

Spinal Column Injuries Among Americans in the Global War on Terrorism

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Background: While combat spinal injuries have been documented since the fourth century BC, a comprehensive analysis of such injuries has not been performed for any American military conflict. Recent literature has suggested that spinal injuries account for substantial disability in wounded service members.

Methods: The Joint Theater Trauma Registry was queried to identify all American military personnel who sustained injuries to the back, spinal column, and/or spinal cord in Iraq or Afghanistan from October 2001 to December 2009. Spinal injuries were categorized according to anatomic location, neurological involvement, mechanism of injury, and concomitant wounds.

Results: Of 10,979 evacuated combat casualties, 598 (5.45%) sustained 2101 spinal injuries. Explosions accounted for 56% of spinal injuries, motor vehicle collisions for 29%, and gunshots for 15%. Ninety-two percent of all injuries were fractures, with transverse process, compression, and burst fractures the most common. Spinal cord injuries were present in 17% (104) of the 598 patients. Concomitant injuries frequently occurred in the abdomen, chest, head, and face.

Conclusions: The incidence of spine trauma sustained by military personnel in Iraq and Afghanistan is higher than that reported for previous conflicts, and the nature of these injuries may be similar to those in severely injured civilians. Further research into optimal management and rehabilitation is critical for military service members and severely injured civilians with spine trauma.

Combat-related spinal injuries have been documented in the historical record since the Ancient Period (fourth century BC to AD 476)^{1,2}. Most published reports have been cursory at best, and the true incidence and epidemiology of spine trauma during war has not been documented for any previous American conflict². At the present time, the United States is involved in the longest ongoing military engagement in its history. The Global War on Terrorism, encompassing Operation Iraqi Freedom (2003 to 2010) in Iraq and Operation Enduring Freedom (2001 to the present) in Afghanistan, has resulted in close to 50,000 casualties with 4623 hostile deaths³. American service members have been confronted with new battle tactics in the current wars. Roadside bombs, landmines, rocket-propelled grenades, and improvised explosive devices have been the weapons of choice against American troops and have resulted

in more severe wounding patterns^{4,9}. Such unconventional warfare has led to more complex multisystem trauma than in previous wars, as well as an increased incidence of spine trauma. Personal protection, in the form of advanced helmets and body armor, has allowed many individuals to survive gunshots and explosions that would have been lethal in previous conflicts. Advanced vehicular protection not utilized in previous wars has also likely prevented an unprecedented number of deaths. Finally, advances in blood product transfusions, modifications in pre-hospital care, and newer designs in the medical evacuation system have all contributed to a lower mortality rate than experienced in other wars¹⁰. These facets have culminated in the fact that injuries that would have resulted in death during prior wars are now being survived; however, the devastating nature of the wounds, including spinal injuries, has not been mitigated^{5,8}.

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Recent data⁸ have demonstrated that spinal injuries are among the most disabling conditions affecting wounded service members, paralleling similar reports of civilian spinal injuries¹¹. The nature of spinal wounds in the present conflict remains incompletely explored. Relatively few publications have addressed this topic, and the information available is largely derived from the records of individual hospitals¹²⁻¹⁴ or specific military units². The information that is available seems to indicate that the incidence of combat-related spinal injuries is on the rise, and currently is at the highest level in American military medical history^{2,11}.

This investigation sought to characterize the incidence and epidemiology of spinal injuries sustained by American service members in Operation Iraqi Freedom and Operation Enduring Freedom, using the Joint Theater Trauma Registry. The registry captures data for most U.S. military personnel injured within a combat zone and, therefore, markedly decreases the potential for selection bias that arises when injuries seen at specific hospitals, or individual units, within a theater of operations are considered. To our knowledge, no other investigation has sought to describe the incidence and epidemiology of traumatic spinal column injuries sustained by American military personnel during the Global War on Terrorism, or for any previous conflict.

Materials and Methods

The Joint Theater Trauma Registry is a database that was instituted during the Global War on Terrorism and is maintained at the U.S. Army Institute of Surgical Research (Fort Sam Houston, Texas). The registry contains medical treatment information on service members injured in a zone of combat operations to include battlefield and noncombat areas, such as military bases located in enemy territory. Medical documentation begins at medical treatment facilities in the combat theater and is continued through evacuation to the main casualty collection point at Landstuhl Regional Medical Center in Landstuhl, Germany, as well as throughout definitive management at military centers within the continental United States. All information in the Joint Theater Trauma Registry is abstracted by dedicated personnel from patients' medical records, and the database is updated continuously. Medical records of patients killed in action are not entered into the registry.

Following approval from the institutional Investigational Review Board, a retrospective analysis was performed by querying the Joint Theater Trauma Registry with use of International Classification of Diseases, Ninth Revision (ICD 9) codes to identify all American military personnel in Operation Iraqi Freedom or Operation Enduring Freedom who sustained injuries to the back, spinal cord, and/or spinal column in the time period from October 2001 to December 2009 (see Appendix). The records of individuals who died of wounds were included if relevant spinal injury data were available in the registry. Injured service members from non American coalition nations and civilian casualties were not included in this analysis.

