Andrew W. Mack, MD, Adam T. Groth, MD, H. Michael Frisch, MD, and William C. Doukas, MD

on

Treatment of Open Periarticular Shoulder Fractures Sustained in Combat-Related Injuries

Abstract

Open periarticular shoulder fractures present a tremendous challenge for orthopedic surgeons. These injuries, albeit rare, are typically caused by high-energy mechanisms and are associated with insult to multiple organ systems resulting in high morbidity and mortality. Although the civilian trauma literature includes several articles on outcomes of closed periarticular shoulder fractures, only 1 peer-reviewed article has focused on this specific open injury pattern. No standard management technique has been adopted for these injuries, and treatment patterns have anecdotally evolved from war to war.

In this article, we review evacuation of patients, management of combat-related open periarticular shoulder injuries, and the pertinent literature; we supplement this review with a description of the recent experience of Drs. HMF and WCD. All cases of combat-related open fractures treated at our institution between March 2003 and January 2007 were reviewed. We identified 44 patients with open periarticular shoulder fractures (33 IIIA, 1 IIIB, 10 IIIC). Inpatient and outpatient medical records, x-rays, laboratory culture data, and photographic documentation records were reviewed. Mean follow-up was 34 months (range, 12-49 months). Rates of associated neurologic and vascular injury were 41% (18/44 patients), and 23% (10/44 patients), respectively. Other associated significant injuries occurred in 38/44 patients (86%). Internal fixation was used as definitive treatment in 26/44 patients (59%). Radiographic union occurred by a mean of 4.5 months (range, 3-9 months) after surgery. Postoperative deep infection/osteomyelitis occurred in 5/35 patients (14%) with more than 1-year follow-up data available. The overall amputation rate was 9%.

Open combat-related periarticular shoulder fractures are complicated injuries, often associated with several traumatic comorbidities that together present difficult challenges to treatment. Meticulous surgical débridement is essential in managing these severely comminuted and contaminated open fractures. In cases in which internal fixation is used, careful timing and patient selection are required to minimize risk for osteomyelitis. Data collection is being continued in this patient cohort to allow for eventual reporting of functional outcomes.

> **"No standard management technique has been adopted for these injuries, and treatment patterns have anecdotally evolved from war to war."**

Nearly universal use of modern thoracoabdominal body armor and increased troop mobility in the form of armored vehicles and aircraft, coupled with the preferred insurgent attack strategy of improvised explosive devices, has resulted in a large number of combat-related open periarticular shoulder fractures not routinely encountered in civilian trauma practices. Managing these fractures presents a tremendous challenge for orthopedic surgeons. These injuries are typically caused by high-energy mechanisms and are associated with insult to multiple organ systems with resultant high morbidity and mortality. Although the civilian trauma literature includes several articles on outcomes of closed proximal humerus and suspensory complex fractures,[1-7] only 1 peer-reviewed article has focused on this specific open injury pattern.[8] No standard management tech-

CPT Mack, MC, USA, and CPT(P) Groth, MC, USA, are Residents, Orthopaedic Surgery Service, LTC Frisch, MC, USA, is Director, Orthopaedic Traumatology Service, and COL Doukas, MC, USA, is Chairman, Integrated Department of Orthopaedics and Rehabilitation, National Naval Medical Center, Walter Reed Army Medical Center, Washington, DC.

Address correspondence to: Andrew W. Mack, MD, CPT, MC, USA, Orthopaedic Surgery Service, Walter Reed Army Medical Center, 6900 Georgia Ave NW, Washington, DC 20307 (tel, 202-782-9548; e-mail, andrew.mack@na.amedd.army.mil).

Am J Orthop. 2008;37(3):130-135.

nique has been adopted, and treatment patterns have anecdotally evolved from war to war.

Injuries sustained in war have been notoriously difficult to treat, and outcomes have been less successful than those of treatment for similar injuries sustained in civilian trauma—because of the extensive soft-tissue injury, gross contamination, and high-energy transfer that occur when munitions and/or projectile fragments contact the body. The most recently described experience with open wartime shoulder injuries came from the Croatian Homeland War and involved treatment with external fixation.[8] Although no deep infection was reported with this treatment method, patients were universally regarded as having poor long-term functional outcomes.

In this article, we review aeromedical evacuation of patients, management of combat-related open periarticular shoulder injuries, and the pertinent literature; we supplement this review with a description of the recent experience of Drs. HMF and WCD.

