

# Spinal Injuries in United States Military Personnel Deployed to Iraq and Afghanistan

*An Epidemiological Investigation Involving 7877 Combat Casualties From 2005 to 2009*

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**Study Design.** Retrospective analysis of a prospective data set.

**Objective.** Determine the incidence and epidemiology of combat-related spinal injuries for the wars in Afghanistan and Iraq.

**Summary of Background Data.** Recent studies have identified a marked increase in the rate of combat-related spine trauma among casualties in Afghanistan and Iraq. Limitations in these previous works, however, limit their capacity for generalization.

**Methods.** A manual search of casualty records stored in the Department of Defense Trauma Registry was performed for the years 2005 to 2009. Demographic information, nature of spinal wounding, injury mechanism, concomitant injuries, year, and location of injury were recorded for all soldiers identified as having sustained combat-related spine trauma. Incidence rates were constructed by comparing the frequencies of spine casualties against defense manpower deployment data. Multivariate Poisson regression was used to identify statistically significant factors associated with spinal injury.

**Results.** In the years 2005 to 2009, 872 (11.1%) casualties with spine injuries were identified among a total of 7877 combat wounded. The mean age of spine casualties was 26.6 years. Spine fractures were the most common injury morphology, comprising 83% of all spinal wounds. The incidence of combat-related spinal trauma was 4.4 per 10,000, whereas that of spine fractures was 4.0 per 10,000. Spinal cord injuries occurred at a rate of 4.0 per 100,000. Spinal cord injuries were most likely to occur in

Afghanistan (incident rate ratio: 1.96; 95% confidence interval: 1.68–2.28), among Army personnel (incident rate ratio: 16.85; 95% confidence interval: 8.39–33.84), and in the year 2007 (incident rate ratio: 1.90; 95% confidence interval: 1.55–2.32). Spinal injuries from gunshot were significantly more likely to occur in Iraq (17%) than in Afghanistan (10%,  $P = 0.02$ ).

**Conclusion.** The incidence of spine trauma in modern warfare exceeds reported rates from earlier conflicts. The study design and population size may enhance the capacity for generalization of our findings.

**Key words:** spine trauma, combat, epidemiology.

**Level of Evidence:** 3

**Spine 2013;38:1770–1778**

*Private [JM]...10<sup>th</sup> United States Cavalry, received a gunshot wound in the neck [and] [c]omplete paralysis of both superior extremities...the ball...penetrated the neck...fracturing one or more of the vertebrae...death on November 28, 1869, about eight days after receipt of this injury.  
George A. Otis, MD (1871)<sup>1</sup>*

The above account of a gunshot wound to the cervical spine during the period of the Indian Wars was fairly typical of the clinical course experienced by US service members with combat-related spinal trauma for the first century and a half of American military medicine.<sup>1,2</sup> Only in the era of World War II did advances in medical technology and surgical capabilities allow military surgeons to intervene in the setting of severe war-related spine wounds.<sup>2,3</sup> Even then, however, spinal injuries were recognized only in 1% to 2% of combat casualties in all major military actions until the start of the wars in Iraq and Afghanistan.<sup>2-5</sup>

A substantial increase in interest regarding combat-related spine trauma has occurred during the last 4 years, as publications have highlighted a marked elevation in the incidence of such injuries among American casualties from the battlefronts in the Middle East.<sup>2-9</sup> Work conducted among a single brigade combat team identified the incidence of combat-related spine injury at 7.4%,<sup>4</sup> and a similar rate was published by Comstock *et al*<sup>8</sup> for Canadian personnel. Another

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Acknowledgment date: March 1, 2013. First revision date: May 2, 2013. Second revision date: May 28, 2013. Acceptance date: May 31, 2013.

The manuscript submitted does not contain information about medical device(s)/drug(s).

No funds were received in support of this work.

Relevant financial activities outside the submitted work: fees for participation in review activities such as data monitoring boards, statistical analysis, end point committees, and the like and royalties.

