Chapter 1

INTRODUCTION: DEVELOPING A SYSTEM OF CARE FOR THE COMBAT AMPUTEE

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INTRODUCTION

For many Americans, the world changed forever on September 11, 2001, when Islamic extremists crashed hijacked commercial airliners into the World Trade Center in New York City, into the Pentagon, and over rural Pennsylvania. In response to these terrorist attacks the president of the United States launched a new war, the global war on terror (GWOT). Soon afterward, military operations were initiated in Afghanistan, on October 7, 2001 (Operation Enduring Freedom [OEF]), followed by the invasion of Iraq on March 19, 2003 (Operation Iraqi Freedom [OIF]). Conducting war against terrorism has proven extremely challenging for US military forces and costly for service members and their families. To date, thousands of young Americans' lives have been lost and even more have sustained serious physical, emotional, and psychological injury, although advances in military medicine have contributed greatly to reducing morbidity and mortality. Improved body armor, advanced capabilities of field medics, forward area resuscitation and surgery, and sophisticated and rapid medical evacuation have all contributed to widespread survival of injuries that would have been fatal in previous wars.

Caring for returning service members with complex polytrauma injuries necessitated flexibility within the Military Health System (MHS) and the Department of Veterans Affairs (VA). Multiple programs needed to be established or upgraded to ensure a well-coordinated system of care to address the needs of injured service members and their families across the entire continuum of care. In particular, given the large numbers of casualties with severe limb trauma and amputation, an amputee patient care program needed to be established within the Department of Defense (DoD). This chapter will document the need for this program within the framework of the core mission and values of the MHS. It will also highlight important lessons learned during OIF and OEF within the context of lessons from prior wars and examine the key components of a successful program.

Over the past decade, a cultural shift has occurred within the military giving individuals with major limb amputation the opportunity to stay in active duty service. Advances in medical, surgical, and rehabilitative care, as well as prosthetic design, are helping individuals achieve this goal. Whether or not the soldier desires or has the ability to remain in active duty service, DoD and VA programs are committed to helping all combat amputees reach their maximal function and return to the highest possible quality of life.

Traditionally a textbook of this nature would not be written until the completion of military operations. This schedule normally allows historians, scientists, and clinicians to formulate their thoughts collectively in a time of peace. Unfortunately, despite over 7 years of active combat, the GWOT continues, military service members remain in harm's way, and casualties continue presenting to the MHS. The DoD and VA leadership contributing to this textbook, therefore, saw the need to capture the lessons learned to date to facilitate ongoing care and planning.

THE MILITARY HEALTH SYSTEM

The MHS is entrusted by the DoD to accomplish five core missions in support of US service members, who are asked by their nation to risk their lives, whether in response to natural disasters or threats to national security. While each mission of the MHS may be distinct, they are interrelated and their synergistic effect contributes greatly to the overall strength and effectiveness of US fighting forces. These missions are summarized as follows:

1. **Combat casualty care**.[1] Unique to the MHS mission is the treatment of combat casualties. On the battlefield, care begins with basic first aid provided by well-trained nonmedical service members as well as trained combat lifesavers. The military has established five levels of care for wounded service members. For minor wounds, patients are treated and returned to duty. For injuries not conducive to immediate return to duty, evacuation to the next level of care is warranted. Depending on the nature and extent of the injury, service members may skip one or more levels of care to expedite immediate medical attention. Because of the capability to rapidly evacuate, medical care in theater is limited to life- and limb-saving procedures. Military surgeons focus their attention on stopping and preventing hemorrhage, debriding wounds to prevent infection, and preserving function. Often decisions about whether to reconstruct or amputate a limb are reserved for level V care within the continental United States treatment areas. The levels of care are categorized as follows:

- **Level I**: Immediate first aid and lifesaving measures are initiated in theater by Army combat medics, Navy corpsmen, and Air Force pararescuemen. Each service member carries a one-handed tourniquet, which may be applied by any member of the unit. Evacuation is then made to either an Army battalion aid station or Navy/Marine Corps shock trauma platoon, where initial resuscitation and advanced trauma life support is initiated. If an injured service member requires surgical resuscitation, he or she will often bypass the aid station and go directly to level II or III care.
- **Level II**: This is the first level of care where surgical resuscitation, basic laboratory, and radiographic capabilities exist. The Army forward surgical team is typically found at this level together with a medical company, which has two operating tables and holds up to 40 beds, with a holding capacity of approximately 72 hours. These medical units are 100% mobile and can provide up to 30 resuscitative surgical operations without resupply. The team is composed of one orthopaedic surgeon, three general surgeons, two nurse anesthetists, one critical care nurse, and additional nursing staff. Navy/Marine Corps level II care is provided by either a surgical company or a forward resuscitative surgical system. The surgical company can support ongoing operations without resupply to sustain four operating tables and a 60-bed capacity for up to 72 hours. The forward resuscitative surgical system is a smaller, more mobile unit, composed of only nine to ten personnel who can treat up to 18 casualties in 48 hours, but the system has no holding capacity. The US Air Force has several different level-II–capable units. The mobile field surgical team, which can provide up to 10 surgical stabilization procedures in 24 to 48 hours, is often combined with a small, portable, expeditionary aeromedical rapid response team composed of 10 members. The expeditionary medical support (EMEDS) basic is a 25-member team with one operating table and four holding beds. Lastly, the EMEDS+10 is a 56-person team with an additional 10 beds. Because of the high mobility of level II medical units, they are assigned to tactical units and are critical in a rapidly moving battlefield.
- **Level III**: This is the highest level of medical and surgical care available within the combat area of operation. Level III hospitals are modular, allowing adaptability to a given tactical situation. Army level III care is provided at the combat support hospital (CSH), which is composed of up to 248 beds, made up of a 164-bed unit combined with an 84-bed hospital company that can split off and act independently. The combined CSH has six operating tables, 48 intensive care unit beds, and 200 holding beds and covers up to 5.7 acres. In addition to laboratory and radiographic capabilities, the CSH also has a blood bank, a full complement of surgical subspecialties, and physical therapy capabilities. Level III care for the Navy and Marine Corps is provided by the fleet hospital. These hospitals comprise 1,000 personnel, six operating rooms, 80 intensive care unit beds, and 500 other beds. Fleet hospitals are also modular to accommodate various tactical situations. The Navy also has two hospital ships, which may act as level III or level IV facilities, with 100 intensive care unit beds, 1,000 other beds, and 12 operating rooms each. The US Air Force theater hospital is similar in capability to the Army CSH.
- **Level IV**: This echelon of care is located outside the combat zone and may be provided by a CSH, a fleet hospital, or a fixed medical facility. During OEF/OIF, most level IV care has been provided at Landstuhl Regional Medical Center in Germany. At Landstuhl, injuries are further assessed, irrigated, and debrided. Definitive surgeries, especially amputations, are still generally reserved for level V facilities. Patients with severe injuries are usually held less than 72 hours before proceeding to the next echelon of care. Casualties with less severe injuries may be able to return to the combat zone from this level.
- **Level V**: This echelon of care is provided within the continental United States at fixed military medical treatment facilities (MTFs). Although every effort is made to evacuate injured service members to an MTF closest to their home duty stations, it is more important for individuals to be sent to the facility capable of providing the most appropriate care. For example, all burn patients, regardless of military service, are

