided to perform further tests in which animals might be exposed to bare charges, completely eliminating missiles, with particular attention paid to blast injury in relation to the extent of the flash area. A complete neurologic study was also to be undertaken in an attempt to ascertain whether lasting damage to the central nervous system might follow exposure to blast. The results of these tests were reported on 24 June 1944. The distance between the experimental animals and charge was in all cases less than that between the charge and the ground, in order that all "reflectance" might be eliminated. Charges of from 0.5 to 20 pounds of TNT were used, with tetryl booster. The animals were suspended in muslin or burlap bags (simulating clothing) so oriented as to face the charge (fig. 157).

From these experiments it was concluded that: (*a*) Injury . . . does not occur when experimental animals are just outside the flash area, but it is a constant finding when they are within the flash area and are burned. (*b*) Microscopically demonstrable changes may occur in the central nervous system following exposure to air blast under extreme conditions; these changes were visible in only two animals out of a series of seven studied for central nervous system pathosis, and were not marked. Depression of the central nervous system occurs, but this may be transient. (*c*) . . . Air blast does not appear to be a serious military hazard.

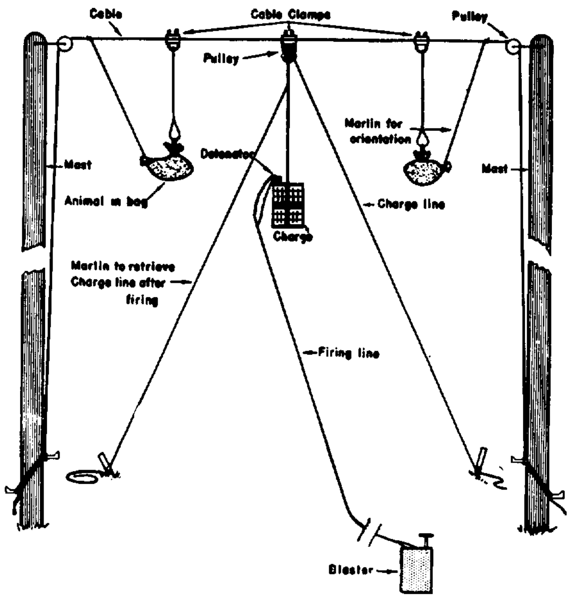

FIGURE 157.—Plan of Navy experiments on air blast, eliminating shell fragments and reflectance.

This closed the subject of air blast *per se* as a casualty-producing agent so far as the Navy was concerned, and no further work was done along the lines of protection. It will be noted, however, that all of the instances referred to apply to blasts in the open, and that no studies have thus far been undertaken concerning the effects of blast upon personnel within confined spaces. This should be investigated, inasmuch as explosions below the decks of naval vessels due to delayed-action projectiles, or indeed any projectile not employing a contact fuse, will often result in just this condition—a powerful blast confined by steel bulkheads. Field observations also indicate that the effects of blast at various heights above ground might bear study.

GUN BLAST

The effects of gun blast upon ship structures and equipment have long been studied by the Navy, and more recently there has been considerable interest in the effects of gun blast upon personnel. The areas about various types of guns at which pressure of 7 pounds per square inch is attained have been carefully delineated and these pressure plots are considered in the placement of gun crews and topside personnel. Particular attention has been paid to blast pressures at ear positions.

Because of gun blast, the problem of the so-called "ear-defenders" has long been studied in an effort to procure the best possible materials and design for earplugs. The problem is complicated by service conditions, because, while blast must be minimized, verbal orders must be clearly detected, and any device of this nature must be small, instantly available, disposable, or simply and quickly sterilized. Furthermore, the material must be one which will not produce skin reactions or inflammation of the meatus. Comfort is a primary consideration; without this feature such devices will not be worn by the men under any condition. In tropical theaters, fungus infection following the irritation of the meatus by the use of earplugs has further complicated the problem.

Audiometry has conclusively shown that tinnitus and deafness after exposure to gun blast is reduced by the use of any type of earplug, and the Navy's "V–51" defender of neoprene with metallic insert has thus far appeared the most efficient of these devices. On the other hand, absorbent cotton, of long tradition among gunners, possesses the advantages of a fair degree of protection, cleanliness, availability, and simplicity in use, as well as being disposable and nonirritating. It is comfortable, light, and eliminates the necessity for washing and sterilization. Therefore, while the specially-designed ear-defenders undoubtedly provide more efficient protection, the familiar absorbent cotton will probably maintain its traditional post at gun positions for some time to come.

UNDERWATER BLAST

During World War II underwater blast was responsible for many more casualties than air blast. This is due to the greater intensity of underwater concussion for a given weight of charge, and to the fact that the sinking of a naval vessel is often accompanied by explosions aboard or by the detonation of depth charges. These explosions may take place in close proximity to a large number of immersed personnel, causing many casualties.

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Early in 1942 Breden et al. reported the clinical histories of 10 victims of underwater blast produced by torpedo and depth charge explosions, and in the summer of that year the Navy began experiments. The results of the Navy study were in almost entire agreement with the findings of later investigators in this field of pathology. Animals of all sizes from rats to goats were used, and experimentation was extended from small-scale tests to the simulation of actual conditions at sea. The pathology as described by Greaves and his associates may be considered typical of this type of injury in all details.

Gross pathology.—In cases of severe injury, the lungs were characterized by diffuse hemorrhage throughout the entire parenchyma, very little aerated pulmonary tissue remaining. Free and clotted blood was found in the air passages, and occasionally there was laceration of the visceral pleura with secondary hemothorax. Subpleural hematomas were sometimes encountered, in some of which small blebs of air were seen. Hemorrhagic discoloration of the lungs was not uniform. The outlines of the ribs and intercostal spaces upon the pleural surface were prominent, particularly so in larger animals. Some disagreement existed as to whether the hemorrhagic stripings represented the impact of the ribs or the transmission of pressure through the intercostal spaces.

In the gastrointestinal tract lesions were primarily of two types—complete perforation and hemorrhagic discoloration of the wall. No lesions were noted in the mesenteric attachments (at least in small animals). These lesions occurred in any portions of the gastrointestinal tract from stomach to rectum and were invariably related to the presence of gas within the lumen. In the guinea pig, the fundus of the stomach, cecum, and lower ileum were particularly vulnerable. The perforating lesions were usually associated with little interstitial hemorrhage and with no hemorrhage into the lumen, thus giving the lesion the appearance of a sudden disruption of the wall from within outward. Not all animals receiving fatal blast injuries showed intestinal lesions.

Sublethal charges produced similar but less extensive damage, and areas of pulmonary hemorrhage were more localized. Pleural laceration was absent and bleeding into the air passages less severe. Gastrointestinal lesions were fewer and smaller in size. Lesions in the lungs were small, few in number, and frequently symmetrical and marginal, involving the antero-inferior edges.

Greaves et al. summarized the gross pathology of underwater blast by stating that "pulmonary lesions were always found if any injuries resulted from the blast," but that "intestinal lesions were quite inconsistent in occurrence." No other organs or tissues showed injury, except that, in animals placed close to the *brisant* area, a few fractured extremities resulted from the intensity of the explosions.

Microscopic pathology.—Minimal lesion was evidenced by rupture of the capillaries and hemorrhage into the interalveolar septum, with separation of the two epithelial layers. Extravasated blood apparently dislodged the alveolar epithelium and found its way into the alveolar spaces. In more serious injury, the interalveolar septa as well as the capillaries were ruptured and destroyed, and there was hemorrhage into the air spaces (traumatic emphysema).

In the gastrointestinal tract there was hemorrhage into the mucosa and submucosa. In perforating lesions the intestinal tissue around the tear was thin and shattered, resembling crushed tissue.

When the head of an animal was immersed coincident with detonation, epidural and subdural hemorrhage occurred and skull fracture was not uncommon.

The chief point of interest in underwater blast injury was the fact that the only lesions uniformly found by all investigators are in *those structures containing gas;* i. e., the lungs, gastrointestinal tract, and bony sinuses. This indicates that blast is only effective at the interface between a fluid or tissue and gas. The phenomenon may be compared to that taking place on the surface of the sea directly above an exploding depth charge. Here the concussion wave traveling outward from the charge produces a "doming" of the surface with a shredding effect, the surface of the water being blown off. This is followed by a geyser of gas and water thrown up at the time that the expanding gas bubble reaches the surface. This latter, more spectacular event is harmless as compared to the compression wave or shock front.

Motion pictures obtained by the Navy and taken at a rate of 1,000 frames per second have shown conclusively that intestinal strips containing saline solution remain undamaged by underwater explosions, even when close to the charge. In contrast, when minute bubbles of air were present, immediate and frank perforation invariably took place at the same range. Underwater blast injury was thus confined to certain definite structures—those containing gas. Clinical reports of injury to other organs have not been confirmed in well-controlled animal experimentation.

DETERRENT AND LETHAL EXPLOSION PRESSURES

Deep-sea divers.—Experiments (figs. 158 and 159) to determine the distances from the detonation of various sized charges at which deep-

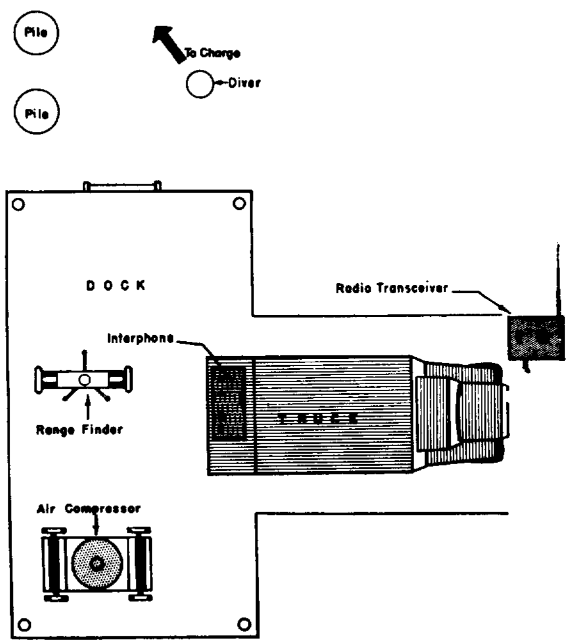

FIGURE 158.—Experimental set-up in determination of deterrent blast pressure for divers (shallow water).

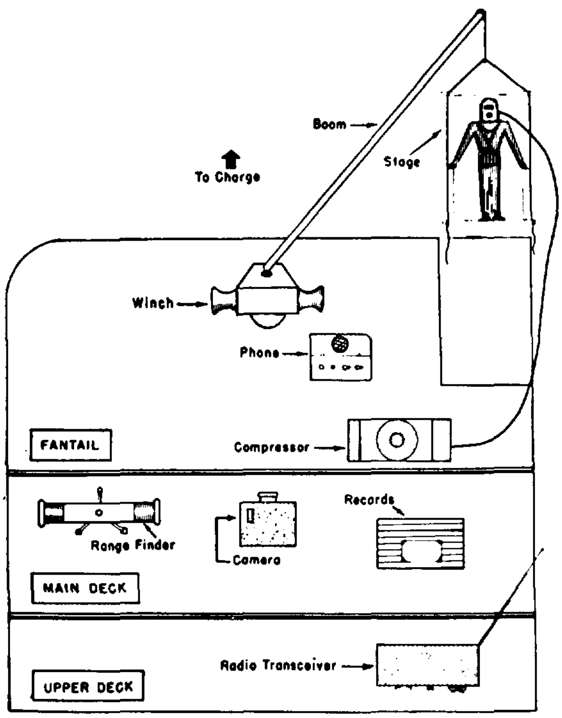

FIGURE 159.—Experimental set-up in determining deterrent blast pressure for divers (deep water).

sea divers might work in safety were begun by the Navy in August 1942 and a complete report of all findings was made 14 January 1943. In this work a total of 46 charges, of from 1 to 300 pounds, were detonated at distances varying from 168 to 3,627 yards. Calculated pressures to which the subjects were exposed were 4.3 to 55.4 pounds per square inch. The depth of water in which the charges were laid varied from 5 to 50 feet, and total depth from 12 to 102 feet. All divers were placed at 20-foot depth, either on a mud bottom, or on a stage, as in the deep-water experiments.

All pressures were calculated by the following formula, based on TNT:

$$p = 13{,}000 \sqrt[3]{\frac{\text{wt. charge (lbs.)}}{\text{distance (ft.)}}}$$

Calculation by formula was preferred to other methods of pressure determination, inasmuch as practicality for field use was desired. Moreover the calculated pressures lend themselves readily to correction for estimate by any other method and for any type of explosive. During the progress of the work, pressure calculations were greatly facilitated by the use of the Webster blast rule, a slide rule designed for the purpose. By means of this device, pressures at any distance from any weight of charge, or the proper distance for the laying of any charge to produce a desired pressure, could be rapidly and accurately calculated. The Bureau of Medicine and Surgery subsequently made this equipment available to the Bureau of Ordnance.

In all of the work with divers, the subjects were instructed to so regulate their air supply that the dress pressed snugly against the legs and abdomen. After each explosion divers were questioned as to: (*a*) Sound: Description of the sound and its intensity; effect on the ears (pressure, pain, et cetera). (*b*) Pressure: Any sensation of pressure ("squeeze") upon the dress, and its location. Tendency to be displaced or thrown off balance, wave motion, et cetera. Jar or blow to the head because of its displacement within the helmet. Displacement of equipment (stage, lines, et cetera). General sense of well-being and desire to continue the work at higher pressures.

The 10 divers used as subjects were exposed to concussion from charges varying from 1 to 300 pounds in weight.

Results.—In no instance did a diver suffer any demonstrable injury. During the work performed on a stage in deep water the divers' heads were at times thrown with different degrees of violence against portions of the helmet and breastplate, but in no instance was the blow to the head of sufficient violence to break or bruise the skin, render the subject dizzy or unconscious, or interfere in any way with prompt mental or physical reactions. These 10 men, exposed on 46 occasions to calculated underwater explosion pressures of from 4.5 to 55.4 pounds per square inch, sustained no injuries whatever, and such exposures under the conditions prevailing in the experiments may be concluded to be entirely innocuous.

Psychic reactions were, however, observed in certain men following initial or early exposure to concussion. In one instance a diver described sensations of concussion and faintness. He feared he would lose consciousness, and asked to be brought to the surface. Other men exposed on the same day to charges 10 times greater at less than one-fifth the distance described no such sensations. Furthermore, the diver who had exhibited the psychic reaction described was subsequently exposed to numerous charges, stating that there was "no pressure or feeling of vibration of any kind." On other occasions, when a man was first exposed to an explosion, a certain amount of anxiety was evidenced by changes in timbre of the voice, inquiries as to the magnitude of the charge to be detonated, or obvious relief on being brought to the surface.

On the other hand, certain divers never exhibited any tension and even pressed the head against the helmet at "standby" in an attempt to accentuate any possible blow or concussion. Once accustomed to the work, all tension seemed to be dissipated, and the experiments were carried out in a routine manner. Those divers interviewed some time after the completion of the tests indicated a desire to "take" even larger charges, apparently out of curiosity as to the effect. It was concluded that the amount of nervous tension exhibited by the subjects was no greater than might be expected in any unusual or unfamiliar situation.

Sound.—The sound of underwater explosion as heard within the diving helmet was described in similar terms by all of the subjects. There was a marked difference, however, between the sound transmitted by charges detonated in shallow, as compared to those fired in deep water.

In shallow water (charge at from 5 to 12 feet, diver at 20 feet) the sound made by exploding charges was described as "like a pebble striking the helmet" or "a sharp crack" depending upon the size of the charge and its distance from the diver. When shallow-water diving equipment was used, with the ears in immediate contact with the water, the sound was described as merely a "swish." A peculiarity of the sound as heard in shallow water was its almost invariable double character described as "two distinct clicks" or "loud crack, the second one not quite so loud." This double sound was attributed to reflection of the blast wave from pilings about the dock, or, more probably, the adjacent shoreline.

In deep water (102 ft.) the detonations sounded similar to explosions in air, but of a muffled character—"a heavy boom;" "a heavy, dull, muffled thud;" "powerful, dull rumble;" "a heavy explosion."

Neither in shallow nor in deep water was the intensity of the noise itself unpleasant, nor was there any complaint of pain in the ears. It was concluded that the character of the sounds produced by underwater explosions, as heard by a diver, may differ widely, depending upon magnitude of charge, distance from charge, depth of water, character of bottom, and the nature of adjacent objects, and that injury to the ears of divers wearing the standard Navy deep-sea dress may not occur at calculated explosion pressures up to 55 pounds per square inch.

Pressure effects.—Reports of pressure sensations were, like those of sounds heard, necessarily subjective.

In the initial experiments in shallow water, the first sensation of "blast" was reported at a calculated pressure of 14.5 pounds per square inch, when the diver described a feeling as of a "gust of wind going by." For some reason, no similar sensations were described at a pressure of 18.2 pounds per square inch. At 16.4 pounds pressure another diver described a "rap" on the wrist which was again detected at 20 pounds. When calculated pressures of 30.4 and 31 pounds were reached, a feeling of slight pressure upon the legs was described, but the diver withstood a calculated pressure of 55.4 pounds per square inch in comparative comfort. Another diver reported a "very noticeable sense of pressure in the ears, with a momentary feeling of pressure on the body" at an explosion pressure of 49.5 pounds per square inch.