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DOI: 10.1097/BRS.0b013e31829ef226

investigation, using the records of combat fatalities, estimated that spinal trauma may be present in as many as 38% of all war-related deaths.<sup>5</sup>

Limitations to these previous works, however, hinder the capacity to generalize their findings to the American military as a whole. These include restrictions in the scope of population under study,<sup>4,5,7,9</sup> consideration of combat units for only a fixed period of time,<sup>4</sup> and patient cachements that consist of a single combat hospital<sup>8</sup> or region of conflict.<sup>4</sup> Possibly, the single greatest limitation among these previous efforts rests in their inability to define a population at risk. Without a reliable estimate of the population exposed to the combat theater, sufficiently broad in terms of demography, military occupation, and exposure to warfare, readily translatable determinations of the character, nature, and epidemiology of war-related spinal trauma are not possible.<sup>10,11</sup>

This investigation was designed to provide information regarding the incidence and extent of combat-related spine wounds in the conflicts in Iraq and Afghanistan, using a population at risk derived from the records of the Defense Manpower Data Center. Wounded personnel with spinal injuries were identified through a manual search of the Department of Defense Trauma Registry (DoDTR). To the best of our knowledge, this effort is the most complete and scientifically rigorous analysis regarding the incidence and epidemiology of spine trauma in Iraq and Afghanistan. The data presented here may be more immediately translatable to American military personnel deployed to combat and might also be applicable to civilian disaster planning and mass casualty events within the United States.<sup>12</sup>

## MATERIALS AND METHODS

Prior to its initiation, this investigation received separate approvals from our investigational review board and the DoDTR. The main population under study consisted of the 7877 combat casualties whose injury-specific data were registered with the DoDTR between 2005 and 2009. The methodology of the DoDTR has been extensively described in previous publications.<sup>6,7,9,11,13</sup> In brief, since 2003, the records of soldiers injured in combat have been registered with the DoDTR. Data from each treatment facility in the evacuation chain are synthesized into a single record for injured personnel accessible through application to the Army Institute that maintains the registry.<sup>14</sup> The data set does not contain information on soldiers who died before reaching a medical treatment facility, nor does it capture details regarding soldiers from coalition nations, American civilians wounded in theater, host nationals, or enemy combatants.<sup>11,14</sup> The DoDTR and its predecessor (the Joint Theater Registry) have been used in previous studies evaluating the nature of war injuries in Afghanistan and Iraq,<sup>6,7,9,11</sup> and data from the system have been found to be both reliable and valid.<sup>13</sup>

A manual search was performed for each of the 7877 soldier-specific records obtained from the DoDTR to identify all soldiers who sustained a spinal injury. Demographic data including age, sex, and rank were abstracted, as was the individual's branch of service (Army, Navy, Air Force,

or Marine Corps). The nature of spinal wounding, along with concomitant injuries, year of injury, location (Iraq or Afghanistan), and trauma mechanism were also recorded. Rank was classified as junior enlisted (lowest 4 ranks in any branch), senior enlisted (all noncommissioned officers), and officers (including general officers and warrant officers). Mechanism of injury was categorized as explosion (including improvised explosive device and explosively formed projectile), gunshot wound, motor vehicle crash, and other (e.g., fall from height, helicopter crash, other mechanism of injury). Concomitant wounds were classified using the Churchill criteria.<sup>15</sup>

Incidence rates (IRs) by location, year, and branch of service were derived by comparing frequencies of combat casualties with spinal injuries with the population at risk as reported by the Defense Manpower Data Center. Multivariate Poisson regression analysis, controlling for other factors present in the model, was then used to develop a predictive model that identified statistically significant independent factors associated with spinal injuries. By convention, the variable with the lowest IR for the category under investigation was used as a referent in the multivariate test. Independent factors associated with spine trauma were considered those that demonstrated IRs greater than the population mean, adjusted incidence rate ratios (IRR), 95% confidence intervals (CI) exclusive of 1.0, and  $P < 0.05$ .

Determinations for the statistical influence of injury mechanism by location, year, and branch of service were calculated using the  $\chi^2$  test. The Iraq theater was considered as more representative of urban warfare,<sup>16</sup> whereas the Afghanistan theater was thought to be reflective of rural asymmetric warfare.<sup>17</sup> The years 2007 and 2008 were maintained to be time periods of more aggressive counter-insurgency operations in Iraq,<sup>16</sup> whereas 2009 reflected similar enhanced operations in Afghanistan.<sup>17</sup> All testing was performed using SAS statistical software (version 9.3, SAS Institute, Cary, NC).