Once all individuals with spinal injuries were identified, electronic medical records were abstracted to ensure accuracy and to eliminate the potential for duplication of injuries documented at disparate levels of care in the evacuation chain. Service members were excluded if medical records describing an injury to the spinal column or spinal cord could not be verified, or if medical documentation was insufficient. Demographic information including sex, age, military rank, year of injury, and final disposition were determined from the Joint Theater Trauma Registry and medical records. Final disposition was listed as died of wounds or alive at the time of final evaluation. Spinal injuries were categorized according to anatomic location, associated neurological involvement, precipitating mechanism of injury, and concomitant wounds. Neurological involvement was graded according to the criteria of the American Spinal

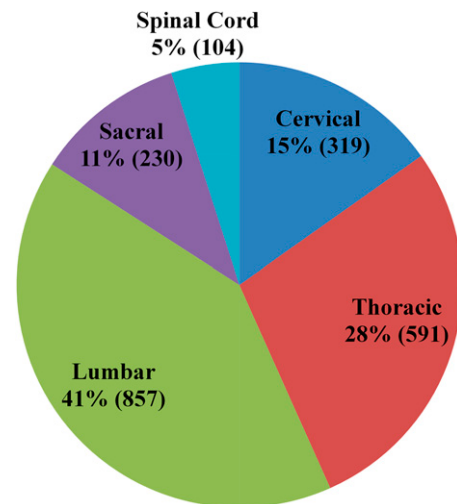


Fig. 1
Individual spinal injuries distributed by anatomic location. The figures in parentheses represent the number of individual spinal column lesions in the entire cohort of patients.

Injury Association (ASIA)¹⁵ whenever possible. All data were securely stored in the Skeletal Trauma Research Consortium (STRc) Spine Database with use of Microsoft Office Access 2007 (Microsoft, Redmond, Washington).

Source of Funding

No external source of funding was used for this investigation.

Results

Between October 2001 and December 2009, 10,979 service members were evacuated as combat casualties and were registered in the Joint Theater Trauma Registry. Among these 10,979 individuals, 598 patients (5.45%) sustained 2101 injuries to the spinal column or spinal cord, 92% (1929) of which were fractures. Ninety-eight percent (584) of the cohort were male, and 90% (540) were enlisted personnel. The mode rank for injured enlisted service members was E-4 (Corporal/Specialist), and the mode rank for injured officers was O-3 (Captain). The average age at the time of injury was 26.5 years (range, eighteen to fifty-six years). The majority of patients (502; 84%) sustained their wounds as a result of combat, whereas the injuries in ninety-six patients (16%) did not occur in a combat setting. Seventeen individuals in this cohort who sustained spinal injuries died of their wounds.

The anatomic distribution of spinal injury followed a general pattern of increasing incidence toward the lumbar spine. Three hundred and nineteen (15%) of the 2101 injuries occurred in the cervical spine, while 591 (28%) were located in the thoracic spine and 857 (41%), in the lumbar region (Fig. 1). Eleven percent (230) of the 2101 wounds were localized to the sacrum. Among the seventeen service members who died secondary to their wounds, seven (41%) sustained spinal injuries to more than one anatomic location, followed by five (29%) with spinal injuries solely to the cervical spine, four (24%) with injuries to the lumbar region, and one with an isolated thoracic spine injury.

