Outcomes of Internal Fixation in a Combat Environment

CPT Daniel J. Stinner, MD,[1] Lt Col James A. Keeney, MD,[2] MAJ(P) Joseph R. Hsu, MD,[1] CPT Jeremy K. Rush, MD,[3] MAJ Mickey S. Cho, MD,[3] Joseph C. Wenke, PhD,[1] COL James R. Ficke, MD,[3] and the Skeletal Trauma Research Consortium

Due to the nature of the wounds and environment, internal fixation in battlefield treatment facilities is discouraged despite the lack of data. The purpose of this review is to describe the outcomes of fractures that were internally fixed in the combat environment. The records of patients who had internal fixation performed in the theater of combat operations were reviewed. Demographics, injury characteristics, procedure history, and outcomes were recorded and analyzed. Forty-seven patients had internal fixation performed on 50 fractures in a combat theater hospital. Hip, forearm, and ankle fractures made up the majority of cases with 14 (28%), 14 (28%), and 10 (20%), respectively. Sixteen (32%) fractures were open. The average Injury Severity Score was 11.4 ± 1.1 (range, 4–34). Thirty-nine fractures (78%) healed without incidence. There was one (2%) infection and one (2%) acute surgical complication. Ten (20%) fractures, including the one infection, required additional procedures. Because internal fixation in the combat environment was used judiciously, complications were not higher than previously reported. (Journal of Surgical Orthopaedic Advances 19(1):49–53, 2010)

Key words: combat injury internal fixation, complications

Consistent with previous conflicts, the vast majority of injuries sustained during Operation Enduring Freedom and Operation Iraqi Freedom involve the extremities (1). Fractures account for 26% of extremity injuries, with open fractures being far more common (82%) than closed injuries (18%) (2). Initial management of these injuries has traditionally included debridement of open wounds and stabilization of unstable fractures within hours of injury in the theater of combat operations (echelon II or III facility). After patients are stable for transfer, they are typically evacuated through Germany (echelon IV) to the United States (echelon V) for definitive care, which usually occurs within 4 to 5 days of injury (3).

Internal fixation in the combat environment is reserved for a limited number of fracture patterns associated with a significant risk of failure if definitive treatment is delayed (4). Because of the limited availability of instruments and radiologic support as well as unconfirmed sterility in the combat environment, damage control orthopaedics remains the standard practice on the frontlines.

Although not common, some surgeons perform internal fixation in the combat environment. Most series documenting outcomes of internal fixation performed during the current conflicts are limited to single-surgeon or single-facility case series (5, 6). They report few complications treating non-US personnel, civilians, and detainees in the combat environment, but are limited by their lack of follow-up. The purpose of this study is to evaluate outcomes of internal fixation performed on US military personnel at multiple institutions within a combat environment. We hypothesize that internal fixation in the combat environment is associated with a high rate of complications.

Methods

Following protocol approval by our institutional review board, we performed a retrospective analysis of US military personnel who had internal fixation performed in the theater of combat operations (echelon 2 or 3 facilities) between October 1, 2001 and June 30, 2008. These patients were identified using the Joint Trauma

From [1]Department of Regenerative Medicine, United States Army Institute of Surgical Research, San Antonio, TX; [2]Department of Orthopaedics, Wilford Hall Medical Center, Lackland Air Force Base, TX; [3]Department of Orthopaedics and Rehabilitation, Brooke Army Medical Center, San Antonio, TX. Address correspondence to: Daniel J. Stinner, MD, Department of Regenerative Medicine, United States Army Institute of Surgical Research, 3400 Rawley E. Chambers Avenue, San Antonio, TX 78234; e-mail: daniel.stinner@amedd.army.mil.

The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the Department of the Army or the Department of Defense.

Received for publication September 10, 2009; accepted for publication October 7, 2009.

For information on prices and availability of reprints call 410-494-4994 X226.

1548-825X/10/1901-0049$22.00/0

Theater Registry, which captures internal fixation procedures regardless of where they occurred during the evacuation chain. Electronic radiograph reports were reviewed for all identified patients to confirm that fixation was performed in the combat environment. These electronic radiograph reports were available in the electronic medical record and have a time/date/location stamp stating where and when they occurred. All patients with radiographic confirmation of internal fixation performed in the combat environment were included for data analysis. Patients were excluded if they had any form of fixation that penetrated the skin, such as external fixation or percutaneous pinning. Paper charts, electronic medical records, and radiographs were then reviewed for all patients meeting inclusion criteria to identify patient demographics, injury characteristics, and procedure history. The operative and postoperative time periods were critically examined to identify intraoperative and postoperative complications, need for revision surgery, and missed injuries.