Medical Evacuation

The US military medical evacuation system is organized into 5 echelons of medical care, with progressively increasing medical, diagnostic, and surgical capabilities available as patients are transported to higher levels. Echelon I care is provided at or near the battlefield front through buddy aide, unit medics, and/or the battalion aid station. Initial field assessment of all combat-injured soldiers follows advanced trauma life support protocols. Patients receive pressure dressings or tourniquets as needed for hemorrhage control, intravenous access, cardiopulmonary resuscitation, and field intubation as required.

Echelon II and III care consists of forward surgical teams and combat support hospitals, respectively. Complete primary and secondary surveys may be delayed until patient arrival at echelon II or III, usually within minutes to a few hours of injury. These units have medical and surgical capabilities for emergency department–type triage and assessment, provisional fracture stabilization, initial surgical wound débridement, hemorrhage control or vascular repair, and advanced medical resuscitation. After being medically stabilized at in-theater echelon II and III facilities, patients are transported from the combat zone, often within 24 hours of injury, to an echelon IV facility. Critically ill patients who remain intubated or require frequent transfusions or continued hemodynamic pressor support are escorted on medical evacuation flights by specially trained critical care teams that include physicians, nurses, and medical technicians.

The echelon IV hospital for combat operations in Iraq and Afghanistan is the Landstuhl Regional Medical Center in Germany. Patients with isolated or less severe injuries may receive definitive surgical or medical treatment at these facilities and then be transferred to the next echelon for rehabilitation rather than be returned to in-theater duty. Patients can remain at the echelon IV facility for several days, allowing for further medical stabilization, operative débridement of contaminated wounds, and arrangement for medical air evacuation to appropriate stateside facilities.

Echelon V facilities are large medical centers equivalent to civilian tertiary referral centers. They are the definitive treatment and rehabilitation centers for the vast majority of severe combat-related casualties.

Patients and Methods

We reviewed the cases of all patients with open upper extremity fractures treated at our institution after the start of Operation Enduring Freedom and Operation Iraqi Freedom (March 2003–January 2007). Forty-four patients had combat-related open periarticular shoulder fractures, including proximal humerus and superior shoulder suspensory complex fractures. We recorded patient demographics and data, including age, sex, mechanism of injury, number of surgical procedures, mode of definitive treatment, and time to fracture healing. Fracture union was recorded as time from definitive surgery to appearance of bridging callus on 3 of 4 cortices on standard x-rays and the patient's ability to perform functional activities without pain at the fracture site. We noted major complications, including infection, nonunion/malunion, and pulmonary embolus. Inpatient/outpatient records, preoperative and postoperative x-rays, laboratory culture data, and photographic documentation records were reviewed.

Results

At our institution, 44 patients (43 men, 1 woman; mean age, 27.5 years; range, 19-55 years) were treated for open periarticular shoulder fractures. A mean of 2.5 (range, 1-6) irrigation and débridement procedures were performed in-theater, before patient arrival at our institution; at our center, a mean of 2.3 (range, 0-13) irrigation and débridement procedures were performed before the definitive fracture stabilization procedure.

Injury Characteristics

High-energy mechanisms (24 blasts, 15 gunshot wounds, 4 motor vehicle crashes, 1 helicopter crash) were responsible for all injuries. All fractures, of proximal humerus (29/44, 66%), acromion (16/44, 36%), glenoid (11/44, 25%), clavicle (10/44, 23%), and coracoid (8/44, 18%), and their associated rotator cuff injuries (4/44, 9%), acromioclavicular separations (2/44, 5%), and scapulothoracic dissociations (2/44, 5%) were open (Table I). These fractures were further characterized as type IIIA (33, 75%), type IIIB (1, 2%), or type IIIC (10, 23%) according to Gustilo-Anderson classification (type IIIA, high-energy or contaminated fractures not requiring additional soft-tissue coverage; type IIIB,

Table I. Injury Breakdown

Injury	Patients (N = 44) n	%
Proximal humerus fracture	29	66
Acromion fracture	16	36
Glenoid fracture	11	25
Clavicle fracture	10	23
Coracoid fracture	8	18
Rotator cuff disruption	4	9
Acromioclavicular separation	2	5
Scapulothoracic dissociation	2	5
Shoulder girdle with multiple fractures	19	43

