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Epidemiology of War-Related Spinal Cord Injury Among Combatants: A Systematic Review

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Abstract

Study Design: Systematic review.

Objectives: War-related spinal cord injuries (SCIs) are commonly more severe and complex than traumatic SCIs among civilians. This systematic review, for the first time, synthesized and critically appraised the literature on the epidemiology of war-related SCIs. This review aimed to identify distinct features from the civilian SCIs that can have an impact on the management of military and civilian SCIs.

Methods: Medline, EMBASE, and PsycINFO databases were searched for articles on epidemiology of war-related SCI among combatants, published from 1946 to December 20, 2017. This review included only original publications on epidemiological aspects of SCIs that occur during an act of war. The STROBE statement was used to examine the quality of the publications.

Results: The literature search identified 1594 publications, of which 25 articles fulfilled the inclusion and exclusion criteria. The studies were classified into the following topics: 17 articles reported demographics, level and severity of SCI, mechanism of injury and/or associated bodily injuries; 5 articles reported the incidence of war-related SCI; and 6 articles reported the frequency of SCI among other war-related bodily injuries. Overall, military personnel with war-related SCI were typically young, white men, with predominantly thoracic or lumbar level, complete (American Spinal Injury Association [ASIA] Impairment Scale A) SCI due to gunshot or explosion and often associated with other bodily injuries. Marines appear to be at a greater risk of war-related SCI than the military personal in the Army, Navy, and Air Force.

Conclusions: The war-related SCIs among soldiers are distinct from the traumatic SCI in the general population. The majority of the current literature is based on the American experiences in most recent wars.

Keywords
spinal cord injury, neurotrauma, military, combatant, war, epidemiology

Introduction

The "military medical revolution" is defined as the combination of the multiple and progressively complex medical advances, and which undeniably saved many lives during the American Civil War, World War I, World War II, the Korean War, and the Vietnam War.[1] The "military medical revolution" includes *prehospital care* (eg, tourniquets, topical hemostatic agents or dressings, hypothermia prevention, hypotensive resuscitation, prehospital resuscitation with fresh frozen

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plasma and junctional tourniquet), *deployed hospital care* (eg, damage-control resuscitation, diagnostic evaluation for explosion injury, vascular surgery, orthopedic wound care, regional anesthesia and total intravenous anesthesia, combat burn care, management of traumatic brain injury, negative-pressure combat wound dressings, intravenous cryoprecipitate and tranexamic acid and coagulation monitoring with thromboelastography/rotational thromboelastometry), *en route care* (eg, global en route care, en route critical care nursing and US Army flight medic training), and *development of trauma systems*.[1-3]

The American Civil War was first large medical experience with traumatic spinal cord injury (SCI), and the surgical and medical advancements in World War I facilitated the maturation of Neurosurgery and Physical Medicine and Rehabilitation in the 20th century, but the turning point in the management of SCI actually occurred during World War II.[4-6] The development of comprehensive multidisciplinary neurorehabilitation and SCI units during World War II created the landscape for the modern spinal cord medicine.[5,6] Advances in the triage of wounded soldiers and battlefield evacuation systems using helicopters marked the Korean and Vietnam wars.[4] The recent decade of Iraq and Afghanistan wars have reshaped the battlefield care of the wounded combatants.[7] For instance, spine trauma care switched from a broad use of spinal precautions to combatants with significant trauma without consideration of tactical concerns or mechanisms of injury to the use of spinal precautions that are not "emphasized for casualties with penetrating trauma only, but still recommended for use as tactically feasible when blunt trauma is present."[7] The Iraq and Afghanistan wars also revealed significant changes from the traditional state-based warfare tactics to conflicts with enemies using less conventional war tactics of human shields and camouflage. Also, the type of craniospinal trauma associated with blast injuries caused by improvised explosive devices has substantially changed since the beginning of the Iraq and Afghanistan wars.

There has been an emerging interest in reporting the prevalence and incidence of war-related SCIs since World War II, when mortality reduced but physical and mental impairments increased among the war survivors. Gunshot-induced spine injures were estimated to represent 0.26% of all injuries of soldiers in the American Civil War but fatal casualties accounted for 55%.[8] According to the American military data, the frequency of spinal injuries of all war casualties was estimated to be 1.2% in the Korea War, 1% in the Vietnam War and Gulf War, and 6% in the Panama War.[9] More recently, Schoenfeld et al reported that spinal injuries occurred in 11.1% of the wounded combatants in the Afghanistan and Iraq wars.[10] Nowadays, spine-related disabling conditions correspond to a major cause of medical discharge from the military service (14%) among American combat-wounded soldiers.[11]

Unlike traumatic SCIs among civilians that are often caused by motor vehicle accidents or falls, the most common mechanisms of war-related SCIs include explosion, gunshot wound, helicopter accident, and motor vehicle collisions.[11,12] A recent retrospective cohort study reported that military gunshot-induced SCIs had different demographics (ie, exclusively males, younger) and injury characteristics (ie, predominantly thoracocervical injuries, more frequent associated injuries) when compared with civilian gunshot-induced SCIs, but the severity of gunshot-induced SCI was comparable between the 2 groups.[13]

In contrast, Blair et al suggested that these war-related SCIs may be comparable to severe SCIs associated with polytrauma in the civilian population.[14] Lehman et al reported that low lumbar burst fractures with a unique injury pattern are the main fracture of the spinal column in combatants.[15]

Given the uniqueness of the war-related SCIs, this study was undertaken to review and synthetize the literature on the incidence, demographics, and injury characteristics of the war-related SCI among soldiers.

Methods

Search Strategy

The primary search was carried out using Medline, Excerpta Medica dataBASE (EMBASE), and PsycINFO in order to obtain articles on the epidemiology of war-related SCI among combatants that were published from 1946 to December 20, 2017. The search criteria included subject headings ("spinal cord injury" OR "spinal cord injuries") AND ("trauma" OR "wounds and injuries"), AND ("military" OR "military personnel" OR "war" OR "veterans" OR "combatants" OR "soldiers"); the search was limited to "humans." Abstracts and, when necessary, actual articles were screened to identify articles that studied the incidence and epidemiology of war-related SCI among combatants. This systematic review included all original articles that reported on the incidence, demographics, and injury characteristics of the war-related SCIs. Case reports, animal studies, conference abstracts, and editorials were excluded.