Results

In the time period under investigation, 124 patients were identified in the Joint Trauma Theater Registry as having internal fixation performed within a combat environment (echelon 2 or 3 facility). Seventy-seven patients were excluded because the method of fixation included external fixation or percutaneous pinning or there was no confirmation that internal fixation actually occurred in the combat environment (no available radiographs or documentation in the medical record). The study population consisted of 47 patients who were confirmed to have internal fixation performed in the theater of combat operations. Three patients had internal fixation performed on multiple fractures (two each). All patients were male with an average age of 25 (range, 19–48; median, 24). The average Injury Severity Score (ISS) was 11.4 ± 1.1 (range, 4–34). The mechanism of injury is described in Table 1. All patients were medically evacuated to echelon IV or V military treatment facilities following internal fixation. Average follow-up was 17 ± 2 months (range, 2 weeks–5 years; median, 15 months).

Injuries

Hip, forearm, and ankle fractures made up the majority of internal fixation cases with 14 (28%), 14 (28%), and 10 (20%), respectively. Sixteen (32%) fractures were open and 34 (68%) were closed (Table 2). The Gustillo and Anderson classification system was not consistently documented for the open fractures within patient charts. Retrospective analysis of radiographs revealed 17 AO type A, 19 AO type B, and 8 AO type C fractures. There were two comminuted patella fractures and one gunshot wound to the spine resulting in paraplegia, treated with decompressive fusion of L4–L5. Incomplete visualization of fracture patterns prevented classification of three fractures: one humerus, one clavicle, and one ankle fracture.

TABLE 1 Mechanism of injury

Mechanism of Injury	Total (%)
Blast (penetrating)	9 (18%)
Gunshot wound	7 (14%)
Blunt	34 (68%)

TABLE 2 Injury characteristics

Fracture (total)	Closed (34)	Open (16)	Total (50)
Ankle	10	0	10
Clavicle	0	1	1
Hip (includes proximal femur)	10	4	14
Forearm	6	8	14
Humerus	0	2	2
Patella	2	0	2
Spine	0	1	1
Talus	4	0	4
Tibia	2	0	2

Procedures

All internal fixation was performed on either the day of injury (82%) or the day after injury (18%). A variety of internal fixation procedures were performed to include 44 plate and/or screw (88%), four intramedullary nail (8%), and two tension band (4%) constructs. The specific medical treatment facility where internal fixation was performed was identified for 32 (68%) patients; all were echelon III facilities. In all cases documenting the surgeon of record (51%), the surgeon was board certified and fellowship trained.

Outcomes

Thirty-nine (78%) fractures healed without incidence (i.e., no postsurgical complications or additional procedures performed). One patient (2%) with a closed medial malleolus fracture that was internally fixed with two cancellous screws developed a postoperative infection. Two weeks postoperatively the patient underwent revision with syndesmosis screw placement due to a widened mortise upon evaluation at an echelon V facility. At that time, there was no documented concern for infection. Two weeks following the revision surgery, the patient had purulent drainage from his medial (original) surgical incision. Intraoperative cultures grew methacillin-susceptible *Staphylococcus aureus.* The infection resolved

TABLE 3 Additional procedures

Fracture Location	Open/ Closed	A/O Classification	Reason for Additional Procedures	Additional Procedures Performed
Ankle	Closed	44B	1. Suboptimal placement of syndesmosis screw was not through the syndesmosis. 2. Medial malleolus fracture not fixed.	1. Revision syndesmosis ORIF 2. ORIF medial malleolus fracture
Ankle	Closed	44B	1. Medial clear space widening 2. Postoperative infection	1. Syndesmosis ORIF 2. Two debridement and irrigations
Hip (femoral neck)	Closed	31B	1. Nonunion, hardware failure	1. Total hip arthroplasty (1 year after initial fixation)
Hip (femoral neck)	Open	31C	1. Iliac artery bypass graft	1. Augmentative hip-spanning external fixator
Forearm	Closed	22C	1. Delayed union	1. Bone graft (10 weeks after initial fixation)
Forearm	Open	22B	1. Symptomatic hardware	1. Hardware removal (1 year after initial fixation)
Forearm	Open	23C	1. Delayed union	1. Revision ORIF with bone graft (6 weeks after initial fixation)
Patella	Closed	Comminuted	1. Symptomatic hardware	1. Hardware removal (Date unknown)
Hip (subtrochanteric)	Closed	32A	1. Symptomatic hardware	1. Hardware removal (2 years after initial fixation)
Tibia (tibial plateau)	Closed	41B	1. ‘‘Improved fixation’’	1. Revised to buttress plate

ORIF, open reduction and internal fixation.

with subsequent debridement and irrigations (two) and intravenous antibiotics. The patient healed the fracture and reported 0/10 pain on the visual analogue pain scale at final follow-up (5 months).