Table II. Definitive Treatment of Fractures

Treatment	Fracture	Patients (N = 44) n	%
Internal fixation used		26[a]	59
ORIF	Proximal humerus	11	25
	Coracoid	4	9
	Acromion	2	5
	Glenoid	2	5
	Clavicle	2	5
Intramedullary nail fixation	Proximal humerus	5	11
Shoulder disarticulation	Proximal humerus	4	9
Osteoarticular allograft	Proximal humerus	2	5
Cemented hemiarthroplasty	Proximal humerus	1	2
Internal fixation not used[b]		18[b]	41
I&D, DPC, rehabilitation	Acromion/spine	14	32
	Glenoid	9	20
	Clavicle	8	18
	Proximal humerus	6	14
	Coracoid	4	9

Abbreviations: ORIF, open reduction and internal fixation; I&D, irrigation and débridement; DPC, delayed primary closure.

[a]7 of 26 patients had multiple shoulder girdle fractures treated with internal fixation.
[b]13 of 18 patients treated without internal fixation had multiple shoulder girdle fractures.

fractures with extensive soft-tissue loss with periosteal stripping and bone exposure requiring fasciocutaneous or muscle flap coverage; type IIIC, fractures requiring associated vascular injury repair or reconstruction).[9] Nineteen (43%) of the 44 patients had shoulder girdles with multiple fractures.

The single type IIIB fracture received a local chest wall rotational fasciocutaneous flap for coverage. Of the 10 type IIIC fractures, 2 underwent in-theater emergent primary amputation. Indications for primary amputation in this setting have included nonreconstructible vascular injury or additional massive soft-tissue/bony injury to the distal extremity resulting in a nonviable limb. The remaining 8 type IIIC fractures underwent emergent vascular procedures to restore limb perfusion (4 were treated with emergent reverse great saphenous vein grafting and the other 4 with primary vascular repair). Of the 8 limbs treated with vascular repair or reconstruction, 6 maintained distal perfusion and have survived to date; the other 2 failed and required amputation at our institution a mean of 15 days after vascular intervention.

Neurologic injuries, defined as loss of motor and/or sensory function in a peripheral nerve or nerve root distribution, were identified in 18 (41%) of the 44 patients. Injuries included neuropraxias and nerve transections. Multiple nerves were injured in 9 (20%) of the 44 patients or in 9 (50%) of the 18 patients with nerve injury. Identified neurologic injuries were brachial plexopathy (6), ulnar nerve (3), median nerve (2), axillary nerve (2), radial nerve (2), musculocutaneous nerve (1), C5 root avulsion (1), and middle cerebral artery ischemic stroke secondary to carotid artery injury (1). Data regarding recovery of neurologic function are being gathered through ongoing protocols.

Associated injuries occurred in 38 (86%) of the 44 patients. The most common associated injury was hemopneumothorax (27%), followed by other upper extremity trauma (25%), lower extremity trauma (18%), head trauma (18%), neck trauma (16%), and rib fractures (14%). Emergent tracheostomy was performed in 3 patients (7%) for airway compromise after injury.

Fracture Management

Initial fracture management and immobilization were performed in theater. Splinting and/or sling and swathe were used in 36 (82%) of the 44 patients. External fixation was applied in 6 (14%) of the 44 patients, primarily to type IIIC fractures to protect the vascular repair or reconstruction during further aeromedical transport. Primary amputation was performed in 2 patients (5%) for nonviable limbs. Open reduction and internal fixation (ORIF) were not used as initial fixation in any patient. Initial intraoperative deep wound cultures were obtained in 31 (70%) of 44 patients. Twenty-two cultures (71%) were positive. The most common organism isolated was *Acinetobacter baumannii* (14 or 45% of cultures).

Definitive fracture management was performed without internal fixation in 18 (41%) of the 44 patients. These fractures were managed with serial irrigation and débridement procedures for wound management, with or without immobilization and subsequent rehabilitative therapy. The other 26 patients (59%) were managed with a variety of internal fixation techniques (Table II). Our decision to use internal fixation in some patients was based on several key factors, most notably the ability to attain a clean and stable soft-tissue wound bed that was free of contamination, as well as presence of an unstable, displaced fracture pattern. Fixation methods included ORIF (plate osteosynthesis, lag screw fixation, and/or tension band wiring) on proximal humerus (11, 25%), coracoid (4, 9%), acromion (2, 5%), glenoid (2, 5%), and clavicle (2, 5%); intramedullary nail fixation of proximal humerus (5, 11%); osteoarticular allograft

