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Reciprocal Learning Between Military and Civilian Surgeons

Past and Future Paths for Medical Innovation

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Numerous surgical advances have resulted from exchanges between military and civilian surgeons. As part of the U.S. National Library of Medicine Michael E. DeBakey Fellowship in the History of Medicine, we conducted archival research to shed light on the lessons that civilian surgery has learned from the military system and vice-versa. Several historical case studies highlight the need for immersive programs where surgeons from the military and civilian sectors can gain exposure to the techniques, expertise, and institutional knowledge the other domain provides. Our findings demonstrate the benefits and promise of structured programs to promote reciprocal learning between military and civilian surgery.

Keywords: damage control, Michael E. DeBakey, military-civilian collaboration, surgical innovation

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The history of medical innovation demonstrates that military and civilian surgical collaborations have profoundly influenced one another, allowing surgeons to achieve critical competencies, exchange knowledge and advance the disciplines of medicine and beyond. Despite the clear benefits of such collaboration, few structured programs exist to promote surgical innovation through military-civilian exchanges. To shed light on how civilian institutions can learn from the military system and vice-versa, archival research was conducted at the U.S. National Library of Medicine of the National Institutes of Health between 2017 and 2018. We reviewed historical case studies in which transfer of experiential learning between the military and civilian surgeons drove major innovations. Military-civilian exchange has benefitted both domains throughout history, and to consistently realize this benefit moving forward, a more deliberate, intentional approach is warranted.

We begin with a brief discussion of how military-civilian collaborations have spurred innovations through select examples from the 20th century. We then turn specifically to Colonel Michael DeBakey's contributions to highlight how military innovations benefitted civilian surgery, and then discuss damage control surgery (DCS) as an example from the more contemporary history wherein a civilian innovation benefitted the military. We conclude with a discussion of the strategies that key stakeholders in government, academia and the military can adopt to harness the opportunities afforded by military-civilian surgical collaboration.

TWENTIETH CENTURY INNOVATIONS IN THE ORGANIZATION AND DELIVERY OF CARE

Wars and international conflicts have acted as a natural setting for military-civilian partnerships. During times of major armed conflict, the U.S. Armed Forces have had a relatively small contingent of medical personnel in uniform, making it both customary and expected that civilian surgeons would be called upon to offer their support and skills to the military sector. Then, during peace-time, these surgeons would bring back to their civilian practices invaluable, and at times life-changing, lessons gleaned from clinical experiences on the battlefield. For instance, the concept of shock as being a distinct pathophysiologic entity from wounds and the evolution of its study and treatment exemplifies a productive bidirectional flow of information between the civilian and military domains. The need for managing disseminated intravascular coagulation and multiple organ failure in the severely wounded, suffering from hemorrhagic shock, evolved from wartime experiences and subsequent studies.[1]

Walter B. Cannon, a civilian physician who served at the Army Expeditionary Force during World War I (WWI), witnessed severe cases of traumatic shock, which led him to investigate the physiological changes in shock.[2] Upon returning to his civilian role at the Harvard Medical School after the war, Cannon performed seminal experiments to better understand systemic inflammatory responses, even coining the term "homeostasis."[3] In his monograph Traumatic Shock, Cannon summarized the knowledge gained during the war, from both direct observation of wounded troops, and laboratory experimentation on the causes and treatment of traumatic shock.[4] The concepts of hemorrhagic shock and rhabdomyolysis after a traumatic injury that he described remain indispensable to effective patient care today.

The National Research Council also presents itself as a prime example of how memorializing military-civilian partnerships left an indelible mark. During WWI, the U.S. government had a compelling need for medical advice regarding military preparedness. To recruit civilian medical consultants and bring their expertise to the military, President Wilson established the National Research Council in 1916.[5] At the end of WWI, Wilson recognized the importance of the bidirectional flow of knowledge between the military and civilian sectors,[6] and ever since, the Council's importance has been affirmed as evidenced through the executive orders by Presidents Eisenhower in 1956 and George H.W. Bush in 1993. President Eisenhower believed that military-civilian cooperation demonstrates its capacity for larger service, and his order stated that the Council should "direct the attention of scientific and technical investigators to the importance of military and industrial problems in connection."[7] Similarly, President Bush's order broadened the Council's charter, specifically to "promote cooperation in research."[8]