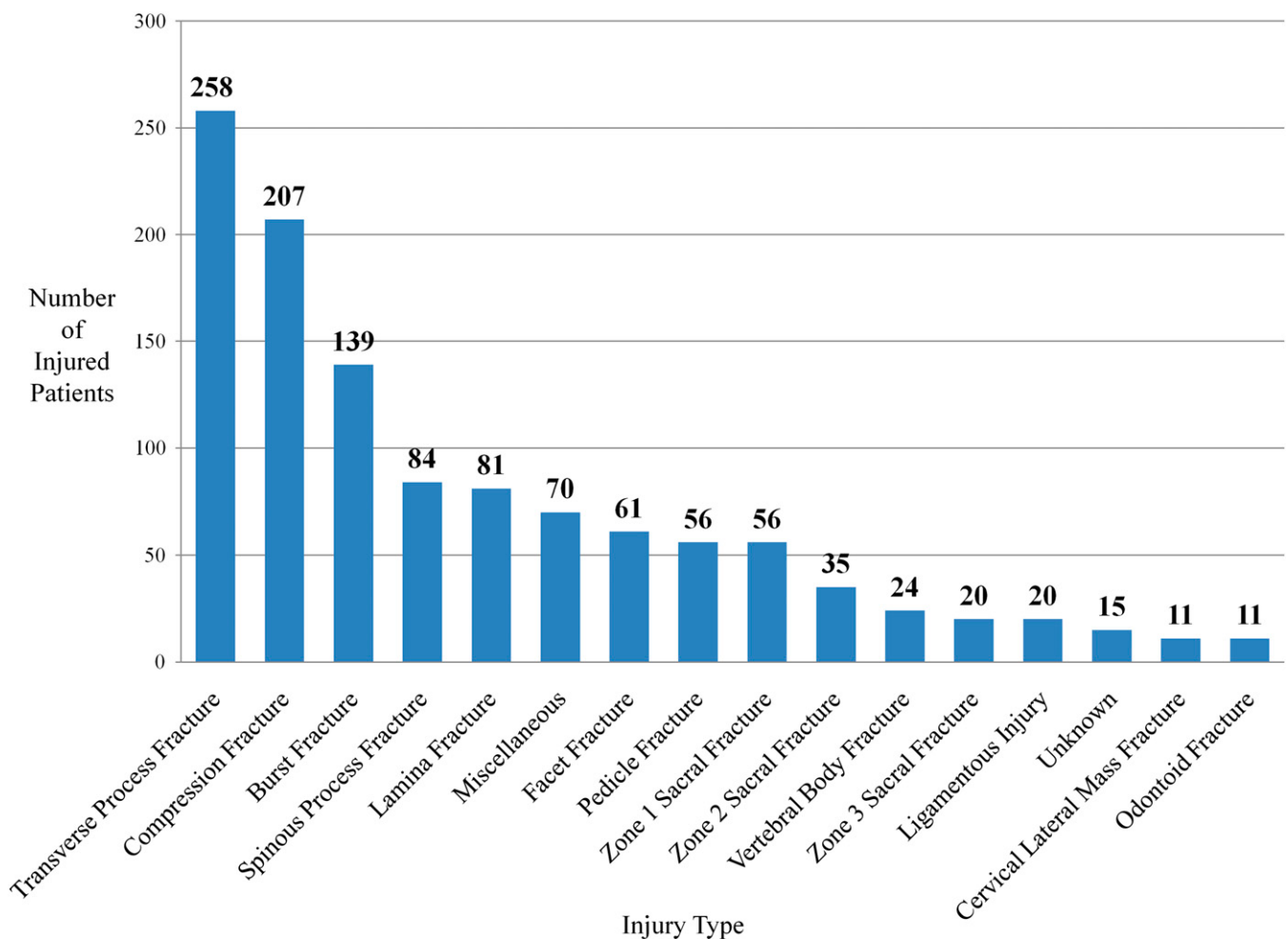


Fig. 2

Spinal column injuries represented by patient. The value associated with each bar represents the number of injured service members with that specific injury. Note that many service members sustained multiple spine injuries.

The most commonly encountered injury was a transverse process fracture, with 636 such fractures occurring in 258 patients (43%). The second most commonly encountered injury was compression fracture, with 362 such fractures seen in 207 service members (35%). One hundred and thirty-nine service members (23%) sustained a total of 173 burst fractures, of which 100 (58%) occurred in the lumbar spine (Figs. 2 and 3). Ligamentous injuries and nonspecific vertebral body fractures were reported in 3% of patients each, and there were ten documented flexion-distraction injuries and two fracture-dislocations.

One hundred and eighty-two patients (30%) underwent operative intervention for their spinal injuries either at Landstuhl Regional Medical Center or in the United States. One hundred and forty-four patients underwent spinal fusions (mean, 4.6 levels fused per patient), 133 patients received spinal instrumentation (mean, 4.5 levels instrumented per patient), and 108 patients underwent a spinal decompression (mean, 1.9 levels decompressed per patient). Three hundred and sixty-two (61%) of the 598 patients in the cohort received nonoperative

management, and fifty-four (9%) received undocumented treatment. An operative intervention was performed on seventy-four (71%) of 104 patients with spinal cord injuries and 101 (73%) of 139 with burst fractures.

Spinal cord injuries were sustained by 104 individuals (17%), of whom forty-seven (45%) were classified as having a complete spinal cord injury. Fifty-two (50%) of all service members with spinal cord injuries were categorized as having an incomplete injury, while five patients had poorly documented neurologic examinations. Explosions accounted for thirty-eight spinal cord injuries (37%), of which seven were complete spinal cord injuries, twenty-eight were incomplete spinal cord injuries, and three had insufficient documentation to determine the exact neurologic deficit. Gunshot wounds caused forty-seven (45%) of the 104 spinal cord injuries. Complete spinal cord injuries were found in thirty-two (68%) of the forty-seven service members, and incomplete spinal cord injuries were documented in thirteen. Two service members who sustained spinal cord injuries caused by gunshot wounds had insufficient documentation to determine an exact neurologic deficit.

