THE MILITARY UPPER EXTREMITY AMPUTEE

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The care of war-injured amputees is a major problem facing any military during wartime. Historically, amputations are a very common consequence of modern warfare. In the civilian setting, the primary cause of leg amputation is vascular disease, accounting for 93% of amputations. Other causes include trauma, malignancy, and congenital amputations.[44] Trauma is the number one cause of upper extremity amputations in the United States with more than 90% caused by accidents.[41] Throughout the history of the major wars, the number and percentage of, indications for, and etiology of amputation has changed (Table 1). This has paralleled the way warfare is fought as well as the evolving medical advances made over time.[9] During the Revolutionary War, most amputations were performed for gunshot injuries. In the Civil War, infections led to the enormous numbers of amputees. Currently, amputations are typically the result of fragment injuries, predominantly from landmines. The devastating trauma suffered during armed conflicts results in substantial numbers of traumatic upper and lower extremity amputations. There is minimal literature pertaining to the upper extremity amputee. Most amputation literature deals with the lower extremity amputation. This article will discuss the military amputee in general and the upper extremity amputee. It will not discuss the different levels of amputation, prosthetics, or the rehabilitation of amputation, except as they are unique to the military setting. Readers are referred to the August 2000 volume of the *Physical Medicine and Rehabilitation Clinics of North America* for a discussion of these subjects.

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Table 1. AMPUTATION STATISTICS DURING SEVERAL UNITED STATES WARS

	Revolutionary War	Civil War	World War I	World War II	Korean War	Vietnam War	Persian Gulf War
Number served		2,213,363	4,734,991	16,112,566	5,720,000	8,744,000	
Total deaths	4,435	620,000	116,516	405,399	36,516	58,198	
Number of amputees		60,000	4,403	14,912			21
% Upper extremity		40.6%	53.8%	23.3%			14%
% Lower extremity		59.4%	46.2%	76.7%			86%
Trauma			25.5%	64%–75%			100%
Infection			74.5%	9.5%–14.3%		1%	
Vascular				14.5%–21.3%			

Data from Department of Defense Statistics and Dillingham TR, Braverman SE, Belandres PV: Persian Gulf War amputees: Injuries and rehabilitative needs. Mil Med 159(part 10):635, 1994 and Dougherty PJ: Wartime amputations. Mil Med 158(part 12):755, 1993; with permission.

The decision of whether to amputate a severely injured extremity is a question that dates back to the origins of surgery and surgeons. In fact, it has been described as the cause of the first international dispute of any dimension in the field of surgery.[8] With increasing technical advances, surgeons are finding themselves at the ''amputate versus limb salvage'' dilemma more often. The surgeon must weigh the extent of the injury and his capabilities to save the limb versus the functionality of a prosthetic limb, which can be immediately afforded with prompt amputation and prosthetic fitting. Oftentimes, a patient will opt for limb salvage only to be left with a nonfunctional or minimally functional extremity. Samuel D. Gross, MD, was a prominent civilian surgeon and professor of surgery at Jefferson Medical College in Philadelphia during the Civil War. He stated that in many instances surgeons may unwittingly mutilate a limb that might have been saved and endanger the patient's life by the retention of one that should have been promptly amputated.[34] The Mangle Extremity Syndrome grading system was proposed to assist in the decision between amputation and limb salvage.[15, 42] Thus, a multidisciplinary approach should be considered in these situations. The physiatrist adds expertise in functional anatomy and can greatly assist with determining the need for or level of an amputation to maximize the patient's subsequent function and quality of life. Although the dilemma of limb salvage is beyond the scope of this article, it is briefly described to illustrate the complexity of the management in a severely injured limb. This complexity is faced by civilian surgeons much more frequently than the battlefield surgeon at the front for reasons that will be discussed.

HISTORICAL PERSPECTIVE

The first US Army physician was Dr. Samuel Prescott. On April 18 1775, Paul Revere rode from Boston to Lexington to warn the minutemen that the British were coming. In Lexington, Prescott joined Revere. They both were captured, however, by the British troops. Unlike Revere, Prescott escaped from his captors and continued on to Concord with the warning and to assist in the fight. After the battle, Prescott took the battlefield wounded back to his house in Lexington for treatment, thus making him the first US Army medical officer and his house the first Army hospital.[16]

Revolutionary War

Little data are available on the wounded of the Revolutionary War. The medical care was rudimentary, consisting primarily of bandaging and dressing wounds. Amputations were performed under suboptimal conditions with suboptimal equipment (Fig. 1). There was no organized evacuation plan. The Continental Congress did provide for the establish-

Figure 1. Upper extremity amputation. (Courtesy of U.S. National Library of Medicine, Bethesda, MD)

ment of a hospital with two surgeons and two assistants known as surgeon's mates. At the end of the Revolutionary War, all medical facilities and staff were discontinued, and the wounded soldiers were left to fend on their own or to die in misery.[16] Captain Albert Roux, Second Continental Regiment of South Carolina, who sustained the loss of his right arm during the Revolutionary War, petitioned the vice president of the United States for compensation because there was no governmental aid to assist the wounded from the war (Fig. 2).

During the War of 1812, Congress established a formal Army Medical Department with an appointed Surgeon General, who eliminated the distinction between physicians and surgeons and thus all military physicians were called surgeons. The Medical Department was disbanded at the conclusion of the war.[16]