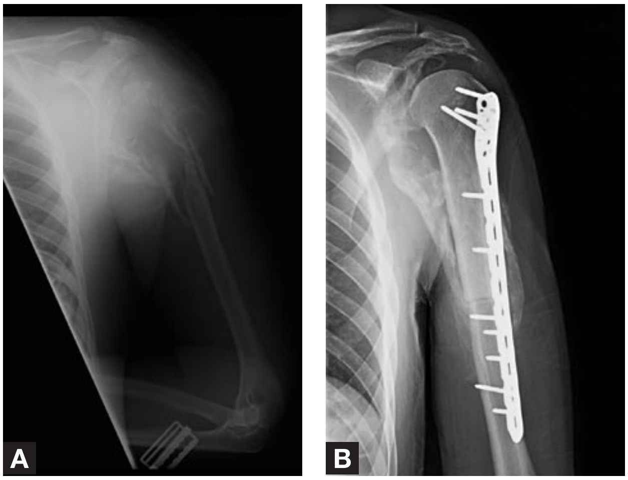

Figure 1. (A) Injury x-ray shows a comminuted type IIIA proximal humerus fracture. (B) X-ray 13 months after surgery shows healing of the osteoarticular proximal humeral allograft.

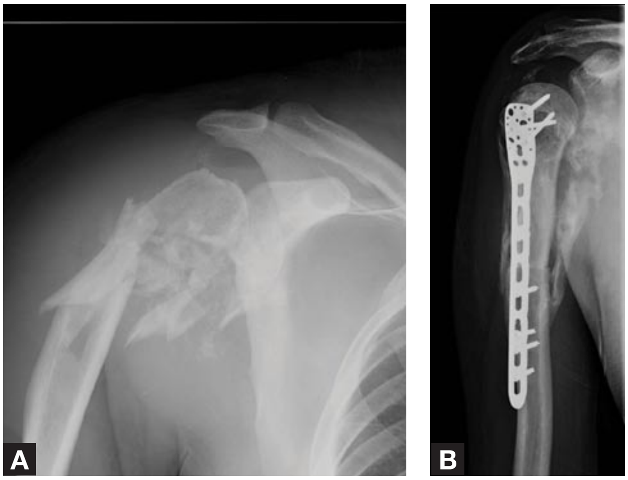

Figure 2. (A) Injury x-ray of another patient with a comminuted type IIIA proximal humerus fracture. (B) X-ray 17 months after surgery shows union across the host–allograft junction.

of proximal humerus (2, 5%); and cemented proximal humeral replacement (1, 2%). Shoulder disarticulation was the definitive treatment in 4 patients (9%).

Adjunctive treatment, with allogeneic bone graft and/or bone graft substitutes/extenders, was used in 12 (46%) of 26 patients managed with internal fixation. The graft materials used were allograft cancellous chips (6), recombinant human bone morphogenetic protein 2 (Infuse; Medtronic Inc, Minneapolis, MN) (4), demineralized bone matrix (Grafton; Osteotech Inc, Eatontown, NJ) (3), fresh-frozen osteoarticular structural allograft (2), and foam bone graft (Vitoss; Orthovita Inc, Malvern, PA) (2).

Radiographic Union

Twenty-nine (76%) of 38 patients with fractures that were followed for healing—not treated with distal clavicle excision (1), hemiarthroplasty (1), or amputation (4)—had radiographic data from follow-up to union. Mean time to union in these 29 patients was 4.5 months (range, 3-9 months), and mean follow-up was 34 months (range, 12-49 months).

Complications

Clinical and radiographic follow-up data, available for 35 (80%) of the 44 patients, were included in our analysis of complications. Postoperative deep infection/osteomyelitis was identified in 5 (14%) of 35 patients. These infections occurred in 4 type IIIA fractures and in 1 type IIIC fracture. The 4 patients with a type IIIA fracture were successfully treated with serial irrigation and débridement, antibiotic-impregnated cement beads, and organism-specific parenteral antibiotics for 6 weeks. None of these patients required repeat bone grafting to effect fracture union. One patient with a type IIIC fracture/near-amputation was definitively treated with shoulder disarticulation after his vascular graft became infected and failed. Three infections were acute or subacute (0 days, 7 days, and 3 weeks after wound closure), and 2 infections occurred late (4 months and 13 months after wound closure). Cultured organisms in the acute infection group included *Klebsiella pneumoniae* (1), polymicrobial bacteria (1), and a *Candida* species (1, a type IIIC fracture patient with infected vascular graft treated with amputation). In the chronic infection group, the organisms isolated included methicillin-resistant *Staphylococcus aureus* (1) and *Escherichia coli* (1).

