

# Orthopedic Injuries in U.S. Casualties Treated on a Hospital Ship during Operation Iraqi Freedom

*CDR Jerome G. Enad, MC USN\*;* *CDR Jeff D. Headrick, MC USN (Ret.)†*

**ABSTRACT** From March to May 2003, the USNS Comfort was deployed to the Persian Gulf in support of combat operations for Operation Iraqi Freedom. The onboard orthopedic service treated 58 U.S. casualties during that period. Eighty-seven percent of the injuries were to the appendicular skeleton. Twenty-four percent were battle injuries, and 72% were nonbattle injuries. Patients with battle injuries tended to be younger and required more orthopedic operations than did patients with nonbattle injuries. Moreover, all patients with battle injuries were evacuated to higher echelons for further care, whereas 19% of patients with nonbattle injuries returned to duty in the short term. Complications were few, with no infections, amputations, or deaths. A descriptive review of the types of injuries, orthopedic care, and eventual disposition is presented.

## INTRODUCTION

Historically, orthopedic injuries in large-scale military conflicts represent >50% of wartime casualties.<sup>1,2</sup> Recent experience during the current global war on terrorism shows that musculoskeletal injuries still constitute a large proportion of casualty care.<sup>3-5</sup> As the nature of war has evolved from large-scale military operations to shorter, high-intensity conflicts, the nature of orthopedic injuries has also changed. Most musculoskeletal injuries are now caused not by bullets but by explosive ordinance, blast waves, land mines, and secondary fragments.<sup>6</sup> In response to the changing characteristics of war fighting, medical support of battlefield casualties at lower echelons of care has become increasingly sophisticated.<sup>7-15</sup> Moreover, casualty reports from Operation Enduring Freedom and Operation Iraqi Freedom have seen new patterns of musculoskeletal injuries, compared with previous conflicts.<sup>14-16</sup>

In January 2003, the USNS Comfort was deployed to the Persian Gulf as a full operating status, echelon III trauma center in support of Operation Iraqi Freedom. The USNS Comfort is a Mercy-class hospital ship with 1,000 inpatient beds, a 50-bed casualty-receiving area, and 12 operating rooms. The ship's primary mission is to provide a mobile, flexible, rapidly responsive, medical treatment facility afloat for medical and surgical care of all deployed Army, Navy, Air Force, and Marine Corps elements and to provide medical support to forces located in areas where hostilities may be imminent.<sup>17</sup> As a secondary mission, the USNS Comfort is capable of providing a full hospital service asset for use by other government agencies involved in the support of relief and humanitarian operations worldwide. The USNS Comfort spent 56 consecutive days in the Persian Gulf, providing critical medical care to combat casualties. The surgical case-

load during this tour was described previously.<sup>3,18</sup> This report provides a descriptive summary of both surgical and nonsurgical orthopedic care rendered to the U.S. service members seen onboard the USNS Comfort during combat operations for Operation Iraqi Freedom.

## METHODS

Our local institutional review board approved this retrospective study. From March to May 2003, the USNS Comfort deployed to the Persian Gulf for 56 days in support of Operation Iraqi Freedom. During that period, 58 U.S. service members were treated for orthopedic injuries, including 22 Marines, 31 sailors, four soldiers, and one Coast Guardsman. There were 54 men and four women (mean age, 27.0 years; range, 19–50 years). Each orthopedic injury could be categorized as either fracture, neurological, penetrating, or mainly soft tissue (Table I). Twenty-one percent of patients (12 of 58 patients) belonged to more than one category because of multiple injuries. The anatomic locations of these injuries are illustrated in Figure 1, with 16% of patients (9 of 58 patients) sustaining injuries to more than one anatomic region. The skeletal distribution of fractures is illustrated in Figure 2.

## Treatment of Injuries

Each patient was evaluated and stabilized in the casualty-receiving area, according to the principles of Advanced Trauma Life Support,<sup>19</sup> before undergoing treatment for orthopedic injuries. Patients with soft tissue wounds of the extremities were taken to the operating room for irrigation and debridement. Open fractures were graded according to the classification of Gustilo and Anderson.<sup>20</sup> During surgery, skin was preserved as much as possible, but nonviable tissue and muscle were excised.<sup>21</sup> Healthy muscle was assessed by its appearance, consistency, contractility, and ability to bleed when incised. Metallic fragments were usually left in situ unless they were intra-articular, compromised neurovascular structures, or were encountered in the normal course of the operation. All wounds were initially left open. Open fractures

\*Bone and Joint Sports Medicine Institute, Naval Medical Center, Portsmouth, VA 23708.