evacuated to the burn center of excellence at Brooke Army Medical Center (BAMC) in San Antonio, Texas. For service members with amputations, centers of excellence have also been established at Walter Reed Army Medical Center (WRAMC) in Washington, DC, and Balboa Naval Medical Center in San Diego, California, to provide expert care more conducive to family and service member travel, and less disruptive of family life.

- **Level VI**: This echelon of care primarily refers to rehabilitation units within the VA system of care; however, the relationship between the VA and DoD continues to evolve, with increasing levels of collaboration as more and more injured service members receive care in both systems. It is important to note that prior to OIF and OEF the Veterans Health Administration had well-established rehabilitation centers for individuals with spinal cord injury, brain injury, blindness, and limb amputation. Over the past decade, however, most amputee care in the VA system involved disease-related amputations such as those seen with vascular disease or diabetes, in contrast to the traumatic amputations in younger service members currently returning from OEF and OIF. This situation, coupled with the desire of some service members to return to active duty following limb amputation, led DoD to create comprehensive amputee care programs within MTFs that cooperate with VA care, especially in the areas of long-term care, veterans' benefits, recreation therapy, and the VA prosthetics and sensory aides service.

2. **Healthcare services to active duty and military beneficiaries**. Despite the attention given to care of combat casualties, military healthcare professionals also provide state-of-the-art primary, secondary, and tertiary care to military beneficiaries in a variety of healthcare settings across the globe. Beneficiaries receive the highest quality of preventive, medical, surgical, and rehabilitative care independent of age or military rank. Pediatric services for dependent children as well as world-class healthcare options for dependent spouses and retirees are equally important missions in preserving the fighting strength and in attaining recruitment goals within the DoD. For service members deployed to remote locations, the security of knowing their loved ones will receive the best of care allows them to remain mission-focused no matter where they may be deployed. To provide these services, most MTFs are staffed with medical professionals in virtually all specialties ranging from pediatrics to geriatrics. In addition, the military has partnered with civilian organizations in forming the TRICARE network throughout the continental United States to augment medical services not available within the MTF.
3. **Military readiness**. In addition to ensuring that medical providers are available to deploy in support of military missions at a moment's notice across the globe, the MHS is also responsible for ensuring that military combat and combat-support personnel are in good health to deploy. These services include health maintenance, dental care, immunizations, and medical clearance and assessment during premobilization and postmobilization. This mission is particularly challenging for the relatively high number of National Guard and reserve soldiers currently being deployed overseas in support of GWOT. Various mobilization/demobilization centers have been established across the United States, which receive staff and logistical support from the MHS.
4. **Health education**. A robust educational program is a fundamental component of the MHS. High-quality training and continuing education are needed to ensure that the highest quality of care is delivered to military beneficiaries. Over a hundred accredited teaching programs exist within MTFs in nearly all medical specialties and across various healthcare disciplines (eg, physicians, nursing, therapists, field medics). Professional skills and expertise to optimally treat the unique healthcare needs of service members are taught. Experience during OEF and OIF has demonstrated the critical impact that graduate medical educational (GME) programs have had in providing the finest care to service members, particularly those with combat injuries. Ongoing educational programs that include military-specific curricula have allowed military facilities to stay current with state-of-the-art medical, surgical, and rehabilitative care.

Examples of this impact can be found throughout the DoD. Practitioners in surgical subspecialties such as orthopaedics and vascular, general, and plastic surgery, by continuing training in combat trauma care even in times of peace, were prepared to deliver life-saving care immediately upon the onset of operations in Afghanistan. The physical medicine and rehabilitation (PM&R) residency program at WRAMC and the National Naval Medical Center in Bethesda, Maryland, through its emphasis on teaching rehabilitation principles for severely injured service members with polytrauma, spinal cord injury, traumatic brain injury, and major limb amputation, produced graduates prepared to help create a system of care for the combat amputee. Air Force training programs and staffing of critical care air transport teams have revolutionized air medical evacuation during OIF/OEF.[2] Intense teaching programs to enhance the skills of combat medics offered through the Tactical Combat Casualty Course at the Army Medical Department's Center and School at Fort Sam Houston in San Antonio continue to help save lives on the battlefield. Furthermore, physical and occupational therapy programs at the Center and School have continued to produce leaders within these fields, enhancing the capacity of the MHS to deliver comprehensive care for wounded warriors and their families.

5. **Biomedical research**. The DoD's investment in biomedical research has made a major contribution to the current 90% survival rate for US service members wounded in Iraq and Afghanistan. Pioneering efforts such as Major Walter Reed's research to unravel the cause of yellow fever have paved the way for generations of military medical researchers, scientists, and engineers to explore ways to save lives and reduce morbidity. Transitioning research discoveries into clinical practice is an extremely challenging process, requiring rigorous studies to demonstrate safety and efficacy, while complying with the regulatory statues of such entities as institutional review boards and the Food and Drug Administration. Examples of the military's commitment to this achievement include the development and deployment of the smallpox and anthrax vaccines as well as recently developed clotting bandages to help control hemorrhage on the battlefield.[3,4] Even simple discoveries such as improved field dressings and tourniquets have revolutionized battlefield medicine and continue to save lives.[5] To keep pace with the technological advances on the battlefield, the MHS must continue to explore new technologies to meet the needs of not just today's injured soldiers but those of the future. This requires continued partnerships between DoD, VA, and civilian academic institutions and industries.