Selection Process, Data Abstraction, and Publication Appraisal

All titles and abstracts retrieved from the literature search were screened by 2 reviewers (JCF and SG). Articles considered relevant based on the title and abstract search were included. Discrepancies between the reviewers were resolved by consensus after ample discussion between the 2 reviewers. When the same authors published more than one article using the same data set, the publication with the most relevant information was selected for inclusion, whereas the other publication was excluded. All articles that fulfilled the inclusion and exclusion criteria were appraised by 2 reviewers (JCF and SG) using the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.[16] Of note, STROBE statement is widely accepted by researchers and endorsed by the editorial boards of several scientific journals (including *Lancet*, *British Medical Journal*, and *Neurology*) as a checklist "to guide reporting of observational research."[17] Although STROBE statement was not developed to directly assess the quality of publications, compliance to the STROBE checklist has been recognized as a proxy for quality of the publications on observational studies since there is no validated instrument for this purpose.[17,18] The items of the STROBE statement were scored as 0 or 1, with a score of 1 provided for each checklist item that was properly completed, or when the item had multiple subitems (ie, items 12, 13, 14, and 16), 1 point was added if the majority of the subitems of that particular item category were properly completed. Using this checklist, a maximum score of 22 would indicate the article fulfilled requirements for a high-quality publication. Any discordance between the reviewers with regard to the article scoring was resolved by consensus. Finally, each selected article was reviewed to abstract the relevant data from the included articles prior to data synthesis. All selected articles were classified by the level of evidence (LOE) as endorsed by the North American Spine Society.

Definitions

For the purpose of this systematic review, *war-related SCI* is defined as a lesion of traumatic nature during an act of war, affecting the spinal cord and causing disruption of nerve fiber bundles that carry ascending sensory and descending motor information.[19,20] *Incidence of war-related SCI* was defined as the proportion of a group of military personnel that initially suffered a SCI during war actions or operations over a given period of time. In this review, incidence of war-related SCI was standardized as the number of cases of traumatic SCI per 10 000 person-years.

Severity of SCI was classified according to the American Spinal Injury Association (ASIA) Impairment Scale (AIS) contained within the International Standards for Neurological Classification of Spinal Cord Injury as follows: (1) patients with motor and sensory complete SCI (AIS A); (2) patients with motor complete but sensory incomplete SCI (AIS B); (3) patients with motor incomplete SCI where the majority of the key muscles below the neurological level have a muscle grade less than 3 (AIS C); and (4) patients with motor incomplete SCI where the majority of the key muscles below the neurological level have a muscle grade greater than or equal to 3 (AIS D).[21]

When available, data from the literature was pooled and analyzed. For instance, when different studies provided mean age and total number of cases, "pooled mean age" was calculated using weighted average age. This means that the mean age was multiplied by the number of cases included in each study, these results were added up, and then the later results were divided by the overall number of cases in all studies.

Results

Selected Publications

The primary search strategy identified 1594 publications of which 25 fulfilled the inclusion and exclusion criteria (Table 1). Of those, 17 articles reported demographics, level and severity of SCI, mechanism of injury, and/or associated injuries[9,10,13-15,22-33]; 5 publications reported the incidence of war-related SCI[8,10,34-36]; and 6 articles reported the frequency of SCI among other war-related bodily injuries.[9,11,30,37-39]

The majority of the 1594 publications were excluded because they were focused on secondary complications, management of SCI, economics of SCI, included veterans with spine disease that occurred outside the scope of a war, or they were case reports, conference abstracts, or editorials (Figure 1). Duplicity of publications using the same data set occurred in 2 circumstances.[9,26,40,41]

All selected articles were either case series or retrospective cohort studies. Their scores based on the STROBE statement varied from 6 to 21, with a trend toward higher scores in the most recent publications (Table 1).

Demographics and Injury Characteristics of War-Related SCI

In this review, the published data on the demographics and impairment characteristics of SCI among combatants was acquired from World War II and the Vietnam, Croatian, Iraq, and Afghanistan wars. Given that there is a predominance of male soldiers in the battle front line, it was foreseeable that war-related SCI is more common in men (frequency range from 91.7% to 100%) than women (Table 2). The mean age at the time of SCI reportedly varied from 21.2 to 30.7 years among the publications, with a composite mean age of all the articles estimated as 26.3 years (Table 2).

Thoracic SCI was the most common level of war-related SCI with a frequency range from 23.6% to 64.8%, followed by lumbar SCI (23.8% to 59.9%) and cervical SCI (1.9% to 52.4%). The war-related SCIs were usually more severe at the time of presentation with the frequency of complete (or AIS A) SCIs varying from 21.7% to 91.2%, while incomplete (or AIS B/C/D) SCIs occurred in 8.8% to 42.1% (Table 2). The most common mechanisms of injury were gunshot (9.4% to 93.3%) followed by explosion (2.7% to 81.8%), motor vehicle accidents (6.1% to 29.3%), and falls (3% to 30.9%), even though there was some variation in their distribution among the selected publications (Table 2).

War-related SCIs were associated with other bodily injuries in 43.9% to 78.1% of cases including head and neck injuries (frequency range from 7% to 73.1%), traumatic brain injuries (20% to 48%), chest injuries (12.5% to 56%), abdominal injuries (10.6% to 65.3%), pelvic injuries (13.2% to 47.2%), and limb injuries (11.1% to 74%; Table 2).

Incidence and Frequency of War-Related SCI

All data on the incidence of war-related SCI in this review is based on the data from the Iraq and Afghanistan wars. The overall incidence rate of war-related SCI varied from 4.3 to 5.6 per 10 000 person-years (Table 3). In a single publication, the incidence rate of war-related SCI among men (4.4 per

Table 1. Included References as Classified by Study Type, War Setting, and Quality of the Publications Based on the STROBE and LOE.