## RESULTS

In the time between 2005 and 2009, there were 1,992,236 person-years of exposure to the combat zones in Afghanistan and Iraq (Table 1). In this same period, 7877 combat casualties were reported to the DoDTR, of which 872 (11.1%) were found to have sustained one or more instances of spinal trauma. In total, 1292 distinct spinal injuries were identified, with a mean of 1.5 spine wounds per injured soldier. The average age of individuals with spine trauma was 26.6 years and approximately 99% of the cohort was male (Table 2). Eighty-one percent ( $n = 707$ ) were members of the Army and 57.1% were junior enlisted (Table 2). Explosions were the most common mechanism of injury ( $n = 650$ , 74.5%), with gunshot wounds occurring in only 14.8% (Table 3). The lumbar spine ( $n = 522$ , 40%) was the most frequently involved region, followed by the thoracic ( $n = 300$ , 23%) and cervical spines ( $n = 231$ , 18%). Injuries to the sacrum and coccyx were identified in 219 instances (17%). Twenty-nine service members (3.3%) died of their injuries after receiving medical care.

**TABLE 1. Combat-Related Spine Casualties as a Percentage of the Total Number of Deployed Personnel (Population at Risk) by Year, Location, and Branch of Service**

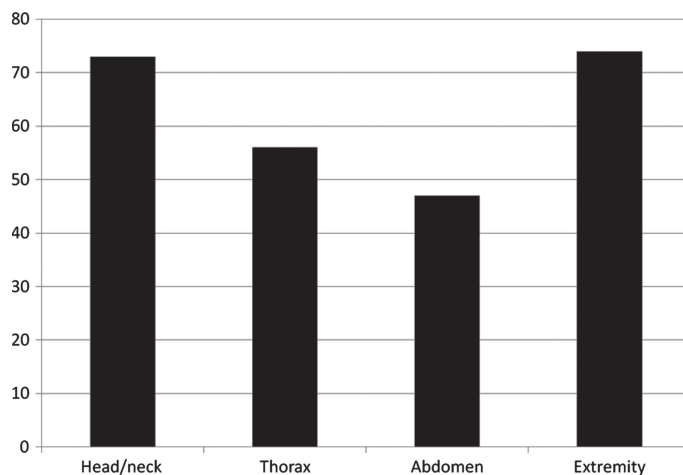
	2005			2006			2007			2008			2009			Total			
	Deployed	Casualties		Deployed	Casualties		Deployed	Casualties		Deployed	Casualties		Deployed	Casualties		Deployed	Casualties		
Iraq																			
Army	185,716	130 (0.070%)		222,046	133 (0.060%)		209,353	165 (0.079%)		234,172	68 (0.029%)		231,305	17 (0.007%)		1,082,592	513 (0.047%)		
Navy	9254	2 (0.022%)		12,062	8 (0.066%)		14,519	6 (0.041%)		17,533	2 (0.011%)		15,308	0 (0%)		68,676	18 (0.026%)		
Air Force	26,892	2 (0.007%)		29,953	1 (0.003%)		37,652	2 (0.005%)		38,775	0 (0%)		30,626	0 (0%)		163,898	5 (0.003%)		
Marines	65,290	27 (0.041%)		67,970	43 (0.063%)		71,241	26 (0.037%)		66,728	1 (0.001%)		37,096	1 (0.003%)		308,325	98 (0.032%)		
Theater total	287,152	161 (0.056%)		332,031	185 (0.056%)		332,765	199 (0.060%)		357,208	71 (0.020%)		314,335	18 (0.006%)		1,623,491	634 (0.039%)		
Afghanistan																			
Army	33,598	8 (0.024%)		37,332	9 (0.024%)		40,135	34 (0.085%)		52,286	30 (0.057%)		85,380	113 (0.132%)		248,731	194 (0.078%)		
Navy	1368	0 (0%)		2241	0 (0%)		2953	1 (0.034)		5765	0 (0%)		8681	1 (0.012%)		21,008	2 (0.009%)		
Air Force	6253	0 (0%)		9946	0 (0%)		13,709	0 (0%)		16,661	1 (0.006%)		23,547	2 (0.008%)		70,116	3 (0.004%)		
Marines	3222	0 (0%)		2350	2 (0.085%)		1381	2 (0.145%)		6300	6 (0.095%)		15,637	29 (0.185%)		28,890	39 (0.135%)		
Theater total	44,441	8 (0.018%)		51,869	11 (0.021%)		58,178	37 (0.064%)		81,012	37 (0.046%)		133,245	145 (0.109%)		368,745	238 (0.065%)		
Total	331,593	169 (0.051%)		383,900	196 (0.051%)		390,943	236 (0.060%)		438,220	108 (0.025%)		447,580	163 (0.036%)		1,992,236	872 (0.044%)		