Practically, however, in the delineation of safe working distances, one must consider the effects of various depths of water, character and conformation of the bottom, depth of charge below the surface, and reflection of the shock front from sloping and vertical surfaces. Hence, to assure safety to divers, even with 100 percent reflectance (as from a vertical shelf or submerged hull) we may be certain that injury from underwater concussion will not occur if calculated explosion pressures do not exceed 25 pounds per square inch.

It is true that 100 percent reflectance might even be exceeded under certain peculiar conditions, as would be the case with the charges placed at the center of a parabolic surface and the diver so located as to receive the reflected shock wave at its "focus." There is the theoretic possibility that such conditions could obtain in practice, as in the detonation of a charge within a parabolic cavity along a shoreline. This possibility, however, is extremely remote.

From these experiments, which represent the only tests of this nature conducted in this country, the following definite conclusions were drawn: (*a*) Divers may be exposed to calculated explosion pressures up to 50 pounds per square inch without marked discomfort or injury. (*b*) The foregoing is true for charges of from 1 to 300 pounds in magnitude.

To complete our knowledge of the effects of underwater blast upon Navy divers and their equipment, further tests were conducted in January 1945 to determine lethal blast pressures in deep-sea diving and to evaluate the resistance to underwater concussion of British anti-blast diving vests and American deep-sea diving equipment (fig. 160).

For the determination of lethal blast pressures, strips of beef intestine were used as test objects. The intestinal strips were filled with saline solution and 5 cubic centimeters of air were added to simulate a gas bubble. The reliability of this method had been proved in earlier Navy experiments, while mechanical devices and artificial membranes had been found impractical. To determine the lethal pressure for a man in Navy diving dress, a standard suit was filled with sea water to the level of the breastplate, with air-supply attached as in actual use. Sections of beef intestine were then suspended inside the dress at the level of the umbilicus by means of a weight and a cord attached to the chin-valve of the helmet. The whole apparatus was then lowered into the water and subjected to blasts from Mark IX (114 lb.) charges. The calculated pressure at which rupture of the intestinal sample occurred was considered "lethal."

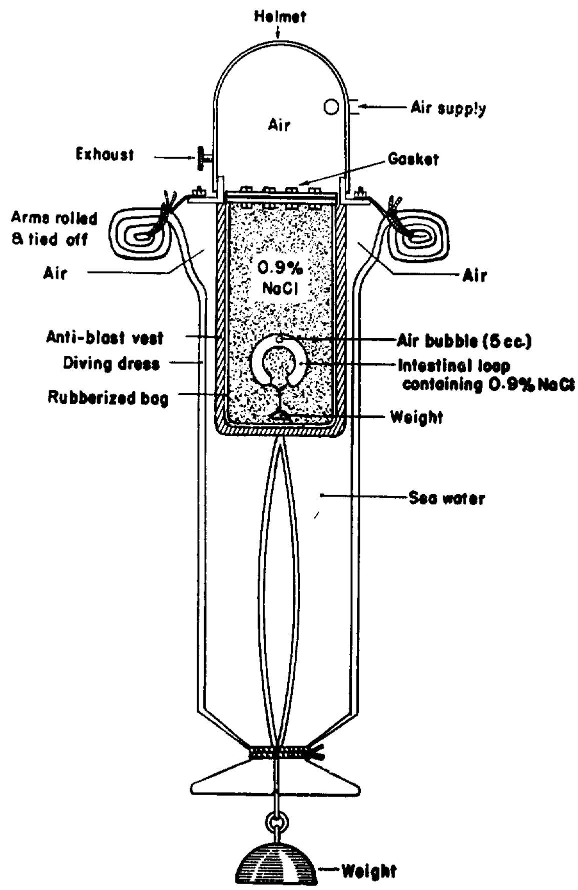

FIGURE 160.—Apparatus to determine efficiency of British anti-blast vest. Identical equipment, omitting the vest, was used as a control.

In order to test the efficiency of the kapok anti-blast vest, a similar technique was used. Special rubber bags sealed by gaskets were constructed to simulate the human torso and so assembled that the blast vest completely enclosed such a bag, with intestinal strips properly located within.

The resistance of the standard Navy deep-sea dress alone was ascertained by exposing fully assembled, water-filled equipment to successively intensified blasts. The conclusions reached were: (a) A calculated underwater blast pressure of 300 pounds per square inch may be considered lethal for divers wearing standard deep-sea diving dress. (*b*) The British anti-blast vest offers a measure of protection against underwater concussion, the "lethal" pressure being raised to at least 525 pounds per square inch. (*c*) A (calculated) blast pressure of 1,000 pounds per square inch approximates the limit of resistance of standard Navy deep-sea diving equipment to underwater concussion. (*d*) A diver exposed to underwater blast may suffer lethal injury at pressures producing no damage to his equipment. That is to say, the lethal pressure for a diver is approximately one-third that necessary to produce failure in the dress. From the above it will be noted that, for the diver, the "lethal" explosion pressure (300 pounds per square inch) is of the order of six times the "deterrent" pressure (50 pounds per square inch), which means that a considerable safety factor is operating even at such short distances from charges that the "deterrent" pressure would be greatly exceeded.

Pressures for immersed personnel.—In 1944, with the increasing use of underwater demolition units and the consequent hazard from underwater concussion injury to personnel, experiments were conducted by the Navy to determine what blast pressures might be considered lethal and "deterrent" for personnel immersed to the neck in shallow water. This was deemed desirable from the standpoint of personnel wading ashore from landing craft, as well as to determine to what ranges demolitionists must retire before firing their charge.

At Fort Pierce, Fla, a group of 11 naval officers approached detonating Mark V demolition charges (110 pounds) over a carefully surveyed and marked course. Six of these men wore swimming trunks only; 1 wore, in addition, an inflatable life belt ("destroyer belt"), and 4 were equipped with the standard Navy kapok life jacket. The water was 5 feet deep over a soft mud bottom, and the charges were detonated at a depth of 3 feet, being supported by floats. At "stand by" the subjects immersed themselves to the neck, with the feet just clear of the bottom, while orienting themselves by means of a rubber raft. Lethal pressure was estimated by employing samples of beef intestine filled with saline solution plus 10 cubic centimeters of air. These were immersed at 10-yard intervals over a course of 210 yards at 1- and 3-foot depths.

The results of the tests constitute the only data available in this country obtained from the deliberate and controlled exposure of human subjects to underwater blast, with the exception of Navy divers. The findings may be summarized as follows:

Underwater concussion produces definite abdominal sensations at rather low pressures (22.5 pounds per square inch), but no impact of the shock wave against the thorax could be detected by any of the subjects. Abdominal sensation, however (borborygmus, shifting gas bubble sensation, "somebody hitting you," "pressing as with the hand"), was uniformly present at calculated pressures from 22.5 to 69.2 pounds per square inch.

Aside from the abdominal (epigastrium) sensations, the explosions elicited a generalized sensation, usually described as a "jar" or "thud." It was concluded that calculated explosion pressures up to 70 pounds per square inch may be readily tolerated in shallow (5 feet) water.

Intestinal strips showed frank rupture at about 300 pounds per square inch (calculated). Petechial hemorrhagic lesions would probably occur at considerably lower pressures. It is known that hemorrhage occurs at pressures incapable of producing frank perforation.

The fact that men clad in standard deep-sea diving dress feel definite pressure at 50 pounds per square inch, while the subjects in this experiment suffered no serious discomfort at 70 pounds per square inch, may be related to the fact that the diver is partially (head and chest) enclosed in a layer of air, and to other hydrodynamic factors resulting from his equipment.

In a second experiment at Stump Neck, Md., under conditions identical with those prevailing at Fort Pierce (with the exception of temperature), a naval officer approached detonated Mark V charges until a calculated pressure of 140 pounds per square inch was attained. At the same time identical tests of lethal pressure (beef-gut method) again confirmed the figure of between 250–300 pounds pressure per square inch as that sufficient to produce intestinal perforation. Still another test, made at Fort Pierce yielded a figure of approximately 260 pounds pressure per square inch. It may therefore be considered as established that an underwater

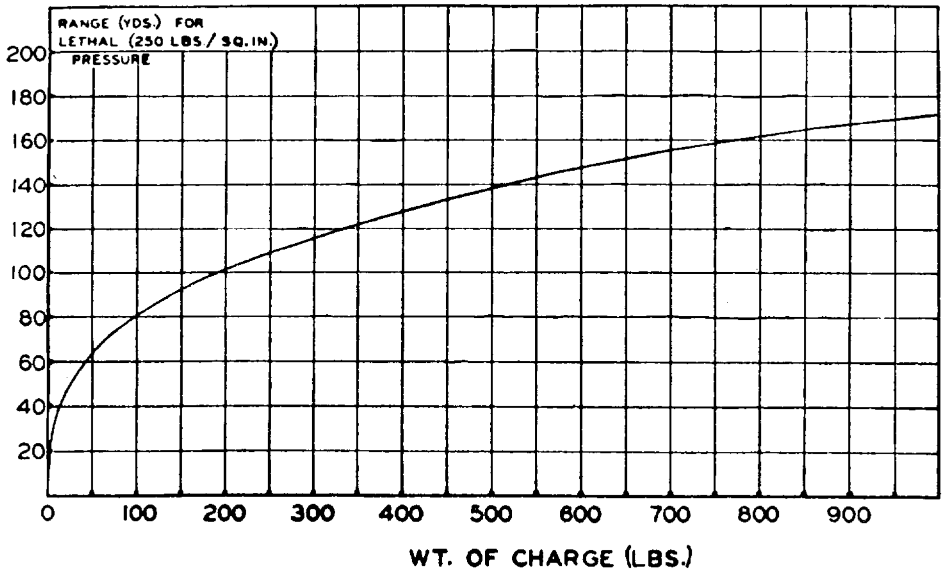

FIGURE 161.—Calculated lethal ranges for immersed personnel exposed to underwater explosions.

blast pressure of over 250 pounds per square inch will result in intestinal perforation, and, for the reasons stated, that even lower pressures must be looked upon as "lethal" (fig. 161), or at least dangerous.

BLAST AND SHIPBOARD PERSONNEL

In the summer of 1942 the Navy conducted a series of experiments at the request of the Marine Corps to determine the effectiveness of shallow-water mines upon personnel occupying assault craft. Charges were arbitrarily limited to 150 pounds, because this was considered to be the maximum weight permissible for laying from small boats in shallow water. Test animals of such size as to simulate men were used. The animals were oriented and stabilized by means of carefully fitted harnesses and lines. All-steel assault craft were used in these tests, the charges (150-pound) being detonated directly below the keel in 12 feet of water. High-speed motion pictures (1,000 frames per second) recorded the explosions. All animals were recovered in less than 5 minutes following each blast.

Results.—Three separate trials were made. In no case was any animal injured, although the high-speed film record showed that some of them were projected an estimated 20 feet into the air. Even when landing craft were so badly holed as to sink almost instantly, this remained true. Moreover, the result was the same whether the animals stood upon wooden decking, sand bags, or a padding of 1-inch rubber sponge. All animals were retained at the National Naval Medical Center for observation and remained entirely normal over a period of months. Indeed, some of the females subsequently became pregnant, giving birth to healthy young. On the basis of these tests it was the opinion of the Marine Corps observers that personnel subjected to the blast of shallow-water mines of this magnitude would not receive sufficiently serious injuries to prevent them from carrying out an assigned mission, and this method for the neutralization of assault craft in shallow water was abandoned.

The fallacy in the method lies in the fact that personnel within assault craft are not in direct contact with the water. Only those parts of the body actually immersed are subjected to the concussion wave, and therefore injury can only occur due to transmitted impact through the hull or to violent displacement, loose gear, striking the body against solid structures, and the like. Because a charge of 150 pounds should be lethal to personnel immersed in water to a distance of over 90 yards, and even 25 pounds of TNT would theoretically kill men throughout a 50-yard radius, it was suggested that a mine be so constructed as to first hole the assault craft, thus placing the occupants in contact with the sea. A second and smaller charge, detonated about 10 seconds after the first, would then become effective. Further experiments designed to demonstrate such a method of neutralizing enemy landing craft personnel were never carried out.

PROTECTION FROM BLAST

Methods thus far suggested for the protection of personnel from blast have been too impractical to warrant serious consideration by the military. As earlier noted, blast in air must be considered as a remote danger indeed as compared with high velocity bomb and shell fragments or with flying stones, debris, falling walls, timbers, and the like, which accompany the detonation of high explosives. Thus, while there can be no doubt that men may be killed by the effect of the blast *per se*, protection from fragments and missiles of all sorts is so much more urgently required (example, body armor) that the threat of injury from air blast becomes, by comparison, extremely remote.

Moreover, the training of the soldier is, of itself, a training in the avoidance of injury from blast. That is to say, the tactics by which the soldier seeks to avoid injury from missiles are the most effective means of escaping the full impact of a blast. The intensity of blast pressure in air is greatly reduced in any depression, behind trees, or behind a vertical wall of any sort. Thus in utilizing even shallow inequalities of the terrain, tree trunks, walls, and ditches, the soldier is almost assured of protection from the blast of a detonating charge. It is well established that a covering of sponge-rubber, kapok, or other resilient material over the chest and abdomen confers a very high degree of protection from blast, but the rarity of such injuries does not warrant the use of such equipment. Even with the ever-present threat of wounds or death from shell fragments, it is only of very recent date that a body armor (with the exception of the helmet) has been considered practical, and in the past troops have tended to discard even such life-saving equipment. Hence the issue of clothing to minimize the likelihood of serious injury by air blast might be said to border upon the ridiculous.

In the case of underwater blast, quite the reverse is true. Casualties from this source continued throughout the war, and injury from this cause may be considered to be common at the site of sinkings during naval engagements. The Greaves experiments, together with the fact that the majority of such cases involved only gastrointestinal lesions, pointed, at an early date, to the fact that the standard Navy kapok lifejacket offers a high degree of protection from underwater blast, and the modification of this jacket to provide kapok padding over the abdomen was suggested by the Bureau of Medicine and Surgery. However, it was felt that such an addition would render the lifejacket too cumbersome for general use. The Royal Canadian Navy, on the other hand, designed and issued just such a jacket. Among American personnel, emphasis was put on the avoidance of injury rather than protection from this recognized hazard, and the following was recommended:

1. Wear your life jacket properly tied and adjusted. It is a "life preserver" that will protect you from underwater explosions as well as from drowning.
2. Swim away from an expected underwater explosion as rapidly as possible. You will be safe at a distance of 120 yards from a 300-pound depth charge, or 150 yards from a 600-pound depth charge, even without your life jacket, and at a considerably less distance if you are wearing it.
3. Make use of any floating object that will support you to draw yourself out of the water, particularly your chest.
4. Keep your head out of the water and when resting float on your back, as high in the water as possible. Remember, only those parts of your body that are submerged will be affected by an underwater explosion.
5. Do not lie on a partly submerged raft when underwater explosions are expected. Stand or sit, so that the shock will not be transmitted to your chest or abdomen.

Thus the matter of the prevention of underwater blast injury rested.

The Bureau of Medicine and Surgery, in an effort to produce a Navy "battle dress" to protect personnel from drowning, flash burns, blast, and missiles, worked on the principle that the one certain means of preventing injury by underwater blast consists of raising the body out of contact with the water. To this end, individual, inflatable floats were fabricated which were enclosed within a small pack worn on the back. These floats, which weighed but 4 pounds complete with gas cylinder, were capable of providing complete flotation and were really very lightweight, one-man rafts. Due to the general unreliability of gas-inflated flotation gear, however, and the likelihood of puncture of the necessarily thin material of which these floats were made, none of the equipment saw service. It is interesting in retrospect to conjecture as to the possible benefit to have been gained by equipping all hands with these small, pack-contained floats in addition to regularly issued gear. A single float would provide flotation for from 6 to 8 men and even a high percentage of failures would leave a great number of such floating mats spread over a large area, were but a few hundred thrown into the sea at the site of disaster.

Another "antiblast unit" of heavier construction was developed by a commercial concern and tested by the Navy. This equipment was also stowed within a small pack worn like a haversack, inflation being accomplished by firm traction on straps beneath the arms. A general trend away from relatively unreliable gas flotation in favor of kapok, fiberglass, or similar material prevented the service trial of this equipment. These proposed solutions of the problem of protection against blast are cited as examples of devices offered to the services that are fundamentally sound in principle but impracticable due to the conditions of naval warfare.

In an attempt to afford maximal protection to deep-sea divers against underwater concussion, an "antiblast" vest was developed in England. The design was based upon the sound principle of covering the thorax and abdomen with a layer of kapok or cotton padding, which had been shown by all investigators in the field to be, to some degree, effective. The design of the vest was excellent, affording complete coverage of the thorax, abdomen, and perineum, and it was secured by simple ties of cotton tape. It was intended to be worn over the diving underwear, next to the rubberized dress.

Tests of two of these vests by the Navy indicated that a certain amount of protection was afforded, but the adoption of this item as standard equipment was not considered justified because of the increased labor entailed in dressing the diver, and the added bulkiness. This equipment was found to increase the "lethal" pressure by 225 pounds per square inch. According to calculation this would reduce the distance at which a diver might survive the detonation of a 300-pound (Mark VI) depth charge from 97 to 55 yards. Thus, this type of equipment would appear worthy of further development, provided the protection of divers from blast is desired. The British gear was loosely-packed and apparently cheaply made, but the results of the tests make it appear that a somewhat heavier, well-packed, and carefully designed garment might offer a surprising degree of protection. Provided such a vest were fully flexible, a reasonable increase in bulk and weight could hardly offer grounds for objection, when the size and weight of our deep-sea gear alone are considered.

