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Internal Fixation in a Combat Theater Hospital

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Abstract: Limited data are available on the use of internal fixation in combat zone hospitals. The authors performed a retrospective review of 713 surgical cases during 2 Operation Enduring Freedom deployments to a Level III theater hospital in 2007 and 2009 to 2010. The epidemiology and short- to intermediate-term outcomes of patients treated with internal fixation devices were studied. The authors found that, with judicious use, internal fixation under a damage control protocol in a combat theater hospital can be performed with acceptable complication rates.

Musculoskeletal extremity injuries are present in 49% to 71% of Operation Iraqi Freedom and Operation Enduring Freedom casualties.[1-3] American military injury treatment in theater is guided by the Joint Theater Trauma System Clinical Practice Guidelines, the Emergency War Surgery handbook, International Committee of the Red Cross manuals, and courses such as the Extremity War Surgery Course.[4-11] Initial treatments are damage control interventions, including hemorrhage control, wound debridement and irrigation, placement of external fixators and negative-pressure wound therapy devices, and amputations or fasciotomies when indicated. Implanting internal fixation devices in American personnel is generally contraindicated in the war zone.[5,6] However, host nation military and civilians often receive definitive treatment of their injuries at these combat hospitals. Treatment may include internal fixation devices as wounds and fracture personalities dictate. Limited data exist on internal fixation performed in the war zone.[12-21]

The Level III hospital facility in Bagram, Afghanistan, receives many Afghan casualties for definitive treatment of their injuries. At the end of February 2007, the hospital moved from the 14th Combat Surgical Hospital to the Craig Joint Theater Hospital. The Combat Surgical Hospital was a traditional field hospital, constructed from temporary structures with operating rooms in storage containers. The Craig Joint Theater Hospital facility is a permanent facility similar in size to a small community hospital in the United States but designed for and primarily dedicated to trauma care (Figure 1). Sterility of operating conditions was more of a concern at the Combat Surgical Hospital. Digital radiography, computerized tomography scanning, fluoroscopy, and a wide complement of orthopedic implants are available. Cases performed in both facilities are included in this study.

The authors deployed multiple times to the Level III hospital in Bagram and selectively used internal fixation devices for definitive fracture treatment. The cost of these implants is substantial, and the ability to remove infected implants after the withdrawal of American military medical personnel may be limited. Many factors affect Afghan patients' ability to follow up, including finances, distance, and

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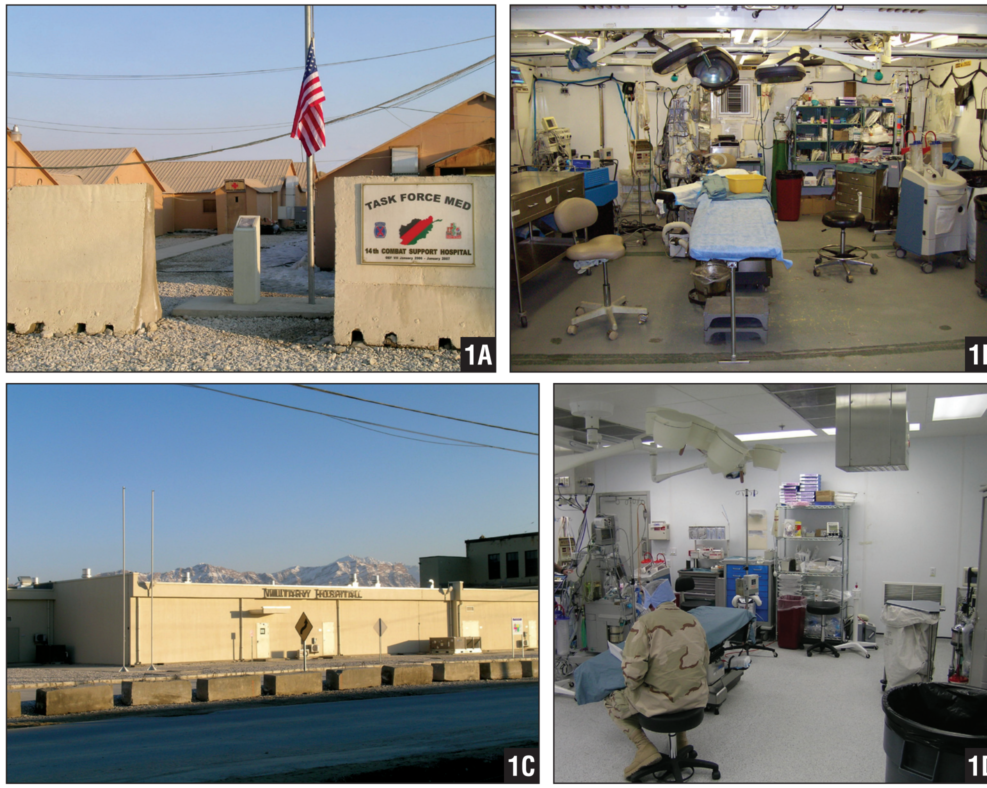