**TABLE 2. Demographic Details of Soldiers With Combat-Related Spinal Injuries by Year and Location**

	2005		2006		2007		2008		2009		Total		
	Iraq	Afghanistan	Iraq	Afghanistan	Iraq	Afghanistan	Iraq	Afghanistan	Iraq	Afghanistan	Iraq	Afghanistan	Total
Age, mean, yr	27.7	26.1	25.8	28.2	25.8	26.3	26.4	27.7	31.3	26.5	26.6	26.7	26.6
Sex													
Male	157 (97.52%)	8 (100.00%)	185 (100.00%)	11 (100.00%)	196 (98.49%)	37 (100.00%)	71 (100.00%)	37 (100.00%)	18 (100.00%)	143 (98.62%)	627 (98.9%)	236 (99.16%)	863 (98.97%)
Female	4 (2.48%)	0	0	0	3 (1.51%)	0	0	0	0	2 (1.38%)	7 (1.10%)	2 (0.84%)	9 (1.03%)
Total	161	8	185	11	199	37	71	37	18	145	634	238	872
Branch of service													
Army	130 (80.75%)	8 (100.00%)	133 (71.89%)	9 (81.82%)	165 (82.91%)	34 (91.89%)	68 (95.77%)	30 (81.08%)	17 (94.44%)	113 (77.93%)	513 (80.91%)	194 (81.51%)	707 (81.08%)
Navy	2 (1.24%)	0	8 (4.32%)	0	6 (3.02%)	1 (2.70%)	2 (2.82%)	0	0	1 (0.69%)	18 (2.84%)	2 (0.84%)	20 (2.29%)
Air Force	2 (1.24%)	0	1 (0.54%)	0	2 (1.01%)	0	0	1 (2.70%)	0	2 (1.38%)	5 (0.79%)	3 (1.26%)	8 (0.92%)
Marines	27 (16.77%)	0	43 (23.24%)	2 (18.18%)	26 (13.07%)	2 (5.41%)	1 (1.41%)	6 (16.22%)	1 (5.56%)	29 (20.00%)	98 (15.46%)	39 (16.39%)	137 (15.71%)
Total	161	8	185	11	199	37	71	37	18	145	634	238	872
Rank													
Junior Enlisted	82 (50.93%)	2 (25.00%)	105 (56.76%)	6 (54.55%)	122 (61.31%)	19 (51.35%)	44 (61.97%)	21 (56.76%)	8 (44.44%)	89 (61.38%)	361 (56.94%)	137 (57.56%)	498 (57.11%)
Senior Enlisted	67 (41.61%)	4 (50.00%)	71 (38.38%)	4 (36.36%)	64 (32.16%)	16 (43.24%)	23 (32.39%)	12 (32.43%)	7 (38.89%)	43 (29.66%)	232 (36.59%)	79 (33.19%)	311 (35.67%)
Officers	10 (6.21%)	2 (25.00%)	8 (4.32%)	1 (9.09%)	13 (6.53%)	2 (5.41%)	3 (4.23%)	4 (10.81%)	3 (16.67%)	12 (8.28%)	37 (5.84%)	21 (8.82%)	58 (6.65%)
Unknown	2 (1.24%)	0	1 (0.54%)	0	0	0	1 (1.41%)	0	0	1 (0.69%)	4 (0.63%)	1 (0.42%)	5 (0.57%)
Total	161	8	185	11	199	37	71	37	18	145	634	238	872

