



Injury-Specific Correlates of Combat-Related Traumatic Brain Injury in Operation Iraqi Freedom

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Background: The prevalence of traumatic brain injury (TBI) has increased during the wars in Iraq and Afghanistan compared with 20th century military conflicts. The aim of this study was to elucidate injury-specific correlates of combat-related TBI that have yet to be clearly defined. **Participants:** Predominately Marine US service members who sustained brain injuries in Iraq between March 2004 and April 2008 identified from clinical records completed in the theater of combat operations ($n = 2074$). **Main Outcome Measures:** Severity of TBI was classified as mild, moderate, or severe. Injury-specific factors, such as injury mechanism and type, were abstracted from the clinical records and were compared with severity of TBI. **Results:** Of all TBIs observed in the sample, 89% were mild. Higher severity of TBI was associated with an increased likelihood of sustaining the injury by gunshot and a lower likelihood of helmet use. Improvised explosive devices were associated with a preponderance of mild TBIs, and frequency of injuries in locations in addition to the head was highest among those with moderate and severe TBIs. Concomitant injuries to the spine/back were associated with blast injury mechanisms. **Conclusions:** Most incidents of TBI occurring during Operation Iraqi Freedom are mild in severity and a result of blast mechanisms. Multiple injuries were common, particularly as severity of TBI increased. Further research is needed to determine effects of combat-related TBI on rehabilitative and adverse health outcomes. **Keywords:** *combat*, *military*, *traumatic brain injury*

TRAUMATIC BRAIN INJURY (TBI) has become more prevalent during the current military conflicts in Iraq and Afghanistan, with recent published reports focusing on the effects of mild TBI.[1–4] Because of the current nature of warfare, head injuries in general are more frequent than in previous conflicts.[4] One study found that among combat casualties of Operation Iraqi Freedom (OIF), more than 50% sustained an injury to the head, neck, or face compared with 15% to 25% in 20th-century military conflicts.[5] Even with this increased prevalence, however, a thorough descriptive analysis of combat-related TBI has yet to be conducted.

Tactics of warfare have changed over the years becoming more asymmetrical with a focus on blast weaponry, such as improvised explosive devices (IEDs). Explosive weaponry has been responsible for 75% of all combat casualties in Iraq and Afghanistan.[6] Characteristics of blasts, such as the concussive effects of the pressure wave as well as the subsequent fragmentation, increase the likelihood of head injuries, particularly TBI.[4] Wade et al[5] and Dougherty et al[7] found that 64% of head, neck, and face injuries were caused by IEDs compared with 41% of extremity injuries. Of all patients admitted to Walter Reed Army Medical Center from January 2003 to February 2005, 59% of those injured by a blast met criteria for TBI.[1] Advances in body armor and battlefield medical care have led to a much higher survivability rate from combat wounds, which will likely result in a greater overall burden of TBI-related adverse health sequelae.[6]

To date, no study has clearly identified the injury-specific characteristics of service members with mild, moderate, or severe combat-related TBI. In addition, the occurrence of concomitant injuries, which have been shown to affect rehabilitation outcome,[6,8] has not been thoroughly examined. A recent study of extremity injuries incurred during OIF found that 1 in 3 service members also had at least 1 injury to the head or neck.[7] The present study aimed to elucidate the demographic and injury-specific characteristics of combat-related TBI across all levels of severity among a population of US service members injured during combat operations in Iraq.

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METHODS

Study sample

The study sample consisted of 2074 US service members who sustained a TBI during combat in OIF between March 2004 and April 2008. Service members were identified from the Expeditionary Medical Encounter Database (EMED, previously named Navy-Marine Corps Combat Trauma Registry), which is maintained at Naval Health Research Center (NHRC), San Diego, California. The EMED contains clinical records completed by providers at forward-deployed medical facilities (ie, US military treatment facilities stationed in Iraq to treat OIF casualties).[9] Documented clinical encounters include those with serious injuries who are subsequently evacuated to higher levels of care, as well as those with mild injury who are returned to duty. The clinical records provide details about the injury incident, such as injury mechanism, as well as the number, type, and severity of injuries. Documentation of TBI on the service members' clinical record was necessary for inclusion in the study. This study was approved by the NHRC Institutional Review Board.