Protection from blast may thus be secured by three principal methods:

1. *Avoidance of the full force of the blast* by utilizing depressions in the terrain, bunkers, and shelters; the use of floating debris in raising the chest and abdomen as far out of the sea as possible; utilizing a knowledge of known lethal distances.

2. *Wearing protective gear* of a soft, yielding material; use of the kapok lifejacket, preferably extended to cover the abdomen; use of Navy "battle dress" or similar equipment.

3. *Entirely escaping the effects of blast* by the use of flotation to raise the body entirely out of contact with the sea; rapid retirement beyond the lethal range of expected blasts.

SYMPTOMS OF BLAST

The victim of blast injury invariably presented a history of being in the near vicinity of an explosion. In the case of underwater concussion, all men taken from the water may be suspected of having sustained this type of trauma in instances where submarine explosions have taken place.

Pulmonary damage or "blast lung" is indicated by blood-tinged sputum or even the frank expectoration of blood. Respiratory embarrassment, pain in the chest, rales, and pulmonary dullness complete the picture. The location, extent, and severity of the lesions may be determined by x-ray examination.

In cases in which the gastrointestinal tract has suffered damage, clear-cut diagnosis may be more difficult. A common indication is the occurrence of loose bowel movements, sometimes accompanied by abdominal cramps and pain while still in the water and shortly following the explosion.

Other patients suffer no distress until drawn from the water, when severe pain may supervene. In frank perforation of the bowel, the symptoms exhibited are those of a rapidly developing peritonitis with elevated temperature, high leukocyte count, and tender, rigid, boardlike abdomen. Shock is of frequent occurrence in blast injury of either pulmonary or gastrointestinal type. Many patients present symptoms of both types of lesion, but in general the lungs appear most frequently affected by air blast. The reverse is true in naval experience with underwater concussion injury.

In those cases in which no perforation of the bowel has taken place at the time of the explosion, hemorrhagic lesions may be present. Such patients may remain symptom free, or perforation of the gut may supervene at a later date. This late perforation is brought about by ischemia of the bowel wall at the site of injury, due to blood clot formation with eventual necrosis and sloughing of small area of the intestinal wall.

TREATMENT

The treatment of pulmonary blast injury is much like that of pneumonia. Shock therapy is often necessary, but here the raising of the blood pressure by intravenous infusions of whole blood, saline, or plasma must be carried out with caution because of the danger of increasing pulmonary hemorrhage. For the same reason, artificial respiration by the Schaefer method or any other drastic manipulation of the patient is contra-indicated except when necessary due to the exigencies of field conditions. Immediate and comfortable bed rest is essential. Sedation is said to be helpful unless contra-indicated by shock, and oxygen administration is often of value. In cases in which hemorrhage has invaded the respiratory passages, aspiration may be of benefit. Tracheal insufflation has been used.

Under ideal conditions, an exploration of the abdominal contents is in order when surgical judgment indicates that perforation of the gut has taken place. This is not always possible, and the conservative treatment of suspected underwater blast injury has, happily, resulted in a high percentage of recoveries. This has been attributed to the fact that in such lesions the peritoneum often remains intact, resulting in a self-limitation of infection. In general, however, one must conclude that the treatment of choice for such patients is prompt surgery when indicated by clinical judgment.

FUTURE RESEARCH

Although our basic knowledge of the effects of blast is fairly complete, at least in its more practical aspects, continued progress in the development of explosives and other methods for the ultra-rapid release of energy make necessary the prosecution of research on the effects of and protection against this weapon.

Such studies will probably be medical in nature only to a very limited degree. They may be expected to center largely around the vulnerability of hulls, bombshelters, buildings, et cetera, resulting in the design of ships, structures, and military and civilian installations of all types which will be resistant to demolition by blast.

The development of blast gages of newer types will probably be continued, with piezoelectric equipment supplanting the cruder methods of pressure measurement now in general use. This is of paramount importance in all studies on the intensity of blast, as accurate pressure measurements, together with time recordings of peak pressures, are essential to an understanding of what has taken place. Cruder methods of pressure estimation may be said to have largely outlived their usefulness.

From the military standpoint, research will probably be continued in many fields. The clearance of underwater obstacles will progress beyond the present stage of development, efficient as those heroic methods were in the Pacific war just closed. Methods for the demolition of caves and the neutralization of personnel by blast will almost certainly progress beyond crude but effective blocks of explosive held together by tape and detonated by means of matches and fuses.

The determination of dangerous and lethal blast pressures needs to be reinvestigated and more accurately determined through the unhurried research which is possible in time of peace. Phases of such research as yet untouched would bear careful study. Thus, the effects of blast within closed spaces should be thoroughly investigated with a view to protection from this hazard. Such research might also be a valuable aid in increasing the casualty-producing properties of anti-personnel bombs and shells, as well as in the improvement of equipment for the neutralization of pillboxes, cave installations, dugouts, and similar fortifications. Much, therefore, remains to be done, requiring the united efforts of our military facilities, the chemist, the physicist, the medical researcher, and the physician.

Chapter XXIII

Roentgenology

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The almost unbelievable technical strides that characterized the progress of modern science were reflected in the types of x-ray apparatus used in the Navy during World War II. The comparatively brief interval of peace before our re-entry into war was fruitful in improvements, but the usual budgetary restrictions applied to the services in peacetime produced a terrific initial handicap in material and personnel.

In 1939 most of our hospitals had high capacity (200 to 500 MA) shock-proof diagnostic units, and the larger hospitals had 200-kv. roentgen therapy units. The hospital ship, U.S.S. *Relief*, had a 200 MA unit for diagnosis and high voltage therapy and an excellent 100 MA urological unit, as well as mobile x-ray machines. Cruisers and battleships had small x-ray units. The U.S.S. *Henderson* had a mobile unit in its sick bay as early as 1923.

On the personnel side, the need for trained radiologists and x-ray technicians was recognized before the war, and insofar as budgeting and personnel limitations permitted, efforts were made to fill the need. Training was given to medical officers in our own hospitals, and in some cases in civilian medical centers. A technicians' school was operated for a time in the Navy Supply Depot, Brooklyn; later a first-rate and well-equipped school was set up at the National Naval Medical Center, Bethesda, Md.

As the war clouds gathered, increased attention was given to problems of x-ray procurement. When it was realized that there was considerable variation in ideas as to adequate installations, a basic x-ray installation for various activities was designated. Hospitals equipped after the outbreak of the war were limited to 200 MA diagnostic machines and 200-250 kv. machines for therapy.

Another problem was the detection of tuberculosis by roentgenogram. World War I demonstrated the magnitude of the tuberculosis problem and postwar studies indicated that physical examination was inadequate for the detection of early cases. The answer to early detection was in roentgenograms of the chest, but the conventional method utilizing 14 by 17 films was enormously expensive and technically difficult on the huge scale necessary. Studies were started at the Naval Medical School on the 35 mm. method that had been successfully initiated in Brazil by Doctor d'Abreu. There were many technical difficulties in producing miniature films that would satisfy exacting standards, and the usual apathy and skepticism had to be overcome. These studies were continued into the actual war period, but by strenuous work, earnest backing of the Surgeon General, cooperation of the U.S. Public Health Service (which was also working along parallel lines), and help from manufacturers, the outbreak of war found the Medical Department with a few photofluorographic units in operation at the naval training stations. At the close of the war, these units, including a mobile type, were in operation at training centers, Navy yards, and receiving stations. The technical methods had been improved, and the program was extended to Hawaii and Guam.

The Army adopted the 4- by 5-inch photofluorographic method for dealing with the problem, because of their preference for the larger image. We found, however, the smaller size much more economical and practical, studies indicating that there was no loss in "case finding" ability.

The matter of field equipment was not neglected, and as was natural the Army was particularly active here. With the cooperation of manufacturers, a "suit-case" model for rapid setting up under difficult circumstances was provided. The Army and the engineers from x-ray manufacturing establishments developed a unit of moderate capacity adaptable to various types of work, including long periods of fluoroscopy or roentgen therapy. The table was of "knockdown" but rugged design, and was provided with an ingenious grid and localizing device. The tube was a marvel of efficiency, equipped with collar-type connections and an oil circulator in the tube head for efficient cooling. The packing was arranged so that individual cases could be handled readily and would withstand brutal usage.

A departure from the usual practice was put into effect as regards equipping new hospitals. Instead of calling for bids on individual units, a single manufacturer was called on to furnish the entire x-ray installation. This simplified procurement and servicing.

Overseas and advance bases were equipped not only with small x-ray units, but also with those of 200 MA capacity when patient capacity justified, as in the case of activities of from 600- to 1,000-bed capacity. Dispensaries of 200 beds were equipped with either 100 or 200 MA units. One-hundred bed dispensaries were usually equipped with 100 MA units. Smaller outfits received portable units.

Hospital ships of the A.H. 12–17 class had a 250 MA radiographic unit equipped with Potter-Bucky diaphragm and fluoroscopic and spot film attachments (fig. 162). All combatant and auxiliary vessels of 400 or more complement were equipped with a 15 MA radiographic unit and those having a dental operating room also had a wall-mounted dental unit.

A manual of instructions and techniques especially adapted to Navy needs became necessary. Other than the conventional textbooks, nothing was available except scattered notes of individual instructors and a collection of questions and answers designed largely for examinations. Accordingly, a text, "Fundamentals of X-ray Physics and Technique," was compiled and distributed to designated activities.

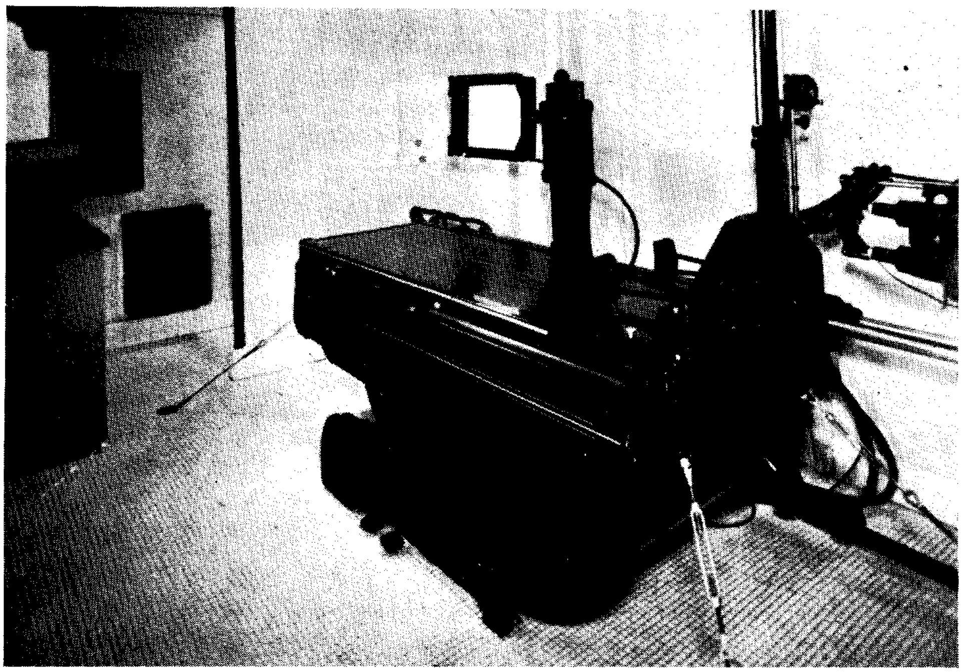

FIGURE 162.—Main x-ray room showing unit secured for sea.

STUDIES AND RESEARCH

Photofluorography.—A number of studies were made of photofluorographic problems. The principal ones included: (*a*) Trials of emulsions, developers, and screens to determine the best combinations. (*b*) Tests to determine the most efficient and practical radiographic factors. (*c*) Comparisons with 14 by 17 films to determine trustworthiness. (*d*) Development of an automatic camera at the Naval Medical Research Institute and the Naval Medical School. (*e*) Studies on condenser discharge units at the Naval Medical School. These made it possible to double capacity and use automatic timing.

Research on fluoroscopic hazards with particular reference to the use of radiographic screens in absence of regular fluoroscopic equipment indicated that the practice was inherently dangerous and justifiable only in real emergencies and on rare occasions.

Detection of foreign bodies.—The detection of low density foreign bodies became a matter of concern because of the introduction of aluminum alloys and plastics such as lucite. Extensive studies were made with various techniques and it was found that sectional radiography was the best method to employ in detecting low density objects in thick parts. This still left much to be desired.

Automatic timing for routine radiographic work.—Studies were commenced toward the end of the war, using apparatus obtained from the University of Chicago. The work, although not completed at the close of the war, indicated definite usefulness.

Trivision.—This was a new departure in radiography undertaken under the auspices of the National Research Council. It called for employment of lenticulated film to obtain a stereoscopic radiograph on single films. The project was that of Mr. Douglas Winnick, who designed and built an experimental x-ray unit and provided the special film, which was put to extensive experiment and trial over a period of several years. A number of very interesting and startling radiographs were made on 4- by 5-inch films, but under existing radiographic limitations it was found impractical to adapt the method to clinical use because of two major difficulties: (*a*) unduly heavy exposure factors, and (*b*) too much loss of detail in heavy parts. This interesting and promising processing venture had to be given up with great regret, but with the hope that technical improvements might make it of practical clinical utility at some future time.

It was necessary to reconsider the need for double focal spots and, in the interest of simplification and economy, be content with the larger spot. The difference in results from the 1-mm. and 2-mm. spots (the conventional arrangement) was rarely significant and in many types of work imperceptible. A tube similar to that used with the Army type field unit should have been adapted for use with a fluoroscopic table. This tube, by reason of an oil circulating mechanism and blower, had a much longer life and operated longer without overheating.

Field units.—Greater ease of setting up and disassembly was desirable for x-ray units used near or at the scene of action. Disassembly and repacking often had to be accomplished in the greatest of haste, and delay meant the loss of parts, breakage, or even complete abandonment. A unit that could be swiftly folded back into a case that formed an integral part of its assembly when in use, was best. The more elaborate type such as the Army field unit was more suitable for use in rear areas.

Plastics.—Consideration should have been given to rendering plastic materials such as lucite and bakelite radiopaque, so they could be readily detected in the tissues.

Radiation safety.—All fluoroscopic apparatus should have been furnished with permanently mounted tags of durable material indicating permissible limits of exposure. Integrating timers should have been in routine use on fluoroscopes. Indiscriminate use of fluoroscopy by personnel untrained in radiology was a matter of grave concern; it probably caused more damage than statistics reflect.

PHOTOFLUOROGRAPHY IN THE NAVY

The early development of photofluorographic equipment and techniques has been cited above.

In the investigations at the Naval Medical School, which were started in December 1939, an old fluoroscopic screen and Captain Chambers' camera (f 1.5, 35-mm. Leica) were used at first, with various types of film. After obtaining some special emulsions from the film manufacturers and a "Fluorazure" screen, results came rapidly. On 19 March 1940, an acceptable technique was outlined; this called for 150 MA, 1/10 second exposure, f 1.5 lens, a tube-to-screen distance of 33 inches, and a plus 5 kv. over the standard radiography tables, using special film and a "Fluorazure" screen (fig. 163).

It was apparent to the workers that the 35-mm. method was adequate for the Navy's purpose and preferable to any of the other rapid techniques which had been or were being developed at that time. The 35-mm. film was inexpensive and the films could be taken as rapidly as 6 or 7 per minute. The processing and reading was done in rolls, and the method was thus expeditious. The films, as shown by many experiments included in the early Navy work, had adequate resolution for screening purposes. The 35-mm. film was read with magnification, but this was not a serious drawback with the type of viewers used, as the films could actually be read much faster in this manner than by any other method.

The Navy was confident that with improvement in technique they would have an adequate tool for tuberculosis case finding, but the reaction of the medical world toward the use of microfilm was still one of skepticism. The Navy's method was not supported by the Army, for that group selected the 4- by 5-inch film for their mass roentgenograms.

In 1940, 7 Leica 250-exposure cameras were obtained and work was started on the first 7 photofluorographic units which were to be installed at the large training stations. Trial runs with the original unit were made on patients at Gallinger Hospital in Washington, D. C., comparing the 35-mm. films with the standard 14- by 17-inch films. This survey gave the Navy confidence in its photofluorography unit. A series of conferences between the services and the manufacturers greatly aided the coordination and the work of various independent workers in this field. Standards for equipment, as well as for physical qualifications

FIGURE 163.—The original photofluorographic unit constructed at U. S. Naval Medical School.