Civil War

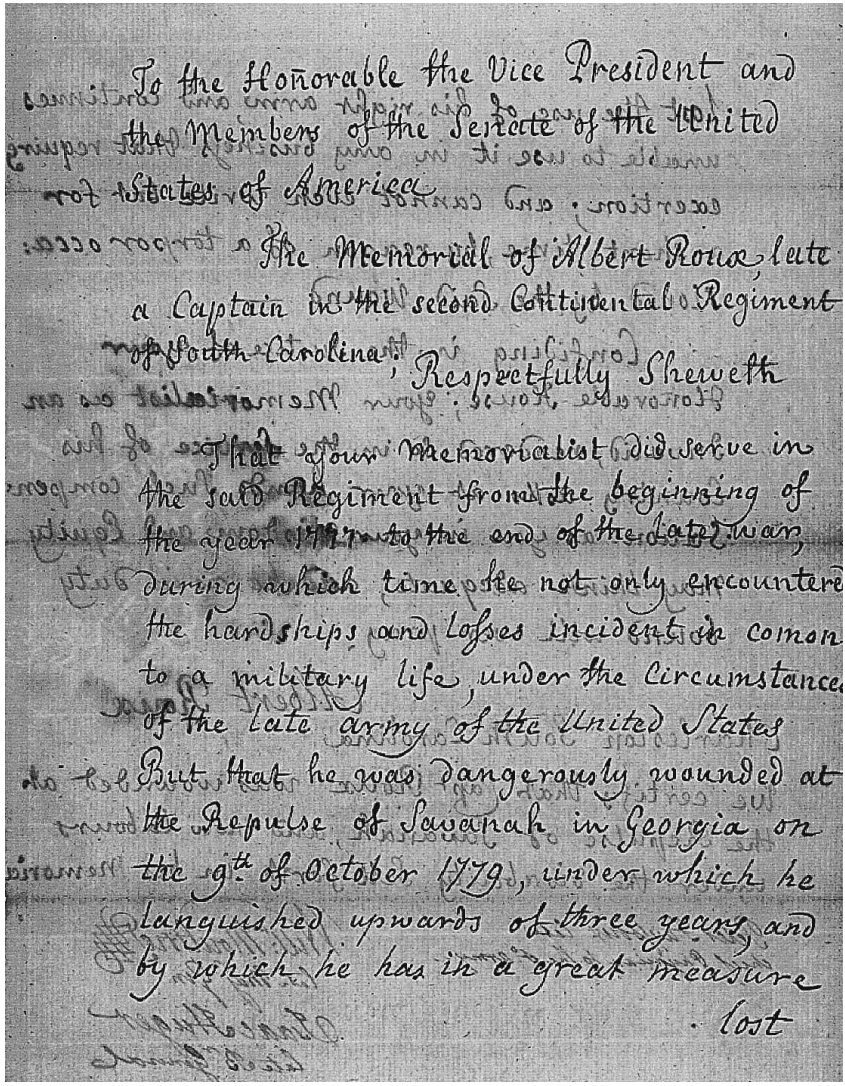
In 1859, the ambulance was introduced as a result of the need for medical transportation during the war with Mexico. It consisted of a mule-drawn wagon holding four to eight patients—four litters or eight

sitting patients. The ambulance corps was formally established during the Civil War. It was known as the Letterman Plan and was first introduced during the Battle of Antietam. It provided for 3 two-horse ambulances for every 500 personnel in an army corps.[16]

Much of the literature regarding military wounded dates back to the Civil War period. There were approximately 620,000 casualties during the Civil War. Of these casualties, approximately 25% died and approximately 60,000 amputations were performed. The number of amputations performed during the Civil War was directly affected by the lack of antiseptic knowledge and by the physicians themselves. Battlefield injuries were contaminated, hospitals were not sterile, and many of the surgical instruments (Figs. 3 and 4) were used from one patient to the next. Disease was rampant. Therefore, the primary reason for amputation was to prevent infection in the wounded. Often the amputations led to infection, however, which often led to increased mortality. In addition, the experience and competency of many medical officers, especially the surgeons, was lacking. Most had no surgical experience before entry into military service, and many volunteered to gain surgical skills. Thus, many unwarranted procedures were performed so that surgeons could perfect their techniques.[3] The indications for and timing of an amputation were controversial. F.H. Hamilton, MD, Professor of Military Surgery and Diseases and Accidents of Bones at Bellevue Hospital in New York City, wrote that the indications for amputation were ''fractures (open or closed) with major nerve or blood vessel injury, open fractures with extensive soft tissue injury, and open joint or open femur fractures. Amputation was to be performed at the site of injury to preserve the length of the injured limb and to decrease mortality.''[12] He advocated two techniques: the flap and circular amputation.

During the Civil War it was recommended that amputations should be of the circular type. The flap amputation was the best technique for the inexperienced surgeon. Complications with the flap amputation included slough and higher incidence of secondary hemorrhage, and dead space when the flap was too large, thus allowing for infection. The flap amputation could be performed faster than the circular amputation; however, the circular amputation was the best for patients who were to be transported. Anesthesia allowed for a more precise operative technique.[12]

Hamilton also divided the timing of an amputation after injury into three periods: (1) immediate, when the patient was still in shock; (2) primary, when the shock resolved but before inflammation occurred, and (3) secondary. The primary period was typically the first 12 to 48 hours, and the secondary period was typically 24 to 48 hours after injury. He advocated amputation during the primary period. C.S. Tripler, MD, once a Medical Director of the Potomac and for whom the Army Medical Center in Honolulu, Hawaii, is named, advocated that amputations should be done in the field, except when the patient was in shock. Others suggested that the amputation be performed during the secondary period. Much of the timing of the amputation, however,


To the Honorable the Vice President and the Members of the Senate of the United States of America

The Memorial of Albert Roux, late a Captain in the second Continental Regiment of South Carolina, Respectfully Sheweth

That your Memorialist did serve in the said Regiment from the beginning of the year 1776 to the end of the late war, during which time he not only encountered the hardships and Losses incident to comon to a military life, under the Circumstances of the late army of the United States But that he was dangerously wounded at the Repulse of Savanah in Georgia on the 9th of October 1779, under which he languished upwards of three years, and by which he has in a great measure lost

Figure 2. CPT Albert Roux's petition for compensation due to loss of upper extremity during the Revolutionary War. (Courtesy of the National Archives, Washington, D.C.)

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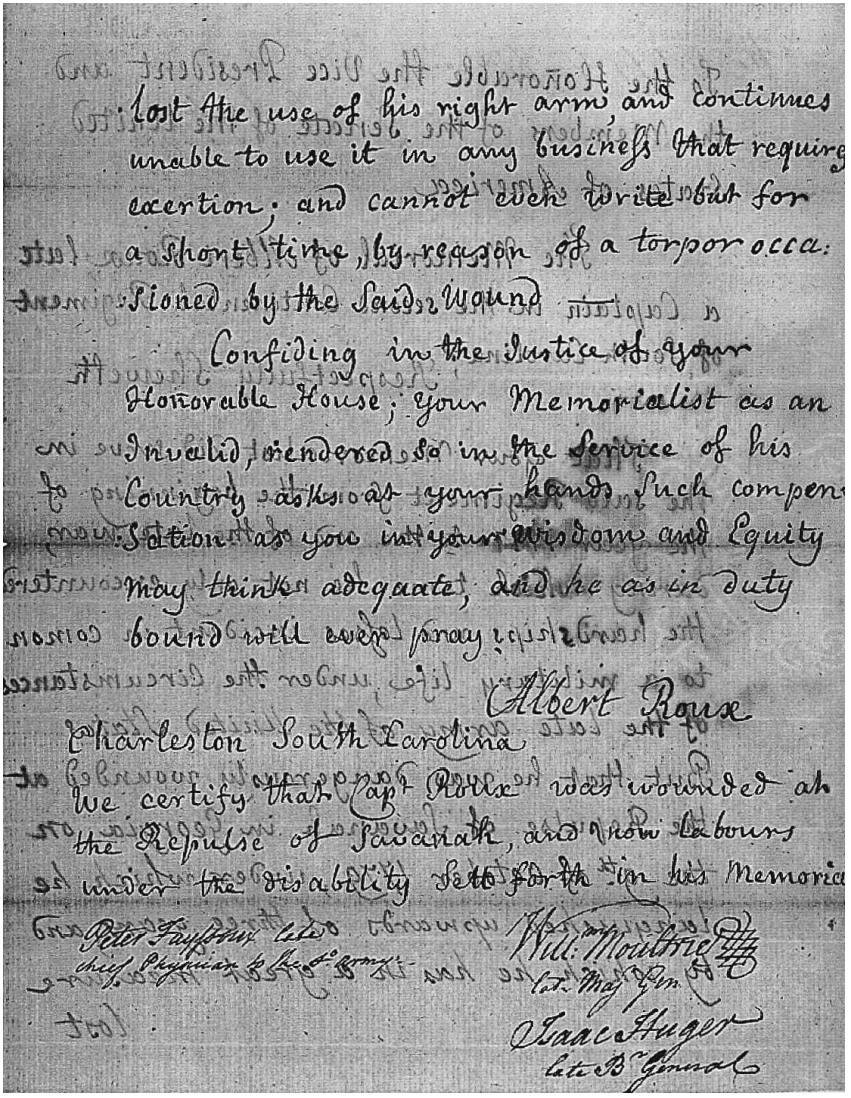
lost the use of his right arm, and continues
unable to use it in any business that require
exertion, and cannot even write but for
a short time, by reason of a torpor occa:
sioned by the said Wound