HISTORICAL LESSONS LEARNED IN COMBAT AMPUTEE CARE

As described in his 1972 autobiography, *A World to Care For: The Autobiography of Howard A. Rusk. MD*,[6] Dr Howard Rusk volunteered for military service in 1942, was commissioned as a major, and served as director of the Army Air Corps convalescent and rehabilitation services during World War II. Dr Rusk quickly recognized that a large number of soldiers in military hospitals did not need full-time medical care, but remained unready for the rigors of returning to their units. Therefore, he began a program of "constructive training" that included physical conditioning exercises, practical courses taught within the hospital (for example, he hung model aircraft from the ceilings in the wards and had patients practice recognizing various airplanes, and later introduced courses such as trigonometry, calculus, and American history), and preparing soldiers for return to duty either in their original military occupational specialty or a new one. Dr Rusk convinced President Franklin D Roosevelt to create a comprehensive rehabilitation program within the Army, stating, "the country owed 'him' [the wounded soldier] more than just an artificial leg, a discharge and the Purple Heart." The program had the goals of

- returning soldiers to physical and mental health,
- finding ways for soldiers to function despite their disabilities,
- helping the Army and Army Air Corps preserve all the personnel possible by sending soldiers back to duty in the best possible condition in the shortest time,
- helping soldiers no longer capable of doing their previous military job to choose new jobs in the military and retraining them.

The Army and Army Air Corps initially created

two specialty amputee rehabilitation programs: one in Pawling, New York, and the other at Walter Reed Army Hospital.

In addition to the new rehabilitation program, World War II saw an improved military effort to provide advanced prostheses. Before the war, military policy had been to stabilize soldiers with major limb amputations and provide them with temporary limbs; after discharge from military service, they were fitted by the VA with durable permanent limbs. To preserve the fighting force, Henry ("Hap") Arnold, commanding general of the Army Air Corps, ordered the Army surgeon general to provide the highest quality artificial limbs available and to begin a prosthetics research program. With General Arnold's urging, Congress passed the first prosthetics research bill, in 1943, to develop scientifically sound and workable artificial arms. This was the beginning of the Army's formal rehabilitation clinical care and research program for soldiers with major limb amputations.

By the end of World War II, with 18,000 amputations across all branches of the military, full-scale efforts to create better prosthetic limbs and improve amputee care were in place. By 1945 engineers and physicians working together had created the best prosthetic arm up to that time, which was demonstrated by a group of soldiers for President Harry S Truman at the White House. In 1946 President Truman appointed General Omar Bradley to head the Veterans Administration and bring about its transformation so that veterans would receive high-quality care and the latest technology. One of General Bradley's accomplishments was to follow the National Research Council recommendation to locate VA hospitals near medical schools to share resources. Paul B Magnuson, MD, an Army physician in World War I, became medical director of the VA and was largely responsible for the current structure of VA medical care.[7]

The Vietnam War brought further advances to military amputee care. Paul W Brown, a retired colonel, had served as an enlisted soldier in World War II and then as a medical officer during the Korean War before becoming a senior orthopaedic surgeon at Fitzsimons General Hospital in Denver, Colorado, during the Vietnam War. His article, "Rehabilitation of the Combat-Wounded Amputee," published by the Army Surgeon General's Office in 1994, provided insights in the principles and practice of combat amputee care.[8] Dr Brown recognized that the key to a successful program lay in tapping into and facilitating the "motivation" of the soldier/patient. His observations and lessons learned during Vietnam can be summarized as follows:

- **Create centers of excellence**. It became clear during the Vietnam War that amputations occurring as a result of combat wounds required specialized care, which an institution could establish only by seeing a high volume of patients. This care was recognized as more important than expediting a soldier's return to his or her hometown. According to Dr Brown, "specialized treatment centers should be established, staffed, and supported to accomplish their clearly defined missions and the patient moved as quickly as his physical condition permits to a definitive hospital for the major portion of his treatment and recovery."[8(p209)] It was also observed that excellence in care could only be achieved with continuing education for practitioners, including active military GME training programs.
- **Incorporate rehabilitation principles early**. Orthopaedic surgeons observed during Vietnam that no matter how competent their surgical skills were, patient outcomes depended most on patient motivation, which was enhanced through early rehabilitation. The paradigm of waiting for all medical and surgical issues to be resolved before beginning rehabilitation was unsuccessful. Rather, rehabilitation principles needed to be incorporated into the treatment process as early as possible in the patient's continuum of care.
- **Limit convalescent leave**. Because of the long and protracted medical evacuation process during Vietnam, which often took several months, many injured service members immediately requested convalescent leave to return home to see their loved ones. This leave often created an unanticipated negative effect: injured service members who returned home prior to fully engaging in the rehabilitation process and not yet independent in many skills were observed to fall into a dependent role within their families, relying on others for bathing, feeding, mobility, and basic hygiene. Despite the families' best intentions, this dependency had a negative psychological impact on the soldiers, who often were never able to reengage in the rehabilitative process of achieving maximal independence, function, and dignity. As the Vietnam War progressed, medical teams at Fitzsimons learned to limit convalescent leave and began linking leave to achieved rehabilitation goals.
- **Introduce recreational/motivational activities.** What had been traditionally referred to as "recreational therapy" was recognized by Dr Brown and his staff as "motivational therapy." Military providers partnered with local and

community groups to develop programs for amputee horseback riding, swimming, and skiing. These programs were observed to have some of the most dramatic positive effects on outcomes. The keys to success were not just getting patients out in the community, but also to challenge them beyond the typical paradigms seen in hospital-based rehabilitation programs. As these programs became more popular, press coverage brought further interest, resources, and opportunities for the injured service members. However, the programs were also scrutinized by many, including the orthopaedic consultant to the Army Surgeon General's Office as well as many Navy orthopaedic surgeons, who claimed that these activities were both "dangerous" and "inappropriate" because they "fostered prolonged relationships with other amputees for companionship deterring from rehabilitation." Fortunately, this criticism did not stop the programs, and many of the programs formed or expanded during Vietnam served as the catalyst for today's numerous national and international sports and recreational organizations for people with disabilities.

- **Better define the VA's role**. During the Vietnam War, transfer to a VA hospital was often viewed as a decrement in medical care and a significant interruption of rehabilitation services. Hospital staff at Fitzsimons were reluctant to send their patients to the local VA for fear of this degradation of services, even if in meant going against the policy dictating that if a patient could not be "made well" within a certain period of time, he or she should be transferred to a VA hospital. If VA hospitals were going to play a significant role in caring for combat casualties, their services would need to improve, their role would need to be clearly articulated, and their staffing would need to be concordant with their mission. Furthermore, transfer to the VA should not have a negative financial or retirement impact on the injured service member.
- **Provide holistic care**. Concentrating on the surgical aspects of care only was not sufficient for optimal treatment outcomes. Practitioners needed also to treat other physical and psychological impairments of each patient, especially those with multiple comorbid injuries. Individualized care was best achieved through a team approach, with practitioners from each discipline working together under one service, enhanced by communication between members as well as with patients and their families. Additionally, it was noted that consistency of care was a key factor in delivering the highest quality of care. The career of General Fred Franks, Jr, whose combat wounds resulted in a leg amputation, illustrates the success of Vietnam-era amputee care programs.[9] During his rehabilitation at Valley Forge Army Hospital, General Franks decided he wanted to continue military service. Aided by his surgeon, Dr James Herndon, Franks remained on active duty. After an exemplary military career, he has served in retirement as a tireless advocate for wounded soldiers and their efforts to remain on active duty.