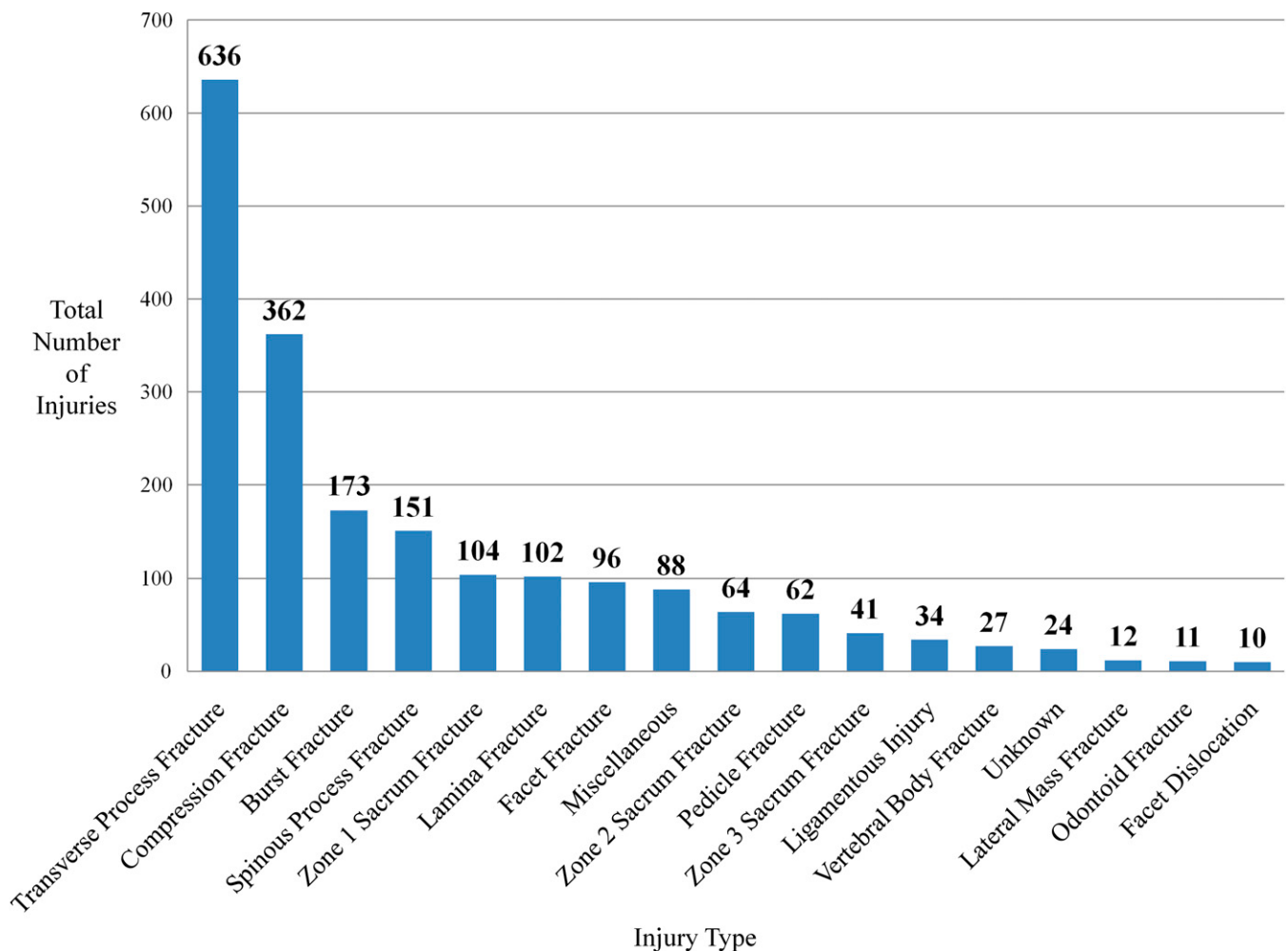


Fig. 3
Spinal column injuries represented by injury type. The value associated with each bar represents the total number of injuries documented in this study's time period. This figure does not include spinal cord injuries.

At least one ASIA grade was available for eighty-seven (84%) of the 104 patients with spinal cord injuries (Fig. 4). Initial and follow-up ASIA grades were available for fifty-nine patients (57%). Of these fifty-nine service members, a total of forty (68%) had undergone a surgical intervention for the spinal injury. ASIA grades remained unchanged for twenty-eight (47%) of the fifty-nine patients at the time of follow-up, whereas the grades for thirty patients (51%), including six who regained full neurologic function below the level of injury (ASIA E), improved from the time of the initial injury. Of the thirty patients who had improvement at the time of follow-up, twenty-two (73%) had had an operative intervention and four of them regained full neurologic function. Eighteen service members had no neurologic improvement or had further decline after an operative intervention. Of all 104 patients with spinal cord injuries, only one was found to have neurological deterioration at the time of follow-up. Of the seventeen patients who died, six had sustained spinal cord injuries. Other documented neurologic injuries included cauda equina syndrome (nine patients), conus medullaris syndrome (two), and nerve root injuries (eight).