Confiding in the Justice of your
Honorable House, your Memorialist as an
Invalid, rendered so in the Service of his
Country asks at your hands such compen
sation as you in your wisdom and Equity
may think adequate, and he as in duty
bound will ever pray.

Albert Roux

Charleston South Carolina
We certify that Capt Roux was wounded at
the Repulse of Savanah, and now labours
under the disability set forth in his Memorial

Peter Fayssoux late
chief Physician to the Southern Army

Will. Moultrie
Lt. Maj. Gen.

Isaac Huger
late B. Genl

Figure 2 *(Continued).*

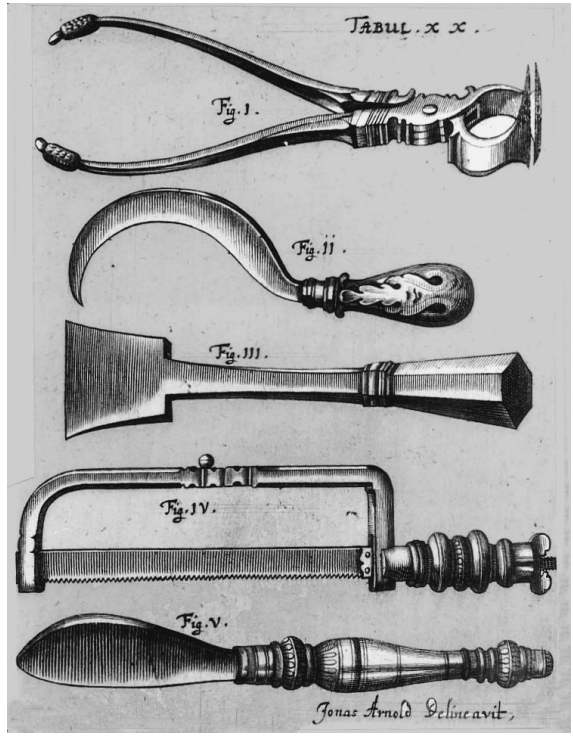

Figure 3. Example of instruments used for amputations during the Civil War. (Courtesy of the National Library of Medicine.)

depended on the evacuation system and the adequacy of the hospitals supporting the battlefield. Jonathan Letterman, MD* became the Medical Director of the Army of the Potomac in 1862 and developed the organization of field hospitals. The field hospitals and the ambulance evacuation system allowed for a more timely evacuation and initial surgical management of the wounded. He established standards by which the most qualified surgeons would perform the operations. The remaining surgeons would assist with dressings, records, and supplies. Thus, as the war continued, the indication for amputation shifted from preventing infection to treating extremity injuries.[12]

It is reported by G.J. Fischer, MD, that in the Battle of Antietam, amputations were performed for projectile injuries (75%), grapeshot (12.5%), and fragment wounds (10.7%). From his studies of amputees, he concluded that primary amputations yielded a lower mortality rate.[12]

*Dr. Jonathan Letterman's memorial at Arlington National Cemetery reads: "Medical Director of the Army of the Potomac, June 23, 1862 to December 30, 1863, who brought order and efficiency into the Medical Service and who was the originator of modern methods of medical organization in armies." (*http://www.arlingtoncemetery.com/; lettermn.htm*)

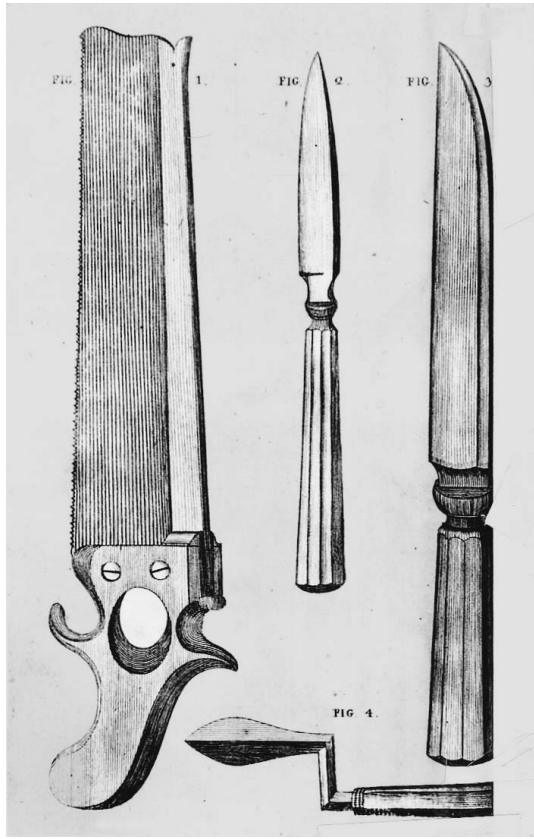

Figure 4. Example of instruments used for amputations during the Civil War. (Courtesy of the National Library of Medicine.)

During the Civil War, there was no standardized prosthetic fitting or rehabilitation for the amputee. James Minor, MD, author of the "Report on Artificial Limbs," recommended that the prosthetic limbs should be of light, strong durable materials well fitting to the stump, and should be of the same size and shape of the limb replaced.[12] Many of the Civil War lower extremity amputees used assistive devices instead of prosthetic limbs for ambulation.