Measures

Discharge diagnoses indicated by the provider and provider notes listed in the narrative fields of the clinical records were retrospectively reviewed by credentialed nurse coders at the NHRC, and injuries were assigned *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*) codes[10] and Abbreviated Injury Scale (AIS) scores.[11] All participants in the present study had TBI, which was defined according to criteria established by the Centers for Disease Control and Prevention as indicated by any 1 of the following *ICD-9-CM* codes: 800.0-801.9, 803.0-804.9, or 850.0-854.1.[12] The AIS was used to describe the severity of these injuries and the injuries were scored according to the following scale: 0, *no injury*; 1, *minor*; 2, *moderate*; 3, *serious*; 4, *severe*; 5, *critical*; and 6, *fatal injury*. As per previous literature, each participant was categorized by the severity of their highest (or maximum) AIS Head score as mild (AIS score = 1–2), moderate (AIS score = 3), or severe (AIS score = 4–6).[13] Because of the austere environment in which these combat injuries are sustained, other measures of brain injury severity, such as Glasgow Coma Scale score, were often not recorded prior to the administration of life-preserving treatments. As such, the AIS is currently the best retrospective measure of TBI severity for this sample.

The Injury Severity Score (ISS) was calculated using the AIS scores. The ISS represents the overall injury severity of each patient and is scored on a range of 0 to 75 points.[14,15] Injuries resulting in an AIS score or ISS of 0 were not included in this analysis since they indicated no injury. The ISS was categorized as per previous literature into mild (ISS = 1–3), moderate (ISS = 4–8), serious (ISS = 9–15), and severe (ISS = 16–75).[16]

Other injury locations were defined by *ICD-9-CM* codes in the Barell injury diagnosis matrix as "other head, neck, and face (HNF)," "upper extremity," "lower extremity," "torso," and "spine/back."[17] The variable "any non-HNF injury" was created to identify participants with any other injury outside the region of the head, neck, or face. Upper extremity and lower extremity injury variables were combined into "any extremity injury" and "both upper and lower extremity injury." A variable was also created to account for the number of different non-HNF injury locations per patient (ie, ranging from 0 for participants with only HNF injuries to 4 for participants with additional spine/back, torso, upper extremity, and lower extremity injuries).

Information was abstracted from the clinical record regarding whether a helmet was worn at the time of the injury. Mechanism of injury was categorized into "IED," "land mine," "mortar," "rocket," "grenade," "blast (not otherwise specified)," "gunshot wound," and "other." "Gunshot wound" and "other" were further categorized into "nonblast" and compared with all other mechanisms, classified as "blast."

The demographic variables age, military rank, branch of service, gender, and occupational specialty were also included in the analysis. Military rank was categorized as junior enlisted (E1–E3), noncommissioned officers (E4–E5), senior enlisted (E6–E9), officers/warrant officers, and unknown. Branch of service was categorized into Marines, Army, and other/unknown. *Occupation* was defined as infantry or noninfantry, based on indication of an infantry-related job specialty (ie, general infantry, rifleman, mortarman, missileman, or machine gunner) via military occupational data.

Data analysis

All statistical analyses were performed using SAS software, Version 9.1 (SAS Institute, Inc, Cary, North Carolina) and SPSS software, Version 17.0 (SPSS, Inc., Chicago, Illinois). Demographic information was stratified and compared on the basis of TBI severity (mild, moderate, or severe). Differences across groups by TBI severity status were tested using chi-square and Fisher exact tests for categorical variables and Wilcoxon nonparametric testing for age (due to nonnormal distribution). Comparisons were similarly conducted for injury-specific variables. The distribution of concomitant injuries was compared between blast and nonblast TBIs,

TABLE 1 *Descriptive statistics, TBI, Operation Iraqi Freedom, March 2004–April 2008*