Reference	Study Type	War Setting	STROBE	LOE
Haynes[22]	Case series	World War II	7	IV
Schneider et al[23]	Case series	World War II	8	IV
Klemperer et al[24]	Retrospective cohort study	World War II	6	III
McNamara et al[37]	Retrospective cohort study	Vietnam War (admissions at the 24th Evacuation Hospital in Vietnam from September 1968 to November 1969)	8	III
Jankovic et al[25]	Retrospective cohort study	Clinical Hospital Split, Croatia (admissions from August 1991 to December 1995—Croatia War)	9	III
Jacobson et al[26]	Case series	Long Beach Veterans Administration Hospital (admission from December 1965 to April 1969—Vietnam war)	8	IV
Alaca et al[27]	Retrospective cohort study	Gulhane Military Medical Academy, Turkey (admissions during a "2-year period")	9	III
Kahraman et al[28]	Retrospective cohort study	Gulhane Military Medical Academy, Turkey (admissions from 1994 to 2000)	10	III
Bhatoe et al[29]	Case series	Three service hospitals in India (admissions from 1995 to 2001)	6	IV
Radonic et al[38]	Retrospective cohort study	Clinical Hospital Split, Croatia (admissions from June 1990 to December 1995—Wars in Croatia, Bosnia and Herzegovina)	8	III
Schoenfeld et al[34]	Retrospective cohort study	American service members serving in the US Armed Forces from January 1, 2000, to December 31, 2009, including Iraq and Afghanistan wars	16	III
Blair et al[14]	Retrospective cohort study	Joint Theater Trauma Registry—Global War on Terrorism (Iraq and Afghanistan wars from October 2001 to December 2009)	15	III
Lehman et al[15]	Retrospective cohort study	All patients with a burst fracture from T12 to L5 who were treated at Walter Reed Army Medical Center from September 2001 to May 2008 (Iraq and Afghanistan wars)	16	III
Blair et al[9]	Retrospective cohort study	Global War on Terrorism (Iraq and Afghanistan Wars from October 2001 to December 2009)	16	III
Breeze et al[30]	Retrospective cohort study	Joint Theatre Trauma Registry—Iraq and Afghanistan Wars (August 1, 2004, to January 1, 2008)	12	III
Possley et al[35]	Retrospective cohort study	American service members serving in the US Armed Forces from March 2003 to December 2009 including Iraq and Afghanistan wars	15	III
Schoenfeld et al[8]	Retrospective cohort study	American service members serving in the US Armed Forces from 2000 to 2009 including Iraq and Afghanistan wars	18	III
Schoenfeld et al[36]	Retrospective cohort study	All service members within the US Armed Forces from January 1, 2001, to December 31, 2010, including Iraq and Afghanistan wars	15	III
Schoenfeld et al[39]	Retrospective cohort study	Individuals with the combat-specific designation of cavalry scout who sustained injuries in the Iraq and Afghanistan wars (2003-2011)	19	III
Schoenfeld et al[31]	Retrospective cohort study	American service members with SCI who were killed in the Iraq and Afghanistan wars (2003-2011)	19	III
Schoenfeld et al[10]	Retrospective cohort study	Casualties in the Iraq and Afghanistan Wars—data from the Department of Defense Trauma Registry (2005-2009)	21	III
Javadi et al[32]	Retrospective cohort study	Iranian SCI veterans of the Iraq-Iran War (1980-1988)	11	III
Galvin et al[33]	Retrospective cohort study	NATO personnel of the Afghanistan war (26 injured during combat operations)	18	III
Rivera et al[11]	Retrospective cohort study	Operation Enduring Freedom and Operation Iraqi Freedom (October 2001 to January 2005)	15	III
Guzelkucuk et al[13]	Retrospective cohort study	Turkish Armed Forces Rehabilitation Center	14	III

Abbreviations: STROBE, Strengthening the Reporting of Observational Studies in Epidemiology; SCI, spinal cord injury; NATO, North Atlantic Treaty Organization; LOE, level of evidence.

10 000 person-years) was significantly higher than women (3.7 per 10 000 person-years).[34] Furthermore, the incidence rate of war-related SCI was significantly higher in the white ethnic group (4.5 per 10 000 person-years) than the black ethnic group (3.8 per 10 000 person-years) or other ethnic groups (4.0 per 10 000 person-years).[34] The military personnel serving the Marine Corps were at a greater risk for a war-related SCI (incidence rate of 5.3 per 10 000 person-years) when compared to military personnel serving in the Army (4.9 per 10 000 person-years), the Navy (4.1 per 10 000 person-years), and the Air Force (3.1 per 10 000 person-years).[34] Among the combatants, the estimated incidence rate of cervical SCI was 0.7 per 10 000 person-years, while the incidence rate of lumbar SCI was 0.4 per 10 000 person-years (Table 3).

Among soldiers the frequency of war-related SCI reportedly varied from 1.2% to 8%, whereas the frequency of war-related spine trauma varied from 1.7% to 31.5% (Table 4). McNamara et al reported that the proportion of military personnel with war-related SCI was 13.7% among soldiers who sustained intrathoracic injuries.[37] Breeze et al documented that 42.7%

