

# Extremity War Injuries: State of the Art and Future Directions. Prioritized Future Research Objectives

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## 1. Data Collection System

A theme common to virtually all discussions has been the need for access to better longitudinal patient data. Current patient care processes, both in theater and at higher level (echelon) care centers, do not include data capture in a way that allows simple electronic linkage of medical records from one level of care to the next. At least two electronic medical records systems are in use, and they are not necessarily compatible with one another. Any electronic medical record used should be Web-based to allow for linkage of patient data from the earliest level of documented care through the VA system. To encourage entry of information critical to outcomes analysis, the system must be user-friendly and not cumbersome. An example of one system with some of the necessary components is the current Joint Patient Tracking Application (JPTA). Unfortunately, the system lacks integration with a trauma registry or database to allow for retrospective or prospective analyses of specific injuries and treatments. Funding is necessary for platform development, information systems infrastructure, and data entry personnel.

## 2. Timing of Treatment

Better data are necessary to establish best practices with regard to timing of débridement, timing of temporary stabilization, and timing of defini-

tive stabilization. Development of animal models of early versus late surgical treatment of open injuries may be helpful. Prospective clinical comparisons of treatment groups will be helpful in gaining further understanding of the relative role of surgical timing on outcomes.

## 3. Techniques of Débridement

More information is necessary about effective means of demonstrating adequacy of débridement. Current challenges, particularly for surgeons with limited experience in wound débridement, exist in understanding how to establish long-term tissue viability or the lack thereof at the time of an index surgical débridement. Because patients in military settings are typically transferred away from the care of the surgeon performing the initial débridement before delivery of secondary care, opportunities to learn about the efficacy of initial procedures are lost. Development of animal models of blast injury could help establish tissue viability markers. Additional study is necessary to understand ideal frequency and techniques of débridement.

## 4. Transport Issues

Clinical experience suggests that current air evacuation techniques are associated with development of complications in wound and extremity management, although the specific role of individual variables in the genesis of these complications

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is unclear. Possible contributing factors include altitude, hypothermia, and secondary wound contamination. Clinical and animal models are necessary to help develop an understanding of transport issues. Development, testing, and approval of topical negative-pressure devices for use during aeromedical transport should be facilitated.

### 5. Coverage Issues

There is a lack of controlled studies that define the role of timing of coverage in outcome following high-energy extremity war injuries. Also necessary is more information about markers and indicators to help assess the readiness of a wound and host for coverage procedures. Both animal modeling and clinical marker evaluation are needed to develop understanding in this area.

### 6. Antibiotic Treatments

Emergence of resistant organisms continues to provide challenges in the treatment of infection following high-energy extremity war injuries. Broader prophylaxis likely encourages development of antibiotic resistance. Choice of antibiotic is not established in extremities contaminated by improvised explosive devices. In the context of a dwindling pipeline of new antibiotics, particularly those directed toward gram-negative organisms, development of new technologies to fight infection is necessary. This patient population offers the opportunity to assess efficacy of vaccination against common pathogens. Partnerships should be developed with infectious disease researchers currently involved in addressing similar questions.

### 7. Management of Segmental Bone Defects

A multitude of different techniques for management of segmental bone

defects is available. These include bone transport, massive onlay grafting with and without use of recombinant proteins, delayed allograft reconstruction, and acute shortening. Although some techniques are more appropriate than others after analysis of other clinical variables, controlled trials comparing efficacy between treatment methods are lacking. Variables that may affect outcome can be grouped according to patient characteristics, including comorbidities, injury characteristics (including severity of bony and soft-tissue wounds), and treatment variables (including the method of internal fixation selected). Evaluation of new technologies for treatment of segmental bone defects should include the assessment of efficacy, with adequate control for confounding variables and evaluation of cost-effectiveness.

### 8. Development of an Animal Model

A military blast-injury survival model using large animals is necessary to serve as a platform to answer multiple research questions. These include assessing (1) vacuum-assisted wound closure versus bead pouch versus dressing changes; (2) wound-cleaning strategy; (3) the effect of topical antibiotics; (4) the modulation of inflammatory response; (5) the timing of wound closure; and (6) vascular shunt utilization.

### 9. Amputee Issues

The development and validation of "best practice" guidelines for multidisciplinary care of the amputee are essential. Treatment protocols should be tested clinically. Studies should be designed to allow for differentiation between the effects of the process versus those of the device on outcome. Failure analysis as a tool to evaluate efficacy of treatment protocols and elucidate short-

comings should be used. Clinically, studies should focus on defining requirements for the residual limb length necessary to achieve success without proceeding to higher-level amputation. Outcomes-based comparisons of amputation techniques for similar injuries and similar levels should be performed. Use of local tissue lengthening and free tissue transfer techniques should be evaluated. In the context of current results and increasing levels of expectation for function following amputation, the development of more sensitive and militarily appropriate outcomes monitors is necessary.

### 10. Heterotopic Ossification

Animal models of heterotopic ossification should be used to develop early markers for the development of heterotopic ossification; these markers could identify opportunities for prevention. Better information is needed about burden of disease, including prevalence following amputation for civilian versus military trauma and the frequency at which symptoms develop. Treatment methods such as surgical débridement, although effective, necessarily interrupt rehabilitation. Prevention could expedite recovery and potentially improve outcome.

### Additional Identified Priorities

#### Development of a Joint Civilian/Military Advisory Board

Establishing and funding a Joint Civilian/Military Advisory Board (JCMAB) to oversee request for proposal (RFP) development will facilitate a productive interaction between (1) military surgeons and researchers with content expertise and (2) civilian researchers and clinicians with methodologic expertise. This joint board also could be tasked

with developing evidence-based “best practice” guidelines. Additionally, coordination of study design and implementation, with external review and oversight, will be required for studies funded both within and outside the military. The JCMAB could serve as a source of expertise for such study advice and oversight. Finally, expert advice in the management of complex wounds in theater was called for during the discussions. The JCMAB could be tasked with developing

mechanisms for providing such “second opinion” advice to surgeons faced with the challenge of making in-theater decisions beyond their own clinical comfort zone.

### **Development of an Extremity War Injuries Course**

An extremity war injuries course for surgeons departing for service in combat theaters should be developed. The course should be specific to the treatment of high-energy ex-

tremity war injuries and focus on the challenges of far-forward treatment, including the timing and techniques of débridement, assessment and treatment of shock, and stabilization before transportation. The course should expand on current offerings so as to increase the level of comfort military surgeons have in the management of these injuries before deployment. Use of survival animal models of high-energy blast injury will facilitate surgical technique development.