Figure 1: Photographs of the 14th Combat Surgical Hospital (A) and the operating room (B), Bagram, Afghanistan. Photographs of the Craig Joint Theater Hospital (C) and the operating room (D), Bagram, Afghanistan, which opened February 2007.

security concerns. However, many patients attend 1 or more follow-up appointments.

The authors studied the epidemiology of deployed orthopedic surgical cases and the short- to intermediate-term follow-up on the use of internal fixation in a combat zone military hospital. They hypothesized that the use of a consistent, defined protocol for the treatment of battlefield fractures would contribute to acceptable rates of infection and union after the use of internal fixation in a Level III combat theater hospital.

Materials and Methods

This study was approved by the institutional review board at David Grant USAF Medical Center Clinical Investigation Facility (protocol number FDG20120011E). A retrospective review was performed of all patients treated surgically during 2 deployments to Bagram in support of Operation Enduring Freedom: January 2007 to May 2007 and November 2009 to May 2010. These cases were logged in the surgeon's (T.M.L.) personal case log. Patients designated as detainee status were excluded from the study. Inpatient and outpatient care were documented in an electronic medical record (Composite Health Care System; Science Applications International Corporation, Tysons Corner, Virginia). The review of patients treated with internal fixation was performed using the Composite Health Care System and Theater Medical Data Store (Akimeka LLC, Kihei, Hawaii) databases and the locally held digital radiology system. Fractures were classified according to the Gustilo-Anderson open fracture classification[22,23] and the AO/OTA classification system.[24]

Outpatient follow-up occurred at the Combat Surgical Hospital, Craig Joint Theater Hospital, or other military facilities throughout Afghanistan. Due to variable documentation, follow-up analysis gathered no data on range of motion or functional outcomes, but rather focused on infection and fracture healing. If the presence or absence of infection was not documented by the provider, the patient was excluded. Fracture healing was defined radiographically as bridging bone on 3 cortices or clinically as full weight bearing without pain. Statistical analysis was performed using Student's *t* test and chi-square analysis with Bonferonni correction.

All patients admitted and definitively treated in theater for battlefield injuries from improvised explosive devices (IEDs), gunshot wounds, and indirect fire mechanisms underwent the same treatment protocol during both deployments. This protocol was devised by the author (T.M.L.) through a combination of recommendations from the Joint Theater Trauma System Clinical Practice Guidelines, Emergency War Surgery handbook, International Committee of the Red Cross publications, relevant Extremity War Injuries Symposia publications, and personal conversations with other military orthopedic surgeons.[4-11]

Patients underwent early, aggressive wound debridement, removing devitalized tissue and foreign debris, generally within hours of their injury depending on the number of casualties received. All wounds were irrigated with a minimum of 9 L of normal saline without additives. Patients returned to the operating room in 24 to 72 hours for repeat debridements as dictated by the extent of the soft tissue injury and contamination. Seventy-two hours was preferred for most cases. All wounds underwent a minimum of 2 irrigation and debridement procedures prior to fixation, at which time wounds were closed or covered with grafts or flaps. Any debridements that occurred at a forward operating base were not counted toward these 2 debridements. Internal fixation was postponed if wounds required additional debridement of devitalized tissue at the third operation.

All wounds associated with open fractures were treated with a negative-pressure wound therapy device (VAC; Kinetic Concepts, Inc, San Antonio, Texas) at 125 mm Hg continuous suction. Internal fixation devices were used if the fracture was thought to be reconstructible and, most importantly, the soft tissue injury and wounds were clean and could be closed or covered.