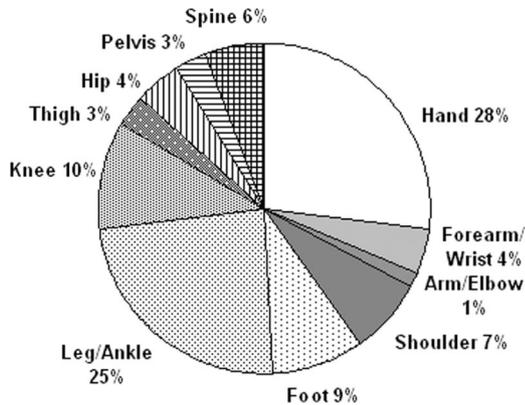
†Center for Orthopaedic Surgery, Lubbock, TX 79423.

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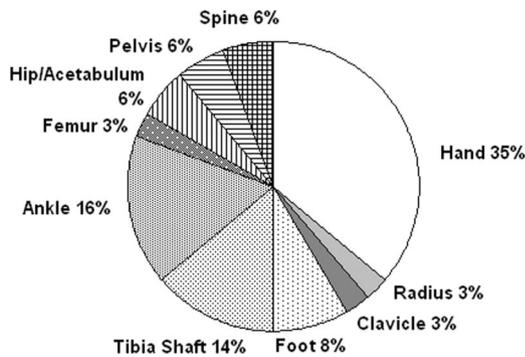
**TABLE I.** Distribution of Injuries Treated by the Orthopedic Surgery Service

Category	No.
Fracture	30
Neurologic	7
Penetrating (gunshot, foreign body, or fragment)	3
Soft tissue only (sprain/strain, compartment syndrome, tendon laceration, or burn)	27
Total	67

were stabilized by using external fixation, intramedullary nailing, Kirschner wire pinning, or plaster splinting. Patients with open wounds were administered broad-spectrum, intravenous, antibiotic therapy that included Gram-negative coverage. Unstable closed fractures were treated with surgical intervention for primary fixation with implants (see below) or splinting/casting with plaster. Patients with closed injuries that could be treated nonoperatively (i.e., “walking wounded”) underwent splinting, corticosteroid injections, and/or physical therapy.



**FIGURE 1.** Anatomic distribution of orthopedic injuries seen by the orthopedic service.



**FIGURE 2.** Skeletal distribution of fractures treated by the orthopedic service.

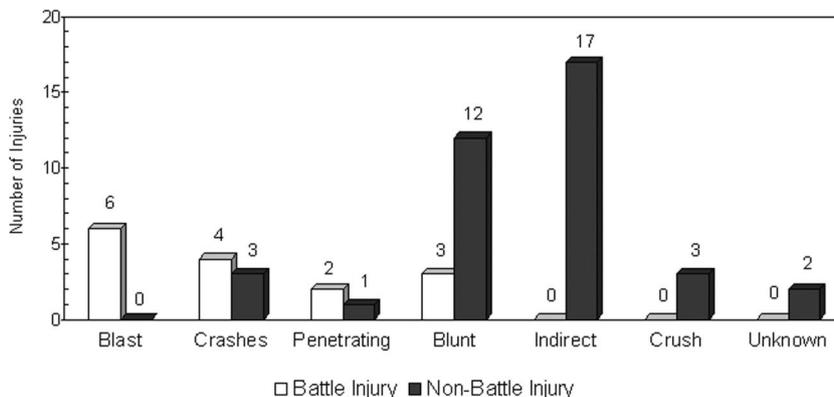
**Data Collection**

Clinical information on each patient was collected mostly on a handwritten chart and a limited electronic record system. A retrospective review of records was performed, and clinical data that were most consistently documented were exported to a spreadsheet for statistical analysis. Patient identifiers and protected health information remained confidential. Long-term follow-up data on patients were not analyzed. The patient population was stratified into two groups for reporting purposes, based on whether the injury was a battle injury (BI) or a nonbattle injury (NBI). Statistical analysis with two-sample *t* tests between BI and NBI groups was performed with respect to age, number of orthopedic operations and total operations performed on site, and return-to-duty rates, with a significance level set at *p* < 0.05.

