

Surgical Lessons Learned on the Battlefield

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"I would remind you again how large and various was the experience of the battlefield, and how fertile the blood of warriors in rearing good surgeons." [1]

"The dividing lines between trauma in the civilian and military populations are becoming, unfortunately, increasingly blurred." [2]

SOME HISTORICAL ASPECTS OF THE ORIGINS OF MILITARY MEDICINE AND SURGERY

(Figure 1) The origins of military medicine in the United States date to the first days of the Revolutionary War. [3] In that campaign, a physician-patriot named Dr. Prescott, of Lexington, Mass, was involved in the activation of the minutemen, fought in the Concord engagement beside these first soldiers, and subsequently transported and cared for those wounded in his home. During the revolution, the Continental Congress approved a medical department, but this was dissolved at the end of the war. At the time of hostilities with Britain in 1812, there was a provision for hospital surgeons but no medical department or surgeon general. Although this was eventually addressed, it was not until after the war with Mexico in 1846 that a study was performed that resulted in the introduction of ambulances for the transport of the wounded from the battlefield. When the American Civil War began, military resources were limited and unprepared for the magnitude of the task required of them. Many different factors contributed to the nonexistent state of readiness present in the medical department. [3-5] There was only a small standing army supported by limited medical resources. The policy of hands-off Federalism practiced at the time resulted in limited commitment of funds to support the medical department, compounded by a surgeon general who publicly denounced the costly practices in the medical care of the day. The standards for medical training in the United States resulted in physicians trained in a variety of different methods with little consistency or competence. Yet all called themselves physicians. The militia system depended on to field the large volunteer army necessary for the conflict was unsuited to the recruitment, training, and equipping of the forces who responded to the call. Death from illness far exceeded death from wounding, with the common soldier and officers sharing equally in the risk of dying from diseases such as typhoid, dysentery, pneumonia, and tuberculosis. [5, 6] Death from wounding was also a significant risk. More soldiers died from wounds in this conflict than in any of the subsequent major wars fought by the United States in total. [4] Several factors, including an ill-prepared military, an inadequate medical department, and the horrendous death rates from illness and wounding, frequently overshadowed the good accomplished by the medical department as it improved during the war years.



Figure 1. William F. Fallon, MD, FACS, President, Eastern Association for the Surgery of Trauma

The origins of military surgery have been felt to date to 1899. [7] Practices before that time involved conservative, observational treatment for penetrating abdominal wounds. Soldiers were kept at rest to limit the extent of peritonitis from wounded hollow viscera and to allow these wounds to seal. It was recognized in the mid 19th century that eviscerated intestine with injury could be closed with sutures, but there was not a general consensus on the use of abdominal exploration for penetrating abdominal wounds. This changed in World War I. [8] Mortality rates from abdominal injury decreased to 50%, and the prompt use of abdominal exploration for injury became the standard for military surgeons. Further refinements of this operative policy for abdominal injury occurred through experience in subsequent wars.

Military surgery does not represent a significant departure from the accepted surgical standards that we practice today. For the military surgeon and the medical department, the challenge is to maintain these principles even under difficult or adverse conditions. There are certainly operational differences between surgery in military and civilian settings, however. These relate primarily to the process of wounding and the types of treatment and evacuation necessary for the care of casualties who must also be removed from the potential for further injury in the ongoing battle. Chief among these is the pattern and type of wound sustained. [9-12] Military weapons are typically high-velocity and are associated with extensive tissue destruction and contamination requiring specific treatment protocols. There is also a pattern of wounding by multiple fragmentation seldom encountered in the civilian setting. The sequential pattern of postinjury wound care and postoperative care necessitated by the echelons of care in which different surgeons and surgical teams may care for the wounded soldier at various points in the recuperation from injury is not practiced in the civilian sector. Finally, although all civilian hospitals practice for mass-casualty events in their facilities, and some occasionally experience them, it is typical of the military surgical hospital to regularly receive large numbers of casualties in short periods of time. This requires a different approach to the wounded than what is routinely practiced in the civilian setting.