External fixator pin sites were curetted and irrigated prior to intramedullary nailing and were left open to heal by secondary intention. Pins were wrapped with bolstered gauze bandages; no cleaning regimen was used. During the 2007 deployment, patients received cefazolin and gentamycin, with penicillin G added for wounds contaminated with vegetative debris. Gentamycin and penicillin G were continued for 72 hours and cefazolin was continued for 48 hours after wound closure or coverage. During the 2010 deployment, patients received cefazolin and levofloxacin; penicillin G was not used. Cefazolin and levofloxacin were continued for 48 hours after wound closure or coverage.

Wounds and surgical incisions were closed in layers using monofilament sutures and sometimes staples. Wounds were not cultured on presentation or repeat debridement procedures. Skin grafts were dressed with nonadherent gauze (Adaptic; Johnson & Johnson Services Inc, New Brunswick, New Jersey) and negative-pressure wound therapy at 125 mm Hg continuous suction for 5 days. Occasionally, negative-pressure wound therapy was used as a dressing over closed surgical wounds, such as fasciotomies or those under any tension, at 125 mm Hg continuous suction for 3 days. The authors estimate that this was done for 20% of patients.

No allograft or autograft bone graft was placed acutely in war-injured open fracture sites. Large segmental defects were treated with antibiotic-impregnated polymethylmethacrylate (PMMA) bead spacers and staged iliac crest autografting in 6 to 8 weeks, occasionally augmented with allograft chips or demineralized bone matrix. Bead pouches were not used as initial prophylactic treatment. No bone morphogenic protein products were used. Small nonsegmental defects were treated with antibiotic-impregnated calcium sulfate beads (Osteoset; Wright Medical Technology, Inc, Arlington, Tennessee) at the time of internal fixation and closure/coverage. Patients without contraindications were started on 30 mg of enoxaparin twice daily after surgery. Enoxaparin was given the night before surgery and not given the morning of surgery. Exceptions to the above protocols occurred as dictated by the clinical situation, such as altered antibiotic regimens due to abdominal injuries.

Results

During the January to May 2007 deployment, 307 surgical cases were performed, frequently requiring multiple procedures on single or multiple limbs (Figures 2-4). Many patients returned for multiple operations, so 118 unique patients were treated. These patients sustained injuries to an average of 1.46 limbs. The mechanisms of injury and patient demographics are summarized in Tables 1 and 2. An analysis of the 307 procedures shows a preponderance of Afghan patients: 21 (6.8%) were performed on US military personnel, 3 (1.0%) on North Atlantic Treaty Organization (NATO) military personnel, 194 (63.2%) on Afghan civilians, 85 (27.7%) on Afghan National Army or Afghan National Police personnel, and 4 (1.3%) on third-country nationals or contractors.

During the November 2009 to May 2010 deployment, 406 surgical cases were performed, again with many patients having multiple operations; 266 unique patients were treated (Figures 5-10). These patients sustained injuries to an average of 1.74 limbs, a significant increase from 2007 (P=.019). The mechanisms of injury and patient demographics are summarized in Tables 1 and 2. An analysis of the 406 surgical cases again shows that a majority were Afghan patients: 126 (31.0%) were performed on US military personnel, 21 (5.2%) on NATO military personnel, 134 (33.0%) on Afghan civilians, 120 (29.6%) on Afghan National Army or Afghan National Police personnel, and 5 (1.2%) on third-country nationals or contractors.

During the 2007 deployment, 66 internal fixation procedures were performed on 50 patients. During the 2009 to 2010 deployment, 87 fixation procedures were performed on 77 patients, for a total of 153 fixation cases in 127 patients. Patients definitively treated with external fixation or casts are not included in these numbers. These numbers include percutaneous and open pinning fracture cases, mostly in the hands, feet, or pediatric elbows. These were excluded, leaving 117 internal fixation cases in 92 patients.

Follow-up was available on 64 (55%) internal fixation cases in 47 patients. Nine (14%) of these cases were performed in the Combat Surgical Hospital and 55 (86%) in the Craig Joint Theater Hospital (Tables 3, 4). The 38 open fractures were classified using the Gustilo-Anderson classification,[22,23] and all fractures were classified with the AO/OTA classification.[24] Two fractures were above amputations. One elective osteotomy case was not classified. Average follow-up was 122 days (range, 14-447 days). Patients included 3 US military personnel, 39 Afghan National Army or Afghan National Police personnel, and 22 Afghan civilians. Four cases were pediatric and 60 were adult. Three cases were referral cases with preexisting infections. Four cases were referral nonunion or pending malunion cases.

