Dismounted Complex Blast Injuries: A Comprehensive Review of the Modern Combat Experience

Jeremy W Cannon, MD, SM, FACS, Luke J Hofmann, DO, FACS, Sean C Glasgow, MD, FACS, Benjamin K Potter, MD, FACS, Carlos J Rodriguez, DO, FACS, Leopoldo C Cancio, MD, FACS, Todd E Rasmussen, MD, FACS, C Anton Fries, MA, Michael R Davis, MD, FACS, James R Jezior, MD, Richard J Mullins, MD, FACS, Eric A Elster, MD, FACS

One of the most challenging injury patterns to emerge from the recent military conflicts in Iraq and Afghanistan is the dismounted complex blast injury (DCBI), with multiple proximal amputations, pelvic fractures, and extensive perineal wounds (Fig. 1).[1-5] Lessons learned from managing patients with this pattern of injury must be captured to minimize the morbidity and mortality of those suffering similar injuries in the future. These lessons also apply to civilian patients suffering open pelvic fractures and crush injuries to the pelvis.[6] The aim of this review was to detail the diagnostic work-up and initial multidisciplinary management of DCBI patients, to describe some of the most common complications after DCBI, and to discuss future research efforts to improve the survivability and outcomes of DCBI.

HISTORIC PERSPECTIVE

Many important iterative advances have been made in combat casualty care throughout history.[7] However, severe blast injuries remained universally fatal until very recently. During the Civil War, nearly all penetrating torso injuries, including perineal injuries, were lethal. Patients who survived to reach medical care were managed expectantly because laparotomy was not performed. For patients with extremity fractures, management consisted entirely of splinting and traction. For severe extremity injuries, battlefield amputation became widely practiced, although many debated the wisdom of this approach compared with limb salvage.

Severe injuries from blast events were common in World Wars I and II; however, survival in patients with combined traumatic amputations and perineal wounds was never specifically reported. In World War I, colorectal injuries carried a mortality rate of up to 77%, which was reduced to 37% in World War II, when colostomy was mandated.[6] Additionally, during World War II, presacral drains were placed for extraperitoneal rectal injuries, and the injury was repaired if possible. Destructive soft tissue injuries were managed with extensive sharp debridement and removal of all accessible foreign bodies at the first surgical procedure. External fixation and intramedullary nailing were also used to a limited extent.

In Vietnam, rectal irrigation was added to the management of destructive rectal injuries to avoid pelvic sepsis.[8] This further reduced mortality from severe colorectal injuries. For fractures, external fixation was prohibited by the US Army based on poor outcomes during World War II. Instead, functional casting and traction with suspension were used extensively, and intramedullary nails were placed in some patients as a second-line therapy. Genitourinary (GU) trauma was reported in fewer than 5% of combat injuries and consisted mostly of renal injuries.[9]

These important advances notwithstanding, the global experience with severe, multisystem injuries, including the combination of traumatic amputations and perineal wounds, was very limited until recently. Now, however, these patients are surviving due to further improvements across the continuum of combat casualty care, ranging

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From the Departments of Surgery, Perelman School of Medicine at the University of Pennsylvania, Philadelphia, PA (Cannon), William Beaumont Army Medical Center, El Paso, TX (Hofmann); and Oregon Health and Sciences University, Portland, OR (Mullins); General Surgery (Hofmann, Rodriguez, Davis, Elster), Orthopaedics (Potter), Vascular Surgery (Rasmussen), and Urology (Jezior), Uniformed Services University-Walter Reed Department of Surgery, Bethesda, MD; the Department of Surgery, Washington University (Glasgow) and the USAF Center for the Sustainment of Trauma and Resuscitative Skills (C-STARS) (Glasgow), St Louis, MO; US Army Institute of Surgical Research, Ft Sam Houston, TX (Cancio, Fries, Davis); and the US Combat Casualty Care Research Program, Ft Detrick, MD (Rasmussen).