DEVELOPING AN AMPUTEE PROGRAM WITHIN THE DEPARTMENT OF DEFENSE

According to data obtained from the Centers for Disease Control and Prevention, an estimated 1,285,000 persons in the United States were living with the major limb amputation (excluding finger and toe amputation) in 1996. Despite better prevention and treatment programs, the number of individuals with major limb amputations continues to increase. Over 82% of US amputations occur as a result of complications from diabetes and vascular disease, mostly in individuals over the age of 65.[10] Additionally, the vast majority of amputations performed in civilian communities involve the lower rather than upper limbs.[11–14]

Data from OEF and OIF reveal a much different patient population. As of August 2009, over 900 service members had sustained a major limb amputation in support of GWOT. Approximately 21% of these individuals have had an upper limb amputated, and over 23% have lost more than one limb. Nearly 90% of these service members were under the age of 35, an age group with unique psychosocial needs, generally seeking to return to a more active lifestyle than older individuals. Adding to the challenges posed by combat-related amputation, the majority of these injuries have not occurred in isolation. Over 50% of the amputees seen during OEF/OIF have a documented traumatic brain injury, many with impaired vision and/or hearing. Additionally, many amputees have multiple complex fractures, soft tissue wounds, paralysis from peripheral nerve injury or spinal cord injury, and mental health problems.

In response, the DoD and VA together created a specialized system of care for combat amputees addressing these unique needs. To ensure communication between DoD and VA, Colonel Paul F Pasquina,

MD, was appointed to the Advisory Committee of the Secretary of Veterans Affairs on Prosthetics and Special Disability Populations. The first step in creating a comprehensive amputee care program within the DoD, in consultation with leaders from academia, consumer organizations, and VA, was to establish a well-articulated mission and vision statement to communicate to military and civilian leaders, as well as medical providers and service members, the intent of the program:

Mission: *Provide the highest quality of care to our soldiers, marines, sailors and airmen who are willing to put their life in harm's way.*

Vision: *Through the collaboration of a multidisciplinary team, we will provide world-renowned amputee care, assisting our patients as they return to the highest levels of physical, psychological and emotional function.*

While these statements articulated the goals of the program, a functioning system of care required acquiring and realigning resources within institutions, forming multidisciplinary teams, establishing productive partnerships with key constituencies (eg, VA, academia, veteran service organizations, industry, and relevant federal agencies and laboratories), and establishing strong leadership at all levels of clinical and administrative processes. It also meant adhering to and building upon the lessons learned from previous wars.

KEY ELEMENTS OF A COMPREHENSIVE AMPUTEE CARE PROGRAM

In preparation for OEF and OIF, WRAMC was designated as the primary site for amputee care in the US Army, with plans to expand the program to BAMC as needed, depending on casualty numbers. At WRAMC, providing holistic care for amputees has been a significant challenge for the medical and administrative staff, who have also been charged with caring for the over 8,000 other injured OEF/OIF service members arriving through August 2009.

During the early phases of the war, amputees at WRAMC received their primary medical and surgical care from a variety of different medical specialties. Because of the complex nature of their injuries, each amputee was admitted to the service that best met their immediate medical or surgical needs. For example, those with cranial trauma were admitted to neurosurgery, those with primary extremity trauma were admitted to orthopaedics, abdominal trauma to general surgery, etc. While each of these patients received expert specialty care, their holistic and amputee-specific care was less than consistent. Additionally, with the constant arrival of new trauma patients, military surgeons found themselves in the difficult position of managing complex acute surgical issues in the operating room at all hours, while at the same time trying to remain attentive to patients on the ward with complex medical, pain, or psychosocial issues.

To help meet this challenge, specialists in orthopaedics and PM&R partnered to help share inpatient and outpatient responsibilities. The PM&R department was well positioned to adjust its practice patterns and residency training program to help create both an inpatient and outpatient amputee service, in which the physiatrist acted as the primary care physician for the patient with complex injuries, allowing medical and surgical subspecialists to continue to provide expert consultation services. This synergistic relationship allowed focused subspecialty care and added consistency to amputee pain management, early rehabilitation, patient and family education, psychological counseling, traumatic brain injury screening, and surveillance and prevention of secondary complications such as infection, deep venous thrombosis, and heterotopic bone formation. Eventually, all the subspecialties critical to the care of amputees (orthopaedics, PM&R, occupational therapy, physical therapy, and prosthetics and orthotics) were united within a single department, a new Department of Orthopaedics and Rehabilitation, under a competitively selected department chief. The new department greatly facilitated communication within the institution and helped establish a clearer clinical pathway for amputee care.

In the new department, the physiatrist, following a rehabilitation model, coordinates the recommendations and interventions of multiple medical and surgical subspecialists, therapists, nurses, prosthetics, psychologists, and social workers. This system best ensures that holistic care is provided and also helps improve the quality and standardization of care across the institution. Weekly interdisciplinary amputee clinics are held in conjunction with interdisciplinary team meetings. The interdisciplinary meetings offer an opportunity for team members to share their observations and help develop unified treatment plans for complex patient issues or bring in other specialists as needed. These meetings have proved especially helpful in identifying patients with problems, which can then be addressed earlier during the recovery process: patients often form closer relationships with certain team members, who identify patient issues as they develop and address them with the rest of the team. The patient flow diagram developed at WRAMC is depicted in Figure 1-1. Although this model may not be adaptable to all military sites, the principles of patient flow should remain consistent across healthcare systems.

