

VIEWPOINT

Implications of Combat Casualty Care for Mass Casualty Events

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Violence from explosives and firearms results in mass casualty events in which the injured have multiple penetrating and soft tissue injuries. Events such as those in Boston, Massachusetts; Newtown, Connecticut; and Aurora, Colorado, as well as those in other locations, such as Europe and the Middle East, demonstrate that civilian trauma may at times resemble that seen in a combat setting. As the civilian sector prepares for and responds to these casualty scenarios, research and trauma practices that have emerged from the wars in Afghanistan and Iraq provide a valuable foundation for responding to civilian mass casualty events. Several lessons learned by the US military were implemented during the response to the bombings in Boston in April of this year.

Military research has found that approximately 25% of persons who die as a result of explosive or gunshot wounds have potentially survivable wounds.¹ These individuals have injuries that are not immediately or necessarily lethal and have a chance to survive if appropriate care is rendered in a timely fashion. The military has learned that implementation of evidence-based, clinical practice guidelines can reduce potentially preventable death.² Certain aspects of these lessons also apply to multiple casualty scenarios in civilian settings.

The care of wounded military service personnel is based on an integrated trauma system and involves timely point-of-injury intervention, coordinated patient transport, whole blood or blood component-based resuscitation, and initial operating focused on control of hemorrhage and optimizing patient physiology. Referred to as *damage control surgery*, this approach involves abbreviated techniques instead of longer definitive operations. The principles of combat casualty care should be considered in 3 phases: point of injury, during transport to the hospital, and hospital-based treatment. The wars have highlighted the importance of a trauma system to coordinate these phases and improve survival. In implementing this strategy, the military developed the Joint Trauma System, which is designed to provide wounded troops an optimal chance for survival and recovery.

Care at the Point of Injury

The majority of wartime deaths occur in the out-of-hospital setting. The point of injury component of care is termed *tactical combat casualty care*. During the past decade, this phase has been transformed to introduce and integrate elements of medical care with military tactics. Combat units are now trained in tactical combat casualty care, a strategy that has reduced preventable death.^{2,3} Kotwal et al³ reported that the 75th Ranger Regiment's implementation of a system based on tactical combat casualty care was associated with a historically low 3% inci-

dence of preventable death. Moreover, none of the regiment's 32 fatalities died of preventable causes during the out-of-hospital phase of care. The critical elements of the protocol include early control of hemorrhage using tourniquets for extremity bleeding and hemostatic dressings for bleeding not amenable to tourniquets.

Care During Transport

Evacuation is the next step in the continuum. Findings from military research have shown improved survival associated with the use of more advanced en route care capability. Mabry et al⁴ demonstrated a 66% reduction in mortality among patients evacuated by critical care flight paramedic teams (16 deaths among 202 patients) compared with casualties transported by basic emergency medical technicians (71 deaths among 469 patients). The survival benefit was attributed to higher levels of training and experience among flight paramedics. Morrison et al⁵ extended these observations in a study of injured military personnel evacuated by the United Kingdom's physician-led platform (aircraft or airframe used to transport patients) referred to as the *medical emergency response team-extended* (MERT-E). In this report, there was a 33% reduction in mortality in the most severely injured who underwent evacuation with MERT-E (47 deaths among 385 patients) compared with those evacuated with conventional platforms (36 deaths among 198 patients). Many of the advanced evacuation platforms include the capacity to administer blood and blood components and to provide other lifesaving interventions prior to reaching the hospital. The personnel on these advanced platforms may be acute care nurse practitioners, flight nurses, critical care flight paramedics, or critical care trained physicians.

Hospital-Based Care

The receiving trauma center provides the third phase of care. The US military's hospital-based experience with multiple casualty scenarios following single explosive events was documented in the 2009 Balad Air Base (in northern Iraq) report,⁶ which described strategies used to mitigate morbidity and mortality in 50 injured patients following 3 consecutive explosive events and quantified estimates of casualty surge capacity. Management of the most severely injured patients with complex penetrating wounds included strategies of damage control resuscitation; treatment of hemorrhagic shock with whole blood or balanced ratios of blood components such as plasma, platelets, and cryoprecipitate instead of crystalloid solutions; and damage control surgery. These approaches to combat casualty care are outlined in the Joint Trauma System clinical practice guidelines.⁷

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Damage control resuscitation is based on results of military research showing a survival benefit associated with administration of equal ratios of plasma, packed red blood cells, platelets, and more recently tranexamic acid.^{8,9} Damage control surgery involves performing only necessary amounts of operating to control bleeding, debride nonviable tissue, stabilize fractures, and restore extremity perfusion. Application of damage control surgery means that more definitive operations are delayed until initial resuscitation has been completed. The Balad report also documented the value of parallel operating, which involves having more than 1 surgical team simultaneously tending to a patient to reduce anesthesia and operative time.⁶ For example, a patient with extremity injuries as well as head and neck injuries may have 2 teams composed of general and orthopedic surgeons operating on these different anatomic locations at the same time. Although this strategy does not apply to all cases, it can be used for patients with multiple extremity fractures or penetrating and soft tissue injuries to several different anatomic locations.