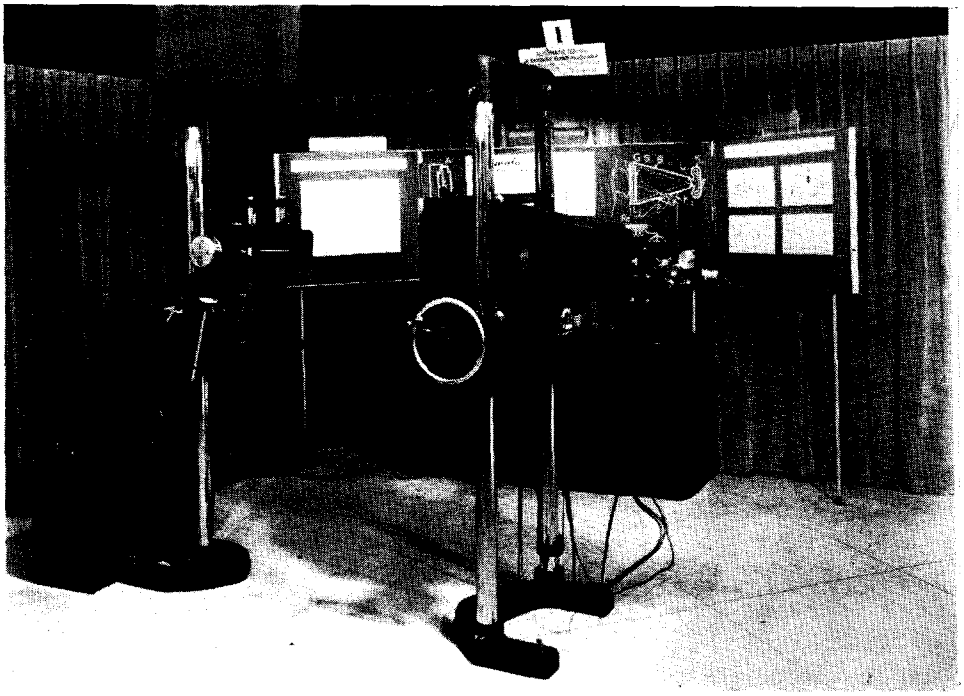

FIGURE 164.—Stationary photofluorographic unit.

for recruits, were formulated. The stimulus provided by the Army, Navy, and the Public Health Service to the manufacturers greatly expedited the production of equipment for the photofluorographic programs.

On 1 January 1941, the photofluorographic mass method of examining the chests of recruits was started at the Naval Station, Norfolk, Va., and between 1 January and 11 March photofluorographic examinations were made of 5,171 recruits. The recruits examined had already passed two physical examinations, but in 15 instances soft infiltration in the lungs was disclosed in the films, and in 3 instances extensive multiple calcifications and fibrosis were found.

Units were installed at other training stations. Meanwhile, the experimental work at the Naval Medical School continued and improvements of various aspects of the program were made from time to time. On 14 April 1941, the Surgeon General directed that the following roentgenographic findings were to be considered as disqualifying for enlistment or commission in the Navy or Marine Corps: (*a*) any evidence of reinfection (adult) type tuberculosis; active or inactive, other than slight thickening of the apical pleura; (*b*) evidence of active primary (childhood) type tuberculosis; (*c*) inactive primary pulmonary tuberculosis, if the degree or extent of involvement appeared to be of present or future clinical significance; (*d*) extensive calcifications in the lung parenchyma and massive calcifications of the hilar regions; or (*e*) evidence of fibrinous or serofibrinous pleuritis. These standards had been worked out in large part in conference with the Army.

In January 1942, the Bureau of Medicine and Surgery directed roentgenographic chest examinations of all Navy and Marine Corps personnel reporting for active duty. This was a tremendous step toward eliminating tuberculosis in the Navy.

After February 1943, photoroentgenograms of the chests of all applicants were made at Selective Service induction centers, and recruits disqualified because of roentgenographic evidence of tuberculosis were rejected at the centers *prior* to entering the service. This saved time, expense, and manpower. The importance of this

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step is reflected in the number of admissions for tuberculosis and the number invalided from the service since that time. Both stationary (fig. 164) and mobile (figs. 165 and 166) photofluorographic units were used.

Dr. Russell H. Morgan of the University of Chicago, prior to 1943, had devised an automatic phototimer for use with fluorographic apparatus. This automatically adjusted the time for each exposure. No adjustment of kilovoltage or amperage was necessary for taking films of different chests. This device improved quality, gave uniform results, and increased the speed with which films could be taken. It doubled the output, or halved the personnel required to operate the unit. The Navy adopted the Morgan phototimer 30 October 1943.

On 1 November 1944, the first naval photofluorographic unit outside the continental United States was established at Pearl Harbor. It immediately began full operation.

In January 1945, a directive required all naval personnel who had not had a chest roentgenogram in the past year to have one made at the earliest convenience, and restated the previous requirements that all personnel under 30 years of age must have a chest roentgenogram each year at the time of discharge, unless an examination had been made during the previous 6 months; 14- by 17-inch films were to be made when abnormal chest conditions were suspected.

In June 1945, the Surgeon General directed the Preventive Medicine Division to plan the installation of photofluorographic units for examination of men being demobilized. At this time approximately 50 photofluorographic units were in operation. In August, projects were underway to provide a floating x-ray laboratory for the fleet, units at Guam and Okinawa, and a mobile unit in addition to the stationary unit at Pearl Harbor. Because of the Japanese surrender these last projects were interrupted and all resources of the program were concentrated at the separation centers. In September 1945, 215,583 photofluorographic films were processed; In October, 275,938; and in December, 407,193. During the year prior to September 1945, about 2,500,000 roentgenograms had been taken.

The components of the photofluorographic unit included:

X-ray unit.—A generator of 200 MA capacity at 100 kv. The unit attained full-wave rectification by means of four valve tubes. X-ray tubes used were the heavy duty and shock-proof type; the distance between the anode and the fluoroscopic screen was 38 inches.

The x-ray tube is the weakest link in the complete unit, insofar as the rapidity with

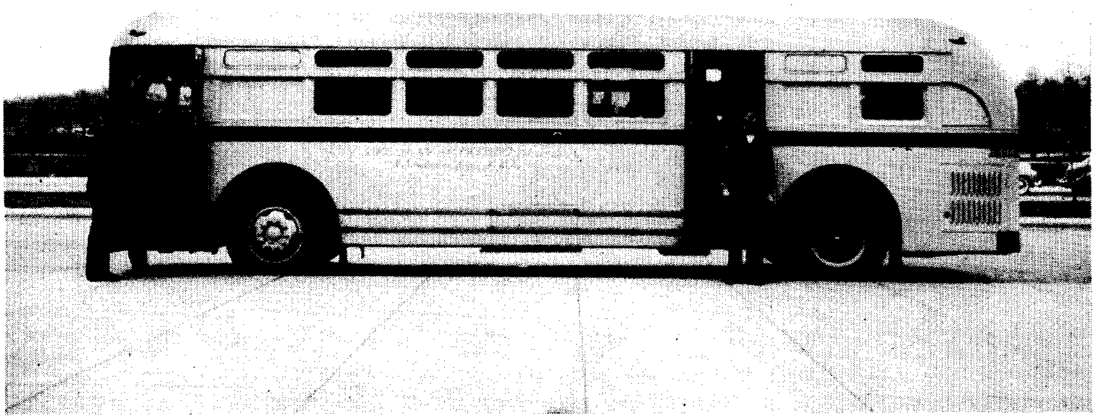

FIGURE 165.—Mobile photofluorographic unit.

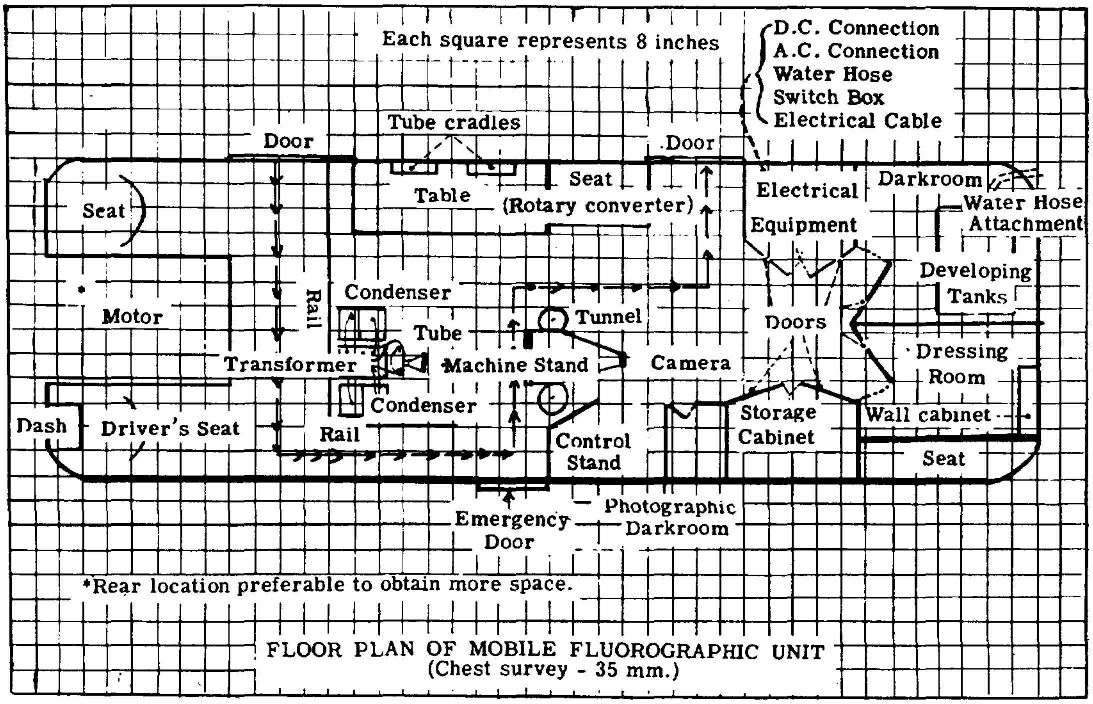

FIGURE 166.—Floor plan of mobile photofluorographic unit.

which exposures can be taken. This fact became obvious during the first portion of the Separation Program, for at the time there was a tendency to overwork the units, with resultant breakdowns caused by the overheating of x-ray tubes. It was necessary in November 1945 to recommend that the rate of exposure not exceed 2 or 3 per minute.

Photofluorographic unit.—The fluoroscopic screen was 16 by 16 inches. Many types of screens were tried. Two factors are of importance in such a screen: (*a*) It must be fast and (*b*) it must not be too grainy. Graininess, which causes loss of detail in the photograph, is directly proportional to the size of the particles of the fluorescent ingredient of the screen, while the speed of a screen increases with the size of the fluorescent particles used. Hence the problem has always been to increase the speed without increasing the size of the particles.

The early Navy photofluorographic experimental work was done with an old green fluorescent screen, but it was both slow and grainy. Later a Patterson "B" screen, which also fluoresces in the green portion of the spectrum, was tried with good results. The blue screen, "Fluorazure," was available and was used also in the early experimentation. It was faster than the regular "B" screen, but not as fast as the special type that was soon made available. A faster type of screen, using "green sensitive" film, was finally chosen.

Fluorescent screens tend to lose efficiency after 2 years of operation. This is believed due to the discoloration of the lead glass shield which covers the back of the screen, and not to the screen itself.

The first camera for photofluorography used by the Navy, of which some are still in use, was Leica 36 exposure, 35-mm., with lens of f 1.5 (approximate cost: $400). This camera is operated manually and this factor, together with the small number of available exposures, makes it unsatisfactory for large scale work.

As the war progressed, it became impossible to obtain Leica cameras, and as an automatic 35-mm. camera was needed and none of satisfactory design was available on the American market, the Navy had to devise its own. The need was acute, for in 1942, after almost 2 years of service, the Leica cameras had begun to break down. Work was begun at the Naval Research Institute, National Naval Medical Center, Bethesda, Md., by Commander R. H. Draeger with the following object in view: to design and construct a model automatic photofluorographic camera to meet the needs of the Navy Medical Department. Two models were constructed, and were tested in laboratory and field over a period of several months. During this time, about 15,000 photofluorographs were taken. Many changes were made in the models after the trials, and in July 1944 the first local contract was let for their production. A manually operated camera, interchangeable with the automatic camera, was also produced.

Mobile units.—The mobility of photofluorographic equipment makes it ideally suited for chest surveys of large groups of military or civilian personnel. Plans for the first Navy mobile units were made in 1942; by July 1943 the first two units (bus type) were ready for

TABLE 33.—*Invalided from the service for tuberculosis (all forms), U.S. Navy and Marine Corps, 1930–1945*

Year	Average strength	Total		Incurred in line of duty		Existed prior to entry	
		Number	Rate per 100,000	Number	Rate per 100,000	Number	Rate per 100,000
1930	117,453	180	153.25	171	145.59	9	7.66
1931	112,767	190	168.49	186	164.94	4	3.55
1932	110,717	137	123.74	136	122.84	1	0.90
1933	108,183	149	137.73	147	135.88	2	1.85
1934	109,383	156	142.62	150	137.13	6	5.49
1935	114,188	130	113.85	126	110.54	4	3.50
1936	124,408	100	80.38	97	77.97	3	2.41
1937	132,855	131	98.60	126	94.84	5	3.76
1938	139,216	93	66.80	90	64.65	3	2.15
1939	149,618	109	72.85	105	70.18	6	2.67
1940	202,614	147	72.55	143	70.58	12	6.91
1941	348,926	425	121.80	221	63.33	204	58.47
1942	834,639	2,220	265.98	262	31.39	1,958	234.59
1943	2,108,379	2,078	98.56	483	22.93	1,595	75.65
1944	3,349,798	1,630	48.66	1,258	36.93	392	11.70
1945	3,673,855	2,620	71.31	2,275	61.92	345	9.39

TABLE 34.—*Original admission rates per 1,000 average strength for tuberculosis (all forms), according to occupation, U. S. Navy and Marine Corps, 1930–1945*

	Occupation [1]	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945
	Total all occupations	1.92	1.70	1.70	1.82	1.63	1.31	1.36	1.14	0.87	1.00	0.94	0.95	0.58	0.48	0.57	1.15
Officers	Navy	1.11	1.20	1.47	0.63	0.94	0.81	1.26	0.85	0.45	0.60	0.53	0.45	0.67	0.52	0.65	1.34
	Marine Corps	1.61	0.00	0.00	0.83	0.84	0.00	1.50	0.71	1.38	0.65	0.52	1.12	0.26	0.48	0.46	0.96
	Nurses	1.99	9.56	3.97	13.19	2.82	5.95	5.46	2.51	2.35	2.28	2.17	1.50	1.13	1.54	1.70	2.44
	Midshipmen	0.51	1.02	0.56	0.00	0.63	1.14	0.00	0.47	0.00	0.00	0.86	0.26	0.00	0.49	0.41	0.49
Artificers	Electricians	2.73	1.59	2.43	2.63	1.61	0.91	2.01	1.87	2.15	1.56	1.69	2.04	0.92	0.85	0.92	1.72
	Engine Room	2.87	2.38	2.48	2.68	2.39	1.95	1.45	1.85	1.06	2.52	1.28	1.25	1.09	0.86	1.13	1.72
	Fireroom	1.74	1.70	0.88	1.58	1.40	1.60	1.23	1.37	0.97	1.29	1.03	1.05	0.89	0.54	0.39	1.11
	All others	2.07	2.11	1.96	3.67	1.67	1.29	1.53	1.15	1.06	1.00	0.21	1.31	1.19	0.33	0.60	1.97
Seaman Branch	Apprentices	0.00	0.42	0.00	0.00	0.41	0.45	0.00	0.37	0.00	0.15	0.16	0.34	0.05	0.07	0.16	0.39
	Ordnance	1.90	2.27	1.78	1.22	1.79	1.95	2.03	0.96	1.34	1.66	0.34	1.98	1.35	1.18	0.89	1.79
	All others	1.70	1.09	1.52	1.63	1.41	1.04	1.05	0.75	0.58	0.60	1.02	0.70	0.48	0.49	0.49	0.87
Miscellaneous	Aviation	2.41	0.64	1.53	1.54	0.61	0.31	1.07	0.86	0.93	0.87	0.72	1.47	0.90	0.50	0.55	1.12
	Marine Corps	1.75	1.81	1.57	1.33	1.77	1.08	1.32	1.19	0.82	0.65	0.66	0.71	0.38	0.38	0.41	0.67
	Hospital Corps	5.06	2.47	2.39	3.04	3.09	0.60	2.69	2.29	0.24	1.60	1.30	2.23	1.19	0.99	1.11	1.75
	Commissary (culinary)	2.64	3.18	2.83	2.93	3.15	3.98	2.14	1.33	1.80	1.65	1.95	2.55	1.47	1.08	1.04	2.09

[1] Rates for 1930-41 omit clerical, Marine musicians, and Navy musicians. Rates for 1942-45 omit clerical, Navy musicians, and specialists (general court martial prisoners also omitted in 1944).

Note: Four groups, Commissary (or Culinary), Hospital Corps, Nurses, and Engine Room, show original admission rates consistently above the mean rate for all occupations. All four of these groups are forced to lead an indoor type of life, and Hospital Corps and Nurse Corps personnel are in many cases more openly exposed to tuberculosis patients than other groups.