Explosive mechanisms were responsible for most spinal injuries (336 service members; 56%) (Fig. 5), but only 32% (106) of those wounded by them had a penetrating injury to the spine, defined as a spinal injury caused by a documented projectile. Motor vehicle collisions, including high-mobility multi-purpose wheeled vehicles ("Humvees"; fifty injuries), helicopters (twenty-seven), and mine-resistant ambush-protected vehicles (MRAP; eighteen) were the cause of trauma in 29% (175) of the 598 service members with spinal wounds. The remaining eighty service members involved in motor vehicle collisions were in undocumented vehicles. Gunshot wounds were responsible for only 15% (eighty-nine) of the spinal injuries. Four hundred and twenty-six service members (71%) had blunt injuries to the spine, and 195 (33%) had penetrating injuries. Of those service members, thirty (5%) had a combined blunt and penetrating injury to the spine. Seven service members had unknown direct mechanisms of injury (Table I). The 195 penetrating spine injuries were considered to be open fractures.

Concomitant injuries were common, as 467 service members (78%) sustained a concomitant injury in association with a

TABLE I Direct Mechanisms of Injury for American Service Members with Spinal Injuries

Direct Mechanism of Injury	No. of Service Members Affected
Blunt	426*
Penetrating	195*
Combined	30
Unknown	7

*These values both include the thirty patients with a combined direct mechanism of injury.

spinal injury. Of these, 266 (57%) sustained concomitant injuries to multiple organ systems. The most common injury associated with spinal wounds was an injury to the chest, which

was sustained by 159 (27%) of the 598 patients, followed closely by injuries to the abdomen, which were documented in 149 patients (25%). The rate of closed head injuries and facial trauma exceeded 20% within the cohort (23% [136 patients] and 21% [127], respectively).

Discussion

Prior to the twentieth century, spinal injuries during combat were not usually survivable, nor were they well documented. In the American Civil War, close to 650 battle-related spinal injuries were documented by Otis, and these were associated with a mortality rate of >50%¹⁶. As the lethality of military weaponry increased, so too did medical technology and techniques, allowing improved survival following combat wounding^{4,5,7}. Prior to the Second World War, most individuals with combat-related spine trauma died from their wounds; beginning with the Korean conflict, an increased number of individuals were surviving to