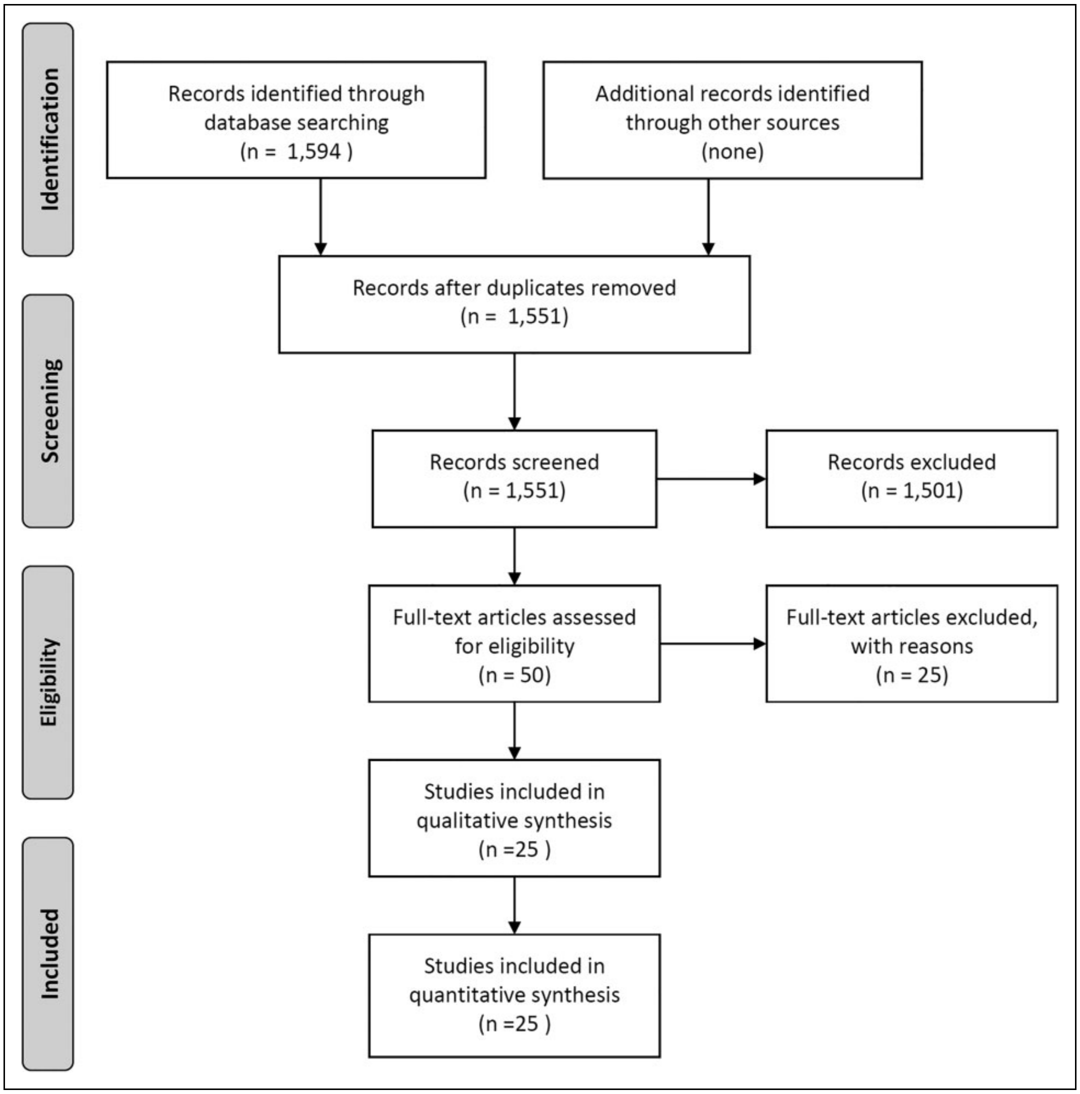

Figure 1. PRISMA flow diagram describing the steps of the literature search and the selection of the articles included in this systematic review.

of the soldiers with neck injuries also sustained a war-related SCI or spine trauma without SCI.[30]

Discussion

The results of this systematic review suggest that war-related SCI is more common among young, white men who typically sustain thoracic, severe (complete or AIS A) SCIs secondary to gunshot or explosion. Unlike civilian SCI, war-related SCI is commonly associated with other bodily injuries including head and neck injuries, traumatic brain injury, injuries to the chest, abdomen, or pelvis, and limb injuries, alone or in combination. According to data from American military personnel who served in Iraq and Afghanistan, the overall incidence rates of war-related SCIs varied from 0.4 to 4.3 per 10 000 person-years, with the highest incidence rates reported among white men serving in the Marine Corps. Overall, a war-related SCI was diagnosed in up to 8% soldiers wounded in the modern war.

Incidence and Frequency of War-Related SCI

The results of this review revealed that the overall incidence of war-related SCI varied from 4.3 to 5.6 per 10 000 person-years, which was significantly higher in white, male, military personnel serving in the Marine Corps, when compared to other military groups. Prior population-based studies have estimated incidence rates of traumatic SCI from 0.3 to 0.5 per 10 000 person-years in the general populations in Australia and United States, respectively.[42,43] A prior systematic review on the epidemiology of traumatic SCI showed that incidence rates vary substantially from 8 to 246 cases per million inhabitants per year (or 0.08 to 2.46 per 10 000 person-years) in the general population worldwide, whereas the incidence rates of traumatic SC in the United States varied from 0.25 to 0.83 per 10 000 person-years.[44]

Table 2. Demographics and Injury Characteristics of War-Related Spinal Cord Injury According to This Systematic Review.