TABLE 35.—*Tuberculosis (all forms), admission rates, noneffective ratios, and death rates, U. S. Navy and Marine Corps, 1930–1945*

[All rates and ratios are per 100,000 average strength]

Year	Incidence rate	Noneffective ratio [1]	Death rate
1930	204.34	106.04	23.84
1931	184.45	87.43	15.08
1932	186.06	93.94	19.87
1933	203.36	111.71	19.41
1934	179.19	99.62	15.54
1935	145.37	77.13	12.26
1936	147.10	75.84	12.86
1937	124.95	78.14	7.53
1938	97.69	65.30	10.77
1939	113.62	65.49	7.35
1940	106.61	49.02	8.88
1941	203.77	48.66	3.44
1942	334.40	44.36	3.35
1943	118.05	28.60	2.85
1944	79.50	25.25	3.04
1945	158.72	57.34	4.11

[1] The noneffective ratio is an indication of the loss of time due to sickness. It represents the average number out of each 100,000 personnel constantly on the sick list for tuberculosis during a given year.

Note: From February 1943 until the end of the war, practically all applicants for the Navy received photoroentgenographic chest examinations in Selective Service induction centers. Men with tuberculosis were rejected prior to entry into the naval service. This is reflected in the abrupt change of the admission rate after 1942.

making roentgenograms of the chests of V-12 students in various colleges and universities. These were later replaced by tractor-trailer units.

The results of photofluorography in tuberculosis case findings are indicated in tables 33, 34, and 35.

The essence of the control of tuberculosis in the Navy required the early diagnosis and isolation of the patient, and the thought of the Medical Department was centered on a rapid, efficient, and dependable program of case finding. It became increasingly obvious that the x-ray offered the most reliable method of diagnosis. The reasons that impelled both the Army and the Navy to finally adopt methods of roentgen-ray examination of all recruits were briefly stated in the following recommendation of the Subcommittee on Tuberculosis of the Committee on Medicine of the National Research Council: (*a*) at least 75 percent of early active tuberculosis can be discovered only by x-ray examination; (*b*) about 1 percent of the male population of military age have active tuberculosis; (*c*) a high proportion of cases of early tuberculosis detectable only by x-ray examination is likely to break down under such a strain as that imposed by military duty, causing incapacitation for further service and creating a menace through contagion; (*d*) x-ray examination is much more expeditious than physical examination, thereby saving considerable time; (*e*) roentgenograms furnish a permanent and authoritative record, which may be useful in subsequent medico-legal adjustments; (*f*) conditions other than tuberculosis that would make the registrant unfit for military duty may be discovered by x-ray examination; and (*g*) the procedure will amply repay the cost by the saving of effective military manpower and the reduction of the ultimate cost to the Federal Government in pensions.

Chapter XXIV

Rehabilitation

Howard K. Montgomery, *Captain (MC) USN*

Rehabilitation became an organized activity in the Medical Department of the Navy during World War II in response to a number of factors. Arrival of increasing numbers of casualties at hospitals on the mainland made it apparent that there was need to supplement treatment with activities that would serve two purposes: (*a*) Promote physical fitness for return to duty of all patients in whom this was possible, and (*b*) minimize the social and economic effects of residual disabilities upon readjustment to civil life, for patients who could not be restored to active duty. The Navy's need to conserve manpower dictated the first; the experience after World War I that medical treatment and an appropriate pension would not sufficiently fulfill the country's obligations to men discharged from the services for medical reasons, dictated the second. There was general insistence that patients be "rehabilitated," but the wide variety of proposals advanced showed that there was no agreement in governmental or civilian circles as to what comprised the process of rehabilitation or how it was to be accomplished.

The Surgeon General, Vice Admiral Ross T McIntire, considered the rehabilitation responsibilities of the Medical Department of sufficient importance to warrant establishing an office of rehabilitation in the Bureau. This office was directed to "develop, place in operation, and direct a program of rehabilitation which would include all activities and services which might be required to supplement the ordinary or usual therapeutic procedures, in order to achieve maximum adjustment of the individual patient, either for further military service, or for return to civil life with the least possible handicap from his disability." To carry out this mission, physical therapy, occupational therapy, physical training, educational services, and civil readjustment were placed within its purview. In its relations with the hospitals, the office informed the commanding officers of developments and trends in the rapidly growing field of rehabilitation, and of procedures and practices of value. It also assisted them in solution of their local problems and coordinated the efforts of the hospitals.

The purpose of the program was to expedite complete recovery and return to duty of the maximum number of patients. When return to duty was not feasible, the program made use of the time the patient had to spend in the hospital in laying a ground work for whatever course he might intend to follow after returning to civil life. The rehabilitation process in fact started in the hospitals in the combat areas, and was completed there for patients who recovered within the period of time specified by evacuation directives. For patients evacuated to the mainland and for those admitted from continental stations, the rehabilitation process started upon admission to a hospital. In practice, however, the rehabilitation program functioned only in the continental hospitals.

The extent of rehabilitation activities in an individual case depended entirely upon the time required to treat the patient's disability. Rehabilitation ceased when the patient was found fit for return to duty, was transferred to a nonnaval agency for further hospitalization, or was discharged from the Navy. Patients were not retained in hospitals to complete a program of education or training in preparation for return to civil life, and vocational training was not a part of the program. It was considered that the responsibilities of the Medical Department had been discharged when the patient had attained maximum benefit from treatment and had been returned to duty or had been started toward the social and economic rehabilitation which could be completed only after his return to civil life.

Responsibility for developing and conducting programs that would accomplish these broad purposes and be suited to local conditions was placed upon the commanding officers of the hospitals. They were directed to designate a medical officer to be Rehabilitation Officer in charge of the program in the hospital. This officer acted as the commanding officer's advisor and was responsible to him for the integration of the medical services into the program, its effective functioning, and its orderly development. The commanding officers were also directed to appoint a rehabilitation board consisting of the rehabilitation officer as chairman and representatives from the clinical services, physical therapy, occupational therapy, physical training, educational services, and civil readjustment departments. It was the function of the rehabilitation board to correlate and integrate the services included in the program with the clinical care and treatment of the patients, to the end that maximum rehabilitation would be affected during the period of hospitalization.

In most instances a rehabilitation service was established as one of the clinical services, with the rehabilitation officer as chief of this service, which included physical therapy, occupational therapy and physical training, educational services, and civil readjustment. In hospitals to which a medical officer trained in physical medicine was attached, however, occupational therapy and physical therapy were combined in a department of physical medicine.

For purposes of scheduling rehabilitation, patients were divided into two general categories. In the first were those admitted for acute conditions in whom recovery and return to duty was the usual outcome. In the second were those requiring prolonged hospitalization, a large part of which would be in a convalescent status, where discharge from the service was expected.

For patients in the first category, rehabilitation consisted of physical training to promote physical fitness compatible with full duty, and physical therapy or occupational therapy if indicated as part of the clinical treatment. When feasible, didactic or practical instruction in subjects related to the patient's usual naval duties was offered.

For the second category, physical training was required to overcome the physical deterioration resulting from inactivity. Physical therapy and occupational therapy were prescribed if indicated. The educational and counseling services were available to all patients. Although patients were encouraged to make profitable use of their time in the hospital, participation in educational activities was entirely voluntary. All patients who were discharged from the service were processed through the office of civil readjustment.

With the basic purposes of the program in view, the commanding officers of the hospitals developed programs appropriate to their particular establishments. The requirements of the patients and the facilities available for rehabilitation in a hospital for convalescents established in what formerly had been a pleasure resort in an isolated area were quite different from those of a general hospital in or adjacent to a large metropolitan area. Blindness and deafness necessitated the development of special facilities and techniques within the overall program.

In spite of variations in scope and content, all programs followed the same general pattern. Upon admission to a hospital, patients were classified by the ward medical officer into one of five groups based on the amount of physical activity permissable. This classification, which was changed in step with the patient's progress toward recovery, governed all assignments to rehabilitation activities.

Physical exercise within the limitations imposed by the ward medical officer's classification was required and was started as soon as the patient's condition permitted. The objective was to maintain a sense of physical well being and to shorten the convalescent period as much as possible. This program was conducted by officers and enlisted men who had had experience in physical education in civilian life. They were selected from personnel under the cognizance of the Physical Training Section of the Bureau of Naval Personnel. One officer per thousand patients and one enlisted man per 100 patients was the minimum complement required for the program. Prior to assignment to hospital duty they received indoctrination and refresher training at a school at the Naval Training Station, Sampson, N. Y.

Hospital ward routines included time for physical exercise. For patients confined to bed or to the ward, the exercises employed were those approved by the ward medical officer from a manual of exercises for patients. Vigorous calisthenics and athletics were conducted for patients whose classification by the ward medical officer permitted such activity. No attempt was made to develop competitive athletic teams among patients. Physical training personnel became particularly adept in such specialized fields as conditioning exercises for amputees prior to fitting a prosthesis and subsequent gait training and in instructing paraplegics in self-locomotion.

Physical therapy and occupational therapy were prescribed by the medical officers when indicated as a part of the treatment. Physical therapy was not new in naval hospitals, but the large number of orthopedic cases requiring it necessitated expansion of existing installations and, in many instances, procurement of special equipment. Some of the wartime hospitals had formerly been civilian health resorts and had extensive facilities for hydrotherapy. These were used as special treatment centers.

The problem of obtaining a sufficient number of trained physical therapists was particularly acute during the early days of the program, and commissions in the Women's Reserve were offered to graduates of schools approved by the American Medical Association. The Bureau made arrangements with the schools whereby students could receive part of the required practical experience after reporting for naval duty. Although it became possible to assign at least one trained physical therapist to each hospital, a sufficient number was never obtained. Beginning in the early days of the war, the Bureau expanded and intensified its training of both male and female members of the Hospital Corps for duty as physical therapy assistants, and they were assigned to the hospitals to work under the graduate physical therapists.

Although occupational therapy had been conducted in some naval hospitals during World War I, there were at the start of World War II no facilities for such therapy in any of the naval hospitals, nor were there any occupational therapists in the Medical Department of the Navy. It therefore became necessary to procure occupational therapists. They were commissioned in the Women's Reserve, from the very limited number available in civil life, and assigned to duty in naval hospitals. The types of work projects employed were, to a large extent, left to the judgment of the therapist. They were advised, however, to employ procedures that might bring to light unrecognized aptitudes and skills. Diversional handiwork was delegated to the Arts and Skills Corps of the American Red Cross, for patients who did not require directed activities for definite therapeutic purposes.

As a general rule, occupational therapy shops included facilities for wood and metal work, printing, and hand weaving. At all times it was stressed that the end to be sought by occupational therapy was curative benefit to the patients rather than the production of articles of practical or decorative value. Therapists were encouraged to undertake bedside therapy, but this was seldom possible because the number of therapists was insufficient to provide the necessary supervision in the shops and at the same time conduct therapy on the wards.

In the early days of the war, the Bureau of Naval Personnel announced a program to develop and expand opportunities for voluntary in-service education of "everyone in the Navy who has a real desire to continue his education when the war is over, or who wishes to improve his position for obtaining employment upon discharge." This all-Navy program was conducted by officers who had been educators in civil life. Pilot educational programs in two naval hospitals were so well received by the patients that Educational Services programs were established in all naval hospitals, as a part of rehabilitation. Educational Services officers were ordered to naval hospitals to "organize and operate the program under the direction of the commanding officer and to function closely with and under the supervision and guidance of the medical staff." The educational program in the hospitals necessarily differed in many respects from the general service program, because of the necessity of coordinating the educational effort with treatment and with the internal routine of the hospitals. Furthermore, the fact that a considerable proportion of the patients in the hospitals were eventually discharged from the service for medical reasons led to the development of counseling in postdischarge problems as an essential feature of the hospital program.

Educational services.—The educational program changed as the war progressed. In the early days, the demand was principally for material relating either to the technical aspects of the men's naval duties or to subjects the men had dropped when they left school to enter service. Later, as the number of patients discharged for medical reasons began to rise, requests for material relating to selection of postservice vocational or educational objectives and to prevocational trials of aptitude increased. With the beginning of demobilization, counseling became the major objective.

This rehabilitation activity offered a wide range of educational opportunities. The correspondence courses of the U. S. Armed Forces Institute provided material for systematized study in many cultural and technical subjects at both high school and college level. These courses were administered by the Educational Services officers who gave the students such assistance as they might require from time to time. Successful completion of any of these courses was in most instances accepted for academic credit by the school or college in which the man had been enrolled prior to entering the service. Studies at the high school level were particularly in demand from men who had enlisted before completing high school. It was not uncommon for the commanding officer of a hospital to present a high school diploma to a patient who had earned sufficient credits by these courses to satisfy his school's requirements for graduation.

Self-teaching materials in subjects such as physics, mathematics, English, history, and aeronautics were provided for patients who desired less formalized study material. The standard naval training publications were available for patients who wished to become more proficient in their naval duties. These were supplemented by the use of strip films, motion pictures, and class instruction and practical demonstrations conducted by Educational Services officers or by qualified patients. Many patients completed the Bureau of Naval Personnel rate training courses while in the hospital, and were given the same credit in their records as though the course had been completed on a duty station. Stations adjacent to the hospitals gave great assistance in this aspect of the educational program, by furnishing items of equipment suitable for instruction and study. The Special Devices Division of the Bureau of Aeronautics enthusiastically worked with the hospitals and installed many excellent and ingenious training aids for use by the patients.

Patients to be discharged from the service for physical disabilities were guided into activities that would facilitate their social and economic rehabilitation. Many of these patients had well-formulated plans to take advantage of educational opportunities provided for them by law; others planned to return to their preservice employment; still others had no objective. This latter group included men who had had no preservice employment experience, or whose schooling had been interrupted by service and who did not desire to return to school, or who found it necessary to revise previously formulated plans because of permanent disabilities, or who were reluctant to do any advance planning.

The first group required assistance in confirming their previously acquired academic credits, advice as to studies that would contribute to their postservice plan and that could be pursued during hospitalization, and guidance in contacting the appropriate nonnaval agencies to arrange for admissions to the school or college of their choice.

The second group, who intended to return to their old jobs, required counseling as to whether permanent disabilities would interfere with their plans and advice regarding study courses to prepare them to perform their old jobs more effectively.

The third group presented many counseling problems. The educational officers were provided with equipment for aptitude testing and a handbook for counseling, and they had the benefit of consultation with representatives of nonnaval agencies responsible for assisting the veteran after his return to civil life. Many hospitals installed various types of mechanical equipment used for testing the aptitude of a patient for the particular vocational activity in which he had expressed interest. Hospitals, particularly those located in metropolitan areas, made arrangements with business and industrial employers adjacent to the hospital, whereby patients who had expressed an interest in seeking employment in a particular type of enterprise were given actual on-the-job work try-outs. In these instances the patients were usually paid for the work they did. They often acquired such interest and proficiency that by the time their treatment was completed they had offers of employment in the location in which they desired to settle. Where feasible, arrangements were made with nearby vocational training schools for patients to pursue formalized training courses during convalescence.

Representatives of the U. S. Employment Service were either assigned to the hospitals or were readily available for consultation. These representatives had up-to-date information regarding employment opportunities in the various occupations in all areas of the country and were of great assistance in placing dischargees in positions in their home communities.

The educational services program, a distinctly wartime activity, was well received by the patients, and the wide diversity of the material it offered gave every man an opportunity to make profitable use of his time in the hospital.

Civil readjustment.—The Bureau of Naval Personnel delegated to the Bureau of Medicine and Surgery responsibility for conducting its civil readjustment program "to advise and assist naval personnel about to be discharged on the process of reclaiming their privileges in their return to civil life" for patients discharged from the service at naval hospitals. This was the closing event in the rehabilitation process. The program functioned within the hospital in a manner similar to other procedures under the cognizance of the Bureau of Naval Personnel which are administered by the Commanding Officer.

Officers of what was then the Hospital Corps were given special instruction in the School of Hospital Administration at Bethesda, Md., before being assigned to civil readjustment duties. At least 1 officer so trained was assigned to each hospital. A discharge rate of 100 patients a month required the full-time service of this officer, and a discharge rate of 250 per month required an additional officer. During the demobilization period, these officers were assisted in conducting the required personal interviews by trained enlisted members of the Hospital Corps.

The procedure in the hospitals usually took several days. The rights and benefits to which prospective dischargees were entitled under existing law were explained in group lectures. While the group was assembled, it was the custom for the insurance officer to explain the status of their government insurance. Subsequently, each individual was interviewed privately by the civil readjustment officer or an enlisted assistant and given an opportunity to request amplification of matters brought out in the group lecture as they might apply to his individual case. The dischargee was then referred to the representatives of appropriate nonnaval agencies for assistance in preparing his claim for pension and in placing his post-discharge plan in effect. Through representatives of the Veterans Administration, U. S. Employment Service, Civil Service Commission, The American Red Cross, and various veterans organizations, it was possible for a dischargee to complete his application for pension and arrange for educational benefits or for employment in the community of his choice before he received his discharge from the Navy.

The civil readjustment process, in addition to acquainting the dischargee with the many rights and benefits provided for veterans, was the mechanism by which the rehabilitation process started in the hospitals was transferred directly to an appropriate nonnaval agency for completion.

Social services.—Other activities of the hospitals that were not a part of the rehabilitation program as such, but which contributed to its over-all purposes, rounded out the rehabilitation effort. The chaplains worked closely with rehabilitation personnel in helping to solve the spiritual and personal problems of the patients and in motivating them to take advantage of the opportunities offered. The American Red Cross provided many services. Their social workers assisted in solving personal and family problems and provided individual and group diversional activities and entertainment for both bedfast and ambulant patients. Trained volunteer workers were obtained when needed for some particular aspect of the program, and assistance in preparing claims for pension and other benefits was given at the time of discharge. Coordination into the general hospital program of offers of recreation and entertainment for patients by individuals and organizations was an incidental but often important service.