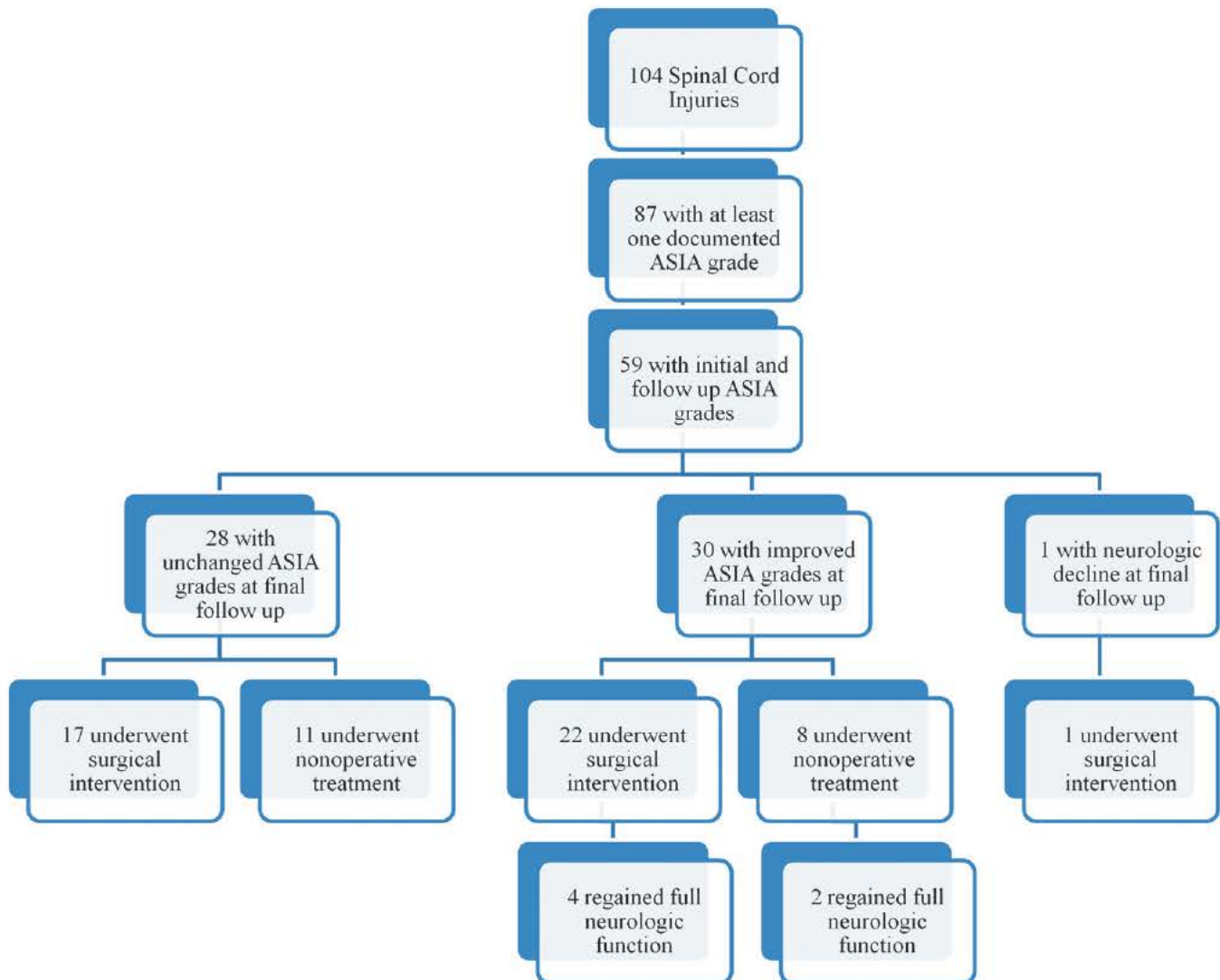


Fig. 4

American Spinal Injury Association (ASIA) grades and treatment at the time of final follow up.

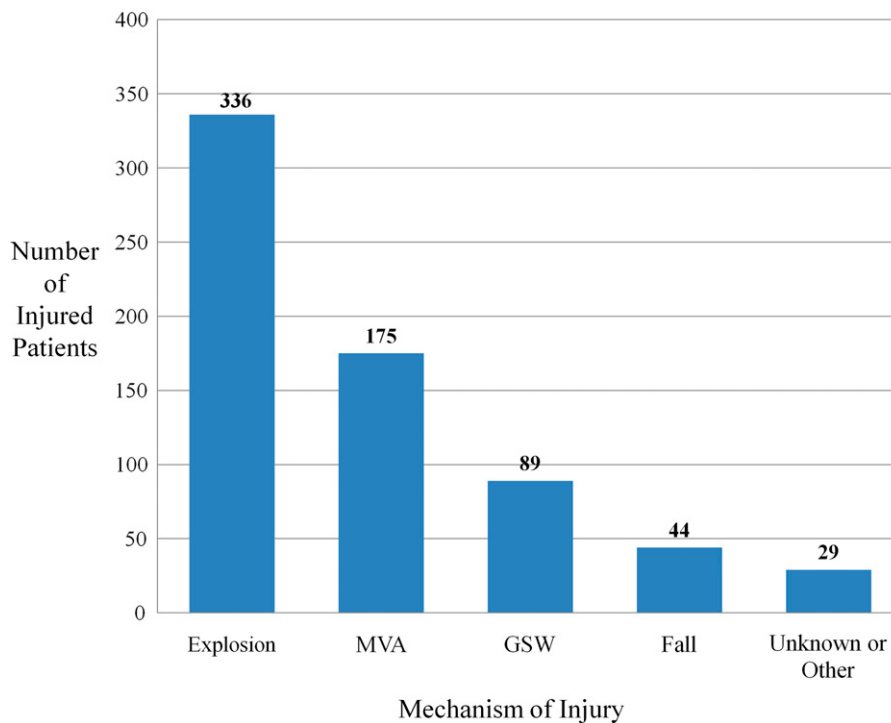


Fig. 5

Mechanisms of injury causing spinal injuries in Operation Iraqi Freedom and Operation Enduring Freedom. The value associated with each bar represents the number of individual service members injured by that mechanism. Note that many service members sustained spine injuries from multiple mechanisms of injury. MVA = motor vehicle accident, and GSW = gunshot wound.

the point at which they could receive treatment². Although the incidence of combat-related spine trauma remained static at approximately 1% for the Korea¹⁷, Vietnam¹⁸, and the First Gulf War¹⁹, approximately 6% of all individuals injured during the American assault on Panama sustained spinal injuries²⁰ (Fig. 6). Moreover, the few reports that have been published regarding spine trauma in the current conflicts point to an increased incidence and heightened severity of such wounds^{2,6,12-14}. However, most works have focused on select populations^{6,13,14}, individual units², or the experiences of specific hospitals¹⁰ and, as a result, the current literature may present an incomplete picture with respect to the spinal injuries in the Global War on Terrorism.

The dataset utilized in this study has the advantage of drawing from all military treatment facilities within the evacuation chain from the combat theater to the continental United States, and is not limited to any particular branch of military service or combat zone. The findings reported in this investigation indicate that the incidence of spinal injuries during Operation Iraqi Freedom and Operation Enduring Freedom was 5.45%, with most injuries resulting from explosive mechanisms. While the seemingly innocuous transverse process fractures were the most common injury, a substantial number of patients sustained compression fractures, burst fractures, and spinal cord injuries. Furthermore, many individuals with spine trauma incurred concomitant injuries to other systems, including the chest, abdomen, head, and face. These associated wounds are not only indicative of the severity of the precipitating trauma,

but also may markedly impair the rehabilitation and recovery of those with spinal injuries⁸.