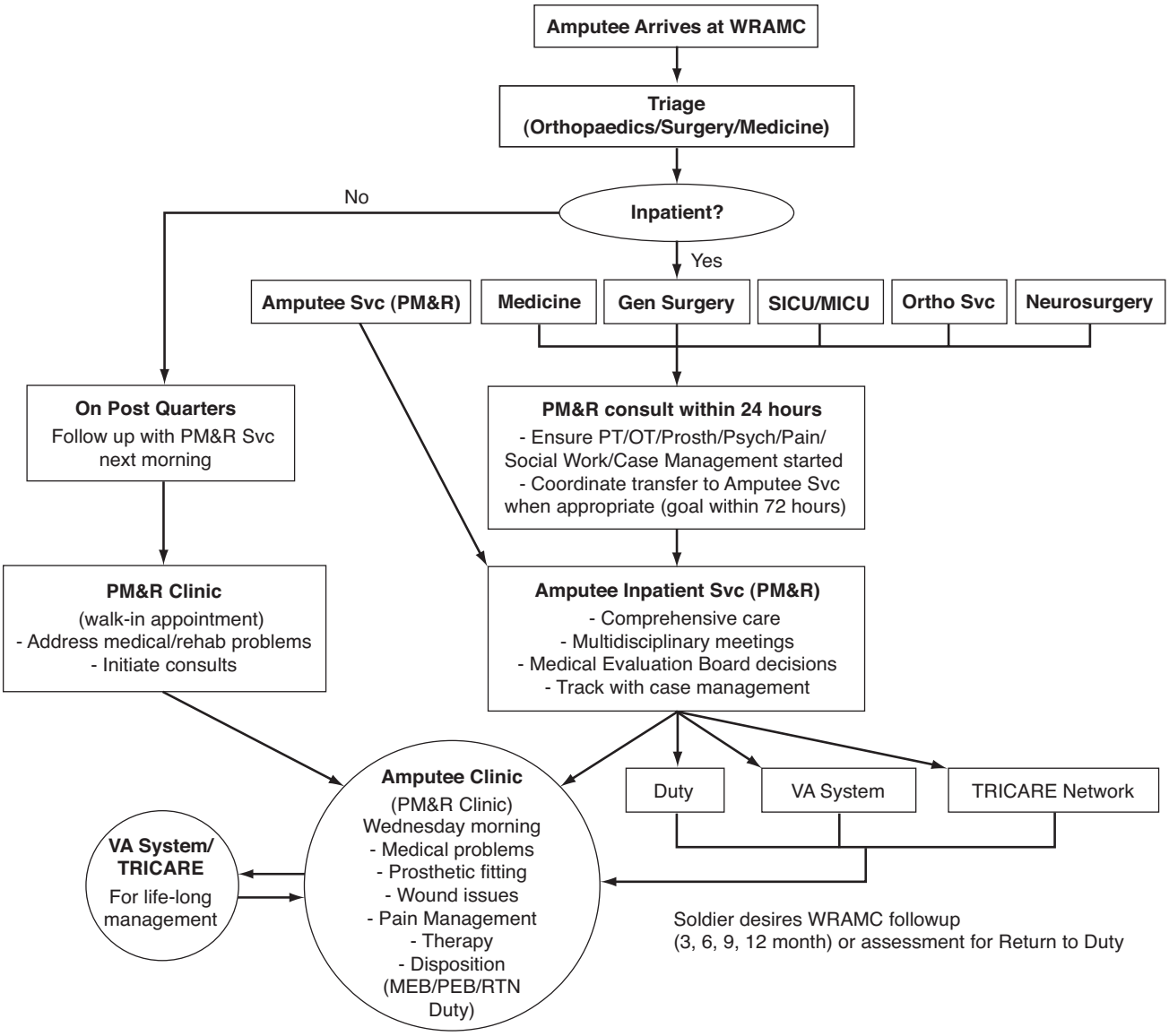

Figure 1-1. Patient flow chart at WRAMC's amputee service.
Gen: general
MEB: medical evaluation board
MICU: Medical Intensive Care Unit
Ortho: orthopaedics
OT: occupational therapy
Pain: Pain Management Service
PEB: physical evaluation board
PM&R: physical medicine and rehabilitation
Prosth: prosthetics
Psych: psychiatry / psychology
PT: physical therapy
RTN: return
SICU: Surgical Intensive Care Unit
Svc: service
VA: Department of Veterans Affairs
WRAMC: Walter Reed Army Medical Center

Organizational Structure

Standardizing medical care across different medical systems and geographic regions is dependent on multiple factors. Patient demographics, provider expertise and experience, and available resources greatly influence outcomes. To ensure that best practices are followed, it is essential to have a well-organized system in place. In addition, a model program should have adequate resources, support ongoing education and research, and incorporate continuous process improvement principles. Strong leadership is essential in implementing and sustaining such a program. The organizational structure of WRAMC's Department of Orthopaedics and Rehabilitation, described above, greatly facilitated the formation and execution of the

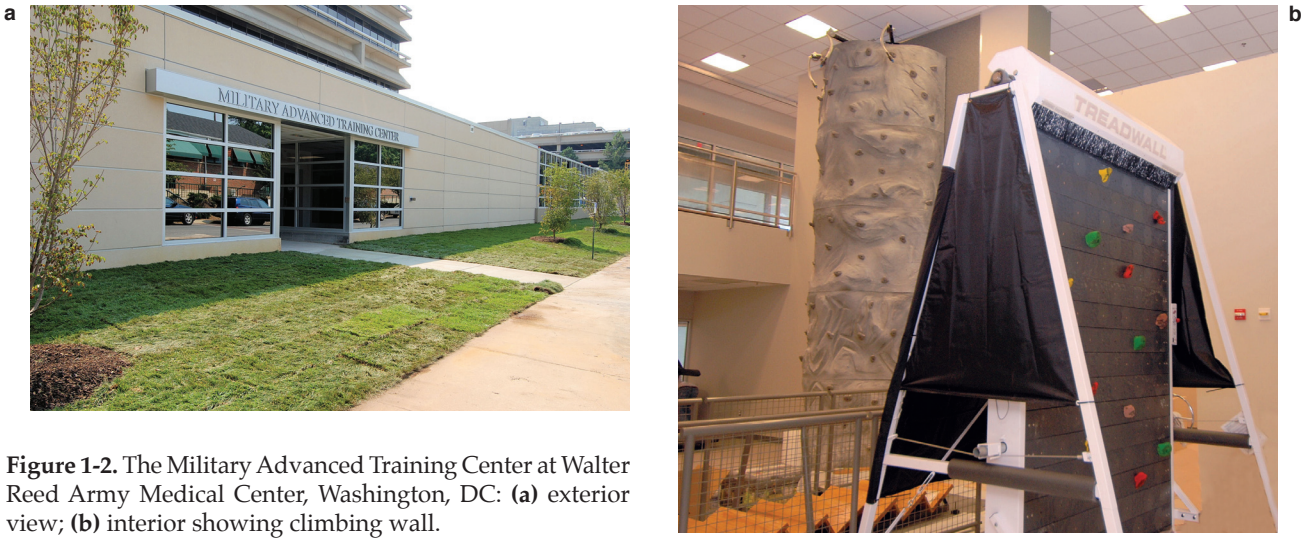

Figure 1-2. The Military Advanced Training Center at Walter Reed Army Medical Center, Washington, DC: **(a)** exterior view; **(b)** interior showing climbing wall.

amputee care program at both WRAMC and BAMC, and also contributed to the formation of two state-of-the-art rehabilitation facilities, WRAMC's Military Advanced Training Center (Figure 1-2) and BAMC's Center for the Intrepid (Figure 1-3). These two facilities were created with public and private funding after military, government, and civilian leaders recognized the need for additional support services at both locations.