World War I

World War I caught the military medical system unprepared. Treatment, however, quickly became organized and effective. The cause of amputations changed with the widespread use of artillery, airplanes, and tanks. Amputations performed in the forward echelons were to

treat the direct effects of trauma. Amputations for infections, secondary hemorrhage, and painful neuromas were performed later at base hospitals. Early in the war, before the entry of the United States, the British were having poor results with primary closure of amputations. The open circular amputation technique was reintroduced by Fitzmaurice-Kelly. This method was preferred by the Americans; however, technique varied depending on the tactical situation. Skin traction was applied until the wound was healed or revised as indicated. With the open circular technique, the patient could be transported safely. Primary closure was technique of choice when the patient was quickly presented to the hospital from the battlefield and when there was localized soft tissue injury. These patients typically needed to be observed for 2 weeks postoperatively.[12]

During World War I, the field and evacuation hospitals were performing initial amputation surgery. Field hospitals were within 8 miles of the combat zone, and their primary mission was to stabilize patients who would not survive the transfer to the next-higher-level facility. It was here where surgeons could perform surgical care quickly. Evacuation hospitals were typically 9 to 15 miles from the front line. They were considered the first surgical hospital care echelon. The evacuation hospitals had bed capacities of 1000 beds. Their primary mission was to prepare the wounded for transportation to the base hospitals. It was at the base hospitals that definitive care was given. The base hospital prepared amputees for the long journey back to the United States. Nearly half of all the amputations were done in the base hospitals. The amputations performed at the base hospital were primarily for infections.[12]

Multiple amputation centers were established throughout the United States and Europe to study amputees. These facilities were staffed with physical therapists, prosthetists, and surgeons. Centers were established in Savenay, France (Fig. 5); Walter Reed General Hospital, Washington, DC; Letterman General Hospital, California; Fort Des Moines, Iowa; Fort McPherson, Georgia; Fort Snelling, Minnesota; General Hospital No. 3 in Colonia, New Jersey; and General Hospital No. 10 in Massachusetts. The Army Surgeon General's office recorded more than 2635 amputations, excluding toes and fingers, in the casualties received in the United States (Table 2). Nearly 80% of the patients at the amputation centers needed further surgery and healing. Within 6 months of healing, the patient was fitted with a temporary prosthetic limb. The patient would practice ambulation and upper extremity adaptive skills as required by the limb loss during the maturation and healing period before the final prosthetic limb.[12]

World War II

Medical advances after World War I and before World War II changed the indications for amputation during wartime. These included shock management and antibiotic use. During World War I, infection

Figure 5. Amputation Center in Savenay, France, during World War I. (Courtesy of the National Library of Medicine.)

accounted for nearly 75% of the amputations, whereas trauma caused 65% to 75% of all amputations during World War II. Unlike during the Revolutionary War where trauma was caused by gunshot wounds, landmines and fragments accounted for nearly 90% of the amputations during World War II (see Table 1). Evacuation hospitals were the sites for the initial surgical management of the wounded. They were smaller and more mobile than those in World War I. This change was reflective of the more mobile type of warfare that occurred during World War II. The amputees were transferred to the base or general hospital where they remained in traction until sent back to the United States.[12] Again, as in World War I, amputation centers were established in the United States. These included Bushnell General Hospital, Brigham, Utah; Lawson General Hospital, Atlanta, Georgia; McClosky General Hospital, Temple, Texas; Percy Jones General Hospital, Battle Creek, Michigan; and Walter Reed General Hospital.[31] Because of the large number of amputees, Thomas England General Hospital, Atlantic City, New Jersey, and McGuire General Hospital, Richmond, Virginia, were added as amputation centers in 1944 (Fig. 6). Many of the amputees at the general hospitals underwent revisions for closure of the wound or for a better prosthetic fit. Lower extremity amputees stayed at the general hospitals until they were able to ambulate without assistive devices in their preparatory prosthesis. They were then discharged to the Veterans Administration for the permanent prosthetic limb. Upper limb amputees were discharged after they could perform activities of daily living with their prosthetic limb.[12]

Major Norman Kirk, MD, studied the amputee population at Walter

Table 2. AMPUTATION LEVELS DURING SEVERAL UNITED STATES BATTLES

	Levels of Amputation					
			World War II Theaters			
	Civil War	World War I	European	Mediterranean	Vietnam	Persian Gulf
Shoulder	4.2%	—	—	—	—	—
Above elbow	26.8%	21.8%	13.2%	9.8%	—	—
Elbow	0.9%	1.6%	—	—	—	—
Below elbow	8.5%	8.4%	11.4%	8.4%	—	—
Wrist	—	1.0%	—	—	—	—
Upper extremity	—	—	—	—	13.9%	17.4%
Total	40.4%	32.8%	24.6%	18.2%	13.9%	17.4%
Hip	0.32%	—	—	—	—	—
Above knee	30.0%	45.1%	27.5%	25.8%	26.6%	—
Knee	0.94%	3.7%	—	—	—	—
Below knee	26.8%	12.9%	47.6%	55.9%	47.6%	—
Ankle	0.78%	5.2%	—	—	—	—
Lower extremity	—	—	—	—	—	56.5%
Total	58.8%	66.9%	75.1%	81.7%	74.2%	56.5%
Multiple					16.3%	26.1%

Data from Dillingham TR, Spellman NT, Braverman SE, et al: Analysis of casualties referred to Army physical medicine services during the Persian Gulf conflict. Am J Phys Med Rehabil 72(part 4):214, 1993 and Dougherty PJ: Wartime amputations. Mil Med 158(part 12):755, 1993; with permission.

Figure 6. Amputees performing therapy at a stateside amputation center during World War II. (Courtesy of the National Library of Medicine.)