**TABLE 3. Mechanism of Injury for Soldiers With Combat-Related Spinal Trauma by Year and Location**

Mechanism	2005		2006		2007		2008		2009		Total		
	Iraq	Afghanistan	Iraq	Afghanistan	Iraq	Afghanistan	Iraq	Afghanistan	Iraq	Afghanistan	Iraq	Afghanistan	Total
Explosion	135 (83.85%)	4 (50.00%)	140 (75.68%)	4 (36.36%)	135 (67.84%)	17 (45.95%)	48 (67.61%)	30 (81.08%)	11 (61.11%)	126 (86.90%)	469 (73.97%)	181 (76.05%)	650 (74.54%)
Gunshot wound	18 (11.18%)	3 (37.50%)	34 (18.38%)	5 (45.45%)	39 (19.60%)	5 (13.51%)	14 (19.72%)	4 (10.81%)	1 (5.56%)	6 (4.14%)	106 (16.72%)	23 (9.66%)	129 (14.79%)
Motor vehicle crash	6 (3.73%)	1 (12.50%)	7 (3.78%)	1 (9.09%)	21 (10.55%)	11 (29.73%)	4 (5.63%)	3 (8.11%)	6 (33.33%)	8 (5.52%)	44 (6.94%)	24 (10.08%)	68 (7.80%)
Other	2 (1.24%)	0	4 (2.16%)	1 (9.09%)	4 (2.01%)	4 (10.81%)	5 (7.04%)	0	0	5 (3.45%)	15 (2.37%)	10 (4.20%)	25 (2.87%)
Total	161	8	185	11	199	37	71	37	18	145	634	238	872



**Figure 1.** The rates of associated injuries, by Churchill region,<sup>15</sup> encountered among soldiers with combat-related spine trauma. Rates are presented as a percentage of the total number of spine injured (n = 872).

The most common injury was a spine fracture, representing 83% of all wounds (n = 1078) and occurring in 91% (n = 797) of all casualties. Open fractures were identified in 26% (n = 231) of the cohort. Spinal dislocations were documented in 78 soldiers (9%), disc displacements were recorded in 28 (3%), nerve root injuries in 24 (3%), and spinal cord injury occurred in 77 (9%). Among the 650 soldiers injured by explosive blast, 204 (31%) sustained injuries involving more than 1 spinal region. Thirty-one percent (n = 64) of these involved the thoracic and lumbar regions and 10% (n = 21) involved the cervical and lumbar regions. Eleven (5%) soldiers had injuries to the cervical, thoracic, and lumbar spines and 5 (3%) were found to have pan-spinal wounds (cervical, thoracic, lumbar, and sacral). Fractures in multiple regions were identified in 197 (30%) individuals, whereas multiregional dislocations occurred in 33 (5%) individuals. Multilevel injuries within a region were documented in 283 cases (44%), with multilevel fractures within the same spinal region recorded in 276 cases.

Injuries to the extremity were the most common associated wound (n = 645, 74%), followed closely by injuries to the head and the neck (n = 637, 73%). The abdomen was the only Churchill region that was found to have an injury prevalence of less than 50% within the cohort (Figure 1). Fifty-seven percent (n = 132) of soldiers with cervical injuries resulting from explosive blast had associated head or neck wounds, whereas a much smaller percentage (16%, n = 84) were found to have lumbar fractures associated with pelvic trauma.

The overall IR for spine trauma in this study was 4.4 per 10,000. The rate of spinal fracture was 4.0 per 10,000 and that of spinal dislocations and spinal cord injury was 4 per 100,000. Overall, spinal injuries were significantly more likely to occur in Afghanistan (IRR: 1.96; 95% CI: 1.68–2.28), among Army personnel (IRR: 16.85; 95% CI: 8.39–33.84), and in the years 2005 to 2007 (Table 4). The highest incidence

**TABLE 4. Unadjusted Incidence Rates and Adjusted Incidence Rate Ratios for All Spine Injuries**

Category	Number of Cases	Person-Years	Unadjusted IR*	Adjusted IRR (95% CI)	P
Iraq	634	1,623,491	3.9	N/A	N/A
AFG	238	368,745	6.5	1.96 (1.68–2.28)†	<0.001
2005	169	331,593	5.1	1.54 (1.24–1.92)‡	<0.001
2006	196	383,900	5.1	1.56 (1.26–1.92)‡	<0.001
2007	236	390,943	6.0	1.90 (1.55–2.32)‡	<0.001
2008	108	438,220	2.5	N/A	N/A
2009	163	447,580	3.6	1.33 (1.05–1.70)‡	0.02
Army	707	1,331,323	5.3	16.85 (8.39–33.84)§	<0.001
Navy	20	89,684	2.2	7.14 (3.15–16.22)§	<0.001
Air Force	8	234,014	0.3	N/A	N/A
Marines	137	337,215	4.1	13.61 (6.66–27.80)§	<0.001