Six patients received antibiotic-impregnated calcium sulfate grafting of a nonsegmental defect. Two patients received antibiotic-impregnated PMMA beads or spacers for segmental defects; 1 patient received an antibiotic-impregnated PMMA tibial nail for treatment of an infected tibial nonunion. Eight patients required split-thickness skin grafts, and 3 had rotational muscle flaps for soft tissue coverage; the remainder with open wounds underwent delayed primary closure. Six patients with tibial fractures had compartment syndrome treated with medial and lateral fasciotomies.

Figure 2: 2007 deployment. Clinical photograph of a left open tibia fracture with a closed medial malleolus fracture and closed calcaneal fracture with a right closed talar neck fracture and open right leg wounds sustained when a rocket-propelled grenade hit a pickup truck (A). Lateral (B), anteroposterior (C), and mortise (D) radiographs at 292-day follow-up. All wounds healed and the patient was fully weight bearing without pain bilaterally.

Figure 3: 2007 deployment. Anteroposterior radiograph in a temporizing external fixator of an improvised explosive device injury with an open tibial fracture (A). Clinical photograph of the wound at 2-week follow-up; it healed uneventfully (B). Anteroposterior radiograph at 159-day follow-up showing a healed fracture (C).

Two (3%) infections occurred: 1 in a patient referred with a preexisting infection and the other in a referral case revised from a lag screw and external fixation construct to a femoral intramedullary nail. The former patient had an ongoing infected nonunion, and the treatment plan moving forward was not clearly documented. The latter patient was treated with hardware removal and intravenous antibiotics, but documentation of infection eradication was not available. Of the 37 patients with adequate follow-up to determine fracture healing, 2 delayed unions and 1 nonunion occurred, a rate of 8%. Of the 2 delayed unions, 1 was treated with tibial nail dynamization and iliac crest autograft, and the other was treated with dynamization and a fibular osteotomy. The nonunion patient was the same with an ongoing infected tibial nonunion mentioned above. In addition, 2 patients with large segmental defects underwent planned exchange of their antibiotic-impregnated PMMA bead spacers with iliac crest autograft. Thus, a total of 5 (8%) cases required additional procedures.

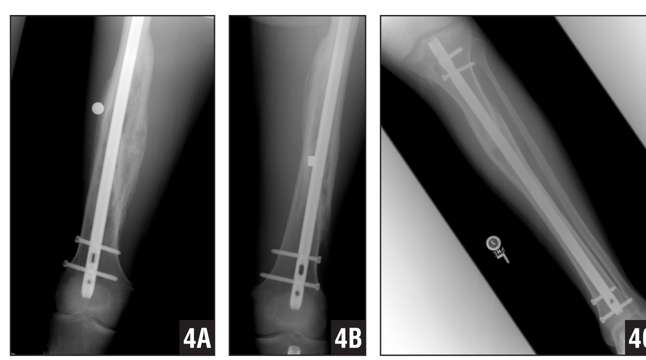

Figure 4: 2007 deployment. Anteroposterior radiographs 233 days after suicide bomber injuries caused right open femur (A), left open femur (B), and left open tibia (C) fracture showing well-healed fractures. The patient was ambulating without pain or assistive devices.

Discussion

The epidemiology of the 713 deployed orthopedic surgical cases presented in this article is similar to that reported by Owens et al[2] in their review of 3575 extremity injuries: 59.8% were from explosions (IED or indirect fire) and 23.3% from gunshot wounds in the current study's most recent deployment data vs 75% and 16%, respectively, in the study of Owens et al.[2] Notably, the percentage of IED injuries increased from 8.5% to 36.5% between deployments ($P<.0001$), reflecting an increased use of this technology. Also, the number

Table 1

Mechanisms of Injury

Injury Mechanism	No. (%) of Unique Patients 2007 Deployment	2009-2010 Deployment	*P*
IED	10 (8.5)	97 (36.5)	<.0001
Gunshot wounds	15 (12.7)	55 (20.7)	—
Indirect fire[a]	41 (34.7)	62 (23.3)	.0196
Other[b]	52 (44.1)	52 (19.5)	<.0001

Abbreviation: IED, improvised explosive device.
[a]*Rocket-propelled grenades, mortars, landmines, suicide bombs, grenades.*
[b]*Falls, motor vehicle and other accidents, knife injuries, elective conditions (osteomyelitis, nonunions, tumors, congenital deformities).*