Although the general program provided rehabilitation for the vast majority of patients, it did not provide the highly specialized requirements of the blind, the deaf, or the amputees. Because of the relatively small number of these patients and the special personnel and equipment needed for both their clinical treatment and their rehabilitation, certain hospitals were designated as centers for treatment of these disabilities.

The blind.—Extensive study of the problem of rehabilitation of the blinded in the Armed Services eventuated in adoption of a policy which governed the care of these patients in the Army as well as the Navy. This policy provided that social readjustment training would be started as early as possible for the blind patient, that this training would be carried on while the patient received treatment for conditions concurrent with his blindness, and that such patients would be continued in active service until social adjustment training had been completed, even though they might have received maximum benefit from hospitalization. During this period of training, the Veterans Administration made arrangements for assuming responsibility for continuing training upon the patient's discharge from the service.

In July 1944, the U. S. Naval Hospital, Philadelphia, Pa., was designated as the center for all cases of bilateral blindness in the Navy and Marine Corps. It continued to perform that function until the program was brought to a close by the discharge of the last blinded patient.

The program was directed by an ophthalmologist, who coordinated his treatment with that of specialists in other fields and supervised the social training and re-education program. The latter aspects of the program were conducted by officers and enlisted personnel trained in teaching the blind—the goal was independence. Acquirement of proficiency in walking, reading, writing, dress, and personal hygiene was required of all patients. The program was highly individualized for each patient on the basis of his intelligence, aptitudes, skills, and aspirations.

The patients, all males, came from every part of the country, from all walks of life, and from various races. Their educational attainments ranged from completion of the fourth grade to graduation from college. In some, blindness resulted from battle wounds or accidental trauma; in others, trauma was not a causative factor.

All hospitals were directed to transfer to Philadelphia blind patients or those in whom blindness was impending. The program started to function as soon as the patient was admitted to Philadelphia, continued while he was under treatment, and was completed when he attained the prescribed proficiency in living as a blind individual. The length of time required to attain this proficiency varied from patient to patient; there was no prescribed minimum period. Patients who made the difficult psychological adjustment to blindness promptly and applied themselves diligently and conscientiously met the proficiency requirements within comparatively short periods. Those with co-existing conditions requiring prolonged treatment were unavoidably delayed in starting the more active phases of their training.

Carefully selected and trained Hospital Corpsmen gave individual instruction in travel and in the details of daily life by accompanying the patients in their hospital and recreational activities and teaching them to meet new situations as they arose. All patients were urged to become proficient in typewriting. Standard typewriters were used without modification for this instruction. Upon discharge from the hospital, patients who could meet prescribed standards of typing proficiency were presented with a portable typewriter through the generosity of an organization that remained anonymous.

Study of Braille was required of all patients. Evidence of desire to master this technique was considered a definite indication that the patient had fully accepted the fact of his blindness and had made a large step forward in his rehabilitation. Instruction was conducted by experienced teachers of Braille, but patients were permitted to discontinue the subject after they had mastered grade one and one-half.

All patients were instructed in the use of the cane in travel; guide dogs were not used in this program. The decision as to obtaining one of these animals through the Veterans Administration or other sources was made by the patient after he was discharged from the hospital.

When training in self care and travel had been completed, all patients were sent to the New York Institute for the Education of the Blind for a 2-week period of vocational aptitude testing and personal and psychological evaluation. This service was generously furnished by the Institute without charge. A copy of the complete profile report which the Institute prepared on each patient was furnished the Veterans Administration at the time the patient was discharged and became the basis for his postservice program.

As part of their social adjustment training, patients attended social functions in the hospital, in private homes, and places of entertainment in the city, and went on shopping trips. They engaged in various work experiences in industries in the city that accepted patients for work trials to determine vocational aptitude. A standard sales stand for a blind operator was installed as a branch of the Ships Service Store, and all patients were given a try-out in this activity. By these practical applications of social readjustment training, the patients learned their abilities and limitations and had definite experiences on which to build their lives after discharge. The fact that the number of patients under treatment was never large at any one time facilitated the individualization that characterized the program.

The deaf.—Experience in the previous war forecast that many cases of loss of hearing were to be expected. An increasing incidence of patients with decreased auditory acuity that interfered with their effective performance of duty focused attention on developing a solution for this major rehabilitation problem. Except in a few isolated instances, all patients had diminished auditory acuity rather than complete loss of hearing.

Deafness in adults had been recognized prior to the war as a problem that could not be adequately met by the traditional practices and processes of most schools for the deaf, and intensive study of its many ramifications was well advanced in civilian life. Dr. Walter Hughson, Director of the Otological Research Laboratory of the Abbington Memorial Hospital near Philadelphia, Pa., had developed equipment and procedures for scientific testing of hearing and for fitting hearing aids, that were far advanced for that time. He made the facilities of his laboratory available to a group at U. S. Naval Hospital, Philadelphia, Pa., headed by an otologist, and gave his full cooperation and assistance in developing facilities within the naval hospital for the rehabilitation of deaf patients and the training of key personnel.

This combined effort led to the development of such a well-organized and effective program that in July 1944, the U.S. Naval Hospital, Philadelphia, Pa., was designated as the center for rehabilitation of deaf personnel of the Navy and Marine Corps. All hospitals were directed to transfer patients with a stated degree of auditory impairment to Philadelphia.

This aural rehabilitation program was a pioneer undertaking to meet the problems of loss of hearing in a scientific and organized manner. It was the objective of the program to overcome psychological reactions to deafness and to restore the person's ability to live an economically and socially efficient life, by supplementing his residual hearing with mechanical and visual aids to the perception of sound. The patients seldom presented concurrent conditions requiring treatment, and there was, therefore, little need for coordinating their aural rehabilitation with other clinical activities of the hospital.

Because the program was a pioneer undertaking, the methods and procedures underwent a continuous process of modification based on experience in treating a large number of persons with impaired hearing. In spite of changes in details, however, the same general pattern of an organized, coordinated series of testing procedures, individual interviews, and class instruction was followed.

The procedure started with individual interviews and group discussions to explain and correct psychological reactions to deafness. Tests were made to determine the exact nature and extent of the hearing loss. Each patient was then furnished a hearing aid that would best compensate for his hearing loss. As part of the fitting procedure, each patient was provided with a plastic ear mold manufactured in the hospital laboratory from a cast of his external ear and auditory canal. In the event the aid issued initially was not satisfactory, other makes or modifications were tried until an instrument satisfactory to the individual was obtained. This became his property upon discharge from the hospital. The schedule also included organized class instruction in speech (lip) reading in groups of 8 to 15, in the physiology of hearing and the factors involved in hearing loss, in corrections of peculiarities of speech, and in the use of the hearing aid and visual clues in conversation carried on against a background of numerous types and intensities of recorded sounds.

The program was conducted in improvised quarters at the outset. Later a building was designed and constructed to include the many features found desirable. It was completely equipped with the electrical apparatus required. The techniques and procedures evolved in this program were major contributions to the advances made in audiology during the war.

Amputees.—Amputation of an extremity presented rehabilitation problems. Early in the war it was determined that they could best be met by sending these patients to special hospitals. Accordingly U. S. Naval Hospitals, Mare Island and Philadelphia, were designated as centers for amputees, and all cases of amputation of an extremity were transferred to one of these centers. As a general rule, the necessity for many surgical procedures prolonged the hospitalization of these patients. During the intervals, however, they were usually able to engage in a wide range of activity. Programs developed in the two centers differed in details, but both had the same basic objective of returning the patient to civil life prepared to engage in normal activities.

Advantage was taken of the intervals between surgical procedures for educational and work trial programs both within the hospitals and in nearby schools and commercial establishments. Looking toward the eventual fitting of a prosthesis, stress was placed on exercises to build up the general musculature as well as the muscles of the stump. As a result, patients were ready to begin learning to use their artificial limb as soon as it was ready for delivery. All limbs were manufactured in the excellent shops in the hospitals, and many fundamental improvements in prosthesis grew out of this work.

After the artificial limb was delivered, the patient was given extensive training in how to use it to best advantage. During this period of actual use, necessary adjustments for a comfortable fit were made in the appliance. As perfect a fit as possible and demonstrated proficiency in using the prosthesis were required before the patient was considered ready for discharge.

As part of their preparation for civil life, all patients were taught to operate an automobile equipped with special controls. The motor vehicle licensing departments of the two states granted driver's permits to those who could meet their requirements.

The rehabilitation program to prepare the patient to resume activity as an effective member of society upon his discharge from the hospital became an accepted feature of medical practice during the war years. It necessitated development of procedures and methods for which there was little or no previous experience to serve as a guide.

During about 18 months between the formal inauguration of the program and the rapid demobilization that started shortly after the surrender of Japan, the problems inherent in establishing a new activity in the naval hospitals had largely been overcome and progress was being made in refining techniques and procedures. Its activities then underwent progressive curtailment as the various specialists were demobilized. There is no doubt, however, that this wartime experience has had a lasting effect on naval hospital practice.

Chapter XXV

Malnutrition in Repatriated Prisoners of War

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On 29 August 1945, the U. S. S. *Benevolence* entered Tokyo Bay as a part of U. S. Third Fleet and was immediately assigned the mission of evaluating the health of American prisoners of war being liberated from that area (figs. 167, 168, 169). On that night and during the succeeding 2 days, 1,520 men were examined. Twelve hundred were considered well enough for evacuation by air or by transport. Some of the men appeared to be in almost normal health. Others showed signs of malnutrition, with minor degrees of edema, muscular wasting, or glossitis. The remaining 320 were considered ill enough to warrant further observation and treatment. All in this group had definite evidence of malnutrition.

With few exceptions, the men admitted to the sick list had been imprisoned for a considerable period of time in either Camp Omori, Camp Ofuna, Shinegawa Hospital, or Kempi (Military Police) Headquarters in Tokyo. Sanitary and dietary conditions were unsatisfactory in all of these detention centers.

Camp Omori, near the beach of Tokyo Bay, was registered with the International Red Cross and was considered by the Japanese to be a show place, but it appears to have been extremely insanitary. It had the highest incidence of prostrating, febrile dysentery (probably bacillary). The toilets consisted of apertures in the floor through which fecal matter dropped into a trench with concrete walls much like an American manure pit. The trench was sufficiently wide to extend beyond the outer wall of

FIGURE 167.—American prisoners of war.

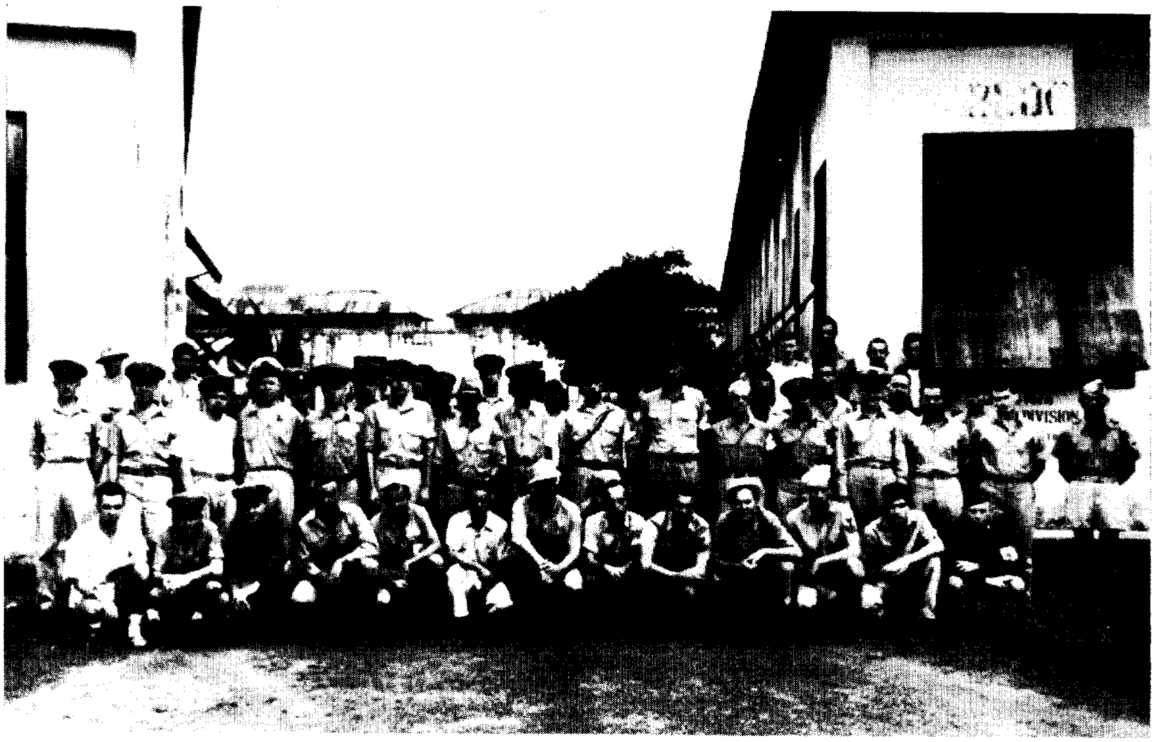

FIGURE 168.—American prisoners of war.

the building, where it was covered with planks. By removal of the planks the partially decomposed fecal matter could be taken out for use as "night soil" on adjacent garden patches. This increased the hazard of disseminating dysentery bacilli by flies, and the risk of transmitting

FIGURE 169.—American prisoners of war in a Japanese hospital.

FIGURE 170.—Daily food ration for American prisoners of war.

amebic cysts on the leaves of vegetables. There were inadequate facilities for washing the hands, so undoubtedly direct contamination of the food also took place.

The diet at Camp Omori was representative of that of Japanese prison camps. The daily ration (fig. 170) consisted of 600 grams of a mixture of unrefined rice, barley, and rye, supplemented at times by a few greens, clear soup, tea, or diminutive servings of fish approximately the size of large minnows. Working prisoners received about 700 grams of the basic grain diet. The intake varied, therefore, from about 2,100 to about 2,450 calories.

There were few complaints of extreme brutality from the prisoners who came from Omori. There were numerous fleas about the camp, but no lice were noted. There was a moderate amount of medical care, and on 15 August when peace negotiations were completed, a daily ration of vitamin pills was commenced. This was given not only to the prisoners who had been interned at the camp for a long period of months, but also to a group of fliers who were transferred at that time from Kempi Headquarters in Tokyo.

Camp Ofuna, situated several miles inland from Sagami Bay, and unregistered with the International Red Cross, was noted for the brutality of its guards, its deficient medical attention, and its fleas. Often on slight or no provocation prisoners were beaten on the buttocks and thighs with a 3–foot bamboo club. The basic diet at Ofuna, as at Omori, consisted of 600 grams of grain. Many of the prisoners, however, were assigned to working details outside the camp and by theft succeeded in supplementing the diet, some of the stolen food being used to bribe the guards into overlooking this irregularity. Thus the prisoners from Ofuna, on the whole, were better nourished than those from Omori, and there appears to have been considerably less dysentery.

Shinagawa Hospital, near Tokyo, was the only military hospital in Japan with Red Cross supplies of vitamins and medicines. It consisted of lightly constructed frame buildings. The wards were furnished in Japanese manner, with mats on the floor instead of cots. These were placed in close proximity to one another around the periphery of the room, leaving a free central area for dressing, eating, and other activities. The toilets, similar to those at Omori, consisted of holes in the floor. There was one bathtub indoors where each prisoner had a weekly bath. For washing the hands, there was an outdoor trough. A placard posted by an American physician divided this trough into two halves, one half for prisoners with tuberculosis and the other half for those free from the disease.

Perhaps because of the restrictions imposed on the Japanese by the extensive bombing of nearby Tokyo and Yokohama, this hospital was indescribably filthy. There were many fleas, and the patients slept in such close proximity to each other that the transmission of communicable diseases was inevitable. The basic diet, as at Omori and Ofuna, consisted of 600 grams of grain daily.

Kempi (Military Police) Headquarters in Tokyo was used for internment of B-29 fliers. Because of their alleged part in bombing civilians, these men were singled out for special punitive treatment. They were given half rations (300 grams of grain daily) and were denied all medical attention. Sixteen prisoners were assigned to each cell. The cells were about 11 feet long and 8 feet wide, and were partitioned with wooden gratings. Each cell had a small high window. In the corner of each cell was a commode, the container for which was removed for cleaning by an orderly who went under the building from the outside. Some of these orderlies were friendly to the prisoners and handed vitamin tablets to them through the commode apertures. Because of the commode in one corner and the small size of the cells, it was impossible for all the men to sleep at one time without lying on each other. There were many fleas. Some of the prisoners had draining wounds for which they could obtain no dressings. Nevertheless, owing to the external disposal of the sewage, there was almost no dysentery. The prisoners in Kempi Headquarters were transferred to Camp Omori on 15 August 1945.

Although during the months immediately preceding V-J day most of the men were in one or more of these places, there had been considerable variation in their treatment before that time. During the early years of the war, some of the prisoners interned in southern Japan had been afforded such luxuries as clean sheets. Many of the long-term internees had been "farmed out" to industrialists or to the railroads. These men had been fed relatively well and in addition had been able to steal additional quantities of food. In the early days some of the prisoners had also been able to buy food. On the other hand, there were those who had been through the "March of Death" to Cabanatuan in the Philippines, and there were others who had spent as much as 30 days in the uncleaned holds of transports, with the decks covered with feces and vomitus.

