

Extremity Injury in War: A Brief History

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Abstract

The complex history of treating traumatic injury in Western warfare consistently included issues such as proximity to surgical care, the organization of medical systems, and the progressive development of technologies and procedures used to treat military service members who are injured in battle. Significant advances have been made in each of these areas, as evidenced in the changes in medical care in conflicts involving US forces. These advances include, among others, organized attempts to improve sanitation; panels of surgeons to assess optimal surgical approaches; the introduction of triage, wound débridement, and delayed wound closure; the development of chemotherapeutics and antibiotics; and increasingly more timely treatment. Perhaps the least recognized historical contribution to military medical care, however, is the compiled medical statistic, which informs bold research and response.

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Early Extremity Trauma Care

Early reports of conflict between organized forces address extremity trauma and offer a glimpse at the response to military injuries: successful amputations are evident, as are splints. Healed long-bone fractures revealed by radiographic examination of ancient Egyptian mummies also suggest an appreciation for the importance of stabilization. Hippocrates (460-377 BCE) wrote about extremity wound healing, as well, passages in multiple volumes offer clear instruction on how to stop bleeding, apply principles of traction and countertraction, correct dislocations, fashion and use splints and bandages, and establish a clean condition at the wound site. Indeed, as the skills required of the physician multiplied, the Hippocratic exhortation that war was a surgeon's best

The American Academy of Orthopaedic Surgeons' superb *Legacy of Heroes*¹ project affirms that a careful look at our military past may plot a trajectory to our surgical future. Through the reflections of World War II veterans, the Academy publication demonstrates that the medical personnel who entered the 20th century as representatives of a field of "strap and buckle" doctors emerged from the war having forged the specialty of orthopaedic surgery. It is a complex story, not without its blind alleys and lessons to be relearned. This brief military history, concentrating on conflicts involving the United States, reveals that two threads must be examined to offer a full picture of the evolution of surgical care: the injuries as well as their causes and treatments, and the systems within which those treatment methods were researched, applied, and disseminated.

training ground was proved to be accurate.²⁻⁵

Galen (129-201 CE) was the best known of the Roman gladiatorial surgeons. He and other physicians of the day refined both the use of the suture and the treatment of arrow and gladius (sword) wounds. They also investigated muscle and nerve repair. Their practical work remained influential for centuries, even as its philosophical underpinnings were challenged. Equally as important, the Roman armies established the military hospital and recognized the importance of its proximity to battle and the physical immediacy of access to care.^{5,6} Bandaging and attempts to stanch bleeding were emphasized in the Middle Ages, and injured soldiers were transported by horse-drawn litters and other means. In this era, early attempts to organize substantial medical services in a military setting (England) and to establish military hospitals (Spain) were seen.^{4,6}

One of the most significant events in the development of military surgery and extremity wound management was the introduction of gunpowder into Europe in the 1300s and 1400s. Foreign substances contaminated the resulting increasingly complex and shattering extremity wounds; other compound fractures and severe burns complicated the wounds, as well. Thus, amputation became the common recourse against sepsis. A widely held belief also developed that gunshot wounds were essentially poisonous. No one better informs our knowledge of the care of those so wounded in the 1500s than Ambrose Paré (1510-1590). He did not believe that gunshots were necessarily toxic. Paré introduced a form of débridement, adopted specialized tools and new techniques for fracture reduction, and developed a simple tourniquet and vessel ligation to use instead of cautery. Limb amputation persisted as a common procedure, however.^{5,7-9}

The military role of the surgeon was recognized anew with the founding of the first permanent military medical hospital, established in the late 1500s and operated by the Spanish Army of Flanders. Throughout the next several centuries, evacuation systems became more sophisticated, with organized attempts to move the wounded out of battle zones as swiftly as possible after cessation of fighting.⁵ In this period, the earliest printed treatises on surgery were produced in the vernacular; they called upon a growing knowledge of anatomy even as they created an empirical record of injury and response. The technical skills of the military surgeon are well represented in these books, in which medical descriptions of battle experiences began to appear in large numbers, initiating a remarkable tradition of accessible dissemination of military medical procedure and reifying a means by which the lessons of military trauma would later inform civil surgery.