Although this cohort represents the largest series of patients with spine trauma incurred during the Global War on Terrorism, its findings are in keeping with several previous works. In their study regarding spinal injuries among soldiers in the Army's basic combat unit, Schoenfeld et al. reported an incidence of 7.4%², a figure closely approximating the rate documented in the present study. The fact that most spinal injuries in the present work occurred as a result of explosive mechanisms is commensurate with evidence presented in most other studies regarding injuries in Operation Iraqi Freedom and Operation Enduring Freedom^{2,5,6,7,9,12}. Owens et al. reported that explosions accounted for 79% of all combat wounds in an early review of the Joint Theater Trauma Registry⁹, while Belmont et al. documented that explosive devices were responsible for 87.4% of the injuries among 390 combat casualties in Operation Iraqi Freedom⁷.

Although gunshot wounds resulted in a relatively small percentage of spinal injuries (15%), they resulted in a large percentage of all spinal cord injuries and complete spinal cord injuries. Complete spinal cord injuries due to gunshot wounds occurred at a rate 3.78 times that of injuries due to explosive devices. Moreover, 53% (forty-seven) of eighty-nine service members who sustained a gunshot wound to the spine had a resultant spinal cord injury. Any high-velocity gunshot wound that causes an osseous injury is likely to impact the adjacent spinal cord because of projectile fragmentation and the destructive energy imparted to the tissue²¹.

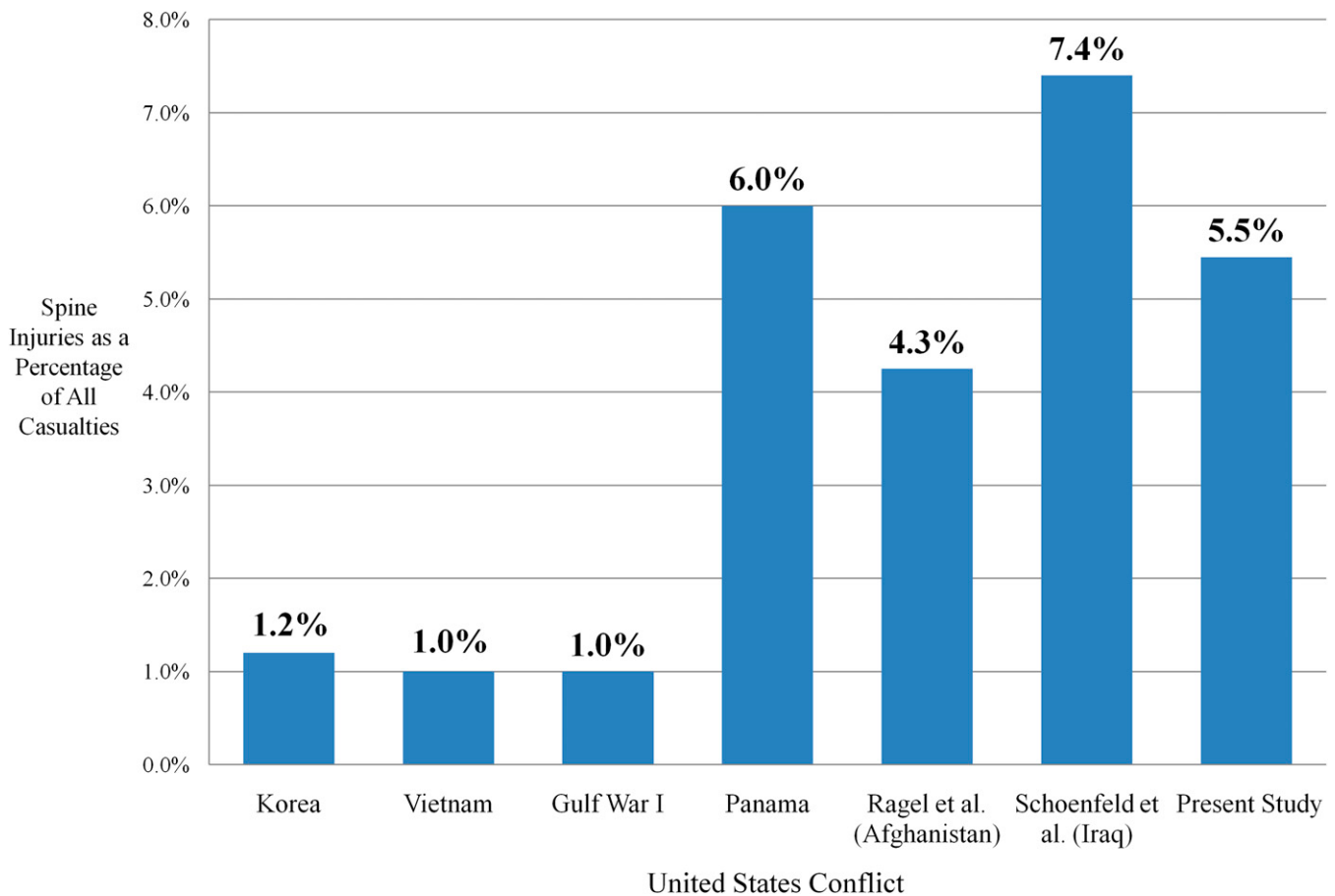


Fig. 6

The percentage of spinal injuries in American military conflicts. The percentages reported are rounded and are derived from various studies^{2,12,17-20}.