Characteristic	Total TBI ($N = 2074$)		Mild TBI ($N = 1852$)		Moderate TBI ($N = 90$)		Severe TBI ($N = 132$)		χ^2	*P*
Age,[a] median (range), y	22.0	(18–57)	22.0	(18–52)	22.0	(18–57)	22.0	(19–49)	0.33	.849
Rank, *n* (%)									8.81	.359
E1–E3	1010	(48.7)	914	(49.4)	33	(36.7)	63	(47.7)		
E4–E5	824	(39.7)	727	(39.3)	43	(47.8)	54	(40.9)		
E6–E9	163	(7.9)	146	(7.9)	7	(7.8)	10	(7.6)		
WO/officer	65	(3.1)	55	(3.0)	6	(6.7)	4	(3.0)		
Unknown	12	(0.6)	10	(0.5)	1	(1.1)	1	(0.8)		
Service, *n* (%)									13.27	.010[b]
Army	282	(13.6)	238	(12.9)	22	(24.4)	22	(16.7)		
Marines	1670	(80.5)	1509	(81.5)	62	(68.9)	99	(75.0)		
Other/unknown	122	(5.9)	105	(5.7)	6	(6.7)	11	(8.3)		
Male, *n* (%)	2063	(99.5)	1842	(99.5)	90	(100.0)	131	(91.2)	0.61	.736
Infantry, *n* (%)[c]	1113	(58.3)	995	(58.3)	50	(59.5)	68	(57.6)	0.08	.963

Abbreviations: TBI, traumatic brain injury; WO, warrant officer.
[a]Kruskal-Wallis test.
[b]Statistically significant at the .05 level.
[c]Missing occupational data: $n = 144$, 6, and 14 for mild TBI, moderate TBI, and severe TBI, respectively.

using chi-square tests for significance. Injury-specific information was further compared using chi-square testing across groups, stratified by helmet use at point of injury. An α level of $P < .05$ was used to determine significance.

RESULTS

The total sample consisted of 2074 service members with TBI who were injured in OIF combat between March 2004 and April 2008. With regard to severity, 89.3% of service members sustained mild TBI, 4.3% moderate, and 6.4% severe. Table 1 shows a breakdown of demographic characteristics for the study sample, stratified by TBI severity status. Among the total sample, the median age was 22 years, the majority of the participants were junior enlisted and noncommissioned officers (E1–E5), more than 80% were Marines, nearly all were men, and more than half had infantry-related occupations. Of the demographic variables, only military service branch differed across TBI severity groups ($\chi^2 = 13.27$, $P = .01$), with a higher percentage of Army personnel in the moderate and severe TBI groups. Among the 2074 participants, there were a total of 2623 *ICD-9-CM* codes indicating TBI. The distribution of these codes by TBI severity, as indicated by the AIS, is listed in Table 2. Nearly all injuries categorized as mild TBI were intracranial injuries without skull fracture (99.6%).

Injury-specific characteristics stratified by TBI severity are shown in Table 3. Improvised explosive devices were responsible for the majority of TBIs overall, though the percentage was highest among service members with mild TBI. Service members with moderate and severe

TABLE 2 *Description of the total number of TBI diagnoses (N = 2623) among all TBI participants*[a]

ICD-9 grouping	Mild TBI ($N = 1880$)		Moderate TBI ($N = 199$)		Severe TBI ($N = 544$)	
Intracranial injury without skull fracture (*ICD-9 850-854*), *n* (%)	1876	(99.6)	115	(58.8)	378	(69.5)
Skull fracture with intracranial injury (*ICD-9 800-801, 803-804* except .0 and .5), *n* (%)	4	(0.2)	68	(34.2)	162	(29.8)
Skull fracture without intracranial injury (*ICD-9 800-801, 803-804* with .0 or .5), *n* (%)	4	(0.2)	16	(8.0)	4	(0.7)

Abbreviations: *ICD-9*, *International Classification of Diseases, Ninth Revision*; TBI, traumatic brain injury.
[a]Participants can have more than 1 TBI diagnosis.