Reference	Group	Number of Cases	Age (Years)	Sex	Level of SCI	Severity of SCI	Mechanism of SCI	Associated Bodily Injuries
Haynes[22]	War wounds of the spine	184	NA	NA	C: 19% (35) T: 44% (81) L: 35.9% (66) S: 1.1% (2)	Complete: 31% (17) Incomplete: 9.2% (57) Unknown: 59.8% (110)	NA	NA
Schneider et al[23]	Penetrating wounds of the spine	94	NA	NA	C: 12.8% (12) T: 48.9% (46) L: 34.0% (32) S: 4.3% (4)	NA	NA	Chest: 31.9% (30) Retroperitoneum: 8.5% (8) Abdomen: 10.6% (10)
Klemperer et al[24]	SCI	201	NA	NA	C: 23.4% (47) T: 46.8% (94) L: 27.4% (55) S: 2.5% (5)	Complete: 55.7% (112) Incomplete: 44.3% (89)	NA	NA
Jankovic et al[25]	Spine injuries and SCI	Soldiers: 86 Civilians: 10	Mean age at injury Soldiers: 28.3 Civilians: 38.8	NA	NA	NA	NA	NA
Jacobson et al[26]	SCI in Vietnamese combat	114	30 years of age or younger: 103 (90.4%) Older than 30 years: 11 (9.6%)	NA	C: 13.2% (15) T: 54.3% (62) LS: 32.5% (37)	Complete: 69.3% (79) Incomplete: 30.7% (35)	Bullet: 50% (57) Shell fragment: 28.9% (33) Blast: 11.4% (13) MVA: 6.1% (7) Other: 3.5% (4)	Head and neck: 7.0% (8) Chest: 37.7% (43) Abdomen: 24.6% (28) Limb/pelvis: 13.2% (15)
Alaca et al[27]	Gunshot wound-induced SCI	105	Mean age at SCI: 25	Male: 100%	C: 1.9% (2) T: 64.8% (68) L: 28.6% (30) S: 4.8% (5)	A: 83.8% (88) B: 4.8% (5) C: 1.0% (1) D: 10.5% (11)	Bullet: 93.3% (98) Shrapnel/mine: 6.7% (7)	Chest: 34.3% (36) Solid organ: 34.3% (36) Peripheral nerve: 1.0% (1)
Kahraman et al[28]	Spinal military gunshot injuries	106	Mean age at SCI: 21.2	Male: 100%	C: 33.0% (35) T: 23.6% (25) LS: 43.4% (46)	Complete: 21.7% (23) Incomplete: 78.3% (83)	Penetrating: 61.3% (65) Perforating: 25.5% (27) Unknown: 13.2% (14)	Overall: 46.2% (49) Chest: 17.0% (18) Abdomen: 20.8% (22) Neck: 8.5% (9)
Bhatoe et al[29]	Low-velocity missile injuries to the spine	22	Mean age at SCI: 30.7	Male: 100%	C: 31.8% (7) T: 54.5% (12) L: 13.6% (3)	Complete: 68.2% (15) Incomplete: 18.2% (4) Cauda equina injury: 13.6% (3)	Splinter-related injury: 81.8% (18) Bullet-related injury: 18.2% (4)	Head and neck: 22.7% (5) Chest: 18.2% (4) Abdomen: 13.6% (3)
Blair et al[9]	War-related injuries to the back, spinal column, and/or spinal cord	598 soldiers sustained 2101 injuries to the spinal column/cord	Mean age at SCI: 26.5	Male: 97.7% (584) Female: 2.3% (14)	C: 15.2% (319) T: 28.1% (591) L: 40.8% (857) S: 10.9% (230) SCI: 5% (104) (out of 2101 spine traumas)	Complete: 45.2% (47) Incomplete: 48.1% (50) Unknown: 6.7% (7) (out of 104 SCIs)	Explosion: 56.2% (336) MVA: 29.3% (175) Gunshot: 14.9% (89) Fall: 7.4% (44) Unknown: 4.8% (29) (Multiple mechanisms apparently occurred)	Overall: 78.1% (467) Multiple: 44.5% (266) Chest: 26.6% (159) Abdomen: 24.9% (149) Head: 22.7% (136) Face: 21.2% (127)
Breeze et al[30]	All United Kingdom service personnel sustaining wounds to the neck	Neck wounds: 75 Spine injuries or SCI: 32	NA	NA	NA	NA	Gunshot: 25% (8) Explosion: 71.9% (23) Unknown: 3.1% (1)	NA
Blair et al[14]	War-related injuries to the back, spinal column, and/or spinal cord	502 soldiers (battle-related injuries)	Mean age at SCI: 26.3	Male: 98.8% (496) Female: 1.2% (6)	C: 14.3% (262) T: 27.9% (511) L: 41.3% (758) S: 11.5% (210) SCI: 5% (91) (out of 1834 spine traumas)	Complete SCI: 45.1% (41) (out of 91 SCIs)	Explosion: 66.7% (335)[a] MVA: 24.5% (123) Gunshot: 16.7% (84) Fall: 3.0% (15) (Multiple mechanisms apparently occurred)	NA

(continued)

Table 2. (continued)

Reference	Group	Number of Cases	Age (Years)	Sex	Level of SCI	Severity of SCI	Mechanism of SCI	Associated Bodily Injuries
		96 soldiers (non–battle-related injuries)	Mean age at SCI: 27.3	Male: 91.7% (88) Female: 8.3% (8)	C: 21.3% (57) T: 30% (80) L: 37.1% (99) S: 7.5% (20) SCI: 5% (13) (out of 267 spine traumas)	Complete SCI: 46.2% (6) (out of 13 SCIs)	Explosion: 1.0% (1) MVA: 54.2% (52) Gunshot: 5.2% (5) Fall: 30.2% (29) (Multiple mechanisms apparently occurred)	NA
Lehman et al[15]	Combat-related injuries and thoracolumbar fractures	32	Mean age at SCI: 26	Male: 93.8% (30) Female: 6.2% (2)	*Low lumbar* (L3-L5): 59.4% (19) *Upper lumbar* (T12-L2): 37.5% (12) *Upper and lower lumbar* (T12-L3): 3.1% (1)	*Low lumbar* Complete: 16.7% (2) Incomplete: 33.3% (4) No neurologic deficit: 50% (6) *Upper lumbar* Complete: 10.5% (2) Incomplete: 57.9% (11) No neurologic deficit: 31.6% (6)	Improvised explosive device (IED): 25% (8) IED/MVA: 34.4% (11) Helicopter: 21.9% (7) Gunshot: 9.4% (3) Fall: 6.3% (2) Unknown: 3.1% (1)	Limb fractures: 40.6% (13) Abdomen: 25% (8) Chest: 12.5% (4)
Schoenfeld et al[10]	SCI identified in autopsies	872	Mean age at death: 26.6 years	Male: 99.0% (863) F: 1.0% (9)	C: 26.5% (231) T: 34.4% (300) L: 59.9% (522) S: 25.1% (219)	NA	Explosion: 74.5% (650) Gunshot: 14.8% (129) MVA: 7.8% (68) Other: 2.9% (25)	Head and neck: 73.1% (637) Abdomen: 47.0% (410) Chest: 56.0% (488) Limbs: 74.0% (645)
Schoenfeld et al[31]	SCI identified in autopsies	2089 service members with SCI	Mean age at death: 26.6	Male: 97.8% (2044) Female: 2.2% (45)	C: 52.4% (1095) T: 44.2% (924) L: 30.5% (638) S: 19.4% (405)	NA	Gunshot: 14.9% (312) Explosion: 67.2% (1403) Aviation: 11.2% (234) Other: 6.7% (140)	Head and neck: 70.2% (1466) Abdomen: 65.3% (1365) Brain: 48.0% (1002) Chest: 44.2% (924) Pelvis: 47.2% (985) GU: 37.9% (792)
Javadi et al[32]	NA	1984	Mean age at the date of study: 46 $\pm$ 6.7	Male: 98.3% (1950) Female: 1.7% (174)	C: 11.0% (219) T: 63.3% (1256) L: 23.8% (472) S: 1.9% (37)	AIS A: 91.2% (1810) AIS B/C/D: 8.8% (174)	NA	NA
Galvin et al[33]	NA	30	Mean age at date of SCI: 27.6 $\pm$ 6.5	Male: 100%	L2 or above: 65% (19) L3 or below: 37% (11)	AIS A/B/C: 43.3% (13) AIS D/E: 56.7% (17)	Blast: 70% (21) Gunshot: 10% (3) Fall: 7% (2) MVA: 7% (12) Other: 7% (2)	Mean ISS: 26.1 $\pm$ 8.7 Brain: 6 (20%)
Guzelkucuk et al[13]	Military gunshot SCI	45	Mean age at date of SCI: 23.1 $\pm$ 4.0	Male: 100%	C: 17.8% (8) T: 51.1% (23) L: 31.1% (14)	AIS A: 64.5% (29) AIS B: 17.8% (8) AIS C: 4.4% (2) AIS D: 13.3% (6)	NA	Overall: 68.9% (31) Abdomen: 40% (18) Chest: 28.9% (13) Limb: 11.1% (5) Other: 4.4% (2)
	Civilian gunshot SCI	57	Mean age at date of SCI: 29.9 $\pm$ 10.8	Male: 82.5% (46) Female: 17.5% (10)	C: 24.6% (14) T: 64.9% (37) L: 10.5% (6)	AIS A: 57.9% (33) AIS B: 15.8% (9) AIS C: 8.8% (5) AIS D: 17.5% (10)	NA	Overall: 43.9% (25) Abdomen: 25.5% (12) Chest: 27.7% (13) Limb: 19.1% (9) Other: 0%