Heterotopic ossification was identified in 13 (37%) of 35 patients; 3 of these cases required excision. Other complications were nonfatal pulmonary embolus (4/35, 11%) and wound dehiscence (2/35, 6%). Hospital readmissions for secondary procedures occurred in 9 (26%) of the 35 patients. These procedures included heterotopic ossification excision (3), tendon transfers/nerve reconstructions (3), revision amputation (2), wound dehiscence (2), and arthroscopic superior labrum anterior and posterior repair (1).

Discussion

High-energy periarticular shoulder fractures sustained during war are devastating injuries that often result in multisystem trauma.[10] The vast majority (89%) of these injuries in our population were caused by high-energy penetrating explosives or ballistics. In addition to local neurologic or vascular injuries, which occurred in 18 (41%) of the 44 patients, other significant associated injuries occurred in 86% of patients. In a series of 18 open wartime shoulder injuries from the Croatian Homeland War, Davila and colleagues[8] reported a similar injury pattern (33% rate of local neurovascular injury, 11% amputation rate). Their long-term functional outcomes were noted to be commonly poor; however, external fixation, used as definitive fixation for all treated fractures, often resulted in a painful, immobile, and

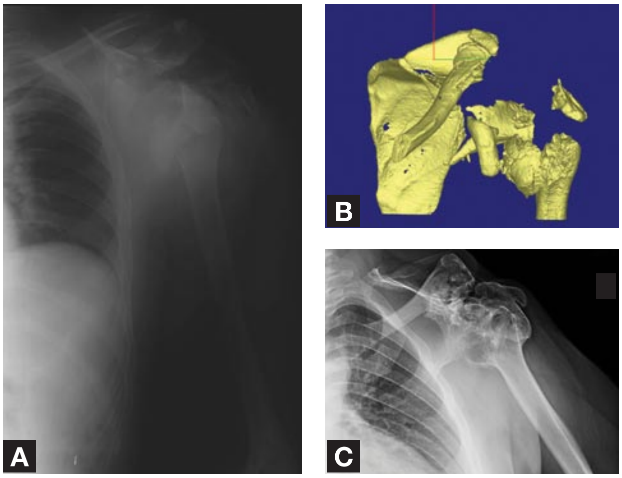

Figure 3. (A) Injury x-ray and (B) 3-dimensional anteroposterior reconstruction image of comminuted proximal humerus, glenoid, acromion, and coracoid fractures with articular destruction and significant bone loss secondary to blast injury. (C) X-ray of same patient 5 months after surgery shows glenohumeral arthrodesis consolidation.

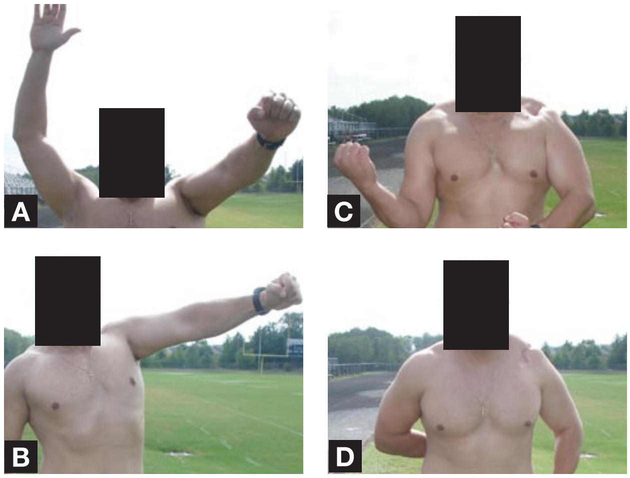

Figure 4. Forward-flexion (A), abduction (B), external rotation (C), and internal rotation (D) in same patient 2 years after surgery.

deformed shoulder. In our series, internal fixation was used to treat these open, comminuted, displaced, and unstable fractures after serial meticulous débridement had been performed to excise all nonviable tissues, stabilize the wound, and minimize the risk for subsequent infection.