\*Incidence rate is per 10,000 person-years.  
†Adjusted for year and service. Iraq was the referent category.  
‡Adjusted for theater and service. 2008 was the referent category.  
§Adjusted for theater and year. Air Force was the referent category.  
IR indicates incidence rate; IRR, incidence rate ratios; CI, confidence interval; N/A, not applicable because this category was used as the referent category for calculations; AFG, Afghanistan.

of spinal trauma occurred in 2007 (IRR: 1.90; 95% CI: 1.55–2.32), whereas the lowest IRs were encountered in 2008 and 2009. Not surprisingly, similar associations were appreciated for spinal fractures (Table 5). Spinal dislocations were significantly associated with the Afghanistan theater (IRR: 2.24; 95% CI: 1.36–3.70) and the year 2009 (IRR: 5.83; 95% CI: 1.74–19.59). The only significant variable associated with spinal cord injury was the year 2007 (IRR: 2.99; 95% CI: 1.41–6.35).

Spinal injuries from gunshot were significantly more likely to occur in Iraq (17% vs. 10% in Afghanistan,  $P = 0.02$ ), whereas explosive blasts were responsible for approximately 75% of casualties in both conflicts. The incidence of explosive mechanisms of injury across years ranged from 64% to 84%, with 2007 demonstrating a significantly lower rate of casualties resulting from explosion ( $P < 0.001$ ). Gunshot wounds ranged from 4% to 20% of all casualties by year, with the highest rates appreciated in 2006 (20%) and 2007 (18%).

## DISCUSSION

Recent publications have highlighted an elevated incidence of war-related spine trauma among casualties from Iraq and Afghanistan when compared with prior wars.<sup>2–9</sup> This substantial increase is thought to be related to enhanced personnel protection and medical advancements that have increased survivability among the combat injured, allowing soldiers to survive wounding mechanisms that would previously have proven lethal.<sup>3,4,6,7,9,11</sup> Whereas in conflicts from ancient times through World War II, soldiers with spinal trauma were injured

so severely that their survival was rendered impossible,<sup>1–3</sup> advances in military medicine are now enabling soldiers to reach medical facilities where their spinal wounds can be identified. Other authors have cited improved surveillance at medical facilities,<sup>3,5,8</sup> as well as enemy combatants' reliance on explosive mechanisms of assault,<sup>3–5,7,9</sup> as the factors principally responsible for the apparent elevation in war wounds to the spine.

A holistic appreciation of the nature and extent of spinal trauma in modern American combat theaters has not previously been possible, however, because the design of previous works obviates their capacity to be generalized to the military as a whole. The methodology used in this analysis, including a manual search of soldier records from a validated database such as the DoDTR,<sup>13</sup> as well as the use of Defense Manpower Data Center statistics to define a population-at-risk, enabled a more complete characterization of the incidence and epidemiology of spinal trauma in combat. The IRs and associated risk factors presented here may be more immediately relevant to modern combat or domestic terrorism and can also facilitate strategic forecasting.<sup>10–12</sup>

The average age, manner of spine trauma, region of spinal involvement, wounding mechanisms, and associated injury patterns of this cohort are concordant with previous works,<sup>4–9</sup> indicating a degree of validity for the data set under consideration. For example, other large studies regarding spine injuries sustained in war have reported explosive blast as the most common mechanism of injury, responsible for 56% to 84% of all combat spine casualties.<sup>4–9</sup> Our rate of 74.5% exists within this range, as does the 14.8% of the