Teamwork

Optimizing care for the individual with major limb loss is complex, and medical, surgical, and rehabilitative care has become subspecialized. In addition, the varieties of prosthetic components available on the market make prosthetic prescribing and fitting a complicated process. Whether providing inpatient or outpatient care, experts agree that formulating an interdisciplinary team is an essential feature of a successful program.

The "centers of excellence" concept developed in earlier conflicts[6–8] espoused the need for interaction of multiple specialties as well as incorporating basic rehabilitation principles to provide holistic care to the amputee. Critical specialties involved in caring for the amputee include physiatry, surgery, medicine, physical therapy, occupational therapy, recreation therapy, nursing, mental health, social work, and prosthetics. This type of teamwork has been shown to improve

Figure 1-3. The Center for the Intrepid at Brooke Army Medical Center, San Antonio, Texas: **(a)** exterior view; **(b)** interior, third floor, showing track and climbing wall. Photograph (b) by Don Clinkscales.

short- and long-term outcomes.[15,16] Additionally, incorporating peer support, vocational rehabilitation, community reintegration, and assistive technology, as well as sports and recreational activities, greatly enhances a comprehensive program and improves the amputee's quality of life and ability to reintegrate with the community.[17] Finally, for a program to be successful, team members must recognize the importance of the patient and family members' participation in the entire treatment process, including the establishment of short- and long-term goals.

Staffing Ratios

As articulated by former Secretary of Defense Donald Rumsfeld, "you have to go to war with the Army you have, not the Army you want."[18] Although this may be true to a certain extent, the MHS strives to provide the best medical, surgical, and rehabilitation care achievable for wounded American service members. Essential to meeting this mission is establishing appropriate medical staffing ratios. Unfortunately, no standard matrix or formula exists to serve the complex needs of this unique patient population. Staffing ratios are dependent on factors such as patient acuity, experience and expertise of the provider, access to resources, and partnerships with other institutions and outside organizations. Table 1-1 presents ratios developed by expert consensus.

TABLE 1-1

SUGGESTED STAFFING RATIOS FOR AMPUTEE CARE

Specialty	FTEs for 10 Ward Inpatients	FTEs for 20 Outpatients (Excluding TBI Impairment)
Orthopaedics	1	1
Physiatry	1	1
Physician Assistant	2	1
Physical Therapy	2	2
Physical Therapy Assistant	2	2
Occupational Therapy	2	2
Certified OT Assistant	2	2
Recreation Therapy	1	1
Nursing (RN)	1	0
Nursing (LPN)	2	0
Social Work	1	1.5
Case Management	.5	1
Administrative Assistant	.5	.5

FTE: full-time equivalent
LPN: licensed practical nurse
OT: occupational therapy
RN: registered nurse
TBI: traumatic brain injury

Graduate Medical Education and Research

Experience treating injured service members during OEF/OIF has demonstrated the critical impact GME has had on amputee care. Ongoing educational programs that include military-specific curricula help military facilities stay current with state-of-the-art medicine, surgical techniques, and rehabilitative approaches to care. WRAMC's PM&R residency program (the only one in the DoD) has greatly enhanced the incorporation of fundamental rehabilitation principles into the care of combat amputees. Even in times of peace, DoD surgical programs emphasized combat casualty care to ensure that today's surgeons are prepared to meet even the most complex trauma surgical issues. DoD-sponsored GME programs are vital to the strength of the MHS and ensure its capacity to meet current and future needs in military medicine.

An active research program is also an essential component of a successful amputee care center of excellence. To ensure that military-relevant clinical research is being conducted, active engagement of clinicians who care for the patients is paramount. Unfortunately, within most military clinical settings, a formal research infrastructure is not as robust as in most university programs. Despite the productivity of individual DoD clinicians and researchers, every opportunity should be taken to bring these groups together to collaborate on solving problems. Partnerships with the VA, universities, and industry have helped to build capacity in performing relevant research that can translate into clinical care.

Involving medical residents in research is also key. The partnership with the VA Rehabilitation Research and Development Service, which incorporates WRAMC residents into VA research activities, has resulted in military amputee care program successes. One such program, which included WRAMC PM&R residents in the Human Engineering Research Laboratories research team at the National Veterans Wheelchair Games and the National Disabled Veterans Winter Sports Clinic, cultivated residents responsive to research and encouraged some to become clinician scientists.

Continuing Education

In addition to GME, an ongoing educational program must be part of successful amputee care because of the varying levels of experience within DoD military treatment facilities and the high turnover of staff. Educational experiences must be comprehensive while at the same time targeting individual disciplines. Key leaders should be identified within each service (PM&R, nursing, orthopaedics, prosthetics, occupational and physical therapy, psychology, etc), who will first identify the educational needs of their services and then determine how these educational needs can best be met. A cost-effective way to meet these needs is bringing in outside experts or partnering with existing national organizations, such as VA, the Defense Advanced Research Projects Agency, and universities, as well as private companies and foundations. Issues of a cross-disciplinary nature, including pain management, wound management, and psychological adjustment, should be presented in a forum with all disciplines present to promote interdisciplinary discussion. The military amputee care program, in partnership with the VA, Human Engineering Research Laboratories, Paralyzed Veterans of America, and University of Pittsburgh, initiated a "state-of-the-science" symposium series in 2004 to bring the nation's best scientists and clinicians to WRAMC to facilitate communication, build collaborations, and accelerate the translation of research into clinical practice. Furthermore, collaborations were established with key universities, government agencies, and veteran service organizations to expand education opportunities, grand-rounds presentations, and clinical training.

Database

Any effective system of medical care requires accessible information on the patient population served; for military amputee care, a database is needed to track all patients as they enter the system. Important data elements include demographics, comorbidities, pathologic anatomy, and etiologic data, as well as interventions and outcomes. This database requires technological support and accurate data entry by employees (other than clinicians) skilled in these areas. Furthermore, the database must be secure, password-protected, and capable of removing all personal identifying information from the data. Data analysis such as prediction of outcomes, utilization of resources and equipment, and identification of areas in need of alternative interventions or approaches provides essential feedback to the clinical team.[19]

Prevention Programs

Preventative programs can help reduce the risk of both traumatic and nontraumatic amputation. Safety education and training have contributed to a significant decrease in trauma-related amputations.[20] The VA Preservation-Amputation Care and Treatment (PACT) program has contributed to an almost 40% reduction in nontraumatic amputations performed each year at VA medical centers. The program incorporates interdisciplinary coordination by the surgeon, rehabilitation physician, therapist, nurse, podiatrist, social worker, and prosthetic and/or orthotic personnel, as well as the primary care medical or diabetes team to track every patient with an amputation, or those at risk of limb loss, who enter the VA healthcare system.[21] Prevention of traumatic amputations from combat is also a priority of military forces. Medical teams have helped partner with military research teams in designing extremity protection armor as well as improving immediate medical aid to help save limbs.