**RESULTS**

**BI and NBI Groups**

Twenty-four percent of patients (14 of 58 patients) presented with a confirmed history of direct combat injury or BI, 72% (42 of 58 patients) had a history of NBI, and 3% (2 of 58 patients) had unknown history. BI patients tended to be younger (mean age, 24.5 years; range, 19–38 years) than NBI patients (mean age, 28.1 years; range, 19–50 years; *p* = 0.051). The distribution of mechanisms of injury tended to cluster around higher-energy mechanisms for BIs (Fig. 3), with six blast injuries, two vehicle and two aircraft crashes,



**FIGURE 3.** Distribution of BIs and NBIs according to mechanism of injury.

three blunt injuries, and two penetrating (bullet or fragment) injuries. The mechanisms of injury tended to be more varied for NBIs (Fig. 3), with 17 indirect trauma (twists/falls), 12 blunt trauma, four unknown mechanisms, three vehicle crashes, three direct crush injuries, and one penetrating (gun-shot) injury.

BI patients underwent more orthopedic operations (mean, 1.6 operations; range, 0–7 operations) than did NBI patients (mean, 0.6 operations; range, 0–6 operations;  $p < 0.01$ ). BI patients also had more total operations (mean, 2.1 operations; range, 0–10 operations) than did NBI patients (mean, 0.8 operations; range, 0–12 operations;  $p < 0.02$ ). All 14 BI patients were evacuated to a higher level of care, and none returned to duty in the short term. Eighty-one percent of NBI patients (34 of 42 patients) were evacuated to a higher level of care or away from theater ( $p < 0.04$ ), and 19% (8 of 42 patients) returned to duty in the short term.

**Orthopedic Surgical Treatment**

Seventeen percent of patients (10 of 58 patients) received orthopedic treatment before arrival at our facility. For this group, the average total number of surgical procedures performed previously was 3.1 (range, 1–5 procedures per patient). The most common previous procedure was formal irrigation and debridement for seven patients, followed by external fixation for three patients and fasciotomy for two patients.

Forty-seven percent of patients (27 of 58 patients) underwent orthopedic surgery at our facility (Table II). Primary fracture fixation with implants (e.g., open reduction and internal fixation [ORIF], lumbar fusion, intramedullary nailing, percutaneous pinning, or definitive external fixation) was the most common surgical procedure (17 patients), followed by irrigation and debridement for nine patients (repeated for two of those patients). Split-thickness skin grafting and tendon repair in the hand were each performed for four patients.

**TABLE II.** Orthopedic Procedures Performed on the Hospital Ship

	No.
Orthopedic surgical procedures	
Irrigation and debridement	9
ORIF or fusion	8
Percutaneous pinning	5
Tendon repair	4
Split-thickness skin graft	4
Hardware exchange/revision	3
Intramedullary nailing	3
Delayed primary closure	3
Joint reduction	2
Fasciotomy	2
External fixation	1
Total	44
Outpatient orthopedic treatment	
Splint, cast, or brace	14
Aspiration or injection	4

Delayed primary closure, revision hardware fixation, and knee arthroscopy were performed for three patients each. Joint reduction and fasciotomy were performed for two patients each. For the 27 patients who required orthopedic surgery, the average number of procedures was 1.8 (range, 1–7 procedures). Eight of those patients required additional nonorthopedic surgery. Definitive nonsurgical treatment provided by the orthopedic service included splinting, casting, or bracing for 14 patients and joint aspiration or injection for four patients.

**Fractures**

Fifty-two percent of patients (30 of 58 patients) sustained fractures (Fig. 2), with two patients sustaining fractures to multiple anatomic regions. Thirteen percent of the fractures (4 of 30 fractures) were open. Primary fracture fixation with implants (e.g., ORIF, fusion, intramedullary nailing, percutaneous pinning, or definitive external fixation) was performed for 17 patients. Closed fracture stabilization with splinting or casting was performed for 10 patients. One open, grade IIIB, tibial fracture was treated with external fixation and irrigation and debridement before evacuation. Another open, grade IIIB, tibial fracture was treated with external fixation and split-thickness skin grafting before evacuation. One open, grade II, tibial fracture was treated with intramedullary nailing, irrigation and debridement, and delayed primary closure before evacuation. One open pelvic fracture was treated with external fixation, multiple irrigation and debridement procedures, delayed primary closure, ORIF, and split-thickness skin grafting before evacuation.