In our series, however, several patients sustained severe shoulder injuries that resulted in bone loss and/or articular destruction such that standard internal fixation of the fractures was not possible or warranted. In these young, active patients, alternative treatment approaches were pursued when possible in an attempt to maintain motion about the shoulder and provide the best functional outcome. Although there are numerous reports on using proximal humerus osteoarticular allograft reconstructions after tumor resections,[11-14] there are no reports of using this technique after open fractures with segmental proximal humerus bone loss.

In our series, 2 patients sustained proximal humerus fractures with segmental comminution, bone loss, and articular surface destruction (Figures 1A, 2A). Both patients were treated with proximal humerus osteoarticular structural allograft reconstruction, each after 7 débridement procedures, negative intraoperative wound cultures, and at 3 weeks after their injuries. In each case, the allograft–host junction healed successfully, and the patient has shown no evidence of infection to date, 13 and 17 months after definitive treatment (Figures 1B, 2B), respectively. Functionally, one of these patients has done well, returning to active duty status with functional range of motion (ROM). The other patient developed significant heterotopic ossification about the shoulder; limited ROM required excision of the ossification.

In another patient, cemented proximal humerus hemiarthroplasty was performed for an open type IIIA comminuted proximal humerus anatomic neck fracture with articular surface destruction. In the literature, one group has reported using major joint arthroplasty with endoprosthesis after wartime open injuries; however, these arthroplasties were performed in a delayed manner, months to years after wound closure.[15,16] Haspl and colleagues[16] reported on 10 arthroplasty procedures (5 knees, 3 hips, 2 shoulders) performed 9 to 42 months after wartime open injuries. Outcomes were satisfactory (able to perform personal hygiene and light physical activities) in the 2 patients who underwent shoulder hemiarthroplasty.

In our series, primary shoulder arthrodesis was performed in 1 patient who had sustained a direct blast injury to the shoulder with significant deltoid and rotator cuff defects as well as proximal humerus and glenoid bone loss (Figures 3A, 3B). Radiographic follow-up showed evidence of arthrodesis consolidation 5 months after definitive treatment (Figure 3C). The patient was essentially pain-free and on active duty status 2 years after injury and exhibited a fairly functional extremity with maintenance of scapulothoracic motion (Figures 4A–4D).

Although there is a tremendous amount of literature that describes the treatment and outcomes of closed proximal humerus and periarticular shoulder fractures, it is difficult to compare data for these injuries with data for the open injury pattern because of the vast inherent differences in injury severity, soft-tissue involvement, and management principles.[17,18] Davila and colleagues[8] did not mention mean time to union after treatment for wartime open shoulder injuries but noted that external fixation was applied until callus or fibrous healing was strong enough to support the weight of the limb: 28 to 108 days (median, 64 days). Mean time from treatment to fracture union in our patient series was 4.5 months (range, 3-9 months), longer than their reported endpoint of duration of external fixation application; however, we strictly reported radiographic and clinical fracture union. Also, we feel that internal fixation techniques provide earlier fracture stability, allowing for the theoretical advantage of earlier ROM and strengthening exercises to maintain shoulder motion and function, though this is currently unsupported by data and awaits further collection of functional measures.

Infection is always a potential risk when treating the open wounds of war, and especially worrisome when using internal fixation. The risk can be minimized by performing serial, thorough irrigation and débridement procedures, excising all nonviable bone fragments and soft tissue to achieve a stable healthy wound bed. We report a 14% (5/35) deep infection rate in our patient series at a mean follow-up of 34 months. The infections occurred in 4 type IIIA fractures (3 proximal humeri, 1 clavicle) treated by ORIF with plate osteosynthesis and in 1 type IIIC fracture with vascular graft failure, which went on to definitive management with amputation. The infections in all 4 type IIIA fractures successfully resolved with serial wound débridement and 6 weeks of parenteral antibiotics, as the fractures all went on to achieve union without any subsequent episodes of infection to date. It is important to emphasize that meticulous wound management and attention to thorough débridement are paramount in the treatment of these wartime open fractures. With this approach, use of internal fixation appears to be an effective treatment method to facilitate fracture union, earlier ROM, and strengthening in carefully selected wounds after wartime open periarticular shoulder fractures with an acceptable postoperative infection rate.