As Dr. Rich alluded to in his Hume Memorial Lecture in 1993, [2] there has been some blurring of the differences between wounding in combat and the pattern of injury seen in the civilian sector. Multi-fire, higher-velocity weaponry is finding its way into the hands of individuals in the civilian sector who use them for all sorts of purposes and with predictable results when the target is another human being. Terrorist groups engaged in campaigns to accomplish specific agendas have resorted to bomb attacks that can result in multiple casualties sustaining wounds from fragments of the device. Civilian refugees from civil strife yield victims wounded by high-velocity weapons of military make, often among the very young and defenseless. The likelihood that civilian surgeons will encounter wounds similar to those seen by our military counterparts is increasing. Fortunately, the modern civilian surgeon caring for critically injured patients has benefited greatly from the century of advances in combat casualty care seen in the medical departments of the United States military. There are several that I wish to discuss with you today. These include principles for the debridement of wounds, resuscitation from shock, the treatment of thoracic injury, and the management of colorectal injury. Although these areas do not represent a complete list of advances in the care of the injured learned from the

battlefield, they are, I believe, the basic treatment methods necessary for every surgeon to know who cares for injured patients today.

WOUND CARE

Wound care strategies are as old as recorded accounts of combat. All are linked by the recognized need to stop bleeding, treat the wound itself, remove impaled, embedded objects or projectiles, and promote healing. In the 19th century, wound care, as described in a surgical text published in London in 1859, [13] entailed the arrest of hemorrhage, the extraction of foreign bodies with the use of probes, and the treatment of the wound itself to limit the inflammation associated with the wound. This often involved incision along the course of the wound. The wound classification system of the 1800s divided wounds into four categories: incised, lacerated, contused, and poisonous. Gunshot wounds were considered contused, lacerated wounds that occurred as a consequence of "the nature of the projectile, the force with which it is [the projectile] driven, and the direction in which it strikes." [13] Because wound healing almost always proceeded by suppuration, incision along the course of the projectile's trajectory may have been an attempt to provide external drainage for the process. An alternative hypothesis has to do with the nature of wounds and how they heal. It was known that clean, incised wounds healed by primary intention more frequently than wounds contaminated with contused, necrotic tissue and foreign bodies. An excisional approach to these wounds perhaps was an attempt to convert a contaminated wound into a clean one for healing purposes. These two approaches are the foundation of the concept of debridement, which was first popularized in this century during World War I. The exact origin of the term is hard to determine. Various authors credit surgeons from Larrey [7, 14] to Hunter [12] to the French military surgeons. [8, 12] The word "debridement" literally means to unbridle, [15] "to dilate by incision the path of the ball." [13] These incisions should be "free incisions, in the direction and the axis of the limb, to lessen inflammatory tension, prevent extension of sloughing and favor the escape of matter." [13] This interpretation of debridement was typical of the French, who practiced three specific maneuvers in wound care: debridement, epluchage, and parage. [12] Debridement is consequently, most likely in reference to the initial stages of wound exploration and fasciotomy, opening and looking at the depths of the wound, which also served to relieve intracompartmental pressure, evacuate hematoma, obtain hemostasis, and assure drainage.

American surgeons took an approach to debridement that was based on an aggressive philosophy. George Crile, writing about wounds seen in the First World War, noted that more than 95% were infected. [8] He proposed and practiced "excision revision" to restore wound resistance to infection and promote wound healing. This was referred to as debridement by the Americans and actually encompassed all the separate phases of wound care practiced by French surgeons and others in staged fashion. [12] In the Second World War, research by the British documented a wound culture-positive rate of 51%, and debridement was less extensive as a result. [12]