Surgical Considerations

Standardizing surgical approaches to amputation is challenging, especially for combat victims whose wounds are not only extensive but also contaminated with dirt, bacteria, and fragments. With most amputees requiring comanagement of multiple surgical subspecialties, good communication between these services is essential. Limb-salvaging decisions remain complex and should be made in conjunction with the patient, as well as the entire medical and rehabilitation team. Tools such as the mangled extremity severity score are helpful in facilitating a decision (but may not be definitive). In addition to anatomic and physiologic factors, anticipated functional outcome should be considered, especially for this generally young and active patient population, many of them eager to return to high-level sporting and recreational activities. Similar considerations must be made when the rehabilitation team decides on amputation length and level. It is critical that the rehabilitation team, especially the prosthetist, be involved in these decisions preoperatively to ensure optimal length for prosthetic fitting and function.

Medical Management

Most service members with combat-related amputations have multiple comorbidities and a greater risk for secondary complications. Traumatic amputees are at increased risk for developing deep venous thrombosis in both their intact and residual limbs. For prophylaxis, all patients are started on low-molecular-weight

heparin (enoxaparin), unless contraindicated. A high percentage of combat amputees also develop heterotopic ossification, although whether this incidence correlates with the nature of injury (typically, from a blast); patient demographics (age, race, genetic predisposition); wound management (vacuum dressings); or perhaps the presence of comorbid head injury is unclear. The secondary effects of heterotopic ossification can be significant pain, skin breakdown, and trouble with prosthetic fitting. All WRAMC patients receive a cyclooxygenase-2–selective nonsteroidal antiinflammatory agent, unless contraindicated, for both prophylaxis and treatment of heterotopic ossification.

Faculty have observed that in this patient population, signs of secondary complications such as deep venous thrombosis or heterotopic ossification are typically very subtle and may first appear only as a mild, low-grade fever; therefore, medical vigilance is imperative. Because of the high incidence of comorbid head injury, it is important that the medical staff have experience in managing patients with cognitive deficits. For posttraumatic seizure prophylaxis and treatment, levetiracetam has been very effective. Finally, because of the high incidence of multitrauma and blood loss, combat amputees have benefited from the use of epoetin alfa to stimulate red blood cell production. This treatment not only helps healing but also increases energy during rehabilitation. It should also be recognized that each patient has his or her own distinctive psychosocial needs, greatly affecting issues such as pain management, adjustment to disability and body image, ease with movement through the military disability system, and reintegration into the community or back to active-duty service.

Pain Management

An essential component to any successful inpatient or outpatient amputee program is expertise in pain management. Residual limb and phantom limb pain, reported in 55% to 85% of amputees, have a significant negative impact on long-term functional outcomes and quality of life.[22,23] The incidence of chronic pain may be reduced by aggressive preoperative and perioperative pain management. New Joint Commission on Accreditation of Healthcare Organizations standards, as well as the Accreditation Council for Graduate Medical Education, recognize pain medicine as a distinct medical subspecialty.[24] These organizations have helped establish institutional guidelines for appropriate pain management, as well as sensitizing medical institutions and clinicians to the patient's right to pain management. Furthermore, advances in medical and procedural interventions offer new ways to mitigate pain associated with trauma care.

The entire medical and rehabilitation staff should be aware of the amputee's pain perception, incorporating questions about pain as part of routine evaluation. Team members who have subspecialty training in pain management contribute greatly to a successful outcome. Within the amputee care program, nurses, physicians, and therapists all play critical roles in monitoring patient pain complaints and optimizing treatment. WRAMC experience has shown that adequate pain control in most combat amputees requires multimodal medication. Nearly every patient is issued a patient-controlled anesthesia pump during the perioperative period and then quickly converted to long-acting opioids after definitive surgery. Short-acting opioids are also used for breakthrough pain or premedication prior to therapy.

Most patients are prescribed an anticonvulsant (gabapentin, oxcarbazepine, lamotrigine); a tricyclic antidepressant (nortriptyline, amitriptyline, desipramine); and a nonsteroidal antiinflammatory agent, typically one that is cyclooxygenase-2–selective, given the number and nature of comorbidities as well as frequent concurrent use of anticoagulation medication. Quetiapine fumarate is a very effective sleep aid, especially in cases when the soldier reports trouble with nightmares. In addition to pharmacological management, physical agent modalities (ice, heat), desensitization, and transcutaneous electrical nerve stimulation units have been helpful. Perhaps most effective, however, has been the support of the regional anesthesia team. The placement of peripheral infusion catheters to the brachial, lumbosacral plexus, or sciatic nerves has had a dramatic positive effect on pain control, reduction in medication use, and participation in therapy.

Cutting-edge programs should consider the use of topical agents, regional anesthesia, and multimodal pharmacological management, as well as complementary, integrative, or alternative measures such as biofeedback, hypnosis, relaxation techniques, and acupuncture. Physical and occupational therapists should be knowledgeable about both the indications and contraindications when applying modalities such as heat/cold, electrical stimulation, and desensitization techniques. The literature does not support clear evidence of a single agent as the treatment of choice for phantom or residual limb pain, but medications such as opioids, anticonvulsants, tricyclic antidepressants, botulinum toxin, and topical agents (lidocaine, capsaicin) may work synergistically along with mechanical stimuli modalities (eg, transcutaneous electrical nerve stimulation, tapping, massage) and mirror therapy to provide optimal pain relief. It is also

generally accepted that the use of an appropriately fitted prosthetic socket reduces pain.

Advances in Prosthetics

Military amputee care providers believe that the technological advances in prosthetic design not only significantly improve patient satisfaction and functional outcomes, but also facilitate progression in rehabilitation.