**Soft Tissue and Neurological Injuries**

Forty-seven percent of patients (27 of 58 patients) sustained isolated soft tissue injuries, including nine patients with sprains/strains, five with hand or wrist tendon lacerations, three with open soft tissue wound injuries without fracture, three with acute or impending compartment syndrome of the leg, two with acute compartment syndrome of the foot, two with meniscal tears, one with an extremity burn injury, one with herniated nucleus pulposus, and one with cellulitis. Twelve percent of patients (7 of 58 patients) sustained neurological injuries, including four patients with neuropraxia (three sensory and one motor), one with incomplete paraplegia attributable to thoracic fracture, one with tibial nerve laceration, and one with traumatic carpal tunnel syndrome.

**Disposition**

Eighty-three percent of patients (48 of 58 patients) were eventually evacuated to higher echelons of care or away from the war zone, whereas 17% of patients (10 of 58 patients) were returned to full duty. Lengths of stay varied widely, mostly because of logistical concerns (the accuracy of this parameter was found to be unreliable during our chart review).

### Complications

Perioperative complications occurred in 3.4% of cases (2 of 58 cases). One patient was involved in a rollover tank accident and presented to our facility 16 hours after injury, with a fracture/dislocation at thoracic spinal levels 7 and 8 and incomplete paraplegia. Urgent anterior reduction, corpectomy, discectomy, caged fusion, and posterior spinal instrumented fusion were performed. Before evacuation to a higher echelon, the paraplegia was unresolved and the patient developed a sacral decubitus ulcer. Another patient was multiply injured from a crushing blast injury and sustained bilateral hip and pelvic fractures/dislocations and bowel injury. He required abdominal exploration, sigmoid colostomy, and multiple orthopedic operations for joint and fracture reduction and stabilization. Before evacuation to a higher echelon of care, the patient developed disseminated intravascular coagulopathy that required medical management. No perioperative infections were identified during the study period. There were no amputations or deaths.

### DISCUSSION

The current report is a descriptive review of the orthopedic injuries among U.S. service members who were treated onboard the USNS Comfort during Operation Iraqi Freedom. Our experience during this unique wartime period included multiple factors that precluded conventional stateside treatment of these injuries, including limitations in manpower and supplies, previous "damage control" treatment, unpredictable medical evacuation schedules, and even the physical layout of the hospital ship.<sup>22</sup>

Although the USNS Comfort served as a echelon III facility in proximity to the war zone, 17% of the patients underwent previous orthopedic operations at a lower echelon of care. This is an evolution in contemporary battlefield medicine; both the U.S. Army and U.S. Navy forces actively deployed forward resuscitative surgical teams on or near the front lines during this conflict.<sup>7-15</sup> Whereas irrigation and debridement and external fixation were the most commonly performed procedures at the lower echelons, the enhanced capabilities of the hospital ship allowed for primary fracture fixation, split-thickness skin grafting, and complex tendon repairs for a large number of selected patients. In contrast, previous studies of hospital ship support during recent conflicts described only the performance of elective operations for noncasualty patients.<sup>23,24</sup>

Our data illustrated that BI patients tended to be younger, and most of their injuries were related to blasts, crashes, or fragments. NBI patients tended to be older, and their injuries were more indirect or from blunt trauma. We postulate that the differences, although multifactorial, may be partly related to the younger soldiers being directly engaged in battle up-front, with increased vulnerability to the blasting and fragmentary effects of improvised explosive devices commonly

used by the enemy forces. Our data showed that treated NBIs tended to reflect more industry-related mechanisms of injury, such as multiple twisting injuries and three severe crush injuries. A significant difference in return-to-duty rates was seen between BI and NBI patients. With exclusion of the crash and crush injuries, 22% of the NBI patients returned to duty, whereas none of the BI patients returned.