TABLE 3 *Injury-related characteristics, TBI, Operation Iraqi Freedom, March 2004–April 2008*

Characteristic	Total TBI ($N = 2074$)		Mild TBI ($N = 1852$)		Moderate TBI ($N = 90$)		Severe TBI ($N = 132$)		χ^2	P
Injury Severity Score,[a] n (%)										
1–3	1124	(54.2)	1124	(60.7)	0	(0.0)	0	(0.0)		
4–8	598	(28.8)	598	(32.3)	0	(0.0)	0	(0.0)		
9–15	132	(6.4)	93	(5.0)	39	(43.3)	0	(0.0)		
16–75	220	(10.6)	37	(2.0)	51	(56.7)	132	(100.0)		
Injury mechanism, n (%)									358.70	<.001[b]
Improvised explosive device	1650	(79.6)	1521	(82.1)	59	(65.6)	70	(53.3)		
Land mine[c]	79	(3.8)	77	(4.2)	2	(2.2)	0	(0.0)		
Mortar	60	(2.9)	48	(2.6)	4	(4.4)	8	(6.1)		
Rocket	68	(3.3)	64	(3.5)	1	(1.1)	3	(2.3)		
Grenade	18	(0.9)	14	(0.8)	3	(3.3)	1	(0.8)		
Blast, not otherwise specified	112	(5.4)	98	(5.3)	7	(7.8)	7	(5.3)		
Gunshot wound	77	(3.7)	23	(1.2)	12	(13.3)	42	(31.8)		
Other	10	(0.5)	7	(0.4)	2	(2.2)	1	(0.8)		
Non-HNF injuries, n (%)										
Any non-HNF injury	835	(40.3)	691	(37.3)	69	(76.7)	75	(56.8)	71.34	<.001[b]
Any extremity injury	633	(30.5)	503	(27.2)	62	(68.9)	68	(51.5)	99.78	<.001[b]
Upper extremity	440	(21.2)	327	(17.7)	53	(58.9)	60	(45.5)	136.83	<.001[b]
Lower extremity	422	(20.3)	328	(17.7)	46	(51.1)	48	(36.4)	81.39	<.001[b]
Both upper and lower extremities	229	(11.0)	152	(8.2)	37	(41.1)	40	(30.3)	147.85	<.001[b]
Spine/back	239	(11.5)	216	(11.7)	14	(15.6)	9	(6.8)	4.34	.114
Torso	242	(11.7)	166	(9.0)	38	(42.2)	38	(28.8)	132.20	<.001[b]
Non-HNF injury locations, n (%)									190.28	<.001[b]
0	1239	(59.7)	1161	(62.7)	21	(23.3)	57	(43.2)		
1	490	(23.6)	448	(24.2)	19	(21.1)	23	(17.4)		
2	208	(10.0)	158	(8.5)	23	(25.6)	27	(20.5)		
3	111	(5.4)	67	(3.6)	22	(24.4)	22	(16.7)		
4	26	(1.3)	18	(1.0)	5	(5.6)	3	(2.3)		
Other HNF injuries, n (%)	1245	(60.0)	1085	(58.6)	81	(90.0)	79	(59.8)	35.30	<.001[b]

Abbreviations: HNF, head, neck, and face; TBI, traumatic brain injury.
[a]Chi-square analysis not performed because of cell counts of zero.
[b]Statistically significant at the .05 level.
[c]Excluded from chi-square analysis because of cell count of zero.

TBI sustained a higher proportion of injuries due to gunshot wounds. Presence of other HNF injuries and non-HNF injuries differed significantly by TBI severity ($\chi^2 = 35.30$, $P < .001$; and $\chi^2 = 71.34$, $P < .001$, respectively). Those with moderate TBIs had the highest proportion of other HNF injuries and non-HNF injuries and more than 1 non-HNF location. Among the total sample, the most common non-HNF injury location involved an upper or lower extremity (21.2% and 20.3%, respectively). Service members with moderate and severe TBI had a greater frequency of all non-HNF injury locations, with the exception of spine/back, than those with mild TBI. Overall 11.0% of service members with TBI also had injuries to both upper and lower extremities, with higher percentages among those with moderate (41.1%) and severe (30.3%) TBIs.

A comparison of service members with blast and nonblast TBIs is shown in Table 4. The majority of TBIs (95.8%) were caused by a blast mechanism. Blast mechanism produced a greater percentage of other HNF ($\chi^2 = 6.30$, $P = .012$) and spine/back injuries ($\chi^2 = 7.58$, $P = .006$). Blast and nonblast TBIs did not differ on any other non-HNF injury variables. Table 5 describes injury-specific characteristics by helmet use at the point of injury. For those personnel with documentation on helmet use (or no use), more than 95% were wearing a helmet at the point of injury. Those wearing a helmet at the point of injury were more likely to have sustained less severe TBIs ($\chi^2 = 33.82$, $P < .001$) and assigned lower ISSs ($\chi^2 = 17.53$, $P < .001$). A smaller percentage of those without a helmet were injured as the result of IEDs ($\chi^2 = 134.72$, $P < .001$).