Table 2

Epidemiology of 713 Deployed Surgical Cases

Characteristic	No. (%) 2007 Deployment	2009-2010 Deployment
Cases	307	406
Unique patients	118	266
Average injured limbs per patient[a]	1.46	1.74
US military personnel	18 (5.2)	120 (45.1)
NATO military personnel	3 (2.5)	19 (7.1)
Local nationals	69 (58.5)	68 (25.6)
ANA or ANP personnel	26 (22)	55 (20.7)
Other	2 (1.7)	4 (1.5)

Abbreviations: ANA, Afghan National Army; ANP, Afghan National Police; NATO, North Atlantic Treaty Organization.
[a]*Statistically significant (P=.019).*

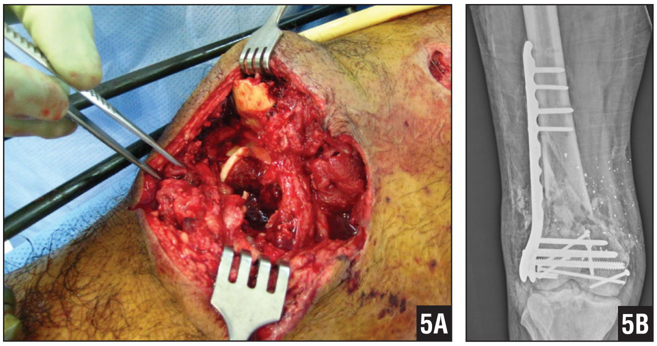

Figure 5: 2009-2010 deployment. Clinical photograph of an open supracondylar femur fracture, patellar tendon laceration, and missing substantial patella due to an AK-47 gunshot wound (A). Anteroposterior radiograph at 8-week follow-up (B). The patient's wounds healed and he began weight bearing 81 days after discharge from hospital.

Figure 6: 2009-2010 deployment. Clinical photographs of wound healing (A) and knee motion (B) 3 weeks after open tibia and closed medial malleolus fractures with compartment syndrome from an improvised explosive device. Clinical photograph of wound healing at 6 weeks (C). The patient was fully weight bearing without pain at 131-day follow-up.

of injured limbs per patient significantly increased from 1.46 to 1.74 (*P*=.019), also reflecting an increasing severity of energy mechanisms during Operation Enduring Freedom. Of the 713 cases, 79% were not American casualties, providing a large number of patients requiring definitive treatment of their injuries in a combat environment.

Internal fixation in US and NATO forces is generally not indicated in the combat zone due to concerns over infection rates and the need for time-sensitive stabilizing procedures as patients move through the evacuation chain.[4-6] In rare injuries, such as a displaced femoral neck fracture, internal fixation may be considered in coalition patients. With minimal data available, it is difficult to conclude whether the benefits of operative fixation would outweigh infection risk. In addition, many Level III and some Level II facilities provide care to host nation personnel, which includes definitive treatment of their injuries. With limited follow-up available, it is difficult to treat these patients definitively in casts or external fixators, and hospital capacities would not

Figure 7: 2009-2010 deployment. Anteroposterior radiograph 10 weeks after open tibia and bimalleolar ankle fractures due to an improvised explosive device (A). Clinical photograph of wound healing at 10 weeks (B). The patient underwent tibial nail dynamization and fibular osteotomy for a delayed union at 160 days.

Figure 8: 2009-2010 deployment. Anteroposterior (A) and mortise (B) radiographs of open pilon, talus, and calcaneal fractures with compartment syndrome after an improvised explosive device injury. Anteroposterior radiograph 2 weeks after treatment with tibiotalocalcaneal fusion nailing using a short femoral nail (C).