Abbreviations: C, cervical; T, thoracic; L, lumbar; S, sacral; LS, lumbosacral: ISS, injury severity score; MVA, motor vehicle accident; AIS, ASIA [American Spinal Injury Association] Impairment Scale; NA, not available; GU, genitourinary system.
[a]Significant differences were reported.

Table 3. Incidence of War-Related Spinal Cord Injury (SCI) According to This Systematic Review.

Reference	War Setting	Case Identification	Numbers	Overall Incidence	Subgroup Incidence Rates	Comments
Schoenfeld et al[34]	American service members serving in the US Armed Forces from January 1, 2000, to December 31, 2009, including Iraq and Afghanistan Wars	Defense Medical Epidemiology Database	13 813 333 military service members; 5928 service members with SCI	*SCI:* 4.3 per 10 000 person-years	*SCI:* Men: 4.4 per 10 000 person-years[a] Women: 3.7 per 10 000 person-years[a] Black: 3.8 per 10 000 person-years[a] White: 4.5 per 10 000 person-years[a] Others: 4.0 per 10 000 person-years Junior enlisted: 4.9 per 10 000 person-years[a] Junior officers: 3.0 per 10 000 person-years Senior enlisted: 4.1 per 10 000 person-years[a] Senior officers: 2.9 per 10 000 person-years[a] Army: 4.9 per 10 000 person-years[a] Navy: 4.1 per 10 000 person-years[a] Air Force: 3.1 per 10 000 person-years[a] Marines: 5.3 per 10 000 person-years[a]	NA
Schoenfeld et al[8]	American service members serving in the US Armed Forces from 2000 to 2009 including Iraq and Afghanistan Wars	Defense Medical Epidemiology Database	13 813 333 military service members; cervical fracture without SCI occurred in 3106 individuals; 942 individuals sustained SCI	*Cervical spine fractures:* 2.9 per 10 000 person-years *Cervical SCI:* 0.7 per 10 000 person-years	*Cervical fractures:* Men: 3.1 per 10 000 person-years Women: 2 per 10 000 person-years Black: 2.5 per 10 000 person-years White: 3.1 per 10 000 person-years Others: 2.8 per 10 000 person-years Junior enlisted: 3.5 per 10 000 person-years Junior officers: 2 per 10 000 person-years Senior enlisted: 2.7 per 10 000 person-years Senior officers: 1.8 per 10 000 person-years Army: 3.2 per 10 000 person-years Navy: 2.7 per 10 000 person-years Air Force: 2.2 per 10 000 person-years Marines: 4 per 10 000 person-years	
Possley et al[35]	American service members serving in the US Armed Forces from March 2003 to December 2009 including Iraq and Afghanistan Wars	Joint Theater Trauma Registry	Service members with spinal injuries: 598 Total of spinal injuries: 1819 Total of 1 074 975 service members-year	5.6 cases of spinal injury per 10 000 service members-year 16.9 spinal injuries per 10 000 service members-year	*Time Period 1:* 17.7 per 10 000 service member-years *Time Period 2:* 16 per 10 000 service member-years *Time Period 1—Mounted:* 4.0 per 10 000 service member-years[a] *Time Period 1—Dismounted:* 13.8 per 10 000 service member-years *Time Period 2—Mounted:* 4.9 per 10 000 service member-years[a] *Time Period 1—Dismounted:* 11.2 per 10 000 service member-years	*Mounted:* Movement in a military vehicle *Dismounted:* Movement on foot *Time Period 1* (March 2003 to March 2007)—the initial fielding of the latest generation in uparmored vehicles *Time Period 2* (April 2007 to December 2009)—after the vehicle fielding

(continued)

Table 3. (continued)