There was only one intraoperative complication in a patient who sustained a closed both-bone forearm fracture from a motor vehicle rollover. The patient had median, ulnar, and radial nerve palsies documented postoperatively, which resolved with no intervention.

Two patients, including the one postoperative infection, had missed injuries. One was a closed bimalleolar ankle fracture that had the fibula fracture and syndesmosis internally fixed. The medial malleolus fracture was not identified until evacuation to an echelon V facility where it was then internally fixed. The second was another ankle fracture that had the medial malleolus internally fixed. Radiographs upon arrival to an echelon V facility demonstrated medial clear space widening and the patient underwent subsequent internal fixation of the syndesmosis without complication. Twenty-one percent of patients ultimately required additional procedures (Table 3).

Discussion

With limited data describing outcomes of internal fixation in the theater of combat operations, its use remains controversial. In addition to unconfirmed sterility in the operating room, many combat hospitals have limitations, such as lack of power equipment and fluoroscopy, making it less than ideal to perform internal fixation in the combat environment. Furthermore, damage control orthopaedics on the frontlines and the uncertainty of mass casualty incidents has made external fixation the standard practice on today’s battlefield for unstable fractures. External fixation can be employed rapidly, often without the need for fluoroscopic guidance. In addition, it provides adequate fracture stabilization for temporary or staged treatment, can be converted to more stable constructs for definitive management, and has reported low complications even in severe open fractures (7–10).

Although generally discouraged, internal fixation has been performed in the combat environment. The few studies reporting outcomes of internal fixation performed in a combat environment are either limited by their lack of follow-up or have high complication rates (5, 6, 11, 12). Of 28 fractures (27 open, 1 closed) that were internally fixed in conjunction with an arterial repair during the Vietnam War, Rich et al. reported 10 (36%) amputations; five were due to infection. This amputation rate was much higher than the 20% amputation rate for arterial injuries with concomitant fractures stabilized by external fixation (11). Zeljko et al. had similarly high complication rates for internal fixation performed on the war wounded in Croatia during the early 1990s. He identified 49 wounded patients with open fractures, of which eight underwent primary internal fixation: six with plates and screws (two humerus, two forearm, and two femur fractures) and two with wires (patella fractures). Two patients with plate/screw constructs and both patients with wire constructs developed osteomyelitis. Based on these results, the authors concluded that external fixation should be used as the primary and definitive method for treating combat-related open fractures (12). However, these studies represent worst-case scenarios in fracture management — open combat-related fractures with associated vascular injuries — and are not representative of our study population.

During the current conflicts in Afghanistan and Iraq, internal fixation has been employed on civilians and host nationals in the combat environment, while those treated provisionally with external fixation were routinely returning to US treatment facilities for follow-on care. Keeney et al. evaluated 22 host nation or third-country patients with diaphyseal and subtrochanteric femur fractures that underwent intramedullary nailing at an Air Force Theater Hospital in Balad, Iraq. Two-thirds of the patients had high-energy ballistic injuries. Although no postoperative complications were reported, the study had limited follow-up with more than 75% of patients followed for 2 or less months and no patients followed beyond 6 months (5).

In our study there was only one patient (2%) who developed a postoperative infection following revision internal fixation of a closed injury at an echelon V facility in the United States. Even with the limited numbers in this study, these results are similar to published infection rates for closed fractures (13–15). While open fractures have a much higher infection rate than closed injuries (16), none of the 16 open fractures that included 11 upper extremities in our study population developed a postoperative infection following primary internal fixation.

Contrary to the prevalence of open fractures during the current conflicts (82%) (2), the majority of fractures in our study population were closed (68%). The vast majority of open fractures that underwent internal fixation were in the upper extremity (69%). The only open fractures that underwent internal fixation in the lower extremity were for proximal femur fractures, which, because of to their anatomic location, offer significant challenges for temporary stabilization. Blunt injuries were also more common in our patient population (68%), which is not typical of the combat injuries sustained during the current conflicts (1). In addition, the average ISS for our study population was 11.4, indicating that the majority of patients had less severe injuries and were not considered polytrauma based on their ISS. Furthermore, internal fixation was only performed on 47 patients over a 6-year period. Although the overall number of extremity fractures was not identified during this review, Owens et al. reported 915 during the first 4 years of the current conflicts. This reflects the selectivity of the surgeons, choosing to perform internal fixation on less severely injured patients with the majority having isolated closed extremity fractures.