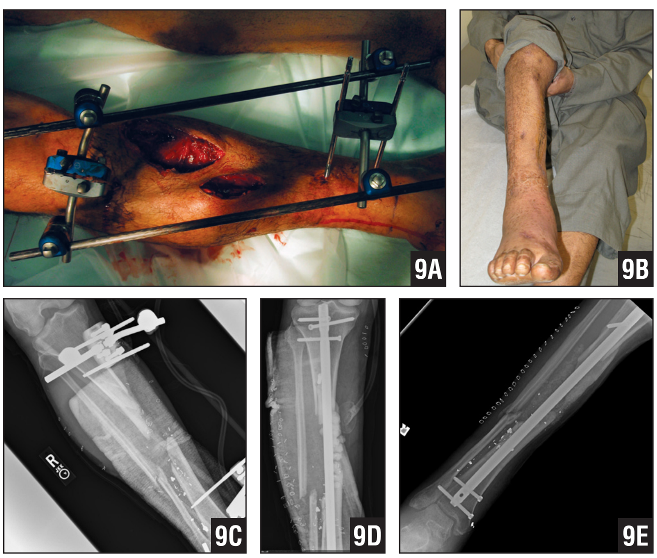

Figure 9: 2009-2010 deployment. Clinical photograph of a tibia fracture caused by a high-energy gunshot wound (A). Clinical photograph of wound healing at 11 weeks (B). Anteroposterior radiographs after external fixation (C), after intramedullary nailing and placement of an antibiotic bead spacer (D), and 3 weeks after posterolateral bone autografting into the bead pouch, performed 8 weeks after intramedullary nailing (E).

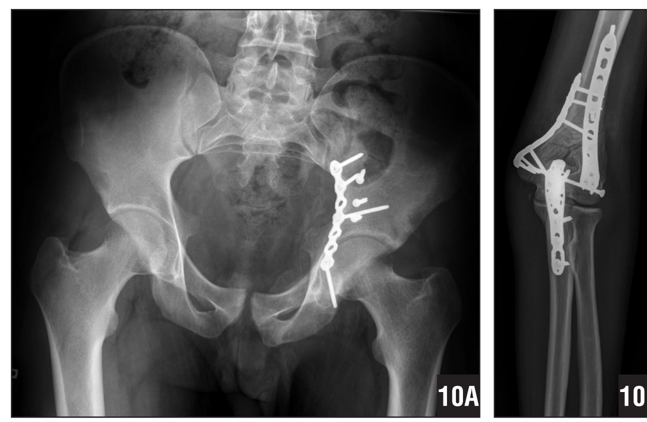

Figure 10: 2009-2010 deployment. Anteroposterior radiographs of a closed anterior column acetabulum fracture at 5 weeks (A) and closed supracondylar humerus and olecranon fractures with 75% triceps laceration at 3 weeks (B) after suicide bomber injuries.

accommodate keeping these patients until fracture healing has occurred, so when soft tissue injuries will reasonably allow the use of internal fixation for reconstructible bony injuries, clear advantages exist. Some data exist on the use of internal fixation in combat zone facilities.

Historical articles from World War II through the Bosnian-Croatian-Serbian War outline many important aspects of damage control treatment of combat orthopedic injuries, but few conclusions can be drawn about the safety or usefulness of internal fixation in combat injuries.[15-21,25] More recently, Keeney et al[13] reported 2-month follow-up on 12 fractures and 6-month follow-up on 5 fractures treated with femoral intramedullary nails in host nation patients at a Level III facility during Operation Iraqi Freedom. They reported no known infections, but no patient with a high-grade soft tissue injury underwent intramedullary nailing, whereas the current study included many patients with high-grade soft tissue injuries.

Stinner et al[14] presented 50 internal fixation procedures in American military personnel performed in a combat environment. Thirty-two percent of fractures were open from a blast or gunshot wound, whereas 68% were closed, blunt injury cases. A higher proportion of ballistic injuries and open fractures are presented in the current study (Table 1), and 82% of their patients had fixation on the day of injury. They reported 1 infection, presenting 4 weeks out, and concluded that the judicious use of internal fixation in an established, well-equipped facility within a combat environment may be safely performed.[14]

Mody et al[12] reported 58 US military patients receiving intramedullary fixation at Walter Reed Army Medical Center

Table 3

Internal Fixation Case Characteristics

Characteristic	No. (%)
Injury mechanism	
IED	14 (22)
IDF	21 (33)
GSW	14 (22)
Other	15 (23)
Open/closed	
Open	38 (59)
Closed	26 (41)
AO/OTA classification[a]	
A	16 (25)
B	23 (37)
C	24 (38)
Gustilo/Anderson classification[b]	
II	5 (13)
IIIA	22 (58)
IIIB	3 (8)
IIIC	2 (5)

Abbreviations: GSW, gunshot wound; IDF, indirect fire; IED, improvised explosive device.
[a]*One osteotomy case was not classified.*
[b]*Six (16%) had inadequate documentation to be classified.*