Reed General Hospital and at General Hospital No. 3 during World War I. He recommended that the open circular amputation be performed in wartime. Kirk later became the Surgeon General of the Army during World War II, and in 1942 he published an article entitled "Amputations in War" in the *Journal of the American Medical Association* as guidelines to be used during the War. The indications for immediate amputation were partial or complete traumatic amputation, a crushed extremity, or uncontrolled hemorrhage. Then the patient was to be placed in skin traction to aid in wound healing and closure.[12]

The public's perception of the quality of amputee care coupled with the high visibility of the World War II amputee caused a public relations problem for the US Army. Leonard Peterson, MD, Chief of Orthopedic Surgery Branch in the Surgeon General's Office, noted that there was lack of experienced personnel and availability of temporary prostheses for mass production. Because of this, the Army established a commission on amputations and prosthetics after the war. From this commission, the Army gained information about suction sockets and cineplastic amputation techniques. Cineplastic amputation technique places a peg transversely through the muscle by which the patients can power the prosthesis with their own muscle power.[12] At the request of Norman Kirk, the National Academy of Sciences organized the surge of research into

improving upper extremity prostheses during World War II. These programs were later shifted to the Veterans Administration.[2]

Korean War

Again, medical advances between wars changed the number and indications for amputations. The Korean War was the first time that helicopter evacuations were used, vascular repairs were performed, and effective surgical hospitals were established. In addition, unlimited supplies of blood were available. Thus, more lives were saved and better outcomes resulted.[16] Vascular repairs accounted for the decrease in amputations performed from 50% to 13% compared to wounded that had the vessel ligated.[12] In addition, the Korean War was the first time in war surgery that disarticulation amputations were advocated. This was preferred to an open-above-the-joint amputation. Overall, the management of the war wounded changed little compared with World War II.[46]

Vietnam War

The problem of being unprepared at the start of the previous wars was not an issue during the Vietnam War. It started slowly, and medical assets were well organized from the beginning. As in the previous wars, however, all surgeons did not know the guidelines for amputation and surgical techniques learned from prior experiences with wartime amputees. During Vietnam, infection and additional surgery continued to be problems. Many wounded had primary or delayed primary closure amputations performed instead of the open circular or flap method. The major problem was the long evacuation times back to the United States, which led to infections. Therefore, a significant proportion of amputees needed revisions or amputations at a higher level. Dr. Alcide LaNoue, chief of orthopedics at Valley Forge General Hospital (an amputee center during the Vietnam War), reported that 88% of the Symes amputations received at the center required revision to a higher level because of infection. In addition, because traction was not widely used, bone protrusion became another complication and reason for revisions. LaNoue considered skin traction to be the "most important" aspect of postoperative care and a serious oversight when not performed in Vietnam.[12] Dr. Henry Schmitt did a retrospective analysis of the amputations treated at the Clark Air Force Base in the Philippines for the 2-year period beginning in July 1965. He analyzed 465 amputees in 385 patients. Twenty-five percent of patients who received an immediate amputation required further debridement or revision to a higher level. The primary reason was infection. Infections were the result of inadequate debridement, underestimation of the damage caused by fragments, or improper initial amputation levels leaving nonviable tissue. Primary closure of a wound over a vascular repair often led to failure and the need for additional

surgery. Of importance, it was determined that early postinjury fracture treatment had no effect on the amputation rate. Rather, it was the force of the wounding agent and size of the wound.[35]

Advances in shock management and vascular repair decreased the need for amputations. Patients could be rapidly evacuated by helicopter to the hospital, the speed of which was not seen in the previous wars. Drs. Seligson and Bailey, surgeons aboard the Naval Hospital *USS Sanctuary*, reported no failures in primary closure and delayed primary closure-treated patients. This category of amputees represented approximately 43% of the surviving patients. Closed amputations, however, were performed only if the patient was treated within 8 hours of injury, the patient could be followed for 2 weeks postoperatively, the closure did not require shortening of useful bone, and the limb lacked significant trauma proximal to the closure. They advocated the use of closed amputations if these criteria were met to allow for a better cosmetic residual limb.[36] Many surgeons performed vascular repairs successfully in the combat zones. Therefore amputation rates were lowered. At Walter Reed General Hospital, a case review of 1000 randomly chosen major acute arterial injuries occurring from 1965 to 1968 showed that the amputation rate was 13.5%, ranging from 2.0% in the upper extremity to 11.4% in the lower extremity. These data excluded 50 carotid artery injuries. This rate was similar to that seen in the Korean War. Unlike Korea, however, more patients were now making it back to the hospital. In addition, it was believed that ''heroic attempts for limb salvage'' were made in spite of hopeless situations noted on operative reports accompanying the wounded.[33]

During the Vietnam War, landmine injuries accounted for a significant portion of all amputees. A review of the patients treated at the Naval Hospital in Philadelphia showed that 41% of patients were injured by landmines. There were 44 patients with upper extremity amputations, representing 12% of the total amputations. This was reported to be approximately the same ratio as seen in civilian life. In addition, few amputations were secondary to infection. Thus, it was suggested that the indication for open amputation might decrease, This was not to be misconstrued, however, as an official Navy policy concerning amputation care during the Vietnam War.[46]

As an aside, in 1963, a trauma center was established at the Walter Reed Army Institute Center (WRAIC) to treat Vietnam War casualties. Many present-day civilian trauma centers were modeled after the trauma center concept and the helicopter evacuation used during the Vietnam War.[16]

Post Cold War Era

Since Vietnam, the United States has been primarily involved in peacekeeping missions. Even the Persian Gulf War was a very short war with a prolonged peacekeeping mission. The actual ''war'' only lasted

from February 24 to 27, 1991. The United States has been since involved in Grenada, Haiti, Somalia, and Bosnia and continues to have troops deployed throughout the world.

Dillingham et al[10] analyzed the casualties referred to the Army Physical Medicine Services during the Gulf War. The period of collection was from January 14, 1991, to July 2, 1991. In the group of 222 casualties, 13 (6%) were for amputee rehabilitation. The amputee population consisted of 4 upper extremity, 13 lower extremity, and 6 with multiple amputations. Nerve injury was found in 67% of the amputees. It was reported that 80% of the amputees had phantom limb pain. In another study, Dillingham et al[11] analyzed the rehabilitation needs of amputees admitted to Walter Reed Army Medical Center. Despite the lessons learned from prior war experience, 50% of the amputees required revision surgery and only one arrived in traction. This supports the claim that with each war surgeons need to be retrained in the surgical techniques and care for wartime amputation casualties.[12] The study emphasized the point that wartime amputees sustain concurrent injuries in addition to the amputation, which require modification of typical rehabilitation plans. In the Persian Gulf population studied, a significantly greater number of amputees had concomitant nerve injuries. Fifty-seven percent of the patients had electrodiagnostic evaluation to define the extent of the nerve injury. Orthotics were used to assist or substitute for the functional losses.[10]