In the early 1600s, labeled by Garrison⁴ as the “greatest period of amputating limbs,” joint exarticulations at the shoulder and hip were performed and favored over those at the elbow and knee because the latter offer less residual material for flap construction. Most amputations were delayed in order to observe patient response to the original injury.⁴

Throughout the 1700s, surgical intervention continued to focus on management of soft-tissue injury; control of bleeding by clamping, tying, and tamponade; avoidance of sepsis; fracture alignment and splinting; repair of muscle and tendon; and reduction of dislocations. The bone ends of fractures that did not unite evenly were rubbed together to encourage better alignment. Gunshot wounds were enlarged to enable probing as well as removal of dead tissue and any retained fragment of projectile. Revolutionary War-era trauma surgery

acknowledged its reliance on the teachings of John Hunter, Surgeon-General of the English Army, and on European principles and became an established part of academic teaching. In the American colonies in 1775, the first surgical text emerged because of military necessity: John Jones' *On the Treatment of Wounds and Fractures...Designed for the Use of Young Military Surgeons in North America*.¹⁰⁻¹⁵

By the time of the War of 1812, early amputation was increasingly regarded as worthwhile, and there is ample evidence of its occurrence. The 1816 medical records of James Mann note that, except for timing of the procedure relative to the time of injury, little technical progress had occurred since the Revolutionary War.^{11,16,17} Two elements determined that timing: the speed with which the injured soldier received medical attention, and the surgeon's approach to treatment.

The most famous advocate for early amputation—Baron Dominique Jean Larrey (1766-1842), Napoleon's physician and military surgeon—became known during the Napoleonic Wars. Larrey is responsible for introducing a casualty support system that remains recognizable today. It involved rapid treatment of the wounded (including amputation), who would be either treated at once at the scene of battle or transported to a nearby facility via the so-called flying ambulance—a vehicle with the speed and mobility of light artillery, made as comfortable for patients as possible, and staffed with technicians trained to render specialized care immediately. Immediate amputation reduced morbidity, mortality, the likelihood of tetanus, and the suffering of the soldier. Larrey himself is reported to have performed more than 200 amputations in a 24-hour period in 1812 at the Battle of Borodino.^{4,5,8,17,18}

During the Crimean War (1854-1856), Larrey's influence strengthened, surgeons' confidence in the de-

sirability of early amputation advanced, and chloroform began to be used as an anesthetic.^{19,20} This period was later seen as offering the best training for surgeons during the US Civil War, not least for the empiric assemblage of surgical experience and for innovations in post-fracture care, including plaster of Paris casting.^{20,21}

United States Civil War and the Spanish-American War

Several medical advances were made during the Civil War era. Nursing became more common; there were organized attempts to improve sanitation, as institutionalized in the US Sanitary Commission of 1861; and health professionals became increasingly sensitive to the idea of preventive medicine. Surgical activities broadened in complexity and scope. Ether and chloroform were used more commonly during most surgical procedures.^{14,22,23} Amputation became the most common surgical procedure. It was essentially a radical débridement that saved lives and facilitated the transport of wounded soldiers. Surgeons performed more than 50,000 amputations, using a broadening array of instruments and procedures and applying an increasingly sophisticated understanding of the importance of the interval between injury and treatment in reducing mortality. Early in the war, panels of surgeons would assess the optimal surgical approach; later, such panels yielded time to expediency and experience. Surgeons characterized and studied wound shock. They also attempted the first open reductions using internal fixation and performed nearly 100 complex hip disarticulations (albeit with 80% to 90% mortality rates). Increasing numbers of excision and resection were done, as well.^{14,18,22-30}