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During WWI, the formation of Red Cross and Reserve military hospitals further bolstered military-civilian partnerships. These hospitals, embedded within medical universities and teaching hospitals, mobilized in times of war to deliver care on the battlefield.[9,10] For example, the 20th General Hospital, organized by the University of Pennsylvania in conjunction with the Red Cross and the War Department, provided care for patients with battle casualties in France. Subsequently, this collaboration with the U.S. Army Medical Corps continued during WWII when, under the command of Isidor S. Ravdin, the 20th General Hospital provided care for over 70,000 patients in Myanmar. Ravdin, who had previously treated victims of the Pearl Harbor attack with an albumin solution for shock in 1941, further continued his investigations on the use of blood substitutes and surgical nutrition to treat war casualties.[11] The Red Cross and Reserve hospitals had another goal – that of providing the U.S. military with ready access to the sharpest minds in the civilian surgical sector. Subsequently, between WWI and WWII, and into the post-war period, ongoing consultation by academic surgeons to the U.S. military became the norm.[12–14]

COL. MICHAEL E. DEBAKEY'S CONTRIBUTIONS

Military experiences in wartime provide unique research opportunities. This is exemplified by the career of Michael E. DeBakey, whose military service is thoroughly documented in the National Library of Medicine archives. Although on active service (1942–1946), DeBakey realized that the medical activities of the armed forces generated vast quantities of data from medical records.[15] This inspired his implementation of a clinical research program, entitled the Medical Follow-Up Agency. DeBakey saw the potential opportunities for clinical discovery that can result from mining patient records, and true to his vision, the Medical Follow-Up Agency allowed for epidemiological research studies that provided significant insights into the after-effects of war trauma.[16] It enabled surgeons and scientists to pursue innovative research into patients' longitudinal well-being after WWII, and also provided unparalleled opportunities to understand the impact of heredity on health and disease through a registry of 32,000 veterans, including data from both fraternal and identical twins. These insights pre-dated our modern-day trauma registries, which are now in routine use in both civilian and military environments for the benefit of injured patients.

Colonel DeBakey's wartime service also included his instrumental role with other civilian surgeons serving in the European theater in creation of the Excelsior Surgical Society and the Association of Surgical Consultants to the U.S. Army. He was a driving force to the latter group, which continued well into the 21st century and served in an advisory capacity to the Uniformed Services University of the Health Sciences and to military medicine.[13] DeBakey, who served in the Surgical Consultant's Division of the Army Surgeon General's Office during WWII, also helped develop Mobile Army Surgical Hospital units during the early years of the war. As a civilian surgeon, DeBakey was familiar with the consequences of severe blood loss, and understood the need for rapid control of bleeding. His proposal for Mobile Army Surgical Hospital units was rooted in his experiences as a surgeon that providing care closer to the front lines would allow for the earliest possible control of hemorrhage, and the auxiliary surgical hospitals ultimately improved battlefield injury survival.[17]

DeBakey also advocated that patients with complex needs be cared for at hospitals with surgeons and physicians experienced in those specific types of diseases and injuries. He observed that these "specialty centers" could facilitate high-quality medical care and the efficient utilization of specialized medical personnel. DeBakey's experience was not an isolated one. The English surgeon Henry Richard Rishworth, who worked on a medical ship throughout WWI, also observed that fracture care improved when all the injured individuals were treated at 1 location with standardized fracture equipment.[18] In a similar vein, Charles Scudder established the Fracture Clinic at the Massachusetts General Hospital in 1917.[19] Thus, the "specialty centers" that came into existence during the WWs at the request of civilian surgical consultants were not only notable for triage of causalities at the battlefield, but they represent an early conceptualization of sub-specialty care in present-day civilian surgery.