The military has also demonstrated the effectiveness of operating on multiple patients simultaneously in a single operating room.⁶ During the surgical surges in Balad, Iraq, more than three-fourths of initial operations (involving a total of 50 patients) were performed in rooms with more than 1 patient without adverse outcomes and an overall 8% mortality. Practices like these demonstrate how space, personnel, operating room tables and supplies, and anesthesia equipment can be used effectively to perform lifesaving operations at a pace greater than that of routine conditions.

The Balad report projected that three-quarters of patients injured enough to require admission to the hospital would need an operation and that nearly 4 procedures would be required per operation to manage penetrating injuries.⁶ Findings from the US military demonstrated that 110 procedures were performed during 40 operations on 38 patients in the first 24 hours. The report also showed that a balanced, blood component–based resuscitation was achievable in the setting of a multiple-casualty event. The report estimated that an average of just more than 3 units of packed red blood

cells, plasma, and platelets would be required per hospitalized casualty. The report also characterized intensive care unit and ventilator requirements, demonstrating that 1 nurse and 1 ventilator would be anticipated for every 2 admitted casualties. The Balad report confirmed that many patients injured during explosive events required multiple operative interventions (191 procedures were performed during 75 operations, translating to 3.8 procedures per patient) in the days after the initial or index procedure (ie, a secondary wave of operating).⁶

Lessons From Wartime Trauma Care

These lessons from the wars in Afghanistan and Iraq are a product of the nation's investment in military trauma care and combat casualty care research. However, few military clinical practice guidelines are the result of standard, randomized clinical trials. Instead, these lessons are the result of a process of focused empiricism, or by "identifying what works and what does not, refining it over time and embracing a culture of continuous process improvement."¹⁰ This pragmatic approach adopted for military combat casualty care has allowed for rapid adoption of lifesaving strategies through practical methods. In this context, the evidence base supporting the military's clinical practice guidelines is driven by the results of basic science, translational large animal research, and retrospective cohort analyses. Despite the lack of randomized trials, the net outcome of the military's approach and other improvements in trauma care is the lowest case fatality rate for US service personnel recorded in the history of war.

As the United States and other nations continue to prepare for casualty scenarios from explosives or mass shooting events involving civilians, lessons from wartime trauma care and resuscitation may be helpful in planning responses. The trauma practices that have resulted from more than a decade of combat casualty care and research are transferable to the civilian world. Continuing to translate these lessons from war should provide a foundation to help reduce mortality and morbidity among civilians injured in future mass casualty events.

ARTICLE INFORMATION

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REFERENCES

1. Eastridge BJ, Mabry RL, Seguin P, et al. Death on the battlefield (2001-2011): implications for the future of combat casualty care [correction published in *J Trauma Acute Care Surg*. 2013;74(2):706]. *J Trauma Acute Care Surg*. 2012;73(6)(suppl 5):S431-S437.
2. Butler FK Jr, Blackburne LH. Battlefield trauma care then and now: a decade of tactical combat casualty care. *J Trauma Acute Care Surg*. 2012;73(6)(suppl 5):S395-S402.
3. Kotwal RS, Montgomery HR, Kotwal BM, et al. Eliminating preventable death on the battlefield. *Arch Surg*. 2011;146(12):1350-1358.
4. Mabry RL, Apodaca AA, Penrod J, Orman JA, Gerhardt RT, Dorlac WC. Impact of critical care-trained flight paramedics on casualty survival during helicopter evacuation in the current war in Afghanistan. *J Trauma Acute Care Surg*. 2012;73(2)(suppl 1):S32-S37.
5. Morrison JJ, Oh J, DuBose JJ, et al. En-route care capability from point of injury impacts mortality after severe wartime injury. *Ann Surg*. 2013;257(2):330-334.
6. Propper BW, Rasmussen TE, Davidson S, et al. Surgical response to multiple casualty following single explosive events. *Ann Surg*. 2009;250(2):311-315.
7. US Army Institute of Surgical Care website. <http://www.usaisr.amedd.army.mil>. Accessed May 29, 2013.
8. Borgman MA, Spinella PC, Perkins JG, et al. The ratio of blood products transfused affects mortality in patients receiving massive transfusions at a combat support hospital. *J Trauma*. 2007;63(4):805-813.
9. Morrison JJ, Dubose JJ, Rasmussen TE, Midwinter MJ. Military Application of Tranexamic Acid in Trauma Emergency Resuscitation (MATTERs) study. *Arch Surg*. 2012;147(2):113-119.
10. Timbie JW, Ringel JS, Fox DS, et al. Allocation of scarce resources during mass casualty events: evidence report 207. Rockville, MD: Agency for Healthcare Research and Quality; June 2012. AHRQ publication 12-E006-EF. <http://effectivehealthcare.ahrq.gov/index.cfm/search-for-guides-reviews-and-reports/?pageaction=displayproduct&productid=1152>. Accessed May 29, 2013.