Reference	War Setting	Case Identification	Numbers	Overall Incidence	Subgroup Incidence Rates	Comments
Schoenfeld et al[10]	American casualties in the Iraq and Afghanistan Wars—data from the Department of Defense Trauma Registry (2005-2009)	SCI identified in autopsies	1 992 236 person-years of exposure to the combat zones; 7877 combat casualties; 872 combatants had spinal trauma	*Spine trauma:* 4.4 per 10 000 person-years *Spine fractures:* 4.0 per 10 000 person-years *SCI:* 0.4 per 10 000 person-years	*Spine injuries:* Army: 5.3 per 10 000 person-years Navy: 2.2 per 10 000 person-years Air Force: 0.3 per 10 000 person-years Marines: 4.1 per 10 000 person-years	
Schoenfeld et al[36]	All service members within the US Armed Forces from January 1, 2001, to December 31, 2010, including Iraq and Afghanistan Wars	Defense Medical Epidemiology Database	Population at risk: 13 871 384 person-years 5277 service members with lumbar spine fractures 518 service members with SCI	*Lumbar spine fractures:* 3.8 per 10 000 person-years *Lumbar spine fractures with SCI:* 0.4 per 10 000 person-years	*Lumbar spine fractures:* Men: 4 per 10 000 person-years Women: 2.8 per 10 000 person-years Black: 1.8 per 10 000 person-years White: 4.5 per 10 000 person-years Others: 3 per 10 000 person-years Junior enlisted: 4.4 per 10 000 person-years Junior officers: 3 per 10 000 person-years Senior enlisted: 3.5 per 10 000 person-years Senior officers: 3 per 10 000 person-years Army: 4.8 per 10 000 person-years Navy: 2.9 per 10 000 person-years Air Force: 2.8 per 10 000 person-years Marines: 4.6 per 10 000 person-years	

[a]Significant differences that were reported.

Table 4. Frequency of Spinal Cord Injury (SCI) Among Other War-Related Injuries According to This Systematic Review.

Reference	Number of Cases	Control Group	Frequency
McNamara et al[37]	547 individuals with intrathoracic injuries: – 400 American service men – 147 individuals from free world military force or civilians	NA	SCI: 13.7% (75)
Radonic et al[38]	Antipersonnel mine injuries in soldiers: 329	Antipersonnel mine injuries in civilians: 93	Spine trauma: 1.7% (7) SCI: 1.2% (5)
Blair et al[9]	Total service members evacuated as combat casualties: 10 979	NA	Spinal column injuries or SCI: 5.4% of all casualties
Breeze et al[30]	Total of individuals with neck wounds: 75	NA	Spine injuries or SCI: 42.7% of the individuals who sustained wounds in the neck
Schoenfeld et al[39]	Total of cavalry scouts: 701	NA	SCI: 8% Spine trauma: 31.4% All casualties: 12% All musculoskeletal wounds: 4%
Rivera et al[11]	Total of wounded soldiers: 450	NA	SCI: 4% At least one spine-related "unfitting condition" (ie, impairment that prevents a soldier to remain on active duty): 14.7%

Demographics and Injury Characteristics of War-Related SCI

The war-related SCIs are unique with respect to their demographics when compared to traumatic SCI in the general population. While data from this systematic review indicates the male-to-female ratio of war-related SCI varies from 11:1 to 1:0, a previous review reported male-to-female ratios between 1.6:1 and 7.5:1 for traumatic SCI in the general population.[12] Pooled data from publications captured in this review also suggests that the mean age of military personnel who sustain a war-related SCI was 26.3 years, which is consistent with the population on military service. Therefore, war-related SCIs usually occur in younger individuals than civilians with traumatic SCI who were reported to occur in individuals with 26.8 to 55.4 years of age.[12]

Although the distribution of the level of war-related SCIs widely varied among the publications, the thoracic level was the most common level of injury followed by lumbosacral and cervical SCIs. Furthermore, war-related SCIs were more severe in nature with a greater proportion of complete injuries than the general population in most jurisdictions.[12] A previous review on traumatic SCI using data from the general population indicated a broad variation of the frequency and severity of SCIs, even though traumatic SCI most commonly affected the cervical level (25% to 88%) followed by the thoracic level (24% to 63%).[12] Also, the proportion of complete injuries (18.2% to 90%) was greater than the proportion of incomplete injuries (10% to 81.8%) in most of the previous studies using data from the general population.[12] Trends in the epidemiology of traumatic SCI in the general population suggest that cervical SCIs are on the rise and complete injuries are in decline.[45] Differences in the level and severity of SCIs have obvious implications in terms of neurologic and functional recovery across the spectrum with least favorable prognosis among tetraplegics with complete (or AIS A) and the most favorable prognosis among paraplegics with AIS D.[46] For instance, Spiess et al showed that only 30.2% of patients with AIS A SCI converted to AIS B (17.3%), AIS C (5.8%), or AIS D (7.2%) within the first year after traumatic SCI, whereas 76.7% of the patients with AIS B or C SCI improved their AIS grade (even though 7% had a significant neurologic deterioration) and only 8.5% of the patients with AIS D converted to AIS E (most likely due to a ceiling effect).[47]

Not surprisingly, gunshot and explosion were the most common mechanisms of war-related SCIs followed by motor vehicle accidents and falls. In contrast, motor vehicle accidents are the most common cause of traumatic SCI followed by falls, acts of violence, and sports in the general population across the world.[48]

Furthermore, war-related SCIs are associated with other bodily injuries in 43.9% to 78.1% including head and neck injuries, traumatic brain injury, chest injuries, abdominal injuries, pelvic injuries, and limb injuries. Using population-based data from 3389 cases of traumatic SCI, Selassie et al reported the occurrence of associated bodily injuries in 33.3% of the cases of traumatic SCI including abdominal and pelvic injuries (20.3%), limb injuries (20.1%), chest (19%), cranium and brain injuries (15.8%), and face and neck injuries (9.4%), which is relatively lower than soldiers with war-related SCI.[49] The authors of that retrospective study also documented that the risk of death in the acute care hospital after traumatic SCI progressively increased as the number of associated body regions increased, regardless of demographic and clinical covariates.[49]

In summary, there are considerable differences between war-related SCIs and non–war-related SCIs with regard to age, sex, level and severity of injury, mechanisms of injury, and associated bodily injuries.

Clinical Implications

The most common mechanisms of war-related SCIs include gunshot and explosive that are considered high-energy injuries.