Most wars in American history have relied on service members getting from one location to another on foot, predisposing the individuals to large amounts of gunfire, which thereby inflicts the majority of combat wounds⁹. However, the current conflicts have seen most American troops mobilizing with the use of vehicles across vast stretches of desert and mountainous terrain. Vehicular transport provides excellent protection from most types of gunfire, forcing enemy tactics to evolve from gunfire to roadside bombs and improvised explosive devices^{5,9,12}. Quite frequently, service members exposed to an explosive blast are riding in up-armored vehicles, which have been modified with supplemental armor to help protect the occupants from gunfire and roadside explosions. While the armor of these vehicles protects some, if not all, soldiers from the devastating effects of the explosion, the forces imparted on the axial skeleton are considerable^{2,5,12}. The force of the blast often lifts the vehicle into the air, likely resulting in substantial axial loads to the spine, which may be compounded by the body armor worn by service members that normally ends around the L2-L3 level¹⁴. In a small series of patients treated for thoracolumbar fractures in Afghanistan, Ragel et al. postulated that these factors may theoretically result in a higher incidence of low lumbar burst fractures and lumbopelvic dissociations¹². One may infer that explosive blast injuries result in a sub-

stantial proportion of penetrating injuries, as Owens et al. reported a 78% rate of injuries from explosions⁹ and an 82% rate of open fractures among all combat-related extremity wounds involving fractures²². However, the present study reports a 56% rate of injuries from explosions with only 32% of those explosions resulting in penetrating injuries to the spine.

The current study has demonstrated that spinal injuries represent 5% of all injuries to any organ system within the context of these wars. As Cross et al.⁸ demonstrated, this 5% is associated with the second highest average disability ranking and fourth highest disability impact among all injured service members who are medically retired from the military. As the survivability of many of these devastating wounds continues to increase, new and complex challenges are encountered in the rehabilitation process. Since the majority of spinal injuries sustained in this war are from a blunt mechanism, these devastating injuries and subsequent disabilities may not be unique to a military population and may be similar to a subset of severely injured civilian patients. According to the American Academy of Orthopaedic Surgeons¹¹, spinal injury with associated low-back pain has the highest prevalence in young adults and middle-aged individuals, causing a markedly reduced ability to work and an overall inability to work. Therefore, continued research and outcome studies performed at civilian

trauma centers could result in a direct beneficial impact to service members injured on the battlefield.

It is important to recognize several limitations to this investigation. Foremost, this work was dependent on cases entered into the Joint Theater Trauma Registry database, a system that was only developed at the start of the Global War on Terrorism. As a result, many instances of combat-related trauma were not logged into the system, especially during the early years of Operation Iraqi Freedom and Operation Enduring Freedom. In their study of the Joint Theater Trauma Registry, Owens et al.⁹ found the database contained information on only 27% of all combat casualties in their time frame (2001 to 2005). Fortunately, data quality and completeness have improved substantially over the past years, and it is now estimated that approximately 86% of all combat casualties have been entered into the registry during this study's time frame (2001 to 2009). This value is calculated by dividing the total number of American service-member casualty admissions in all hospitals throughout Iraq and Afghanistan by the total number of patient entries in the registry. Although these data do not represent a complete analysis of all spinal injuries sustained in these wars, it remains the most complete analysis to date. While some data regarding soldiers who died of wounds were included in the present work, much information with respect to the combat wounds resulting in the death of these service members is not available as medical records of patients who were killed in action are not routinely entered into the registry. The development of a military orthopaedic trauma registry would greatly enhance the accuracy and efficiency with which a search for a specific injury could be performed. Such a database is currently being implemented²³.

While accepting these weaknesses, it is important to acknowledge that the cohort of 598 service members presented in this investigation is larger than the number of patients with spinal wounds detailed in any prior study^{2,6,12,14}.

In conclusion, the results of this study support prior claims that the incidence of spinal injuries among combat casualties in the Global War on Terrorism are among the highest in American military medical history (Fig. 6). Although survival rates for such wounds remain high, the devastating nature of these injuries imparts substantial disability, which must be borne by the wounded service members, their families, and the American health-care system^{5,8}. It is believed that the change in weaponry has had a more substantial impact on the injury profile of injured service members. Further research must be performed, including subsequent analyses of the Joint Theater

Trauma Registry in future years, as well as implementation of the Military Orthopaedic Trauma Registry²³, before a true appreciation for the character of combat-related spine trauma in Operation Iraqi Freedom and Operation Enduring Freedom is apparent.

Appendix

eA A table showing the International Classification of Diseases, Ninth Revision (ICD-9) search terms used in the query of the Joint Theater Trauma Registry is available with the online version of this article as a data supplement at jbjs.org. ■

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