**TABLE 5. Unadjusted Incidence Rates and Adjusted Incidence Rate Ratios of Spine Fractures**

Category	Number of Cases	Person-Years	Unadjusted IR*	Adjusted IRR (95% CI)	P
Iraq	575	1,623,491	3.5	N/A	N/A
AFG	222	368,745	6.0	2.02 (1.72–2.37)†	<0.001
2005	150	331,593	4.5	1.52 (1.21–1.91)‡	<0.001
2006	182	383,900	4.7	1.60 (1.29–2.00)‡	<0.001
2007	216	390,943	5.5	1.92 (1.55–2.37)‡	<0.001
2008	101	438,220	2.3	N/A	N/A
2009	148	447,580	3.3	1.29 (1.01–1.66)‡	0.049
Army	645	1,331,323	4.8	15.45 (7.69–31.05)§	<0.001
Navy	18	89,684	2.0	6.44 (2.80–14.83)§	<0.001
Air Force	8	234,014	0.3	N/A	N/A
Marines	126	337,215	3.7	12.65 (6.18–25.89)§	<0.001

Incidence rate is per 10,000 person-years.

†Adjusted for year and service. Iraq was the referent category.

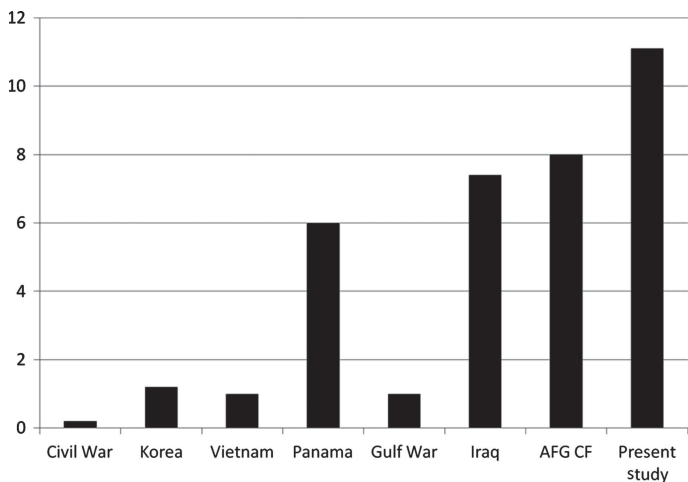
‡Adjusted for theater and service. 2008 was the referent category.

§Adjusted for theater and year. Air Force was the referent category.

IR indicates incidence rate; IRR, incidence rate ratios; CI, confidence interval; N/A, not applicable because this category was used as the referent category for calculations; AFG, Afghanistan.

population that was injured by gunshot (range, 3%–15% in previous reports<sup>4–9</sup>).

No previous efforts have reported IRs for spinal injuries over a long duration. This renders our results, calculated using



**Figure 2.** Known rates of spinal injuries, as a percentage of total combat casualties, for soldiers in American military conflicts from the Civil War (1861–1865) to the present. Data for the Civil War were calculated from reported combat casualties for the Union Army and spinal injury rates as documented in Schoenfeld *et al.*<sup>2</sup> Rates for Korea, Vietnam, Panama, and the Gulf War are reported in the study by Blair *et al.*<sup>6</sup> The Iraq figure is derived from the work of Schoenfeld *et al.*<sup>4</sup> and that for CF in obtained from Comstock *et al.*<sup>8</sup> CF indicates Canadian Forces; AFG, Afghanistan.

5 years worth of data, as novel contributions to the literature. We found that, overall, 4.4 incidents of spine trauma occurred per 10,000 soldiers, with spinal fractures documented at a rate of 4.0 per 10,000. By comparison, injuries to the extremities are anticipated in 15.4 soldiers per 10,000.<sup>11</sup> It is also interesting to note that our findings for the rate of spine trauma, as well as spinal fractures, outpace the calculated incidence for both thoracic (2.95 per 10,000<sup>11</sup>) and abdominal (3.0 per 10,000<sup>11</sup>) wounds.

A previous estimate regarding the incidence of spine fractures, presented by Possley *et al.*<sup>9</sup> for a 2.5-year period of the Iraq and Afghanistan wars, returned a higher rate of 16 per 10,000. Similarly, our previous work considering 4122 personnel deployed for a single year to Iraq resulted in a determination of 5.6 spinal injuries per 1000.<sup>4</sup> These discrepancies illustrate the large differences that may result from calculations subject to variance in sample size as well as the definition of population at risk.<sup>10</sup> In light of the methodology used in this work, our findings may be considered as less subject to sampling error and other potential biases.