All concepts of debridement take into consideration the wounding potential of projectiles. It is well known that the mass and velocity of the projectile set the theoretical limit of potential disruption of tissue that can occur with wounding. The construction and shape of the projectile limit the potential that can be reached. Debridement is a particularly important treatment for the "compound" full metal jacket projectiles used in every conflict since the turn of the century. [16] It recognizes and accommodates the ballistic behavior of these projectiles and is particularly suited to addressing the secondary cavitation that has been recognized since the introduction of these bullets. [12, 16] It is very appropriate for the care of wounds in which fragmentation has occurred. Debridement as practiced today includes using a minimal skin incision. [7, 12] Wounds may be extended to allow exposure. If this is done, it should be along the long axis of the extremity. The fascia should be incised liberally as well, to achieve exposure of the depth of the wound. Injured muscle should be excised to bleeding tissue, normal color, consistency, and contractility. Bone incised should be conservative, with only nonviable fragments removed from the wound. Tendons, nerves, and blood vessels should be debrided sparingly. Blood vessel repair should be performed if indicated after excision of the gross injury at the end of the vessel. Arteries and veins are treated in the same way. All wounds are left open for delayed primary closure or skin graft at a later date.

SHOCK

Like wound care and debridement, shock was a phenomenon recognized in the 19th century. It was, however, less well characterized than wounding. A surgical text published in London in 1859 had a total of 1,000 pages. Three were devoted to the subject of shock. [13] Despite the relative paucity of description, many of the observations are quite accurate and pertinent to how we view shock and injury today. Shock was considered to be an immediate and constitutional effect of injury. This was noted to lead to disturbance of the functions of the circulatory, respiratory, and nervous systems. The magnitude of the manifestation correlated with the severity of the injury and the duration of the condition was proportional to the extent of the injury. The condition was noted to last for a variable period of time. The duration depended on the severity of the injury and the extent of the "nervous susceptibility" [13] of the individual. It was recognized that this susceptibility might lead to death from shock in some individuals. Most recovered, however. Reaction set in and the disturbed balance was gradually restored. This reaction, however, could progress beyond normal limits and lead to febrility as well as remote local consequences. Read in the context of our present understanding of shock after injury, this sounds as if the author is describing the systemic inflammatory response seen with some forms of severe injury today. Another prescient observation was that this reaction beyond certain limits was recognized to be the source of many structural diseases. This observation was based on autopsy data obtained when the patient with shock died months after injury. Alterations in structure with extensive, local mischief, usually of an inflammatory character, was noted on autopsy. This appears to be one of the first references to multiple organ failure as a consequence of the injury and shock state. There is no mention, however, or recognition of the correlation of shock with blood loss.

Death from blood loss on the battlefield is the result of a complex interaction involving the type of wound sustained, the time interval from wounding to definitive care, and the treatment employed. In the 19th century, improvements in the evacuation of the wounded from the battlefield occurred with the innovations of Larrey in the Napoleonic Wars and with the organizational improvements introduced by Letterman in the American Civil War. [3, 15] In the wars of this century, improvements in evacuation were associated with decreasing mortality rates. In World War I, it was observed that mortality was only 10% in those who reached care within 1 hour versus a 75% mortality rate for those who reached care more than 8 hours after wounding. [3] It appears that this is the origin of the observation of the "golden hour" after injury. In terms of the treatment available, blood transfusions were used to treat the low venous pressure seen among patients with shock. Surgeons recognized the necessity to balance restoration of blood pressure with surgical control of the wound and hemostasis. In the Second World War, after a shaky start, the wounded soldier benefited from improvements in evacuation, resuscitation, and the use of blood products. Reports of organ failure, particularly renal failure, began to be observed among some who were treated for massive shock. In Korea and in Vietnam, there was a steady improvement in the evacuation to definitive care that lessened death on the battlefield from wounding. The military employed the helicopter, first introduced in World War II, to rapidly transport wounded soldiers, often directly from the battle or forward aid stations. Resuscitation with blood products primarily was supplemented by the aggressive use of crystalloid. There was increasing experience with organ failure. The exposure of our soldiers to wounding has not decreased as the century draws to a close. This final decade has seen short, fierce engagements throughout the world with wounded soldiers as a result. A report from the experience of the U.S. Army's 7th Corps in Operation Desert Storm, recently published in the Journal of Trauma, describes 143 casualties that were treated. [17] Of those who arrived at the hospital to receive treatment, three died. All of these deaths were the result of extremity exsanguination. Two occurred from traumatic proximal amputations and one from blood loss not controlled by a tourniquet. The tourniquet is difficult to use correctly in controlled circumstances. When not properly applied, it clearly is problematic. As early as 1924, the tourniquet was viewed with skepticism. George Crile stated, "Were the tourniquet [and the probe] lost at sea, it would be a question as to whether it would be a loss or a gain." [8] Just as our experience with wounding, blood loss, and hemorrhage control are clearly connected to the early experience with these entities, so too is our present understanding of shock. We recognize that a complex set of neuroendocrine reflexes is induced by shock and injury stimuli. The goals of therapy, both on the battlefield and in the civilian trauma center, include correcting tissue injury and restoring effective circulation.