Correspondence address: Jeremy W Cannon, MD, SM, FACS, Penn Presbyterian Medical Center, Division of Trauma, Surgical Critical Care and Emergency Surgery, 51 N. 39th St, Medical Office Building, Suite 120, Philadelphia, PA 19104. email: jeremy.cannon@uphs.upenn.edu

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Abbreviations and Acronyms

DCBI = dismounted complex blast injury
DRE = digital rectal exam
GU = genitourinary
HO = heterotopic ossification
IFI = invasive fungal infection
REBOA = resuscitative endovascular balloon occlusion of the aorta
VCA = vascularized composite allotransplantation
VTE = venous thromboembolic event

from tactical care under fire to the first echelon of surgical care (level 2) and in-theater hospital-based care (level 3) followed by evacuation to definitive care in regional care centers (level 4) and large military treatment facilities in the US (level 5). Specific advances include pre-hospital tourniquet application, rapid evacuation to surgical care, advanced resuscitation techniques, multidisciplinary surgical interventions, and skilled perioperative critical care and long-range Critical Care Air Transport.[10-12] Furthermore, reconstructive surgical techniques and advanced prostheses have enabled functional recovery for many of these severely injured DCBI patients. This review details our current accrued knowledge and future directions in the management of DCBI.

BLAST INJURY DEMOGRAPHICS AND PATTERNS OF INJURY

Explosions now represent the most common mechanism of injury (78%) and death (63%) on the modern battlefield. Explosions create a wide range of injuries across multiple body regions.[13] Specific injuries are determined by the energy level of the blast and the individual's protective equipment (Table 1). Blast injuries sustained by casualties in a vehicle are termed *mounted injuries*; those sustained outside a vehicle are termed *dismounted*. Heavy armor incorporated into military vehicles, such as the Mine-Resistant Ambush-Protected (MRAP) vehicle, affords excellent protection. However, even with this protection, severe injuries can occur, including comminuted calcaneal fractures (ie deck-slap injury), long bone extremity fractures, vertebral fractures, blunt thoracic injuries, and traumatic brain injuries.[14]

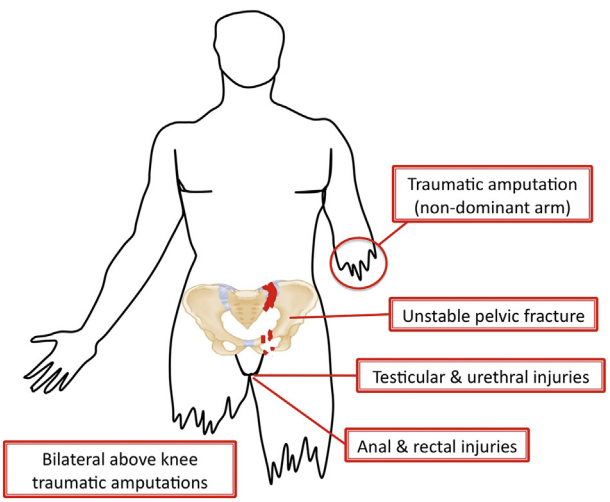

Figure 1. Classic pattern of dismounted complex blast injury.

Dismounted events are classified as low- or high-energy. Low-energy blast events result from relatively small explosive devices or when the explosion occurs at a significant distance from the individual. Typical injuries from these low-energy events include relatively minor wounds to the extremities and perineal soft tissues. In contrast, high-energy blasts from large explosions in close proximity to dismounted personnel result in traumatic lower extremity amputations, upper extremity open fractures or amputations, severe pelvic fractures, and destructive injuries to the perineal soft tissues.[1-3] This constellation of injuries—the primary focus of this review—carries a mortality of up to 73%.[5]

INITIAL RESUSCITATION AND EARLY MANAGEMENT

The most common cause of death in DCBI patients is catastrophic hemorrhage,[15] so the top priority in DCBI patients is hemorrhage control beginning in the pre-hospital setting.[16] On arrival at the surgical facility, these patients typically have multiple tourniquets and a pelvic binder in place. The facility's massive transfusion protocol should be initiated early. Attention should be focused on adhering to damage control resuscitation principles, including preventing hypothermia, minimizing crystalloid, and transfusing a high ratio of plasma and platelets to red blood cells.[17] When blood-product availability is limited, a "walking blood bank" should be initiated to collect fresh whole blood from suitable donors. Hemostatic adjuncts such as tranexamic acid should be considered early (ie within 3 hours of injury). On physical examination, the surgeon must be mindful that a pelvic binder can obscure penetrating inguinal and gluteal wounds. Chest and pelvic radiographs enable the early identification of radio-dense fragments; a positive focused assessment with sonography for trauma (FAST) examination may indicate the need for early laparotomy. In a stable DCBI patient, contrast-enhanced CT scan is useful to evaluate for intra-abdominal, rectal, and bladder injuries.