Peacekeeping missions do not have the warfare casualties typical of war. Peacekeeping missions often lead to urban combat with significant numbers of casualties in a very short period.[26] In addition, the battlefield enemy of today is the landmine. Landmine injuries are often fatal. Those who are not immediately killed often have an extremity amputation injury,[18] with the lower extremity usually being affected. Burkle et al[4] studied the Persian Gulf War casualties and found that 48% were fragmentation wounds, mostly from landmines, and only 10% were from gunshot wounds. Korver[24] reviewed more than 2000 patients at an International Red Cross hospital in which landmine injuries were the main cause of wartime amputations. A study of the Croatian Army soldiers during the war in Croatia from 1991 to 1992 showed that the type of injury sustained was a result of the type of landmine. In the study, the landmines were either pressure-activated or pull-action type. The severity and localization were directly related to the type of mine causing the injury. The pressure-activated mine causes extensive mutilating injury to the lower extremity, often leading to primary or secondary amputations. A pressure-activated mine has a pressure-sensitive plate, which when triggered causes injury by mine fragmentation and explosive gases. The pull-action mine injures not only the person who triggered it but also anyone within a 100-meter radius of it (e.g., the Claymore mine). On activation with a pull wire, the explosive force causes the body of the mine to form fragments which are propelled with a larger wounding circumference. Therefore, there are more upper extremity and facial injuries.[43] Hull[18] identified patterns of injury associ-

ated with landmines. Upper extremity amputations resulting from blast injuries typically involved the lower third of the forearm or hand. This could not be significantly assessed, however, because of the small number of upper extremity amputees. It was surmised that perhaps a large number of the upper extremity casualties died because of fatal head trauma sustained during the blast. Therefore, those casualties were not included in the data. The transtibial amputation was more common in the lower extremity casualties. Jovanovic et al[22] studied wounded persons treated at the Osijek University Hospital from 1991 to 1992 (Eastern Slavonia). There was no mention if the casualties were military, civilian, or both. They found nearly twice as many upper extremity amputations compared with lower extremity. They included finger amputations, however, in the upper extremity statistics. Excluding finger amputations, upper extremity amputations comprised 36% of the total amputations. Fragments—either from shells, bombs, or mines—caused most amputations. Bullets caused only 10% of the amputations, which is consistent with what has been reported previously.[27, 28, 45] During peacetime, amputation injuries still occur. The Armed Forces Epidemiological Board (AFEB) Injury Prevention and Control Work Group issued a report that cited injuries as the leading cause of morbidity and mortality among military members. The data indicated that training injuries, sports, falls, and motor vehicle crashes are among the most important causes of morbidity for military personnel.[21] Most injuries are musculoskeletal or orthopedic in nature. Within this category is a small subset of amputation injuries. This is supported by a study by Writer et al.[48] They studied nonbattle injuries during the Persian Gulf War and during deployments to Haiti, Somalia, and Egypt. It is recognized that disability is a major health and economic issue for the Armed Forces associated with the increased use of medical care, the loss of active-duty time, and substantial compensation cost.

AMPUTATION AND MILITARY DUTY

After an amputation injury, all soldiers undergo a fit-for-duty evaluation with a physical evaluation board (PEB). It is rare that a soldier who sustains an amputation will remain on duty. Kishbaugh et al[23] studied the return to duty of injured soldiers sustaining an amputation. They looked at the records of all amputee soldiers undergoing a PEB during the 8-year period from October 1980 to September 1988 at four Army PEB centers. Of the 469 soldiers with amputations, only 11 continued on active duty. Of these 11, three had partial foot amputations and two had transtibial amputations. The remaining six were upper extremity amputees. In the study by Dillingham et al[11] of Gulf War amputees, only one was able to remain on duty. None of the upper extremity amputees were allowed to continue on active duty. The one patient who was allowed to remain on active duty was an officer with a below-knee

amputation. These data represent a 2% to 5% retention rate for the military amputee.

PROSTHETIC LIMBS

Sherman[37] did a pilot study of US veterans with traumatic amputations. The subjects were young, healthy servicemen who had recently (within the past 10 years) been boarded out of military service because of the amputation. He surveyed 170 subjects, with a respondent rate of 26% (45 respondents). Of these, 11 had upper extremity amputations. In the group of 45, 43 reported using the prosthesis; however, all had some problems with it. Nearly all stated that they had significant problems using their prosthesis for work. Further, extended use of the prosthetic limb caused significant phantom and residual limb pain, skin breakdown, and other problems. The problems caused significant impairment in life and work. This study is based on a "best case" population because the subjects were otherwise healthy individuals and had near limitless access to free medical care and technology; still, however, they all had problems with their prosthetic limbs. Extrapolated to the general amputee population, Sherman suggests that there is a large problem with prosthetic fit and therefore use. A 10-year follow-up of the patients treated at the Valley Forge General Hospital amputee center showed that 96% were fitted for a prosthesis with 88% using that limb: 83% single upper, 92% single lower, and 76% multiple amputees.[12]

Within the civilian population, Millstein reviewed the records of 314 patients in the Ontario Workers' Compensation Board with upper extremity amputations. Sixty to eighty-nine percent of the amputees were using their prosthetic limb on a regular basis, with only 10% using a cosmetic prosthesis. Durance and O'Shea did a literature review and found that 75% of upper limb amputees had to change jobs as a result of the amputation. Further, they studied 26 upper amputees at Ontario Clinics and found that 81% used their prostheses for all or part of the day, with half wearing them up to 10 hours. The major problems with the limbs were discomfort and poor fit.[37] At the Mayo Clinic, Wright et al[47] studied the upper extremity amputee population evaluated at the clinic from 1975 to 1987. Trauma was the cause of the amputation in most patients. The overall prosthesis acceptance rate was 62% without statistical differences for hand dominance. Further, the below-elbow amputee was more likely to use the prosthetic limb. In addition, 75% of prostheses continued to be used with a 68% change in job due to the amputation. Gaine et al[14] studied both traumatic and atraumatic upper extremity amputees. Their study supported the conclusion by Wright that the hand dominance did not affect the acceptance of the prosthesis. The findings by Gaine et al showed less usage and satisfaction with the prosthetic limb in the traumatic amputee population. Importantly, all traumatic amputees who were fitted with a prosthetic limb 12 weeks after injury did not regain employment.

Of an interesting note, Ospina and Antunano[30] reported a case of a pilot who sustained a bilateral hand amputation. He was fitted with bilateral myoelectric prostheses and was certified to continue to fly.

LONG-TERM EFFECTS

Hrubec and Ryder[17] showed an increased risk for ischemic heart disease, cardiovascular diseases, suicide by ingestion, alcoholic cirrhosis, and acute pancreatitis for a group of men who sustained a limb amputation during the period from 1944 to 1945. The men were followed from 1946 until 1977. The group was compared to men who sustained disfigurement without body part loss and those with partial loss of the hand or foot during the same timeframe. All were army soldiers.

