

9

Acute arterial injury in U.S. military surgery



AMERICAN COLLEGE OF SURGEONS

*Inspiring Quality:
Highest Standards, Better Outcomes*

100+ years

AUTHORS

Nils-Tomas D. McBride, MD

Jay B. Fisher, MD, FACS

Harjeet Kohli, MD, FACS, MRCP, FRCS

Department of Surgery, Easton Hospital, Easton, PA

CORRESPONDING AUTHOR

Nils-Tomas D. McBride, MD

Easton Hospital, Department of Surgery

250 S. 21st St

Easton, PA 18042

610-250-4000

NilsTomas_Mcbride@chs.net

Hippokrates of Kos said, "He who wishes to be a surgeon must first go to war." New surgical techniques are discovered and old ones are perfected close to the battlefield.¹ Surgery for arterial injury is a perfect example of how a century of American military conflicts established modern principles of vascular repair.

Civil War

I noticed a heap of amputated feet, legs, arms, hands, etc. – about a full load for a one-horse cart.

—Walt Whitman

In the Civil War amputation was the sole lifesaving option for acute arterial injury (Figure 1). From 1861-1865 an estimated 60,000 amputations were performed, accounting for about three-fourths of all operations performed during the four years of the conflict, most of which were for gunshot injuries to the limbs.² Technical manuals describe arterial ligation and primary amputation by a circular incision under tourniquet for hemostatic control in cases of arterial injury.³

Because prompt surgical control of bleeding dictated survival, the majority of soldiers with arterial trauma died. In the First Battle of Bull Run (Battle of First Manassas, July 21 1861) wounded soldiers had to make their own way from the battlefield to the only hospital in Washington, DC, a distance of 27 miles, to receive medical care.⁴ General George McClelland, commanding general of the Army of the Potomac, gave Major Jonathan Letterman, MD, authority to reorganize the medical care of his troops. By war's end Letterman had been given Presidential authority to organize hospitals in cities and on trains and ships to create a national network of an estimated 400,000 beds to transport, receive, and care for the Union wounded.⁴

Letterman's efforts had an immediate impact on survival from gunshot wounds and arterial injuries. More soldiers survived transport to field hospitals where they underwent amputations sooner after initial injury and at more distal levels. Mortality rates decreased as the war progressed as a result of the reorganization of field care,⁵ the primary reason for the reduction in mortality in previous major conflicts such as the Crimean war.⁶