Upper-Limb Prosthetics

Because of the complex nature of combat wounds, prosthetic fitting is often delayed to allow time for graft healing. Comorbid fractures, nerve plexus injuries, or soft tissue defects often prohibit the use of body-powered prostheses and suspension harnesses or cables. During the immediate postoperative period, myoelectric control sites should be identified. At WRAMC, occupational therapists work closely with the patients using preamplified electrodes over remaining intact muscles. These electrodes capture electromyograph signals that trigger audio and video feedback to the patient and therapist. These signals are also used to operate video games, which create a friendly and therapeutic competitive environment for the patients and quickly lead to mastering of certain skills. Once these skills are acquired, patients progress rapidly to operating myoelectric prostheses as soon as their limb is cleared for fitting. Body-powered prostheses are introduced later, as comorbid injuries permit. Today's advanced prosthetic components allow simultaneous operation and control of both the elbow and terminal device. The addition of a wrist control unit permits more useful upper-limb functioning in some patients. Newer terminal devices allow faster and more responsive opening and closing. They also have the ability to maintain constant grip force, utilizing built-in sensors within the fingertips.

Lower-Limb Prosthetics

Advances in technology have been applied to both prosthetic component design and socket fabrication. Traditional plaster casting, while still utilized, is augmented with computer-aided design and manufacture equipment, which has contributed to a more rapid and standardized approach to socket delivery for traumatic lower-limb amputees. The computerized system allows the fabrication of a custom-made socket in a fraction of the time needed for traditional casting. The shorter fabrication time is especially helpful in caring for the combat amputee, whose residual limbs have complex scar and suture lines and experience substantial rapid volume changes.

Advanced components, such as microprocessor knees and dynamic response feet, have not only enhanced function but also promote a more rapid progression through rehabilitation. The prosthetist's ability to program microprocessor knees to provide more or less stance or swing control assists advancement from early weight bearing to initial ambulation and, eventually, to stair and obstacle negotiation, without having to change prosthetic components or alignment. MHS and VA providers have also found that during initial ambulation, patients perform well with multiaxial feet and vertical compression pylons. As patients' confidence and activities increase, they perform better with lighter-weight feet that have vertical compression features built into the heel of the foot itself.

A fully equipped gait laboratory provides useful functional measures during the early phases of fitting to aid with prosthetic alignment and choice of components. Staff can also provide feedback to the patients and therapists on specific items to work on during therapy sessions.

Peer and Psychosocial Support Programs

An extremely important aspect of a comprehensive program includes professional behavioral health and amputee peer support. DoD amputee programs have formed partnerships with VA and the Amputee Coalition of America to find and train outstanding individuals with limb loss who volunteer their time to support combat amputees returning from war. It is ideal if these volunteers have military experience. In addition to the emotional support they provide patients, they also provide valuable feedback to the rehabilitation team as to how a patient is progressing in rehabilitation both physically and emotionally. Family members are also encouraged to be fully engaged in the rehabilitation program. The DoD has been proactive in supporting nonmedical attendants, often family members, who stay with injured service members during their recovery. DoD provides travel and housing allowances to nonmedical attendants, enabling them able to assist in the recovery of the injured service member and provide much needed emotional support through the process. The VA should consider adopting a similar model based on the success of this program and the positive impact it has had on veterans and their families. Communication among patients, their families, and their multiple providers is greatly facilitated by social workers and nurse case managers, who help to coordinate continued care, discharge planning, and equipment purchases.

Events such as the National Disabled Veterans Winter Sports Clinic, National Disabled Veterans Summer

Sports Clinic, National Veterans Wheelchair Games, and the Paralympics, sponsored by VA in coordination with public and private organizations including the Paralyzed Veterans of America, Disabled American Veterans, Disabled Sports USA, Wounded Warrior Project, US Paralympics, Achilles Track Club, Team River Runner, the Yellow Ribbon Fund, and numerous others, introduce patients to the variety of sports and recreational opportunities available for individuals with disabilities. Improving both access and awareness of these programs is essential to the success of the amputee program.

Military Medical Disability System

Navigation through the military medical disability system is complicated. A single amputee service promotes communication and standardization. Physicians should be well educated and experienced in writing medical evaluation boards. In addition, a physical evaluation board liaison officer should be assigned to each patient during his or her inpatient stay. VA counselors are also necessary to ensure that patients are aware their potential benefits. Educational programs must be tailored to the service member's needs, especially those with head injury, hearing loss, or vision loss.

Optimal disposition of patients is often complicated by the frequent geographical challenges created when the patient's duty station, home of record, and nearest military or VA medical facility are far apart. In these situations, medical follow-up must be coordinated through the TRICARE military healthcare system. Unfortunately, standards and availability of healthcare services vary in both the private and public sectors across the United States. Through partnerships between the DoD and VA, military amputee programs are committed to provide ongoing care to veterans with limb loss for the rest of their lives, as needed to supplement VA programs.

Outcome Measures

An essential element to developing a program focused on best practices is a mechanism for collecting and analyzing outcomes. New Joint Commission on Accreditation of Healthcare Organizations and Accreditation Council for Graduate Medical Education guidelines emphasize the importance of outcomes-based practices. A multitude of outcome measures are available for the amputee population. While numerous reliable and validated measurement tools have been reported in the literature, considerable debate continues as to which tool is best for the various populations of patients. Additionally, the success or failure of a particular intervention in amputee care is often the result of many factors. Therefore, several tools may need to be employed to adequately assess a particular patient population.

The most common outcome domains to be examined in various amputee populations include mobility, function, and quality of life. Tools employed to measure these domains are generally self-reporting (survey) or observation based. Several examples of measurement tools are listed below.

Self-reporting measures:

- the Medical Outcomes Study Short Form 36-Item Health Survey[25]
- Legro and colleagues' prosthesis evaluation questionnaire[26]
- the locomotor capabilities index[27]
- the sickness impact profile[28]
- the questionnaire for persons with a transfemoral amputation (Q-TFA)[29]
- the Trinity Amputation and Prosthetic Experience Scale (TAPES)[30]

Performance-based measurement tools and devices:

- the "get up and go" test[31,32]
- the 6-minute walk test[33]
- Gailey and colleagues' amputee mobility predictor[34]
- the disabilities of the arm, shoulder, and hand (DASH) questionaire[35]
- the box and block test[36]
- the Jebsen-Taylor hand function test[37]
- the step activity monitor[38]
- three-dimensional gait and motion analysis[39,40]
- energy consumption measurements[41,42]

New technologies and improved methods are being developed to record activity in unstructured environments within the home and community to measure community participation, provide further insight into the usage and effectiveness of technology, and assess the impact of various rehabilitation interventions.

CONCLUSION

Today, science, advanced technology, and improved material design are being brought together to revolutionize the care for individuals with amputation. Optimizing this care requires significant teamwork and partnership both across and within different disciplines. Current medical research must involve all areas of sci-

ence, including those not traditionally associated with healthcare. Clinicians must clearly identify and communicate the functional needs of patients to engineers, biologists, computer scientists, and systems scientists to achieve common goals. Furthermore, a mutual sharing of ideas among public and private universities, federal agencies and laboratories, and industry is essential to further advancements in the field.

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