TABLE 4 *Distribution of concomitant injuries by blast, nonblast mechanism, traumatic brain injury, Operation Iraqi Freedom, March 2004–April 2008*

Injury type	Blast ($N = 1987$)		Nonblast ($N = 87$)		χ^2	P
Other HNF injuries, *n* (%)	1204	(60.6)	41	(47.1)	6.30	.012[a]
Non-HNF injuries, *n* (%)						
Any non-HNF injury	807	(40.6)	28	(32.2)	2.46	.117
Any extremity injury	611	(30.7)	22	(25.3)	1.17	.279
Upper extremity	423	(21.3)	17	(19.5)	0.15	.696
Lower extremity	407	(20.5)	15	(17.2)	0.54	.462
Both upper and lower extremities	219	(11.0)	10	(11.5)	0.02	.890
Spine/back	237	(11.9)	2	(2.3)	7.58	.006[a]
Torso	231	(11.6)	11	(12.6)	0.77	.772
Number of non-HNF injury locations, *n* (%)					2.62	.454
0	1180	(59.4)	59	(67.8)		
1	475	(23.9)	15	(17.2)		
2	199	(10.0)	9	(10.3)		
3	107	(5.4)	4	(4.6)		
4[b]	26	(1.3)	0	(0.0)		

Abbreviation: HNF, head, neck, and face.
[a]Statistically significant at the .05 level.
[b]Excluded from chi-square analysis because of cell count of zero.

DISCUSSION

The present study examined the largest sample, to date, of US service members who sustained TBI during combat operations in Iraq. More than 95% of service members in the study were injured by blast mechanisms, and approximately 90% sustained a mild brain injury. These findings are similar to other studies from varying periods of OIF.[6,18,19] In contrast, a study that examined patients admitted to Walter Reed Army Medical Center

TABLE 5 *Distribution of injury factors by helmet use at the time of injury, TBI, Operation Iraqi Freedom, March 2004–April 2008*

Factor	Helmet ($n = 1592$)		No helmet ($n = 83$)		χ^2	P
Injury Severity Score, *n* (%)					17.53	.001[a]
1–3	919	(57.7)	33	(39.8)		
4–8	464	(29.1)	29	(34.9)		
9–15	104	(6.5)	7	(8.4)		
16–75	105	(6.6)	14	(16.9)		
TBI severity, *n* (%)					33.82	<.001[a]
Mild	1484	(93.2)	63	(75.9)		
Moderate	53	(3.3)	9	(10.8)		
Severe	55	(3.5)	11	(13.3)		
Other HNF injuries, *n* (%)	968	(60.8)	48	(57.8)	0.29	.589
Injury mechanism, *n* (%)					134.72	<.001[a]
Improvised explosive device	1305	(82.0)	33	(39.8)		
Land mine	68	(4.3)	2	(2.4)		
Mortar	32	(2.0)	13	(15.7)		
Rocket	48	(3.0)	10	(12.0)		
Grenade	13	(0.8)	4	(4.8)		
Blast, not otherwise specified	79	(5.0)	12	(14.5)		
Gunshot wound	41	(2.6)	9	(10.8)		
Other[b]	6	(0.4)	0	(0.0)		

Abbreviations: HNF, head, neck, and face; TBI, traumatic brain injury.
[a]Statistically significant at the .05 level.
[b]Excluded from chi-square analysis because of cell count of zero.

in the United States found that only 44% of patients in the sample sustained mild TBI.[1] The referenced study likely included a preponderance of individuals with severe injuries, whereas the present study assessed service members who received medical care at forward-deployed medical facilities in Iraq, which included those who were returned to duty with minor injury.