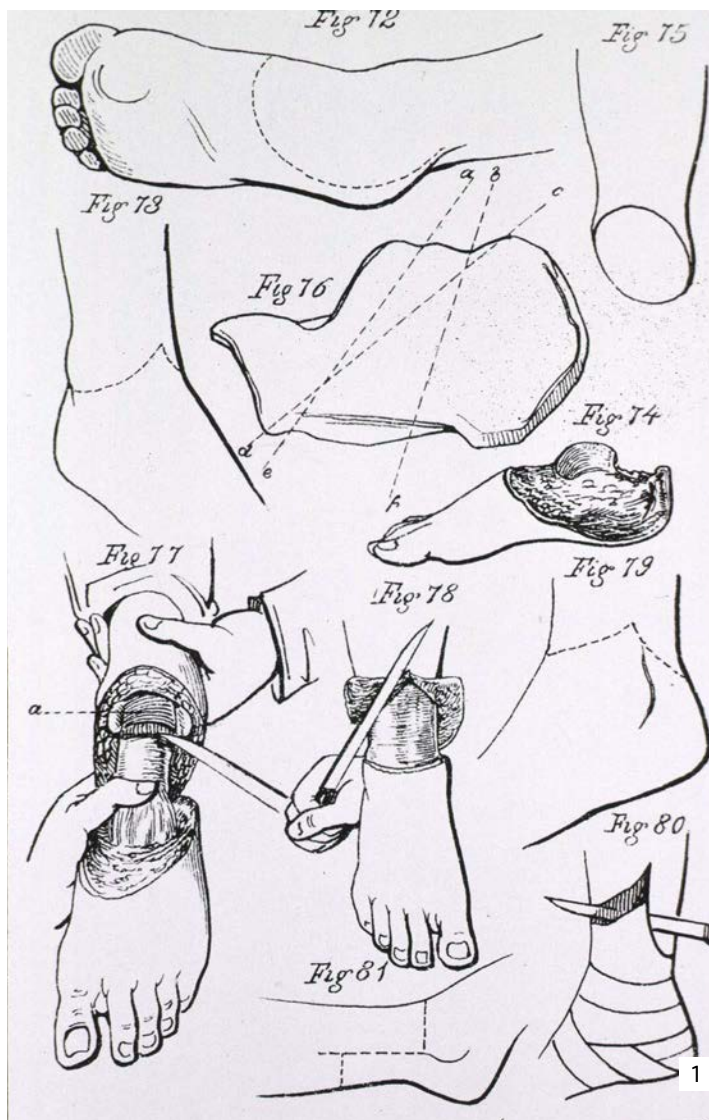
World War I

Your blood coagulates beautifully.

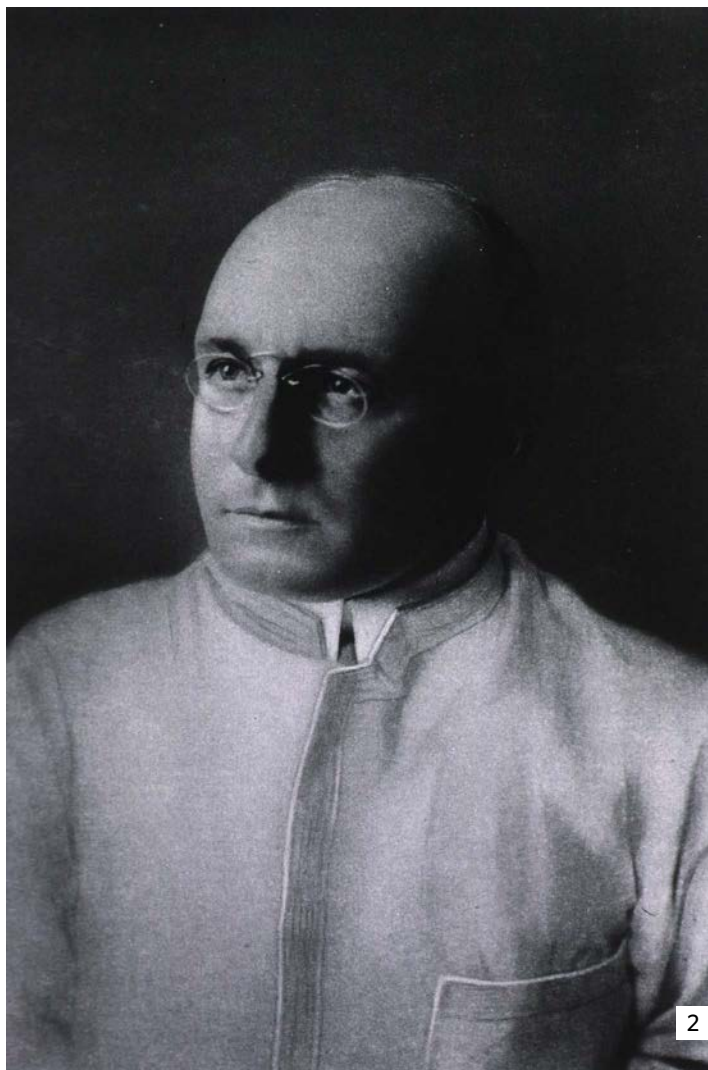
—Ernest Hemingway, *A Farewell to Arms*

World War I brought the myriad advancements in medicine and technology in the last half of the 19th century and the beginning of the 20th to military medicine. Systems of field surgery were well-established by the time the U.S. entered the war in 1917. American physicians and surgeons attached with the American Expeditionary Force saw the operation of British Casualty Clearing Stations (CCS) staffed by surgeons, anesthetists, and nurses just 6 to 9 miles behind the front lines.⁶ U.S. military surgeons adopted the French system of triage of the wounded developed by Antoine De Page (1862-1925).⁷

Karl Landsteiner's work delineating the major ABO blood types and the experience of the surgeons in the British Second Army



with transfusion led American surgeon Oswald Robertson (1886-1966) to deduce in 1917 that stored universal donor whole blood could be given quickly and safely in forward medical units.⁸ English chemist Henry Dakin (1880-1952), joined French-American surgeon-scientist Alexis Carrel (1873-1944; Figure 2) to develop the Carrel-Dakin method of wound decontamination, irrigating battle injuries with his namesake solution prior to closure.^{9,10}