Gunshot injuries in the spinal cord are typically associated with greater mortality and morbidity when compared with other causes of SCI.[50,51] While the civilian gunshot wounds are usually caused by low-energy projectiles travelling at 1000 to 2000 feet per second that are fired from pistols and revolvers, the military gunshot wounds are produced by high-energy projectiles bullets travelling at 2000 to 3000 feet per second fired from rifles and military weapons with resultant greater tissue damage.[50] The management of gunshot-induced SCIs is unique in different aspects. First, gunshot-induced injuries appear to be less associated with instability of the spine when compared to blunt injuries, which suggests that immobilization may not be necessary in the battlefield prehospital care.[52,53] In fact, cervical collars may hide potential and developing life-threatening conditions.[52] Second, the presence of any metallic foreign body is a contraindication for magnetic resonance imaging, and spine angiography, especially for the vertebral artery anatomy, should be considered prior to the surgical exploration.[52] Third, the use of steroids in gunshot-induced SCIs may not be beneficial to improve neurological recovery and may cause additional risks of complications.[51] Finally, decompression of the spinal cord or theca in gunshot-induced spine injuries remains a controversial topic in the literature.[51,52,54] Based on a systematic review, Sidhu et al reported that surgical treatment may improve neurological recovery in the gunshot-induced lumbosacral SCIs, but not in the gunshot-induced thoracic or cervical SCIs.[51] Generally speaking, surgical treatment is considered to increase the risk of complications in gunshot-induced injuries of the spine, even though a prior systematic review suggested that the level of evidence is low to recommend against or in favor of surgical treatment.[51,52] Nonetheless, surgery may be beneficial in certain circumstances such as cerebrospinal fluid fistula, infectious and compressing foreign bodies in the injury site, spinal instability, and rapid neurological deterioration.[28,50]

Explosive blasts result in a cascade of events that begin with the primary explosion followed by the secondary, tertiary, and quaternary effects causing a multiplicity of severe tissue damage.[53,55] The primary injuries to the spinal cord include blast wave-induced concussion and barotrauma associated with ischemia and infarction caused by acute gas embolism.[55] The secondary blast injuries occur when objects are propelled into the person, which causes blunt and penetrating injuries of the spine depending on the proximity to the primary explosive site, interposing structures, and chance.[55] The tertiary blast injuries occur in high-energy explosion that propels the person through space and into other objects. The spine can be injured in different ways by the rapid acceleration, sudden deceleration, and impact of the body on other projected and fixed objects.[55] The quaternary blast injuries are caused by random circumstances such as the collapse or displacement of structures and heavy objects onto the person, the effects of toxic gases and solutions that are released, and the effects of fire.[55] The injuries caused by explosive blasts are commonly fatal or, in survivors, cause critical and complex polytrauma including injuries of the central and peripheral nervous system. In general, the timing of spinal surgery in patients with severe multisystem injuries after trauma remains controversial in the literature. The most recent Clinical Practice Guideline for the Management of Patients with Acute Spinal Cord Injury and Central Cord Syndrome recommends early decompression of the spinal cord (up to 24 hours after trauma) "as a treatment option in adult patients with traumatic central cord syndrome" and "as an option for adult acute SCI patients regardless of level."[56] Those recommendations were inspired in clinical studies that revealed potential benefits of the early surgical decompression of spinal cord are mostly based on cohorts of civilians with traumatic SCI.[57-59] However, the military medical experience from the recent Afghanistan and Iraq wars, where most of the battlefield-inflicted SCIs were caused by explosive blasts (70%), suggests that the perceived benefits of early spine surgery should be weighed against the greater risks of performing extensive spinal surgeries on multiply injured combatants.[33] In a retrospective case series, Galvin et al documented that delayed spine surgery may reduce the risk of complications in borderline unstable patients by allowing physiologic stabilization in the intensive care unit and avoiding the systemic inflammatory response syndrome.[33] Overall, some principles of management of traumatic SCIs applied to civilians may not be suitable for use in the treatment of severely and complexly injured combatants with SCI.

Study Limitations

To our knowledge, this is the first systematic review focused on the epidemiology of war-related SCI. Although the results of this review revealed substantial differences between war-related SCIs and non–war-related SCIs, there are limitations worthy of consideration, prior to generalizing the results. First, all data included in this review was derived from case series and retrospective cohort studies, which are vulnerable to potential bias and methodological limitations. Second, the majority of the data from the selected articles was obtained from the Iraq and Afghanistan wars where contrasting apparatus (advanced weaponry vs improvised explosive devices) and less conventional battle strategies (eg, suicide bombers) were used. Although data from Iraq and Afghanistan wars may be more representative of the contemporary wars, the mechanisms of injuries are substantially distinct from the more conventional wars such as World War I and II, Vietnam War, and Korean War. Finally, many recent studies analyzed data from the same US database (ie, Defense Medical Epidemiology Database) that may not represent the reality of other military populations involved in different war settings in other parts of the world.

Conclusions

This systematic review, for the first time, summarized and appraised data from publications on the epidemiology of SCI in the military personnel who sustained their injury during combat acts. Those results underscore the singularities of epidemiology of war-related SCIs among combatants in terms of their age at injury onset, sex distribution, ethnic groups, mechanisms of injury, severity of injury, and associated bodily injuries with potential effects on survival and recovery when compared to civilians with SCI. At large, military personnel with war-related SCI are predominantly comprised of young, white, men who mainly sustained thoracic (followed by cervical level) and severe (complete or AIS A) SCI caused by gunshot or explosion, and often associated with at least another bodily injury. Marines appear to be the highest risk for war-related SCI among the military personnel. Overall, the principles of management of traumatic SCIs in the civilian population may not all be suitable for the treatment of war-related SCIs. Additional investigations are required to further improve preventive measures (eg, protective apparatus), prehospital care (eg, early recognition and proper mobilization of wounded soldiers with SCI), transportation (eg, maintenance of mean arterial blood pressure), deployed hospital care (eg, adequate spinal cord blood perfusion, steroid therapy, and early surgical decompression when recommended), and rehabilitation.[57,58,60-63]

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