An often underestimated and overlooked factor is the psychologic effects of an amputation. Often within the battlefield setting, minimal attention is given to this aspect of the injury because of the nature of the battlefield. Beasley[14] described three phases of reaction to traumatic amputation: disbelief, realization, and adaptation. This has been likened to the grieving reaction. He believes the crucial stage is that of realization. During this period the amputees begin to accept the impairment allowing for adaptation to occur. If there is failure at this point, there is failure in the rehabilitation of the patient and functional prosthetic use.[14]

Compton[7] studied the veterans of the Vietnam War. Because of the improvement in evacuation of the injured, the war produced more survivors with extensive injuries. In addition, the homefront's attitude regarding the war had significant impact on the injured soldier's acceptance and societal acceptance of his injuries. A significant alteration in the person's personal identity development is caused by the trauma. Typically, personal identity development is the life stage that occurs during young adulthood. A majority of wartime casualties are young adults. The personal identity is composed of the somatic, sexual, occupational, and social identities. All amputees undergo a somatic identity change except for those who persistently deny the loss of the limb. It is during young adulthood that physical attractiveness is at its peak. Thus, it has a major impact on this population of patients. The use of prosthetic limbs allows a greater independence and return to a more normal body image.

Sexual identity in the young adult is of great importance. Often the first thing an injured soldier did was to check if his genitals were still present. Aggressive behavior is an affirmation of the male identity. It was common to see amputees banging wheelchairs into walls, racing down hallways, and taking on daredevil behaviors. Occupational identity allows us to have the sense that we have done something constructive and worthwhile with our lives.

Social identity melds what you are to others with what you are to yourself. Again, social acceptance of war greatly impacts the processing of social identity changes during crises. Social interaction allows one to

reestablish the concepts of who he or she is. Without this, inevitable harm can occur.

As Compton[7] states, "Men whose ego identity thrived in military service sometimes broke down after discharge, when it appeared that the war had provoked them into more ambitious self-images than their restricted peacetime identities could afford to sustain."

PHANTOM PAIN

Nearly all amputees experience either phantom limb sensation or pain. Mitchill first described phantom pain in his study of American Civil War amputees in 1872.[6] For most amputees, the pain is episodic and not disabling; however, there is a subset in which the pain is very disabling.[13] The subject of phantom pain is one that provokes controversy. There is no full agreement on the existence of phantom pain, the mechanism by which it occurs, and what the presurgical and post amputation treatment should be. Numerous treatment modalities have been proposed for treatment of phantom sensations, both painful and painless. Some of the newer treatments include calcitonin,[19] capsaicin,[5] acupuncture,[29] and therapeutic touch.[25] Jensen et al[20] studied 58 patients prospectively. They assessed the preamputation level and duration of pain as well as follow-up to 2 years after amputation. Their conclusion was that the level and length of pain before amputation plays a role in the level of pain early after amputation but not probably in persistent phantom pain. Sherman and Sherman[38] studied both the military- and nonmilitary-acquired amputation populations. They reported that there was no significant difference in the treatment or in the characteristics of the painful and painless phantom sensations. Most patients in both categories had phantom pain lasting seconds to hours, occurring more than 11 days per month and described as a sharp shock or shooting pain. Few patients (less than 21%) were offered treatment for the pain. The success rate for long-lasting major benefits from treatment was less than 2%. A multitude of treatments were tried, with minimal improvements. In fact, a significant number of patients either had no improvement or only minor change in the pain with analgesics. Their initial study of 1200 was a self-selected population of military amputees responding to a questionnaire. The population was derived from the National Amputation Foundation database of American Veterans with military-related amputees.[39] A follow-up study of more than 5000 randomly selected amputees with a respondent rate of 55% showed similar results. Both studies looked at level of amputation (finger/toes, foot/hand, etc.) instead of upper extremity versus lower extremity. The reason for treatment failure was believed to be caused by the complexity of the etiology of phantom pain and the lack of awareness of the degree and pervasiveness of phantom pain in the amputee community.[40]

A good review of post amputation phantom pain is presented by Vaida and Friedman in the May 1991 clinic.

ARMY PROSTHETIC PROGRAM

After the Revolutionary War there was little recourse for the war-wounded soldier. The injured usually had to fend for themselves and find a profession that would afford them an ability to support their family. Figure 2 is an illustration how one soldier petitioned the vice president for compensation for the loss of his right arm while serving as a soldier during the war. Although the outcome of his request is unknown, it does emphasize the few resources that the government had available for the military.

Few prosthetic companies existed in the United States before the Civil War. Most amputees had to do without their limb or make prostheses out of any available materials. Again, no governmental program existed for the war injured. Prosthetic companies began to form after the Civil War. Figures 7 to 9 depict upper extremity prosthetic limbs

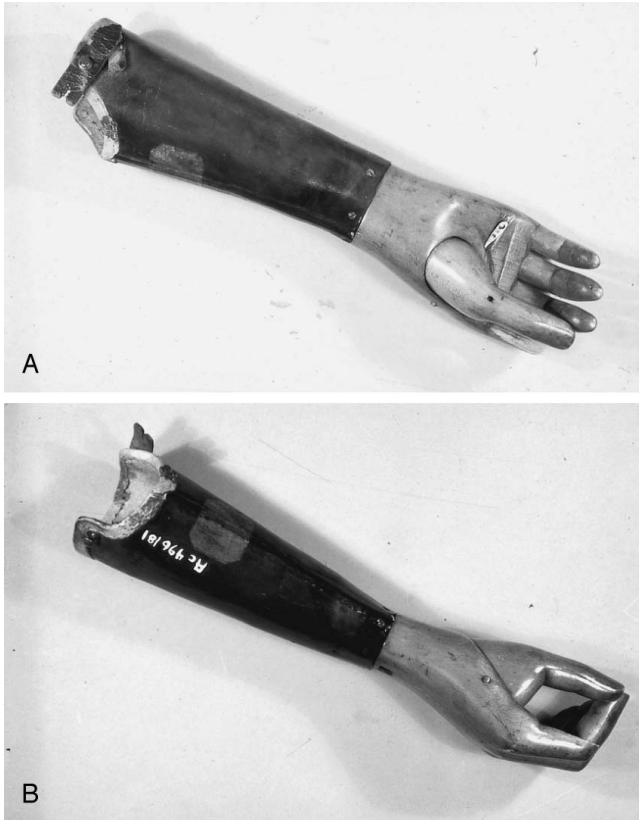

Figure 7. *A* and *B,* Below-elbow prosthesis from the Civil War. (Courtesy of the Armed Forces Institute of Pathology Museum, Washington, DC.)