Carrel's technical achievement of vascular anastomosis, for which he received the Nobel Prize in medicine in 1912, and the improvements in wound care that he put forth with Dakin encouraged American surgeon Bertram Bernheim to attempt primary repair of vascular injuries. While he had some success, he was discouraged due to the high rate of infection. "(It) would have been a foolhardy man," he said, "who would have essayed sutures of arterial or venous trunks in the presence of such infections as were the rule in practically all of the battle wounded."¹¹ Repair of arterial wounds in battle would need advances in infection control, resuscitation, and continued logistical improvements to reduce the time between injury and definitive care.

World War II

It doesn't make a damned bit of difference who wins the war to someone who's dead.

—Joseph Heller, *Catch-22*

During World War II (WWII) American forces had 535,000 medics, 57,000 nurses, 47,000 physicians, and 2000 veterinarians under the leadership of Surgeon General Norman Kirk (1888-1960). Each battalion had two combat medics to make an initial determination whether if an injured soldier required evacuation to a battalion aid station. If an injury needed additional treatment, the patient was sent to a divisional clearing stations where urgent surgical took place. Definitive care was provided at 700 overseas hospitals and military facilities stateside. Kirk's guidelines, developed before his appointment as Surgeon General, were adopted as standard procedures: Leaving skin and soft tissues longer than the bone in amputations, double ligation of blood vessels, and delayed closure of contaminated wounds.¹²

Improvements in record keeping allowed Michael DeBakey (1908-2008; Figure 3), Colonel and Chief of the Surgical Consultants Division, and Colonel Fiorindo Simeone to track outcomes of 2471 cases of acute arterial injury during WWII.¹³ Primary repair was attempted only 81 times, with only a slightly improved subsequent amputation rate (36%) compared with arterial ligation (50%). They recognized significant obstacles to successful arterial repair, including delays in treatment and the hazard of contamination of the wound and subsequent infection, often precluding vascular anastomosis.¹³ Overcoming these problems would allow primary repair of arterial injuries in subsequent American military conflicts.

Korean and Vietnam Wars

Major Taylor: A British artery in an American leg, eh?

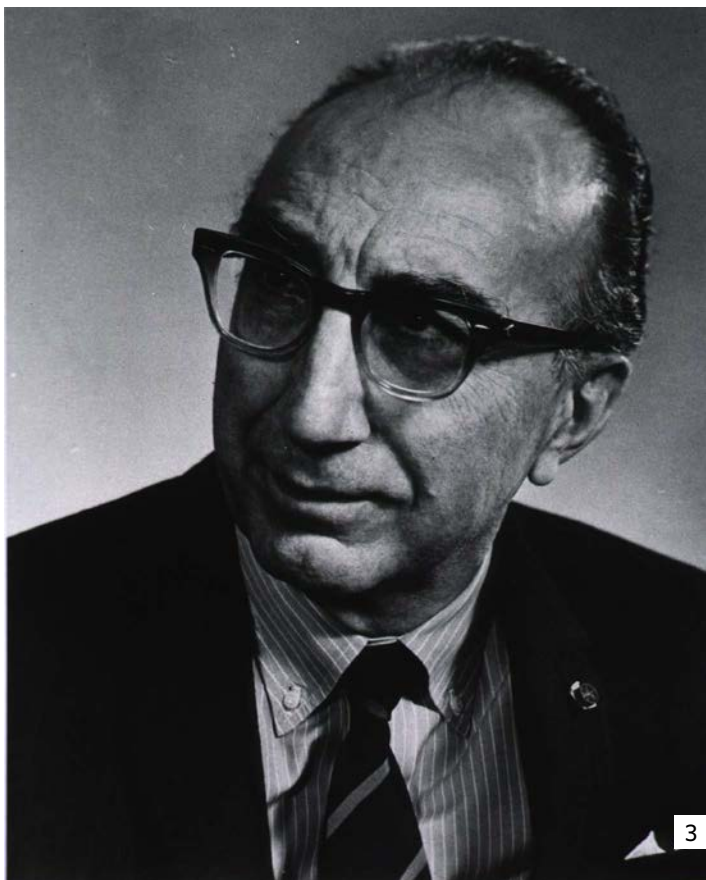
Capt. Benjamin Franklin "Hawkeye" Pierce: Right.