The 11.1% rate of spinal injuries encountered in this investigation represents the highest published statistic for Iraq, Afghanistan, or any other American conflict (Figure 2).<sup>2–9</sup> It is commensurate, however, with a previous number largely derived from personnel killed in the combat zone.<sup>5</sup> When this fact is considered in conjunction with our study design, a strong case may be made for the 11% value as translatable for the purposes of strategic planning and military preparedness.<sup>10–12</sup>

The statistical association between the Afghan theater and spine trauma may be indicative of a heightened risk for these injuries in asymmetric rural warfare. Findings specific to Iraq point to elevations in the rate of gunshots to the spine in the setting of urban conflict. Perhaps, not surprisingly, periods of intense combat and/or aggressive counterinsurgency, such as the year 2007,<sup>4,16,17</sup> are also associated with a concomitant increase in spinal trauma.

When compared with reports of civilian spine trauma, we note that our study indicates a much higher prevalence of multiregional injuries (31% as compared with 20% in the report of Pirouzmand<sup>18</sup>). Elevated rates of associated wounds, such as concurrent injuries to the head and the neck, were also appreciated.<sup>19,20</sup> Previous works have highlighted facial fractures and/or head injury as associated risk factors for the presence of cervical trauma.<sup>19,20</sup> Such findings speak to the destructive power inherent in modern-day military grade explosives, a fact that has important implications for those who may be called on to treat civilian casualties after a domestic attack.<sup>21</sup>

The results of this investigation should not be accepted without acknowledging inherent limitations and the potential for bias. Foremost, this effort was retrospective and conducted using incident-level data from the DoDTR and population-based information as reported by the Defense Data Center. As all of our calculations are reliant on information derived from these data sets, the integrity of this work is highly dependent on the fidelity of information reported to these systems. Intrinsic errors within these registries, including mistakes related to injury reports or the number of deployed personnel, would adversely impact our conclusions. Other limitations based on the source of our data include a lack of information regarding specific treatments, as well as details related to long-term outcome.

It should also be appreciated that Defense Manpower Data Center statistics are annual estimates, used with certain assumptions. In light of the need for operational security, however, the values from the Manpower Data Center may be considered the most accurate information available on deployed troop numbers. Finally, the DoDTR is not comprehensive and has been unable to capture the records of all combat casualties for any year. Several authors, however, maintain that reporting to the database has approximated 90% of war-injured for every year since 2007.<sup>6,7,9,13</sup> Therefore, the determinations presented here should not be considered exhaustive, although they likely represent some of the best available data as well as the most generalizable information, in light of our methodology and the size of the population examined.

## CONCLUSION

This epidemiological study was performed using combat casualty data derived from the DoDTR and population at-risk determinations made from the Defense Manpower Data Center. Our results confirm notions expressed in prior works that the incidence of spine trauma in modern warfare

exceeds that encountered in earlier conflicts, perhaps by a factor as high as 10. Moreover, the IRs of spine trauma as well as fractures of the spinal column surpass previously published calculations for war-related thoracic and abdominal injuries. The determinations encountered in this work may have an enhanced capacity for generalization on the basis of the strengths of our methods, the size of the population at risk, and the number of incidents of war-related spine trauma.

## ➤ Key Points

- ❑ The incidence of combat-related spinal trauma in this study was 4.4 per 10,000, whereas that of spine fractures was 4.0 per 10,000.
- ❑ The 11.1% rate of spinal injuries encountered in this investigation represents the highest published statistic for Iraq, Afghanistan, or any other American conflict.
- ❑ The determinations encountered in this work may have an enhanced capacity for generalization based on our methodology, the size of the population at risk, and the number of incidents of war-related spine trauma.

## Acknowledgments

Some authors are employees of the U.S. Federal Government and the United States Army. The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or reflecting the views of William Beaumont Army Medical Center, the Department of Defense, or the United States government. The Department of Defense Trauma Registry (DoDTR) remains the full and exclusive property of the United States Army Institute of Surgical Research. The United States Army Institute of Surgical Research is not responsible for any claims arising from works based on the original data, text, tables, or figures.

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