DAMAGE CONTROL AND THE PROMISE OF CIVILIAN-TO-MILITARY LEARNING

In more contemporary history, developments in trauma surgery demonstrate how the flow of knowledge between the civilian and military surgeons has reshaped current battlefield practices. Between 1985 and 1999, largely owing to the availability of semi-automatic handguns, the number of gunshot wounds and ballistic injuries per patient increased drastically in civilian urban hospitals.[20] Trauma surgeons were witnessing unconventional wounding patterns as urban America transformed into civilian battlefields.[21,22] In response to the epidemic of gun violence, surgeons at several U.S. trauma centers began to pioneer an approach wherein major surgery would be delayed until a patient's physiology was stabilized and could better tolerate operations.[23–26]

Traditional surgical practice until the 1990s emphasized definitive repair of an injury regardless of the patient's physiological state. In 1993; however, surgeons at the Hospital of the University of Pennsylvania coined the term "damage control surgery" (DCS) and suggested that patients with a maximum injury subset and exsanguination sustained the highest mortality because the physiology was too deranged to tolerate prolonged or protracted surgical procedures.[26] Interestingly, although DCS was proposed by an academic surgical team, the idea drew inspiration from the senior author's time in the U.S. Navy. Damage control is the capacity of a naval vessel to absorb damage and yet maintain its mission integrity. During a damage-control call, the ship's crew works to seal the damage to a vessel, prevent it from sinking, and keep the ship underway. These measures are conceptually similar to the steps surgeons must take to restore normal physiology when faced with massive bleeding.

DCS can be understood as a 3-phase procedure (Fig. 1). The first step emphasizes rapid control of hemorrhage and contamination with abbreviated procedures; the second step focuses on life support and restoring physiology; the third step, once the patient is stable, completes the sequence with definitive surgical repairs.[27] Promising results from the use of DCS in civilian surgical centers later led military surgeons to embrace it as a new paradigm of care. Military surgeons were placed at civilian trauma care centers to learn the new technique, and DCS was then successfully implemented during the conflicts in Iraq and Afghanistan.[28] Additional surgical techniques to abbreviate the time to control bleeding and restore perfusion to vital structures came forth, and were widely applied by military surgeons and other specialties.[29,30] To control blood vessels and re-establish perfusion, temporary vascular shunts had been used in civilian injuries.[31] Subsequently, use of temporary vascular shunts for war injuries allowed for efficient patient resuscitation whereas maintaining perfusion of the extremities. In the decades before DCS, during WWII, arterial injuries were treated by immediate ligation and had a 49% amputation rate.[32] In contrast, the DCS technique temporized limb perfusion allowing interval limb revascularizations and led to limb salvage rates of >90%.[33] More broadly, the concept of DCS was useful in the surgical team's ability to handle mass casualty in settings with limited resources.[29]

Many other innovations have resulted from military-civilian partnerships, such as breakthroughs in burn trauma care at the U.S.

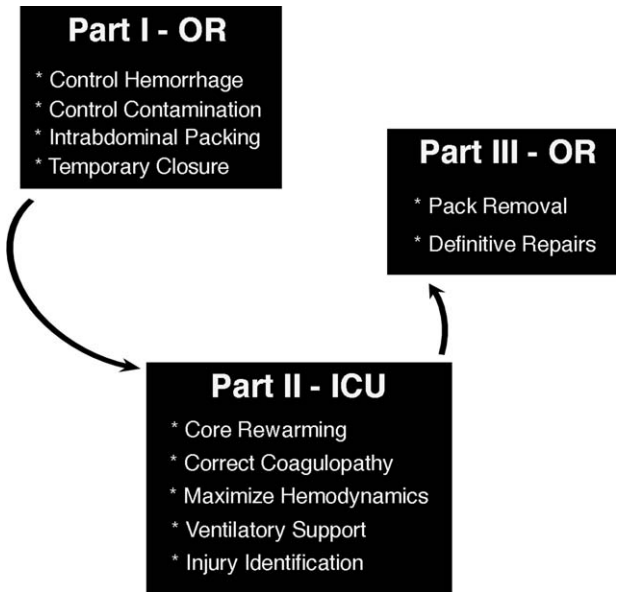

FIGURE 1. The original 3-phase damage control proposed by the surgical team at the University of Pennsylvania. The surgeons advocated for a systematic approach designed to disrupt the lethal cascade of events leading to the death by exsanguination. Source: Rotondo MF, and Zonies DH. The damage control sequence and underlying logic. *Surgical Clinics of North America,* 1997.

Army Institute of Surgical Research, and most recently, bystander and prehospital tourniquet use. Some of these initiatives are summarized in Table 1.