Two sample groups of patients were selected for clinical analysis: (1) 25 B–29 fliers who, on the average, had been interned for from 6 to 9 months and had lost 44 pounds in weight; and (2) 28 other prisoners of war, who had been interned for an average period of 17.4 months and had lost 46 pounds in weight. All the patients retained on the U. S. S. *Benevolence* for treatment were screened before admission. There were 225 B–29 fliers who came aboard for screening, of whom 85, or 37 percent, were admitted to the sick list. Of 1,295 other persons who came aboard for screening, 235, or 10.8 percent, were retained. These figures indicate that the degree of disability of the B-29 fliers as a whole was much greater than that of the other personnel (table 36).

All the patients studied were on three adjacent medical wards under the care of the same professional personnel.[1] Before the patients

[1] In this work the authors were assisted by Lt. Mack L. Gottlieb, MC, USNR, Lt. (jg), Fennimore T. Johnson, MC, USNR, Surgeon Commander Hugh L. Cleave, RN, and Surgeon Lieutenant Anthony D. Grove, RNVR.

TABLE 36.—*Physical condition of repatriated prisoners of war*

	B–29 fliers	Other personnel
Average duration of internment (months)	6.9	17.4
Average weight loss (pounds)	44	46
Symptoms (percent):		
Weakness	88	82
Diarrhea	64	78
Edema (history)	44	68
Sore mouth	24	32
Incoordination	4	3.7
Physical signs (percent):		
Wasting	84	78
Rice belly	80	68
Glossitis	56	43
Hyporeflexia	24	28
Hypesthesia	12	25
Nerve-trunk tenderness	4	3.7
Hemoglobin (grams)	11.0	11.2
Erythrocyte count (millions)	3.4	3.3

were admitted, a nutritional survey form had been devised, enumerating the principal symptoms and findings to be anticipated. These abnormalities were kept in mind during the history taking and physical examinations. The most important positive findings appear in the foregoing table and in figures 171 and 172.

The acute onset of symptoms of malnutrition could best be observed in the B–29 fliers. Many of these men had been shot down during the heavy raids of 25 and 26 May 1945 and had had 3½ months of internment at Kempi Headquarters on 300 grams of grain daily. On 15 August they had been transferred to Camp Omori where they had received vitamin therapy for 2 weeks before being received on this vessel. The patients of this group who were admitted to the sick list had lost from 30 to 70 pounds.

The earliest and most distressing symptom was weakness. Some of the men were so prostrated they could not stand up; others would become exhausted after the effort of folding a blanket. Next in importance were numbness, tingling, and pain. Such paresthesias were noted most often on the anterior aspects of the thighs and in the lower legs, but not infrequently in the back. Soreness of the mouth was described by 24 percent of the patients. Diarrhea was not prominent until transfer to Camp Omori on 15 August 1945. There it occurred in epidemic form and may have been bacillary in origin. This will be discussed further. Symptoms less frequently encountered are discussed in connection with the effects of malnutrition on the various systems of the body.

On physical examination, most of the B–29 fliers were found to be extremely emaciated. The facies were drawn, giving a macabre appearance and masking the characteristic visage of the individual. The frontal bosses were prominent and the veins of the forehead stood out in relief. The subcutaneous tissue had been exhausted and marked wasting of the musculature was noted. This was maximal in the thighs, upper arms, and the abdominal wall. Indeed, many of the victims were reduced to "skin and bones." One of the most constant features was the "rice belly" which 80 percent of the patients demonstrated. The abdominal wall was almost paper-thin and flaccid, yet distended by intestinal contents. A majority of the B–29 men showed bluish erythema of the tongue, with flattening of the papillae and a smooth surface, many tongues appearing larger than normal. Edema of the lower extremities was present in 24 percent of the aviators at the time of examination, but as many as 44 percent had had this finding at one time or another. Neurologic changes included grossly diminished or absent tendon reflexes, noted in 24 percent of the cases, and hypesthesia to touch, which was observed in 12 percent. Nerve-trunk tenderness was elicited in only one instance. The mean hemoglobin was 11 grams, and the average red blood cell count, 3,400,000.

The clinical features of the second series were more variable, because the conditions under which these persons had been interned were less constant. There were several in the group who showed comparatively little evidence of malnutrition. On the other hand, many had been on deficient diets for a long period of time. A greater number had suffered from edema (68 percent) and from hypesthesias (24 percent). The classic signs of "wet" and "dry" beriberi were more frequently encountered in this group. There were 3 men who had had bleeding gums and several who had been aware of dimness or blurring of vision or scotomata. The mean hemoglobin concentration was 11.2 grams and red blood cell count, 3,300,000. The average weight loss and the state of tissue depletion was roughly similar in both series.

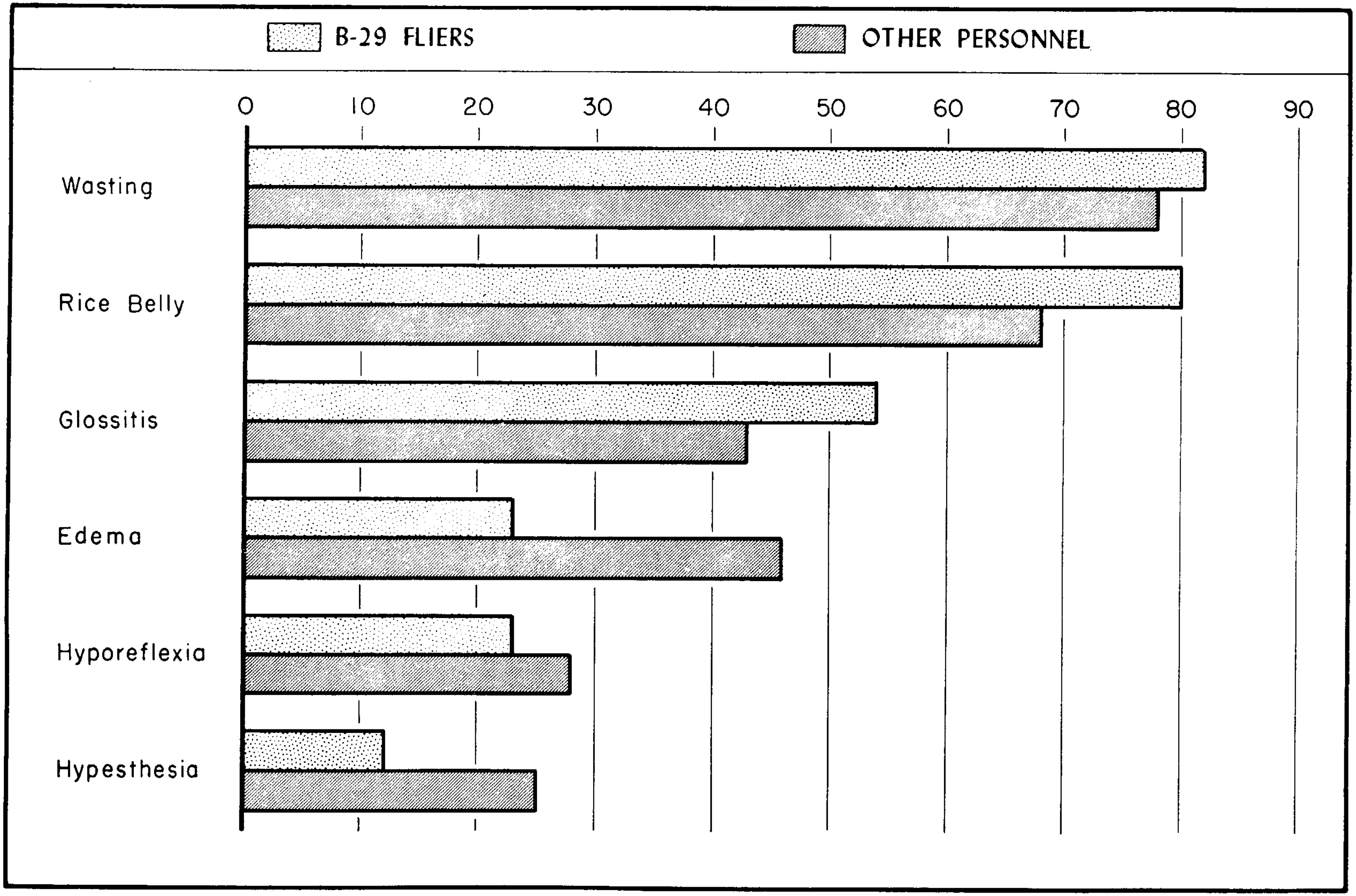

FIGURE 171.—Percentage incidence of symptoms of malnutrition in two groups of patients studied clinically. The minor differences between the two groups are of doubtful statistical significance.

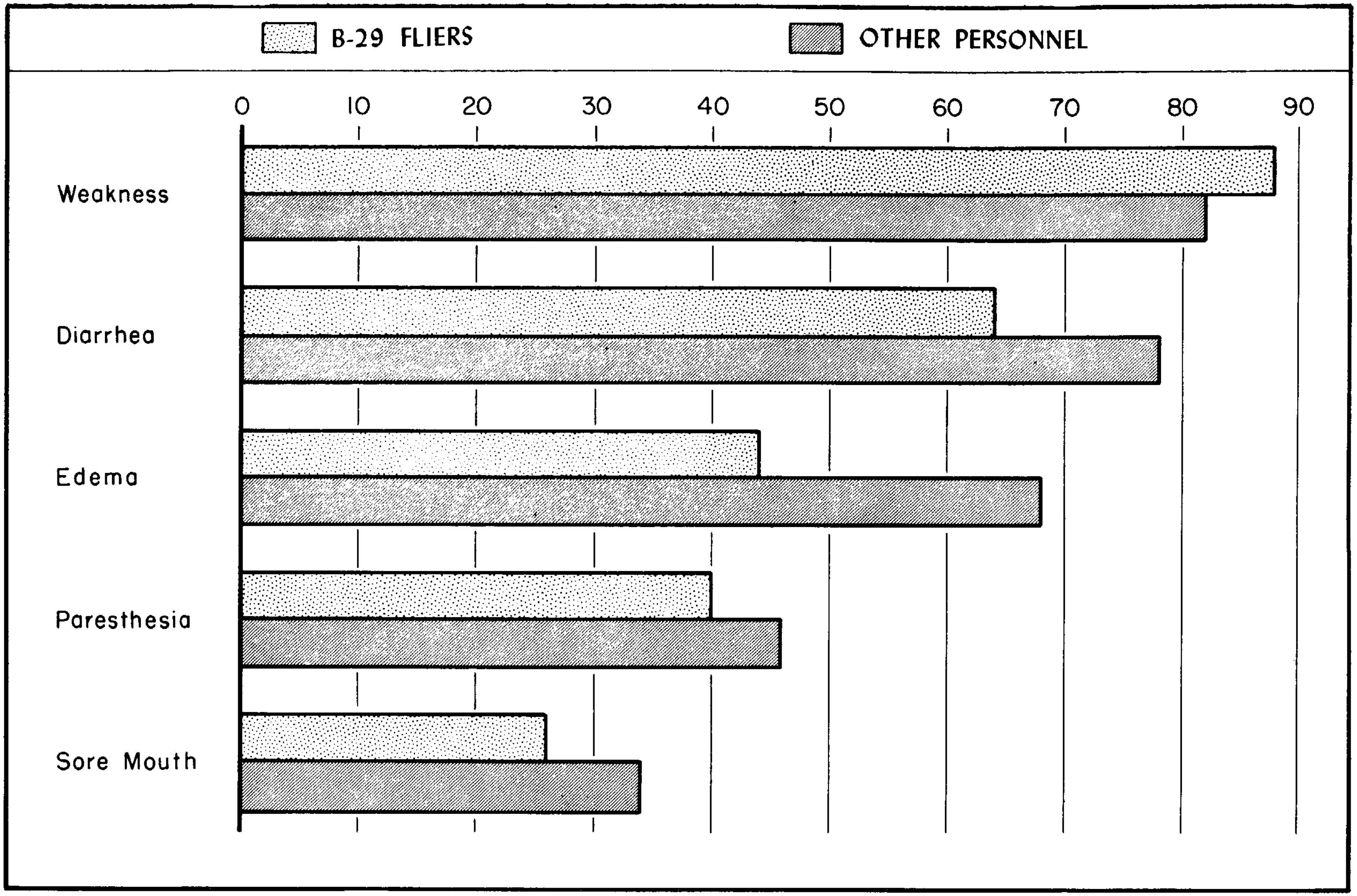

FIGURE 172.—Percentage incidence of signs of malnutrition in two groups of patients studied clinically. The similar degree of disability in the two groups is attributable to the criteria used in selecting prisoners for admission to the wards. Of all the B-29 fliers whose state of nutrition was surveyed, 37 percent were admitted to the sick list whereas only 10 percent of the other personnel required hospitalization.

SPECIAL OBSERVATIONS

The patients studied clinically constituted a representative sample of the men admitted to the sick list of the ship. Other representative samples were studied by specialized clinical services or by laboratory examinations. These studies afforded a more detailed picture of the effect of malnutrition and avitaminosis on the various systems of the body.

Eyes.—Forty patients were examined by the Ophthalmology Department to determine the integrity of the peripheral visual fields. External evidence of disease of the conjunctiva and of the cornea was also sought. Bitot's spots, indicative of vitamin A deficiency, were observed in 1 B-29 flier who had been on bare subsistence for 13 months. Subjective photophobia was present in a number of instances. No patient showed the conjunctivitis, pericorneal vascularization, or interstitial keratitis described as due to riboflavin deficiency. Slit-lamp observations were not made. The visual fields were contracted in all 140 patients. The ability to recognize color at the periphery of vision was particularly impaired. Eight patients were reported as being wholly unable to recognize green and one patient could recognize neither red nor green. In addition there were central scotomas of varying sizes in the majority of cases studied. Some of the optic disks were slightly pale but no other fundal abnormalities were noted.

Psyche.—On the night of 29 August 1945, when the first group came aboard, many of the repatriates were excited and euphoric. Their pupils were widely dilated. Later, when those who were admitted to the wards were studied more carefully, it was noted that they displayed an indifference toward their harrowing experiences. The psychiatrist expressed the view that this indifference was a manifestation of apathy, and he noted that the men were less boisterous than one would expect a healthy group of their age to be. Some of the men complained of what they called "Tokyo memory." They noted a spotty amnesia for both recent and remote occurrences. Several had amnesias for the events associated with their parachute jumps. Others could remember their children's faces but not their names. On the whole, however, there was little evidence of disorientation, and there were no confusional psychoses or states of increased irritability or abnormal anxiety.

The absence of confusional psychoses or other profound mental disturbances can apparently be explained only on the basis that psychotic prisoners did not survive. There were several reports of prisoners who had been removed from their cells because of mental aberrations of one type or another. It is possible that they were neglected or killed. Many prisoners reported that cellmates had lost their will to live. They said that such a change in mental status was usually followed by anorexia, failure to eat, and starvation.

Oral cavity.—Fifty patients were examined by the Dental Department. Almost all showed bluish-red injection of the tongue, flattening of the papillae, and a rather smooth surface indicative of mild niacin deficiency. There was no instance of really severe glossitis, and although many had soreness of the tongue at the time of admission, this was thought to be due to excessive smoking. The corners of the mouth were singularly free from cheilosis. There were no frank instances of spongy or bleeding gums suggestive of scurvy, although the interproximal papillae were often inflamed and bright red in color. There was surprisingly little evidence of Vincent's infection, and the amount of dental caries did not exceed that which would have been anticipated in a group of well-nourished persons.

Skin.—Dermatologic consultants took part in the screening of prisioners and in the care of patients admitted to the wards. No instance of pellagrous dermatitis was observed. One patient, who complained subjectively of chapped lips, had fine, scaly, somewhat crusted desquamation of the nasolabial folds, and a dry, corrugated. inelastic atrophy of the skin of the neck. It was believed that the lesions of the nasolabial folds might indicate a deficiency of riboflavin. Many patients were covered with bluish-bronze plaques of cutaneous erythema, indicating sites of previous insect bites. Numerous prisoners had observed the slow healing of cutaneous sores during their confinement. A striking observation was the absence of acne among the malnourished repatriates.

Cardiovascular system.—There was one patient who died shortly after admission with classic right- and left-sided congestive heart failure. This man had such great muscular weakness that he could neither swallow nor talk. In addition he had tachycardia, distant heart sounds, rales at the lung bases, orthopnea, edema, cyanosis, complete auriculoventricular dissociation, and premature ventricular systoles. The electrocardiogram failed to show abnormal T waves or prolongation of the Q–T interval. The pathologic findings were typical of beriberi heart disease, including accumulations of fluid in the serous cavities, degeneration and edema of the myocardium, and marked dilatation of the right auricle.

With the exception of this one case, there was no patient with findings suggesting congestive heart failure. One patient, during the initial screening examination, had a gallop rhythm which promptly disappeared with rest and restored nutrition. Despite muscular weakness, dyspnea was not a common finding and in no case, except the fatal one described before, was orthopnea noted. The cardiac sounds were for the most part of excellent quality. Intravenous fluids were freely administered to the patients without evidence of left heart failure.