This retrospective review is limited because of the heterogeneity of injury patterns even within this group of open periarticular shoulder fractures, because of the lack of standardized treatment, and because of the lack of a control group. In addition, we report a nonoptimal 76% rate of radiographic follow-up to union. This rate is secondary to the nature of modern military medicine, which may provide for the transfer of patients to outlying military and civilian treatment facilities closer to the patient's home and/or duty station after definitive management of their injuries. However, this article represents the largest series to date describing this rare injury pattern. Internal fixation can be carefully used in select patients within this population of wartime open injuries to facilitate fracture healing and early rehabilitation with an acceptable complication rate. Ongoing research at our institution aims to report validated functional outcome assessments for this patient cohort to allow for better characterization and evaluation of the treatments provided.

Conclusions

This patient cohort demonstrates that wartime open type III proximal humerus and shoulder suspensory complex fractures are indeed complicated injuries that present difficult challenges to shoulder reconstruction efforts. These injuries are often associated with substantial traumatic comorbidities and associated postoperative complications. Reconstructive efforts are often difficult, challenging the orthopedic surgeon to restore functional ROM and adequate strength to the upper extremity after such devastating injuries.

Authors' Disclosure Statement and Acknowledgments

The authors report no actual or potential conflict of interest in relation to this article.

This investigation was performed at the Integrated Department of Orthopaedics and Rehabilitation, Walter Reed Army Medical Center, Washington, DC.

References

1. Neer CS. Displaced proximal humeral fractures: part I. Classification and evaluation. *J Bone Joint Surg Am*. 1970;52(6):1077-1089.
2. Bhandari M, Matthys G, McKee MD. Four part fractures of the proximal humerus. *J Orthop Trauma*. 2004;18(2):126-127.
3. Cofield RH. Comminuted fractures of the proximal humerus. *Clin Orthop*. 1988;(230):49-57.
4. Fankhauser F, Boldin C, Schippinger G, Haunschmid C, Szyszkowitz R. A new locking plate for unstable fractures of the proximal humerus. *Clin Orthop.* 2005;(430):176-181.
5. Hintermann B, Trouillier HH, Schafer D. Rigid internal fixation of fractures of the proximal humerus in older patients. *J Bone Joint Surg Br.* 2000;82(8):1107-1112.
6. Kristiansen B, Christensen SW. Plate fixation of proximal humeral fractures. *Acta Orthop Scand*. 1986;57(4):320-323.
7. Wijgman AJ, Roolker W, Patt TW, Raaymakers EL, Marti RK. Open reduction and internal fixation of three and four-part fractures of the proximal part of the humerus. *J Bone Joint Surg Am*. 2002;84(11):1919-1925.
8. Davila S, MikulićD, Davila NJ, PopovićL, ZupancićB. Treatment of war injuries of the shoulder with external fixators. *Mil Med*. 2005;170(5):414-417.
9. Gustilo R, Mendoza R, Williams D. Problems in the management of type III (severe) open fractures: a new classification of type III open fractures. *J Trauma.* 1984;24(8):742-746.
10. Ficke JR, Pollak AN. Extremity war injuries: development of clinical treatment principles. *J Am Acad Orthop Surg.* 2007;15(10):588-595.
11. Rödl RW, Gosheger G, Gebert C, Lindner N, Ozaki T, Winkelmann W. Reconstruction of the proximal humerus after wide resection of tumours. *J Bone Joint Surg Br.* 2002;84(7):1004-1008.
12. Getty PJ, Peabody TD. Complications and functional outcomes of reconstruction with an osteoarticular allograft after intra-articular resection of the proximal aspect of the humerus. *J Bone Joint Surg Am.* 1999;81(8):1138-1146.
13. Temple HT, Kuklo TR, Lehman RA Jr, Heekin RD, Berrey BH. Segmental limb reconstruction after tumor resection. *Am J Orthop.* 2000;29(7):524-529.
14. O'Connor MI, Sim FH, Chao EY. Limb salvage for neoplasms of the shoulder girdle. Intermediate reconstructive and functional results. *J Bone Joint Surg Am.* 1996;78(12):1872-1888.
15. Erceg M, Maricevic A. Shoulder arthroplasty in war wounds. *Mil Med.* 1998;163(6):436-438.
16. Haspl M, Pećina M, Orlíc D, Cicak N. Arthroplasty after war injuries to major joints. *Mil Med.* 1999;164(5):353-357.
17. Stanec Z, Skrbic S, Dzepina I, et al. The management of war wounds of the extremities. *Scand J Plast Reconstr Surg Hand Surg*. 1994;28(1):39-44.
18. Keller A. The management of gunshot fractures of the humerus. *Injury.* 1995;26(2):93-96.

This paper will be judged for the Resident Writer's Award.