Table 4

Internal Fixation Procedures

Procedure	No.
Tibia IMN	15
Femur IMN	10
Ankle ORIF	8
Humerus ORIF	6
Tibia pilon ORIF	3
Proximal tibia ORIF	3
Forearm ORIF	3
Pelvis ORIF	2
Calcaneal ORIF	2
Talus ORIF	2
Supracondylar humerus and olecranon ORIF	2
Humerus IMN	1
Supracondylar humerus ORIF	1
Hand proximal phalanx ORIF	1
Acetabulum ORIF	1
Femoral neck ORIF	1
Distal femur ORIF	1
Tibiotalocalcaneal arthrodesis IMN	1
Pelvis/femur osteotomy ORIF	1

Abbreviations: IMN, intramedullary nailing; ORIF, open reduction and internal fixation.

for battlefield femur and tibia fractures. Eighty-eight percent of their fractures were open vs 59% in the current study. They had a 40% infection rate, with a median time to infection of 15 days. Fifty-seven percent of infections occurred within 1 month, and 75% presented by day 113.[12] Thus, the current study's follow-up of 14 to 447 days should have captured the majority of infections.

More recently, Burns et al[28] reported a 27% infection rate in 213 Gustilo-Anderson type III combat open tibial fractures. Patients received an average of 6 debridements, and the timing of infections was not reported. Patients with positive surveillance cultures were more likely to develop an infection or undergo an amputation, but these cultures were not predictive of the infecting organism.[28] The current authors did not perform surveillance cultures in this series. Although it is likely that some patients from the current series presented elsewhere with late infections, it is unlikely that these missed infections would increase the infection rate from 3% to the 27% to 40% rates reported above[12,28]; however, the patients in these other series had more extensive wounds.

Two infections occurred in the current series, 1 in a patient being treated for a preexisting tibial infection that recurred. Two other patients treated for preexisting infections were cured of ongoing infection at most recent follow-up. The low rate of infection experienced here may be due to many factors. A consistent damage control protocol with a minimum of 2 debridements was used prior to any fixation procedures, so all open fracture internal fixation procedures occurred on day 5 to 10, the physiologic ideal time for definitive surgery in Pape's[27] description of the immunologic response to polytrauma. Despite the poor access to health care for most Afghan people, multi-drug resistant organisms are frequently present in Afghan patients in Bagram.[28] Environmental or genetic factors may help explain the current study's lack of surgical infections from antibiotic-resistant organisms reported by others on combat casualties.[29-31]

The current authors aggressively used negative-pressure wound therapy and antibiotic-impregnated calcium sulfate or PMMA beads, which have been shown to decrease infection rates.[32-37] Intravenous cefazolin was continued for 48 hours after the wounds were closed or covered. Others have recommended discontinuing antibiotics 24 hours after the wound is clean, even if it is not closed.[38] A recent review provides recommendations on antibiotic use for combat extremity injuries, which also covers different antibiotic selections between deployments.[38]

The 5 (8%) patients in the current series requiring additional procedures compares favorably with the 21% reported by Stinner et al.[14] Longer follow-up would likely result in a higher number. Although the follow-up rate of 55% is a limitation of the current study, given the challenges related to following patients and collecting data in deployed locations, this is the largest series reported on the use of internal fixation in a combat hospital. A major contribution from this study is an evaluation of the possible burden left from Operation Enduring Freedom after the withdrawal of American medical assets. Advanced implant use could leave thousands of Afghan patients with implants that local surgeons cannot remove if they become infected. This is an ongoing concern, but based on the experience presented here, does not seem likely to be a widespread burden.

Conclusion

The authors' purpose is not to advocate for aggressive internal fixation use in combat hospitals. The majority of these procedures were performed in Craig Joint Theater Hospital, where the operating rooms have a modern ventilation system and can be kept clean. Treating infection in a developing country is challenging and resource intensive. The best treatment is prevention. The presence of internal fixation complicates the treatment of infection and presents challenges in hardware removal and fracture union. Without more data to support the safety of internal fixation in a field environment, the authors believe that the least invasive treatment that will adequately treat the fracture should be used.

The goals of fracture treatment in an austere environment should balance the benefits of fracture stabilization with the risks of operative interventions. In many cases, this is a complex decision due to extensive wounds or substantial bone and articular surface loss. Many patients treated during this time period had casts, definitive external fixators, or percutaneous pinning. However, in other cases, internal fixation devices were the treatment of choice. This study's results support that internal fixation, when used selectively under a reproducible damage control protocol, can be safely used in a combat environment with a low complication rate. Further study and longer-term follow-up on this issue will be critical.

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