Figure 8. Above-elbow prosthesis from the Civil War. (Courtesy of the Armed Forces Institute of Pathology Museum, Washington, DC.)

manufactured after the Civil War. War-injured amputees themselves started many of these companies. One of the best known is the J.E. Hanger Company. Mr. Hanger, an engineering student, was injured while serving in the Confederate Army. He lost his leg in a rifle ball injury early in the war. Displeased with the prosthetic limb given to him, he developed a lower limb prosthetic limb. The leg that he developed was far superior to those available at the time in 1861. Because of this, Mr. Hanger was given an exclusive contract to provide limbs for the Confederate amputee veterans.[32] The J.E. Hanger Company continues to exist today. Few advances were made in prosthetic limbs during the period between the Civil War and World War II. Before the early 1900s, most of prosthetic limb development was limited to the lower extremity. This was understandable because most veterans were lower limb amputees. Further, it was easier to replicate the functions of standing and walking than those of the upper extremity and hand. Upper extremity prostheses were primarily for cosmetic appearances and were worn only for formal occasions. In 1909, however, D.W. Dorrance sustained a right hand amputation in an accident. Because of his dissatisfaction with the prosthetic limbs at the time, he developed a hook, which could be opened and closed utilizing a strap that went across the back. He traveled the United States introducing his prosthetic innovation to physicians, prosthetists, amputees, and anyone who would listen.[32] His company still exists today as the Hosmer Dorrance Corporation, and anyone who works with upper extremity prosthetics is familiar with the Dorrance name.

Many amputee companies sold their prosthetic limbs using door-to-door salesmen. Many of these salesmen were amputees themselves. It is believed that the salesmen would follow ambulances or frequent

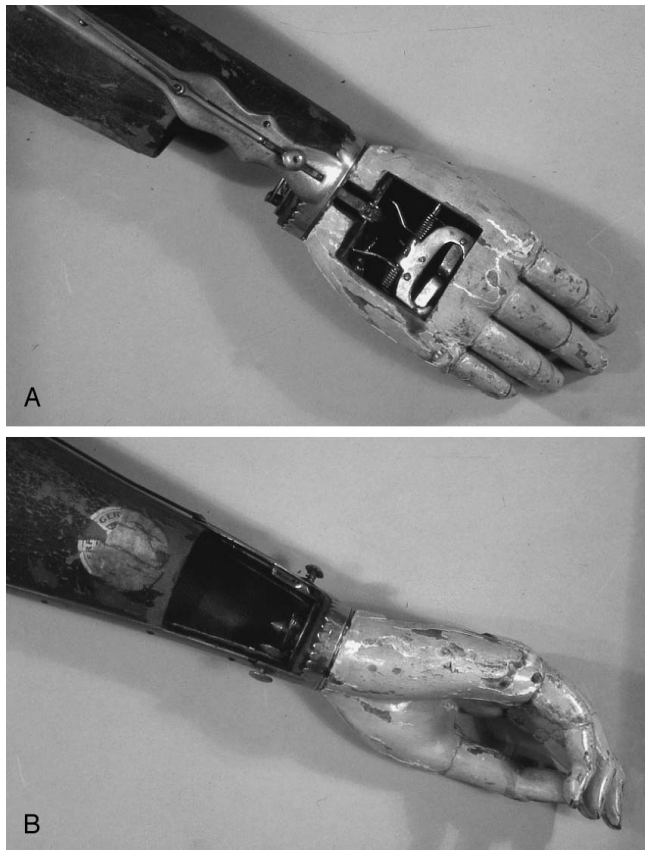

Figure 9. *A* and *B,* Examples of prosthetic hands used during the Civil War. (Courtesy of the Armed Forces Institute of Pathology Museum, Washington, DC.)

hospitals in hopes of obtaining new customers; hence the term "ambulance chaser."

After World War I, numerous organizations were established to assist the amputee. In 1917, the United States Council of National Defense organized the Artificial Limb Manufacturers Association to meet the needs of the veteran amputees. The Artificial Limb Users Association was a group formed for the exchange of information among amputees and encouragement for continued experimental work into improving prosthetic function. It ceased for only 4 years. Paul Cambell founded the Fraternity of the Wooden Leg in the 1930s. The Fraternity published a bimonthly magazine called *Courage.* The magazine assisted in the rehabilitation of many of the World War II and Korean War amputee veterans. The Conquerers was formed as an amputee consumer's group

in 1940. Its purpose was to help amputees secure employment opportunities. Today it continues as a strong advocacy group for amputees.[32]

Many upper limb prosthetic advances occurred during World War II. The federal government funded research endeavors into upper extremity research. Contracts were initiated with Northrop Aviation, IBM, and the University of California at Berkeley and at Los Angeles. Interestingly, the federally funded research developments were free of patent restrictions. Thus, no one company or party could have exclusive rights to a device or technique, thus allowing technologic advances to serve more people. It was at this time that Dr. Howard Rusk, MD, introduced his concept that rehabilitation should be the third phase of medicine.[32]

The Army established five amputation centers in 1943 to provide the highest quality of care for the war's amputee population. These included Bushnell General Hospital in Brigham City, Utah; Lawson General Hospital in Atlanta, Georgia; McCloskey General Hospital in Temple, Texas; Percy Jones General Hospital in Battle Creek, Michigan; and Walter Reed General Hospital in Washington, DC.[31] Because of the large number of amputees, Thomas England General Hospital, Atlantic City, New Jersey, and McGuire General Hospital, Richmond, Virginia, were added as amputation centers in 1944.[12] These centers were responsible for any necessary revisions and for the fitting and training of prosthetic limbs. They also allowed for the coordination and standardization of care. Soldiers were usually discharged from service before the residual limb was ready for the definite prosthesis. Typically, the prosthetic limb was provided by the Veteran's Administration. Currently, an agreement still exists between the Army and the Veteran's Administration that all new amputee cases are to be referred to the Veteran's Administration, at least in name. In 1944, the War Department published a pamphlet entitled "Helpful Hints to Those Who Have Lost Limbs" to assist the amputee's emotional and psychologic needs. In addition, the War Department produced two "moving pictures"; one depicted the life of a bilateral upper extremity amputee and the other the process of the amputee program from injury to rehabilitation.[31]

Congress legitimatized vocational rehabilitation in the 1950s. The Committee on Prosthetic Research and Development was established under the National Academy of Sciences—National Research Council and funded by the US Army and Navy. Both the Army and Navy established their own research facilities (Army Prosthetic Research Laboratory and Oak Knoll Naval Hospital Amputee Center). In the early 1950s, prosthetic courses at several universities were developed to educate prosthetists, physical and occupational therapists, physicians, and surgeons in the new technologies. As a result, the concept of amputee clinic teams was established.[32] Patients benefited from the collective input of the different specialists on the team. At Walter Reed Army Medical Center, the physiatrist is the team leader; at other military facilities, the team leader is often an orthopedic surgeon.

SUMMARY

Throughout the course of military history, soldiers have continued to sustain amputation injuries during war times and during peacetime and training missions. What has changed over time is the etiology of, indication for, and management of the amputations. Technology has advanced significantly, often with some military connection. More work still needs to be done, especially in the areas of greater prosthetic limb function and usage as well as phantom pain and sensation management. Collaborative efforts among physiatrists, surgeons, prosthetists, and therapists can only benefit the patient.

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