The current study has several limitations. First, this was a retrospective study and retains the inherent shortcomings of such studies. Second, although internal fixation was performed in the combat environment, the injuries seen in this patient population were generally less severe than those typically seen during the current conflicts (1, 2, 17, 18). In addition, documentation was not always complete within patient charts to include time from injury to operating room and Gustillo and Anderson classification of the open fractures, which limited the amount of analysis possible, although we had no postoperative infections in this group. Finally, while this is the largest study describing internal fixation performed in a combat environment, it is still limited by the small sample size and heterogeneous population, which prevented analyzing subgroups (e.g., anatomical location, fracture type, and fixation method).

In summary, although not a common or suggested practice in the theater of combat operations, internal fixation in this patient population did not result in a high number of complications or additional procedures. Over a 6-year period, a heterogeneous group of board-certified, fellowship-trained orthopaedic surgeons employed internal fixation in only a small handful of orthopaedic injuries. Compared with previously defined populations of extremity injuries, these represented less severely injured patients with less complex wounds and bony injuries.

The results of this study suggest that internal fixation can be safely performed on select patients, within established and well equipped facilities, in a combat environment. Further study is needed to define the patient population in which internal fixation in a combat setting is most appropriate. Obtaining follow-up data on host nation wounded who underwent internal fixation would better define the boundaries of safety.

References

1. Owens, B. D., Kragh, J. F., Wenke, J. C., et al. Combat wounds in Operation Iraqi Freedom and Operation Enduring Freedom. J Trauma 64(2):295–299, 2008.
2. Owens, B. D., Kragh, J. F., Macaitis, J., et al. Characterization of extremity wounds in Operation Iraqi Freedom and Operation Enduring Freedom. J. Orthop. Trauma 21(4):254–257, 2007.
3. Tenuta, J. J. From the battlefields to the states: the road to recovery. The role of Landstuhl Regional Medical Center in US military casualty care. J. Am. Acad. Orthop. Surg. 14(10):S45–S47, 2006.
4. Pollak, A. N., Ficke, J. R. Extremity war injuries: challenges in definitive reconstruction. J. Am. Acad. Orthop. Surg. 16(11):628–634, 2008.

5. Keeney, J. A., Ingari, J. V., Mentzer, K. D., et al. Closed intramedullary nailing of femoral shaft fractures in an echelon III facility. Mil. Med. 174(2):124–128, 2009.
6. Ingari, J. V., Powell, E. Civilian and detainee orthopaedic surgical care at an Air Force theater hospital. Tech. Hand Upper Extrem. Surg. 11(2):130–134, 2007.
7. Lerner, A., Fodor, L., Soudry, M. Is staged external fixation a valuable strategy for war injuries to the limbs? Clin. Orthop. Relat. Res. 448:217–224, 2006.
8. Dougherty, P. J., Silverton, C., Yeni, Y., et al. Conversion from temporary external fixation to definitive fixation: shaft fractures. J. Am. Acad. Orthop. Surg. 14:S124–S127, 2006.
9. Keeling, J. J., Gwinn, D. E., Tintle, S. M. Short-term outcomes of severe open wartime tibial fractures treated with ring external fixation. J. Bone Joint Surg. 90-A(12):2643–2651, 2008.
10. Coupland, R. M. War wounds of bones and external fixation. Injury 25:211–217, 1994.
11. Rich, N. M., Metz, C. W., Hutton, J. E., et al. Internal versus external fixation of fractures with concomitant vascular injuries in Vietnam. J. Trauma 11(6):463–473, 1971.
12. Zeljko, B., Lovrć, Z., Amć, E., et al. War injuries of the extremities: twelve-year follow-up data. Mil. Med. 171(1):55–57, 2006.
13. Philips, W. A., Schwartz, H. S., Keller, C. S. A prospective, randomized study of the management of severe ankle fractures. J. Bone Joint Surg. 67-A:67–78, 1985.
14. Hughes, J. L., Weber, H., Willenegger, H., et al. Evaluation of ankle fractures: non-operative and operative treatment. Clin. Orthop. Relat. Res. 138:111–119, 1979.
15. Fernandez Dell'Oca, A. A., Tepic, S., Frigg, R., et al. Treating forearm fractures using an internal fixator: a prospective study. Clin. Orthop. Relat. Res. 389:196–205, 2001.
16. Gustilo, R. B., Anderson, J. T. Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones. J. Bone Joint Surg. 58(4):453–458, 1976.
17. Covey, D. C. Combat orthopaedics: a view from the trenches. J. Am. Acad. Orthop. Surg. 14:S10–S17, 2006.
18. Mazurek, M. T., Ficke, J. R. The scope of wounds encountered in casualties from the global war on terrorism: from the battlefield to the tertiary treatment facility. J. Am. Acad. Orthop. Surg. 14:S18–S23, 2006.