Organization was the key to effectiveness. Early in the Civil War,

the Army placed the system of trauma care and its infrastructure under medical command and control.⁵⁻¹⁴ Jonathan Letterman, Medical Director of the Army of the Potomac, devised that infrastructure, which included mobile field hospitals near battlefields, stratified organization of combat care, boats and railroad cars outfitted to transport the wounded in relative comfort and safety, and careful record keeping. The Letterman system strongly influenced not only care provided during the Civil War but also military medicine worldwide.^{29,31} Not only did the surgeons of the Spanish-American War inherit this organizational system, but they were also armed with shipboard radiographic technology on the US Army Hospital Ship *Relief*. Additionally, the greater medical community benefited from the dissemination of an effective germ theory and antiseptic technique as well as knowledge of even more effective anesthesia delivery mechanisms.

World War I

The physical and technologic environment of World War I challenged the earlier progress made in wound healing. To conserve fighting forces, surgeons built heavily on the Allies' experiences with healing wounds caused by grenades, aerial bombing, and the infections bred in the trenches, enabling the soldier's potential return to active duty. However, surgeons also had to contend with changes in projectiles themselves and the progressively greater use of rapid-fire artillery. Most importantly, triage emerged as a standard procedure.^{5,32} Débridement of complex wounds, followed by open treatment with antiseptic techniques and delayed primary closure, became so refined that surgeons all but abandoned prophylactic amputation for all compound fractures.

In some patients with compound fractures of long bones, bone frag-

ments were left in place to preserve their continuity and facilitate repair. Some authors credit the technique of splinting for gunshot wounds with a significant reduction in mortality. When amputation was necessary, surgeons used both flap-building and circular approaches. Surgeons also drew from well-documented British experiences of repairing joint injuries as an alternative to amputation. Wide excision of tissue was done to reduce the mortality of those wounded by projectile.^{14,18,27,33-35}

Awareness of the mechanisms of hemorrhagic shock and fluid volume depletion went hand in hand with the use of blood transfusion, when available.^{4,6,36,37} By the end of the war, first aid kits (first issued in 1892) included specially prepared bandages and items that could accelerate care at the battle site. Increased knowledge of drainage, immobilization, and local antiseptics was also disseminated.^{38,39}

Some lessons would be relearned after US entry into World War II—techniques such as delayed primary closure and managing joint wounds by simple débridement. Surgeons during World War II also could refer to research from the interwar period. Military initiatives provided a solid understanding of the mechanisms of and protection from wounds caused by high-velocity missiles.⁴⁰ Groups that had traveled to Europe in the 1910s—such as the American Expeditionary Force's Goldthwaite Unit under Major R. H. Goldthwaite—became the leaders of medical professional societies that prepared the way for treating soldiers in the next war. These surgeons served on special committees of surgical associations, participated in international conferences, and documented their experiences in the medical and surgical literature.⁴¹ Those academic underpinnings of World War I were reassembled into nationally organized research initiatives, such as the Office of Scientific Research and Development during World War II,

and allowed the military medical community of the era to revalidate many of the lessons of the earlier war. The field advanced under the growing influence of specialists and experts as its practitioners gained influence and standing in the military and directed the attention of military research organizations to battle trauma.^{14,42-45}

World War II

Chemotherapeutics and the introduction of antibiotics (eg, sulfonamides, penicillin) distinguish trauma treatment in World War II. The development of antibiotics and blood substitutes advanced faster during warfare than they likely would have in peacetime,^{5,45-47} and surgical techniques progressed apace. Although the Army mandated delayed closure procedures in 1943, new traction technologies facilitated success. Indications for amputation included severe mangling, significant joint damage, poor distal limb perfusion, impending gangrene, and severe nerve injury. Surgeons performed procedures at the lowest limb-salvage level possible. The tubed pedicle flaps used in World War I were adopted to address the chronic problem of osteomyelitis. Antimicrobial therapies for combating both the invasion and proliferation of infecting bacterial organisms multiplied, as did devices for the increasingly successful internal and external fixation procedures.^{10,27,33,48} The discipline of hand surgery, led by Sterling Bunnell, MD, came into its own in this environment. Many postwar amputation centers were built, which housed research on both the development and use of prosthetics.