Routine 6-foot heart roentgenograms were made on all the patients—these failed to suggest right cardiac enlargement in a single instance. The volume of radiographic work unfortunately precluded fluoroscopic examinations or special oblique views. Electrocardiograms were made in 50 patients. These showed a tendency toward the low voltage type of tracing, but in none did all the complexes register less than 5 milivolts. None showed inversion of the T waves in the first or second leads, and none showed prolongation of the Q–T interval. Although the myocardium may well have been involved in many of the patients, there was little evidence of sufficient disease to produce significant congestive failure.

Gastrointestinal tract.—On arrival, most of the men had voracious appetites. An unsuccessful attempt was made to control overeating, and although the majority of the patients tolerated large quantities of food without discomfort, a small percentage began to complain within 24 hours of abdominal fullness, distention, and cramping. On physical examination, the abdomens of some of these individuals were tense and tympanitic, with hypoperistalsis. Most of these symptoms and findings disappeared after limitation of food and water intake and the administration of simple enemas.

About 50 percent of the patients had severe watery diarrhea at the time of admission. Although 196 stool specimens were examined microscopically, there were less than 10 patients with proved amebiasis, which responded to therapy with emetine. There was a considerably larger number from Camp Omori who, on about 15 August 1945, had suffered from an epidemic of prostrating febrile diarrhea probably of bacillary origin. Stools from 50 of the more persistent ones were cultured on Salmonella-Shigella agar, but no suspicious organisms were isolated. On the other hand there were several patients with cellular exudates characteristic of bacillary dysentery. None presented symptoms of ulcerative dysentery. Sigmoidoscopic examinations were not performed.

The management of diarrhea varied somewhat on the different wards. Most of the patients were given low-residue diets which they freely supplemented by visits to the general mess. Symptomatic medication, such as paregoric and bismuth, was employed in most cases. Half the cases of diarrhea subsided after about 3 days, and the great majority disappeared within 1 week.

Blood plasma.—Determinations of the plasma proteins by the plasma-specific gravity technique were made in 16 patients with edema and 15 patients without edema. Three of the edematous patients had concentrations below normal (5.0, 5.3, and 4.5 grams percent). In these, the edema was attributed to hypoproteinemia. The remainder had protein concentrations between 6.5 and 8.4 grams percent. The mean concentration of the entire series, including the 3 low readings, was 6.8 grams percent. This compares with a mean concentration of 7 grams percent in the nonedematous subjects.

Separate determinations of the albumin and globulin components were not made.

CLINICAL EVIDENCE OF SPECIFIC DEFICIENCIES

Fat.—Weight loss and emaciation indicated that the subcutaneous fat stores were depleted in most of the patients at the time of admission. The blood cholesterol concentration, which may be a comparative index of total blood lipids, is said to be depleted in starvation. Unfortunately there was no opportunity to make determinations of cholesterol levels.

Protein.—Weakness is a predominant symptom of protein depletion, and marked asthenia was prevalent among the repatriates, as were edema and weight loss, with extreme wasting of skeletal muscle. The comparatively normal plasma-protein concentrations would, at first, appear to contradict protein lack. It is known, however, that the plasma protein exists in a state of dynamic equilibrium and tends to maintain its concentration even with experimental variations in the blood volume. It is recognized, moreover, that plasma proteins and tissue proteins are independently synthesized from amino acids, which are the circulating reservoir from which both are derived. Thus the plasma proteins are not the stock proteins of the body, nor do they even represent proteins in transit; therefore the plasma protein concentration is not a reliable guide to malnutrition. Conversely the amount of protein necessary to restore the plasma values to normal cannot be calculated from the deficit in the circulating blood. A much greater amount is needed.

Carbohydrate.—No studies were undertaken to show the effect of long-standing malnutrition on the liver. Undoubtedly the glycogen stores were grossly depleted much of the time, although temporarily restored following meals. Gross examination of the one liver available at autopsy showed marked atrophy. The right and left lobes were little more than an inch in thickness, and there was a yellowish color suggestive of fatty infiltration, which may have resulted from combined deficiency of both carbohydrate and protein.

Vitamin A.—No dark adaptation test or determinations of plasma vitamin A were performed. None of the patients complained of night blindness, generally considered to be the earliest manifestation of vitamin A deficiency. A careful search was made for Bitot's spots—small triangular regions of cornification at the medial and lateral poles of the corneal limbi, which represent the earliest epithelial change resulting from deficiency of vitamin A. These were seen in only one case, that of a B–29 flier who had been on extremely sparse rations for over a year. Photophobia was noted by a number of prisoners, but severe ocular manifestations such as keratomalacia and xerophthalmia were not encountered. Hyperkeratosis follicularis was also absent. Some vitamin A was doubtless afforded by the few green vegetables and the fish eaten by the prisoners, and, as Luck points out, the body stores of vitamin A are adequate for many months. In general, there was little evidence of vitamin A deficiency.

Vitamin B_1 (thiamine).—Deficiency of thiamine unquestionably played an important role in producing the paresthesias, hypesthesias, and reflex changes so often observed. It was probably responsible for most of the visual disturbances, particularly the constricted fields of color vision and the central scotomata. The nervous system showed indication of thiamine lack. With the exception of one fatal case of congestive failure from beriberi heart disease, however, there was less striking evidence of cardiovascular damage. The role of thiamine in producing hunger edema is discussed later.

Vitamin B_2 (riboflavin).—One of the patients in the B-29 flier group was noted to have areas of scaly erythema at the nasolabial folds. This is described as one of the characteristic features of riboflavin deficiency. There was a suggestion of magenta macroglossia in many cases, but little cheilosis, so that there was minimal evidence of ariboflavinosis.

Niacin.—There was no classic pellagra. Many of the patients had bluish–red injected tongues, with flattening of the papillae and smooth surfaces. In some instances these tongues were sore, although excessive smoking after liberation was undoubtedly a factor. The glossitis was undoubtedly the result of a mild deficiency of niacin. As previously noted, there were no confusional psychoses, and no examples of pellagrous dermatitis. Diarrhea was a prevalent symptom, but this may have resulted from infectious or nutritional causes other than niacin deficiency. These are discussed in a subsequent paragraph.

Pyridoxine.—It has been noted that, in some cases of human vitamin B deficiency, complete recovery has not followed the use of crystalline thiamine, riboflavin, and niacin alone. There has been residual muscular weakness or evidence of central nervous system damage. In these cases, pyridoxine is reported to have been effective. A very few of the patients observed by us gave evidence of neuromuscular incoordination on the heel-to-knee test, or had positive Romberg tests or Babinski's sign. It may be that some of these findings were due to lack of pyridoxine.

Pantothenic acid, biotin, inositol, paraminobenzoic acid.—Deficiencies of these substances, customarily considered to be components of the vitamin B complex, give rise to no known symptoms or signs. There is consequently no clinical evidence indicating that the repatriates were suffering from a lack of these components.

Vitamin C.—Although the blood concentration of ascorbic acid was not determined, it is certain that all the patients had suboptimal levels of this substance. Full saturation requires from 80 to 100 milligrams daily, and the diets were obviously inadequate to furnish this amount. Although a few of the long-term prisoners stated that at one time or other they had had bleeding gums, at the time of admission there was no clinical evidence of scurvy. Apparently the diets consumed were at least adequate to prevent widespread suffering from this cause.

Vitamins D, K, and E.—There was no clinical evidence of deficiency of any of these substances.

Extrinsic factor.—The hepatic hematopoietic factor necessary for the prevention of macrocytic anemia requires for its synthesis (*a*) an extrinsic factor which is present in yeast, beef, and other substances, and (*b*) an intrinsic factor secreted by the gastric mucosa. Pernicious anemia results from deficiency of the intrinsic factor, whereas deficiency of the extrinsic factor is one of the mechanisms which lead to sprue. None of the repatriates had classic sprue, but there were some manifestations of the disease which deserve comment.

Almost all of the patients had marked anemia. This was approximately normochromic (mean hemoglobin, 11.1 grams; mean red-blood corpuscle count, 3,350,000; mean color index, 1.05). The anemia of sprue may be hypochromic and microcytic in the early stages, but is characteristically macrocytic when well established. The mean color index encountered among the repatriates is, therefore, not inconsistent with the anemia of sprue. Volume indices would have been of value, but were not available. The possibility that the anemias observed in the repatriates were related to sprue, or deficiency of the extrinsic factor, gains strength from the fact that anemia is not described as a classic finding in any other deficiency disease except severe pellagra, which was ruled out by the absence of characteristic mental or cutaneous findings.

The distribution of the muscular wasting and the protuberant soft abdomens (which the prisoners called "rice bellies") were typical of sprue. Many of the prisoners had suffered from longstanding diarrhea, but the stools were not large and foamy as one would expect in sprue. There was no oral moniliasis. Glucose tolerance tests were not performed, because the curve is flat not only in sprue, but in other states of malnutrition as well, and would hardly have been of value in differential diagnosis. In short, there was no classic sprue syndrome, but a deficiency of extrinsic factor may well have contributed to the development of anemia, the selective muscular wasting, and the protuberant abdomens.

Management.—On arrival of the repatriates, an initial attempt was made to give them comparatively light diets composed of readily digestible substances. It was feared that more substantial food would produce gastric and intestinal distention as well as other digestive disturbances. It was soon discovered, however, that the patients would eat several servings in spite of all efforts to prevent their doing so.

Inasmuch as the voracious appetites of those fed first left nothing for the late comers, larger quantities of food were served. It developed that about 90 percent of the patients could eat 6 full meals a day, supplemented by ice cream and chocolate bars, without any untoward symptoms. The dietitian estimated that the average repatriate took at least 5,000 calories a day, 15 percent being derived from protein, 40 percent from fat, and 45 percent from carbohydrates. The vitamin supplements varied somewhat on the different wards. A sample basic daily ration is as follows:

Vitamin A	15,000 units
Vitamin B_1 (thiamine)	20 mg.
Vitamin B_2 (riboflavin)	10 mg.
(niacinamide)	60 mg.
Vitamin C (ascorbic acid)	225 mg.
Vitamin D	1,200 units

In addition, 25 milligrams or more of intramuscular thiamine were given to all patients with neuropathies, and 150 milligrams of niacinamide were administered to those with diarrhea.

Even with subsiding edema, the patients gained weight with amazing rapidity. In some cases, 24 pounds were gained in a week. The patients on whom this observation was made lost their edema during this time and their well-being increased tremendously. The neurologic signs and symptoms showed less rapid improvement, and most of the patients were transferred for air evacuation or to other vessels before much change was noticed.

COMMENT

Edema.—The standard literature on beriberi heart disease is largely based upon two sources: Autopsy studies of oriental beriberi, and clinical observations on malnourished alcoholics in city hospitals. The onset of cardiac failure is associated with changes in the nervous system, in the peripheral vascular system, and in the myocardium. The muscle of the heart often shows hydropic degeneration and an increase in intercellular substances. The cardiovascular disturbances, however, do not follow a rigid pattern. Right ventricular failure is most typical, but left ventricular failure, arteriolar dilatation, and peripheral circulatory collapse occur singly or in combination.

The "hunger edema" of inanition has been ascribed to thiamine lack causing congestive cardiac failure. In our series, there was one autopsy of a case of typical beriberi heart with failure. There was one case of temporary gallop rhythm. Examination of all of the other patients with edema did not, however, disclose *any* evidence of significant cardiac involvement. The 6-foot heart roentgenograms and the electrocardiograms showed normal findings in all the surviving patients. The patients did not have dyspnea, orthopnea, tachycardia, arrhythmia, or radiographic evidence of cardiac enlargement. It is noteworthy that clinical and laboratory findings which might be interpreted as evidence of congestive failure were not encountered with sufficient frequency to explain the edema seen.

Serum albumin is the most important protein factor in the maintenance of the osmotic pressure of the circulating plasma, globulins making a lesser contribution. Measurement of the total plasma proteins indicated hypoproteinemia in only three instances. Most of those with edema had normal protein values. Thus no correlation between the total plasma protein and the edema could be made.

Estimation of the plasma albumin might have detected a significant number of cases of hypoalbuminemia. In inanition, albumin is the first protein to be depleted after stored tissue protein. Regeneration of albumin from endogenous or exogenous protein is a complicated and sometimes retarded process. A more rapid globulin manufacture might have compensated for depletion of albumin and so obscured the essence of the deficiency. Furthermore, as the plasma albumin falls and transudation occurs, there may be a reduction of plasma volume. These variable factors have the effect of making a quantitative measurement of the total protein in the plasma of the malnourished patient an unreliable measurement of the actual albumin deficit.

The relative roles of thiamine and protein in the treatment of hunger edema is not clear. Among the malnourished repatriates thiamine hydrochloride was not specific in relieving the edema, even in cases where the total plasma protein was normal. In association with a protein-rich diet, however, thiamine undoubtedly contributed to the disappearance of edema. Protein hyperalimentation, plasma infusions, and blood transfusions had a more rapid beneficial effect in relieving edema among the evacuated war prisoners than did large parenteral doses of thiamine hydrochloride. This was noted in some patients who had been receiving it in daily doses of 50 milligrams. Many of them showed no subsidence of edema until 200 grams of oral protein hydrolysate or intravenous infusions of whole blood or plasma were given as a supplement to the high protein diet.

Some of the patients became edematous after coming aboard, despite a high intake of both protein and thiamine hydrochloride. A liberal intake of fluids and the ingestion of normal amounts of salt seemed to be a factor, the physical economy having been adjusted to a poor salt intake during months of deprivation. Recovery from edema was hastened when, in addition to the other measures, the daily salt intake was restricted to less than 5 grams and the fluid intake to 2 liters.

Digestive symptoms.—Gastrointestinal disturbances, especially diarrhea and constipation, are among the commonest manifestations of vitamin deficiency. In the absence of pellagrous dermatitis and fatty stools characteristic of sprue, it was not possible to be specific in classifying the diarrheas as expressions of unitary dietary deficiencies. Specific therapy with parenteral liver extract was not employed, so that its therapeutic effect could not have been a factor in the rapid recovery observed in most of the cases. The "rice bellies," however, resembled those seen in the typical cachexia of sprue. The restoration of the stools to normal consistency within a short period of time without large amounts of specific therapy indicated that the total nutrition was related to the diarrhea, and it, therefore, appears to have been the result of multiple dietary deficiencies. In every case of diarrhea, shigellosis and amebiasis were considered and ruled out.

Adaptation to deficient diet.—The repatriates under consideration had subsisted on varying types of diets, all inadequate according to recommended standards. The majority had lived on a mixture of grains, consisting of unrefined rice, rye, and barley. Fish, breadstuffs, and a few green leaves boiled in water were occasionally added. It is apparent that several factors were deficient; notably protein, an extrinsic factor. There were also suboptimal amounts of vitamin A, thiamine, vitamin C, and vitamin D. The presence of these substances in small amounts, however, may explain the relative absence of more specific symptoms and signs of avitaminosis. The repatriates, who had subsisted on prison rations of the worst sort, did not show evidence of typical vitamin A deficiency, ariboflavinosis, sprue, pellagra, or scurvy. The absence of such avitaminoses raised the question of whether the minimum daily requirements of many vitamins might not be lower than generally thought. It is common knowledge that frank nutritional disease was not common in Great Britain during the war, even though the average diet for years was well below recommended standards.

Among the patients studied on the *Benevolence* were a number of rugged and aggressive individuals who had been in prison camps for as long as 3 years. Their ability to do hard work had gained for them jobs on road projects and farms. These men took food when they could find it, foraging in freight cars containing sacks of grain, and thus supplementing their issued rations. Most of them showed little evidence of malnutrition. The answer to their comparative well-being was found in their acquisitive habits.

The condition and survival rate of the much larger group of prisoners who had not foraged were harder to understand. The survivors among them appeared to have made a selective adaptation to their limited diets.

The capacity of the organism to adjust gradually to low levels of intake is still undetermined. The effect of sudden and rapid withdrawal of nutritional essentials in precipitating severe states of malnutrition has not been studied in human beings, and the question of adaptation is not answered by the uncontrolled study of these prisoners. It is considered justifiable, however, to theorize that vitamin and other nutritional requirements have been placed too high, and that men do adapt themselves to abnormally low levels of nutritional intake.

SUMMARY AND CONCLUSIONS

1. Examination of 1,520 repatriated prisoners of war aboard the Navy hospital ship U. S. S. *Benevolence* resulted in the admission of 320 to the sick list because of physical disability. The remainder, with minor degrees of disability not requiring hospitalization, were immediately evacuated to the United States on transports.

2. Fifty-three patients who had been on deficient diets were studied clinically and their symptoms and signs of malnutrition were tabulated.

3. In most of the ex-prisoners there was clinical evidence of multiple dietary deficiency, but none of the syndromes indicated classic beriberi, pellagra, scurvy, or sprue. The absence of these clinical entities suggests that the usual standards of vitamin requirements may be too high.

4. Edema was one of the most puzzling findings. In only one case could this be traced to right-sided congestive heart failure. In general, there was no response to thiamine hydrochloride alone, but addition of extra protein rations, casein hydrolyzates, and intravenous blood and plasma gave prompt relief.

5. Despite the dramatic response of edema to protein restoration, the total plasma proteins on admission were found to be depleted in only three instances.

6. Clinical findings indicated definite deficiency of the vitamin B complex, extrinsic factor, and protein. On the other hand there was little indication of deficiency of vitamins A, C, D, E, or K, or of essential minerals.

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