A primary finding of the present study was the significant number of concomitant non-HNF injuries, particularly among those with moderate and severe TBIs. To our knowledge, these results have not been previously identified in the literature and suggest that there may be an injury-specific profile for combat-related TBI that differs by TBI severity. For example, more than 30% of service members with severe TBI and 40% of those with moderate TBI sustained concomitant injuries to both upper and lower extremities. Another notable finding among the non-HNF injuries was the higher proportion of spine/back injuries among those with blast-related TBI. Some researchers suggest that the presence of other injuries may adversely affect the rehabilitation process for TBI, thus leading to a poorer outcome.[8,20,21] The contribution of concomitant injuries to longer-term outcome of combat-related TBI warrants further study.

The present study was also one of the first to examine the relationship between helmet use and severity of combat-related TBI. As expected, those who reported not wearing a helmet at the point of injury sustained more severe TBIs and more severe injuries overall. In addition, helmet use was associated with injury mechanism; IEDs were responsible for less than half (40%) of the attacks on those not wearing a helmet compared with 82% of the attacks on those wearing a helmet. One possible explanation for this difference in helmet use by mechanism of injury is that IED attacks tend to occur when individuals are in vehicles on convoys, where helmet use is required. In contrast, other modes of attack, including sniper fire, mortars, and rockets, can occur while individuals are in situations where attacks are unexpected, such as in berthing areas or on base where units may ease restrictions on helmet use.

Some notable strengths of the study include that this analysis was the first to thoroughly examine injury-specific information from the point of injury and across all severities of combat-related TBI. Specifically, this study included service members with mild TBIs who were returned to duty. The returned to duty population from forward-deployed medical facilities is unique only to the EMED and has added importance because many service members with mild TBIs can go unrecognized and untreated after initial presentation. Another strength of the present study was that brain injury was diagnosed by medical providers immediately following the injury; this is in contrast to 2 recent studies that relied on self-report information, which is subject to recall bias.[22,23]

The present study also had limitations that warrant mention. As indicated in the description of the methodology, due to the austere environment, some details may have been lacking in the clinical records (eg, Glasgow Coma Scale score, use of a helmet). The coding of the injuries could be only as comprehensive as the information available in the records. The missing data in the helmet use analysis led to a small sample size in the "no helmet" group that may have influenced the results. Finally, because the study population was identified from Navy-Marine Corps medical facilities, the study sample does not include all TBIs occurring in the theater of combat operations; those treated at Army facilities were not included. This sample, however, represents the largest number of service members with clinically diagnosed TBIs ever studied among deployed OIF personnel.

In conclusion, the present study characterized service members with mild, moderate, and severe TBIs and was consistent with previous literature in finding that a large majority of combat-related TBIs are mild in severity and are caused by blast-related mechanisms. The identification of a significant number of concomitant other HNF and non-HNF injuries among those with TBI may indicate the need for intervention during the rehabilitation phase among this injured subgroup. The helmet use findings reaffirm the need for and value of personal protective equipment in a combat theater. Overall, this study takes an important step in further defining combat-related TBIs during OIF and identifies potential areas of future research to include the effect of concomitant injuries on long-term rehabilitation outcome of TBI. Sequelae of combat-related TBI will likely continue long after OIF operations have ceased and, as such, it is essential to further elucidate injury profiles and patterns related to TBI in the current wartime environment.

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14. ABSTRACT (maximum 200 words)

Background: Traumatic brain injury (TBI) has become more prevalent during the wars in Iraq and Afghanistan. The aim of this study was to elucidate injury-specific correlates of combat-related TBI that have yet to be clearly defined.

Patients: US service members injured in Iraq between March 2004 and April 2008 were identified from clinical records completed in the theater of combat operations (*n* = 2074).

Main Outcome Measures: Severity of TBI was classified as mild, moderate, or severe. Injury-specific factors, such as injury mechanism and type, were abstracted from the clinical records and were compared by severity of TBI.

Results: Of all TBIs in the sample, 90% were mild. Higher severity of TBI was associated with a greater proportion of gunshot wounds and lower frequency of helmet use. Improvised explosive devices were responsible for a preponderance of mild TBIs, and frequency of other injury locations was highest among those with moderate TBI. Concomitant injuries to the spine/back were associated with blast injury mechanisms.

Conclusions: Combat veterans with TBI often sustain multiple injuries, though profiles differ by severity of TBI. Further research is needed to determine effects of combat-related TBI on rehabilitative and adverse health outcomes.

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traumatic brain injury, combat, military

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