PAST AND PRESENT AVENUES OF INSTITUTIONALIZING MILITARY-CIVILIAN RECIPROCITY

Before 1973, when conscription was still in place in the U.S., flow of surgeons between the military and the civilian sectors was rather seamless due to the requirement of obligatory military service.[34] This allowed for ongoing transfers of knowledge gained from experience in combat conditions. Today; however, there is a relative paucity of military-civilian partnerships that facilitate the bidirectional flow of expertise between surgeons. Nonetheless, the achievements of the few cross-institutional programs that do exist should act as an impetus for the government to invest in jumpstarting these programs. An example of a successful platform is embodied by the U.S. Navy training center at the Los Angeles County and University of Southern California trauma center. Since 2003, this program has sought to integrate Navy personnel within the civilian trauma program to provide training for reserve surgeons before deployment. The program also has Navy Trauma Call days where both civilian and noncivilian surgeons on the medical team act as Navy personnel under the Navy Surgeon's leadership.[28] Another exemplary collaboration can be observed between the U.S. Air Force and the University of Maryland School of Medicine at the Center for the Sustainment of Trauma and Readiness Skills. Through the Center for the Sustainment of Trauma and Readiness Skills, Walter Reed National Military Medical Center and University of Maryland have worked together to develop a framework for clinical management of penetrating trauma and integrated rehabilitation services.[35] Similarly, the U.S. Army partnership at the Jackson

TABLE 1. Selected Examples of Military-Civilian Exchanges that Lead to Innovations in Patient Care, Advances of Scientific Understanding and Policy Change

Innovation Stemming from Military-Civilian Reciprocity	Description of the Innovation
Formation of the U.S. National Academy of Sciences	President Lincoln established the National Academy of Sciences n 1863 during the American Civil War as a scientific consulting body.[42]
Abbreviated surgeries for hemorrhage control	J. Hogarth Pringle proposed hepatoduodenal ligament clamping[43] for patients with hepatic lacerations. In the early 1900s, the Finish veteran war surgeon Richard Faltin[44] and William Haslted[45] described cases where definitive repair of organ injuries was performed days after hemodynamic stabilization of the patient.
Establishment of the National Research Council	President Wilson established the National Research Council in 1916 to recruit civilian medical consultants and bring their expertise to the military.
Red cross and reserve military hospitals	When the U.S. military needed additional access and expertise from civilian surgeons during the Great Wars, the military-civilian partnership took the form of Red Cross and Reserve military hospitals that mobilized in times of war to provide care at the battlefields.
Conceptualizing ''wound shock'' as hemorrhage	Walter Cannon spearheaded the investigations into the basic concepts of traumatic, hemorrhagic shock. Additionally, Edward D. Churchill, a combat consultant in WWII, challenged the U.S. Army leadership to treat hemorrhagic shock with blood rather than plasma. Chruchill refined Cannon's insights, and advocated for whole blood transfusions in the treatment of shock.[46]
Mobile Army Surgical Hospital (MASH)	Colonel DeBakey advocated for auxiliary surgical hospitals that could provide care to the troops, closer to the front lines.
High altitude cold injuries and headgear for aviators	In World War II, Colonel Loyal Davis, MD, PhD, served in the Army as neurosurgical consultant in Europe. He developed a helmet to protect airplane crewmen from shrapnel and also improved the treatment of injuries resulting from high-altitude frostbite.[47]
Characterizing the physiologic dysfunction in burn injury	Although commanding the US Army Institute for Surgical Research, the trauma surgeon Basil Pruitt observed how thermal injuries could alter basal metabolic rate.[48] Pruitt and his colleagues subsequently established a scientific program whose investigations prompted groundbreaking insights into the physiological and metabolic dysregulation in burn trauma victims, changing the surgical practice in both the military and civilian sectors.[49]
Bystander and prehospital tourniquet use	Following the applications of tourniquets by the US military to control hemorrhage, the number of combat-related deaths due to severe extremity hemorrhage decreased by 85% between 2005 and 2007, from 23.5 to 3.5 deaths per year.[50] In civilian trauma centers, the use of a tourniquet also helped reduce mortality due to bleeding in cases of mass casualties and terror attacks.[51,52]

Memorial Hospital and the University of Miami has continually trained military trauma teams at the Ryder Trauma Center.[35]