THORACIC INJURY AND TREATMENT

Management of thoracic injury has progressed significantly from the treatment methods described in the 19th century. Military lessons learned have been instrumental in this progress. Treatment in the 19th century for gunshot wounds to the chest was rather limited. [13] The reported mortality was 50%. If a patient survived expectant management for 3 days, then treatment of the wound site would often be initiated. This treatment would entail closing the wound, removal of foreign bodies if accessible, and bleeding the patient to reduce

venous pressure. This last maneuver was purported to reduce the bleeding that occurred within the chest after wounding. Nineteenth century physicians recognized the importance of closing penetrating wounds to the chest, the importance of removing foreign bodies, and that surgery might be required for ongoing hemorrhage. The common opinion of the time was that bleeding within the chest would serve to tamponade the site of bleeding from the injured lung. Later, for retained blood clot or infection, puncture and aspiration might be required.

The treatment of thoracic wounds in World War I started with many of the basic principles of 19th century medicine. [8] Specifically, there was persistence of the expectant therapy for hemothorax. Hemothorax was not aspirated in the belief that tamponade of the injured lung occurred. Surgeons practiced airtight closure for wounds and removed foreign bodies. Surgery, however, was delayed for 24 hours to ensure that the patient was likely to survive the wounding event. When surgery was practiced for thoracic injury in the First World War, it was very aggressive and largely successful. [18,19] In contrast to their surgical counterparts in the German army, American surgeons with the Allied Expeditionary Force used positive pressure anesthesia and a nitrous oxide/oxygen mixture. Formal thoracotomy allowed for the best exposure. The chest injury was handled with resection, suture ligation, and irrigation of the cavity. The thoracotomy incision was closed airtight, traumatic wounds were all excised, and no drains were placed. This technique was associated with a decrease in mortality to 9% in these patients. [18-20]

In World War II, there was a recognition of the frequency of problems associated with hemothorax after wounding, and aggressive conservatism for hemothorax was widely adopted. Thoracentesis was used, often repeatedly, until the chest was dry. No air was injected into the pleural space, and the lung was allowed to re-expand and tamponade the bleeding. This was also obviously good for returning pulmonary function to more normal levels. Thoracotomy was reserved for those in whom this maneuver was unsuccessful. Water-sealed, intercostal catheters were placed in patients with tension pneumothorax. Additional indications for thoracotomy included thoracoabdominal wounds, continued hemorrhage or significant air leaks, mediastinal structure injury, traumatic thoracotomy (the sucking chest wound), and some forms of foreign bodies. Overall mortality with treatment of chest wounds was reported as 7.9%. [21-23]

The conflict in Korea was a challenge for the medical corps components. [24-26] Rugged terrain and chaotic, often unstable or unfavorable tactical conditions coupled with numerous casualties placed tremendous pressure on forward treatment areas. Early air and sea evacuation of patients who often still required resuscitation was a logistic necessity. The medical support was unprepared for the rapid escalation of this conflict. The conservative management of traumatic hemothorax was a treatment strategy very suited to these conditions. In one series of patients reported from the Korean War, 80% were managed by repeat thoracentesis alone. In contrast, there was a poor experience with the intercostal catheter for drainage of hemothorax. The introduction of more advanced resuscitative techniques helped to compensate somewhat for the problems encountered with forward treatment.