Vascular surgery and important research into the metabolic response to trauma became paired to save life and limb. Although inadequate capillary perfusion was cited as the cause of shock in World War I, in World War II its cause was discov-

ered to be inadequate arterial blood pressure. Military surgeons performed important research on the nature of capillary perfusion in order to discern the cause of shock. Their growing appreciation of the phenomena facilitated successful resuscitation, and the transfusion and whole blood distribution programs begun during World War II continue to save thousands of lives.^{8,37}

Korean Conflict

After World War II, mainstream medicine became more specialized as technically trained surgeons, tested in battle, returned stateside. Topics evidencing these special interests proliferated in the medical journals and developed in the civilian sphere, so much so that the Korean Conflict marked the first time civilian trauma surgical developments informed military surgery. Helicopters evacuated more than 22,000 patients in Korea as part of an increasingly swift medical transport system, ensuring that the injured would receive significant surgical treatment within 2 to 4 hours of being wounded, including the vascular repairs that reduced the need for amputation to its lowest level in twentieth-century combat. Manuals explained ways to assess the viability of muscles injured in trauma. The mortality rate from wounds dropped to 2.4%.⁴⁹⁻⁵² Shock and blood loss were better understood during this conflict; whole blood was available in adequate amounts, and related research began to illuminate intracellular fluid mechanics.

Vietnam Conflict

The Vietnam conflict saw not only increased success with vascular repair, use of mobile blood banks, and treatment of hypovolemic shock, but also new classes of reperfusion injury. Transportation by helicopter remained commonplace, effecting an injury-to-surgical care period of 1

to 2 hours^{7,33,37} and setting the stage for increasingly mobile and flexible levels (echelons) of staged medical care of the type seen in more recent engagements. Amputation rates in more recent engagements have remained at nearly the same level as in Vietnam (approximately 14% of serious wounds), with limb salvage rates today near 20% to 25%.^{53,54}

Future Directions

Injuries from high-velocity weapons and blast injuries are complex; they are deeply penetrating and also involve burns and blunt trauma. However, the more ambitious limb salvage attempts, which often require the new "battlefield band-aids" (ie, bandages treated with chitosan) to assist clotting, as well as demanding pain management techniques, are increasingly successful. These procedures are performed in individuals with multiorgan trauma who require prolonged external fixation and many surgical procedures.^{53,54} As combatant forces disperse, so must the medical system; as weapons increase in lethality, medical assets become more vulnerable. Nevertheless, transportation systems and echeloned care have remained highly mobile and responsive to surgical need. The mobile army surgical hospital unit has given way to deployable rapid assembly shelters and combat support hospitals. Forward surgical teams can now begin treatment within minutes of injury and offer carefully staged medical care.

The trauma care of the future may continue to build on that of the past. Already the old dog tags, complete with blood type, have given way to the personal identification card bearing more extensive patient information, thus enabling more efficient information gathering and recording. The mortality rate from trauma continues to decline as medical infrastructure and organization become more sophisticated and as infection management, anesthesia,

and antiseptic techniques successfully meet new challenges. Care now is offered almost immediately, decreasing the achievable “golden hour” to a much smaller interval, and all armed services are involved in surgical care and transport. All the while, military trauma teams maintain morale and fulfill a moral imperative to provide state-of-the-art care for those who serve in harm’s way.⁵⁵

Perhaps the least recognized contribution has been that of the compiled medical statistic, that registry of procedures, results, images, and reports that informs bold research and response. It finds expression also in the hand-carried medical texts, whether those of the medieval barber-surgeon or the *Emergency War Surgery NATO Handbook* and the latest edition of the *Textbook of Military Medicine*. This information is the foundation of future advances, as demonstrated by the Extremity War Injury Symposium and these published proceedings.

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