Other regional and local agreements also exist between military commands and nearby centers to afford military healthcare providers access to maintain their surgical skills. It is worth noting, however, that the existing military-civilian trauma partnerships have been developed largely through individual or small group efforts, and are rarely memorialized as doctrine by policy efforts. This is especially surprising given the practical benefits of military-civilian surgical collaboration. For instance, the military healthcare system is distinctive in the standardization and codification of its innovations, and it is often swift at enshrining improvements into policy. This is evident in the recent permanent placement of the Joint Trauma System and its related Training Directorate into the Defense Health Agency to improve the readiness mission of the Army, Navy, and Air Force.[36,37]

The existing partnerships, both formal and informal, serve as a strong base upon which more comprehensive avenues can be developed to augment the crosstalk between military and civilian surgeons and scientists. Indeed, there have been some recent efforts to establish more robust platforms that can enable a consistent transfer of knowledge between the military and civilian domains. Many of these follow on the 2016 report by the National Academies of Science, Engineering, and Medicine,[36] which brought to the fore how integrated military-civilian trauma systems can assure optimal care in both sectors with the singular goal of achieving zero preventable deaths after injury. Subsequently, congressional appropriations were achieved to direct the implementation of many of the recommendations. For example, Congress recently approved the Mission Zero Act,[38] which calls for funding support from the Department of Health and Human Services to encourage partnerships between military and civilian trauma centers. Similarly, the Department of Defense and the American College of Surgeons have also established a Military Health System Strategic Partnership program to formalize partnerships with civilian academic and large Level I trauma centers.[39] Yet, the creation of additional policy and doctrine is essential to potentiate these efforts, as is also recommended in the National Academies of Science, Engineering, and Medicine report. In the final section, we suggest returning to some form of a military-civilian surgical thinktank, comprised of the nation's most experienced surgeons in the military, and civilian surgeons with academic and research experiences.

THE NEED FOR DOCTRINE IS, A FORTIORI, PRESSING IN TODAY'S TIME

Beyond what has been previously proposed,[12,14,28,37,40] we suggest that the U.S. Military, in partnership with the Department of Health and Human Services and Department of Defense, should create a National Military-Civilian Medical Readiness Center. The goal of this center would be to encourage bidirectional transfer of expertise between military and civilian surgeons at all levels. The Defense Health Agency and The Uniformed Services University should take the lead at creating the Center, which can act as a breeding ground for research initiatives led by combined military-civilian teams of surgeons, scholars, and scientists. The Center could benefit by being housed at Uniformed Services University of the Health Sciences at the crossroad of military academic medicine and science, and in proximity to the leading institutions of medical research. We envision the Center to have 3 main areas of focus. One division would specifically focus on the circulation of surgical skills in the fields of combat casualty care, battlefield medicine, and critical care. The second division would focus on scientific innovation, acting as a hub for research projects where civilian and military personnel work together to solve mutually beneficial problems. Examples of these might include scientific investigations on the deranged physiology in shock, or translational research on regenerative engineering for patients with an amputation or limb loss. The third division would be a policy think tank, bringing together leaders from the domains of military and civilian medicine with the goal of devising sound recommendations for agencies and institutions at both the local and the national level; examples of this might include improving response for mass casualty events and disasters.

Creation of such a Center by the government would put in place a formal structure to foster military-civilian crosstalk. Our suggestion of creating the Center stems from the fact that throughout history, as we have described, military-civilian exchanges have impacted clinical medicine, spawned basic science breakthroughs, and inspired future government policies. The call from the National Academies for a national, integrated trauma care system,[36] past initiatives by the American College of Surgeons such as the Senior Visiting Surgeons Program,[41] congressional efforts such as the Pandemic and All-Hazards Preparedness and Advancing Innovation Act of 2019 and the National Defense Authorization Acts, and other reports[37] are all in line with our proposal. Although there are other ways to formalize military-civilian crosstalk, we argue that, much like the National Research Council, creation of a National Military-Civilian Readiness Center would create a strong vehicle to boost advances in both civilian and military medicine, beyond trauma and surgery.

In summary, we provide a historical perspective on the benefits of military-civilian partnerships. The contributions of Cannon, DeBakey, and many other surgeons can be traced back to their cross-institutional, firsthand experiential learning. These insights stress the need for developing formal and sustainable bidirectional platforms where surgeons from both the military and civilian sectors are afforded avenues for jointly pursuing ideas as integrated teams. Past initiatives resulting from military-civilian reciprocity provide a strong incentive for a consistent, collaborative platform such as a National Center that can enhance the transfer of knowledge and continuously nurture surgical innovation.

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