Taylor: Probably develop an irresistible urge to drive on the left side of the road.

Pierce: Quite.

*M*A*S*H Season 3, Episode 17: The Consultant*

DeBakey's WWII experience led to the development of Mobile Army Surgical Hospital (MASH) units in the Korean War. Thus operations to save life and limb were performed within 10 miles of combat. Helicopter evacuation became the modern equivalent of Dominique Larrey's *ambulance volante* (flying ambulance) during the Napoleonic Wars. Research at the Walter Reed Army Hospital before the war focused on homograft replacement of injured arteries and prolonged ischemia on muscle cell death.¹⁴ Army surgeons therefore were ready to attempt primary vascular repair in field hospitals. Pioneering vascular surgeons Carl W. Hughes, Edward J. Jahnke,



John M. Howard, and Curtis P. Artz visited MASH units in Korea and employed up-to-date techniques and vascular instruments. With the advantages of antibiotics and blood products, the first 130 cases had an 89% limb salvage rate using either direct anastomosis or vein grafts.¹⁵ Army surgeons ultimately finished the conflict with a 13% amputation rate over 304 cases, compared to an overall amputation rate of 49% in World War I.¹⁵ Non-vascular specialist surgeons performed vascular repair in the Vietnam War, still achieving a limb salvage rate of 87% despite their varying levels of skills and training.¹⁶

References

- 1 Schlager N, Lauer. The Military Medicine of Ancient Rome. Science and Its Times. Ed. Vol. 1. Detroit, Gale, 2001. World History in Context. Web. Accessed September 29 2016.
- 2 Figg L, Farrell-Beck J. Amputation in the Civil War: Physical and social dimensions. *J Hist Med Allied Sci.* 1993;48(4):454-475.
- 3 Hamilton, FH. A Manual of Military Surgery and Hygiene. New York: Bailliere Brothers, 1865.
- 4 Hawk A. An ambulating hospital: or, how the hospital train transformed Army medicine. *Civil War History.* 2002;48:197-219.
- 5 Ellis H. Civil War Medicine: Challenges and Triumphs. *BMJ : British Medical Journal.* 2002;325(7356):170.
- 6 Ellis H. A History of Surgery. London, England: Greenwich Medical Media Ltd; 2001.
- 7 Iserson KV, Moskop JC. Triage in medicine, part I: concept, history, and types. *Ann Emerg Med.* 2007;49:275-281.
- 8 Stansbury LG, Hess JR. Blood transfusion in World War I: The roles of Lawrence Bruce Robertson and Oswald Hope Robertson in the "most important medical advance of the war. *Transfus Med Rev.* 2009;23(3):232-236.
- 9 Carrel A, Dehelly G. The Treatment of Infected Wounds. New York, NY: Paul B. Hoeber; 1917.
- 10 Hirsch EF. "The treatment of infected wounds," Alexis Carrel's contribution to the care of wounded soldiers during World War I. *J Trauma.* 2008;64(3 Suppl):S209-10.
- 11 Bernheim B. Blood vessel surgery in the war. *Surg Gynecol Obstet.* 1920; 30:564-567.
- 12 Manning MM, Hawk A, Calhoun JH, Andersen RC. Treatment of War Wounds: A Historical Review. *Clinical Orthopaedics and Related Research.* 2009;467(8):2168-2191.
- 13 DeBakey ME, Simeone FA. Battle injuries of the arteries in World War II. An analysis of 2,471 cases. *Ann Surg.* 1946;123:534-579.
- 14 Warren R. Report to the Surgeon General, Dept of the Army. Washington, DC, April, 1952.
- 15 Hughes CW. Arterial repair during the Korean War. *Am Surg* 1958;147:555-561.
- 16 Rich NM, Baugh JH, Hughes CW. Acute arterial injuries in Vietnam: 1,000 cases. *J Trauma.* 1970;10:359-369.

Legends

- 1 Amputation of the foot. A Manual of Military Surgery. Richmond, Confederate States of America, 1863. Image from National Library of Medicine.
- 2 Alexis Carrel. Image from National Library of Medicine.
- 3 Michael DeBakey. Image from National Library of Medicine.