In Vietnam, chest tube drainage for chest injury and hemothorax was widely practiced. [27] Casualties arrived early at the hospital, often within 90 minutes of wounding or directly from the site of wounding. Well ordered and organized "trauma centers" functioned with good resuscitation protocols. Given the success of tube thoracostomy in this environment, early thoracotomy was indicated for fewer patients with hemothorax, although the other indications for its use remained. Tube thoracostomy today is still the mainstay for the treatment of traumatic hemothorax.

COLORECTAL INJURY AND TREATMENT

In World War I, wounds of the colon and wounds of the rectum occurred with differing frequencies, 22 and 2.4%. Mortality for these wounds was not too different, however, 60 and 45%, respectively. [7, 8, 28-31] Although mortality was substantial, it nevertheless represented real progress over the experience previously reported. A policy of immediate operation for penetrating abdominal injury was largely responsible for these gains. Crile, in his monograph on wartime surgery, described the components of immediate operation. [8]

These included concepts that are very familiar to the trauma surgeons of 1997. A midline incision, extending from xiphoid to pubis, was essential for adequate exposure. The concept of damage control, e.g., the use of an

abbreviated laparotomy with temporary abdominal closure to control fecal contamination and hemorrhage control, for patients who were unstable at the time of surgery was embraced. Repair of the kidney if injured was used. Pancreatic injury was drained. The risk associated with a colorectal injury involving the retroperitoneum was understood. Unresolved at the end of the experience of the First World War, however, was the issue of primary repair or diversion for the treatment of colorectal injury. In fact, some experience seemed to favor primary repair. Other reports were not as laudatory, and diversion with colostomy became the required approach.

Based on recommendations from the Surgeon General's office for the management of colorectal injury, a pattern of treatment evolved in World War II and in the Korean conflict. [31] The use of colostomy for these injuries became a mandatory part of treatment. The colostomy had to be fully diverting to completely divert the fecal stream. This was particularly important for colorectal injury. And with this treatment plan, mortality from these injuries continued to decline. In World War II, it averaged 30 to 40%, and in Korea, it decreased even more to 15%. [28] A key component of this strategy, often overlooked, was the policy of not closing any wounds. This reduced the risk of infection and eliminated the wound as a potential source of missed infection that might possibly complicate treatment during the evacuation process. [7]

In Vietnam, distal washout was added to the treatment plan for rectal injury. In a series of cases comparing the use of distal washout with patients for whom it was not used, Lavenson and Cohen [32] documented dramatically different outcomes. With distal washout, there was minimal morbidity (10%) and no mortality; without distal washout, there was significant morbidity (72%) and substantial mortality (22%). Standard care for rectal injury had thus developed into four distinct maneuvers: diverting colostomy, presacral drainage, washout of the defunctionalized distal segment, and repair of the rectal injury if possible.

Other aspects of the treatment of colon and rectal injury learned from the battlefield included the concept of prompt abdominal re-exploration. With soldiers receiving care at different intervals after wounding as well as receiving different aspects of care at various locations, surgeons practicing at different sites in the evacuation chain must exert due diligence to avoid any delay in detecting intra-abdominal post-operative complications.

Leaving abdominal wounds open to the fascia was one technique used to adapt the treatment of the wounded to the constraints of evacuation. A high index of suspicion regarding missed injury and intra-abdominal abscess with the early use of reoperation was another important technique to promote optimal care through the evacuation process.

The method of stoma closure when no longer necessary was also unique in the military. Colostomy takedown also used the technique of delayed closure of the abdominal wound to minimize infectious complications, primarily wound infections.

CAVEAT EMPTOR

Historical reviews such as this one are always highly personal. My interest in this topic and my perspective on the issues discussed stem from my experience with military medicine as a resident in the surgery program at Walter Reed Army Medical Center from 1977 through 1981. Many readers will have far more experience and expertise than I in the care of the injured soldier. And I certainly would not criticize other scenarios for surgical lessons learned from the battlefield, particularly from those who have actually experienced surgical practice in those settings. Yet, my practice has been significantly influenced by the lessons of combat casualty care in the areas I have outlined, and I feel that I am a better surgeon for it.

Thank you all very much.

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