In contrast to other reports of wartime casualties,<sup>1,2,7-15</sup> the fractures seen in our population were mostly of the hand, followed by the tibia and ankle. Furthermore, the number of open fractures treated was low (13%), and there were no amputations among our patients. One factor that influenced this distribution was the military medical evacuation system, which transported U.S. military patients with more severe or more proximal fractures to fixed treatment facilities in country or bypassed our hospital for higher levels of care. Another factor was the use of innovative military body armor by the U.S. forces, which optimized protection of the trunk more than the distal extremities.<sup>9,14-16,25</sup>

Few complications occurred among our patients. Despite the reported prevalence of colonization and infection with *Acinetobacter baumannii* in casualties returning from the Persian Gulf region to other U.S. treatment facilities,<sup>26</sup> there were no identifiable infections in our patients during the study period (obviously, variable lengths of stay and lack of long-term follow-up monitoring prevent definitive evaluation of infection rates for this population). Predictably, the two patients with the most-severe injuries sustained complications while still under our care. One patient developed a pressure ulcer at the sacrum following spinal fusion for thoracic fracture/dislocation and partial paraplegia. Another patient, who sustained severe blast injuries to the pelvis, hips, and rectum from a surface-to-air missile, merits further discussion. His injuries included soft tissue loss to the left buttock with an exposed sciatic nerve, a closed right femoral neck fracture, an open inferior pubic ramus fracture, and a burn injury to the distal 9 cm of the rectum. Before orthopedic management, the general surgeons treated the bowel injury while the orthopedic surgeon manually held the right lower extremity for nearly 3 hours to prevent the femoral neck fracture from displacing. The orthopedic treatment included spanning external fixation from pelvis to femur, to facilitate multiple irrigation and debridement procedures before ORIF of the hip 10 days later. The patient required multiple blood transfusions for his operations and later developed coagulopathy, requiring further resuscitative medical management.

### SUMMARY

Based on our data, the following observations and recommendation can be made. First, the hospital ship capabilities allowed each phase of damage control orthopedics to be performed. Damage control surgery is an approach to emergency surgery consisting of (1) initial rapid surgery, including temporary fracture stabilization, to control hemorrhage

and contamination, (2) further resuscitation, rewarming, and correction of coagulopathy, and (3) surgical reexploration and secondary definitive repair.<sup>27</sup> We found that wartime damage control orthopedics must take into account many factors, including the number of patients needing treatment, a patient's concomitant nonorthopedic injuries, and whether the patient is in stable condition for helicopter transport. Other factors include enemy fire, weather conditions, availability of medical evacuation, and accessibility of the next higher level of care. Given the constellation of considerations unique to combat, the term tactical orthopedic intervention may be more appropriate in this environment. Our results illustrate that damage control surgery can be successfully practiced by the hospital ship because of rapid medical evacuation and its intensive care capabilities. Second, a quick, efficient, portable, electronic record system would eliminate some of the difficulties of transferring patient data from one level of care to another. Surgical records and other important patient data were usually handwritten, and such records can be lost along the medical evacuation chain. There is also a need for a Department of Defense orthopedic trauma database that incorporates all orthopedic care from the battlefield to the tertiary medical center, as well as a need for dedicated research coordinators to collect and to mine the data to identify trends so that course corrections can be made in orthopedic casualty care. A Joint Theater Trauma Registry was recently established to address these concerns. Third, although the classification for open fractures presented by Gustilo and Anderson<sup>20</sup> is a useful system to describe civilian fracture wounds, it was not developed from patients with war wounds and it did not accurately account for the massive soft tissue injuries to multiple extremities from explosive munitions that we encountered. A consistently used, simple, grading system for rapid battlefield classification of musculoskeletal war wounds, which takes into consideration entry and exit sites, presence of a cavity, type of fracture, injury of a vital structure, neurological function, and vascular integrity, is needed.

The current report presents the largest series of orthopedic casualties treated in the post-Cold War era by a hospital ship during active conflict. We found that the musculoskeletal injuries in U.S. patients treated onboard the USNS Comfort during Operation Iraqi Freedom were predominantly of the distal extremities and were often amenable to definitive fracture fixation. We also saw that the types of injury, aggregate orthopedic care, and eventual disposition were associated with whether the injury was sustained in battle or not in battle.

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