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Injuries sustained in noncombat motor vehicle accidents during Operation Iraqi Freedom[☆]

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ABSTRACT

Objective: To examine injuries sustained in noncombat motor vehicle accidents (MVs) during Operation Iraqi Freedom by injury type, site, and severity.

Methods: Three hundred and forty-eight military personnel injured in noncombat MVAs from March 2004–June 2007 were identified from clinical records completed near the point of injury.

Results: On average, personnel suffered two injuries per accident. The most frequent MVA mechanism was non-collision due to loss of control (30%). Overall, 16% were injured in a collision accident and 19% in a rollover accident. Rollovers were associated with more severe injuries. A greater proportion of drivers sustained head/neck/face injuries, whereas gunners and pedestrians had higher percents of extremity injuries.

Conclusions: This analysis provides a thorough overview of injuries incurred in nonbattle MVAs in the combat environment. Future research should combine injury data with accident reports to elucidate areas for improvements in vehicle safety.

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Introduction

In recent military conflicts, nonbattle injuries have accounted for a significant proportion of overall morbidity and mortality.^{1–4} Motor vehicle accidents (MVAs), a major source of nonbattle injury, were the leading cause of nonbattle admissions during Operation Desert Storm (19% of all admissions).⁵ More recently, nonbattle MVAs accounted for 12–16% of all nonbattle injury air evacuations during Operations Enduring Freedom (OEF) and Iraqi Freedom (OIF).⁴ Even with this prevalence, the specific nature of injuries resulting from noncombat MVAs has not been thoroughly described.

The operational environment presents a variety of driving risks for military personnel. Oftentimes, military vehicle drivers are young adults who do not have many years of driving experience.⁶ Amongst civilian populations, young adults in general have higher rates of MVAs.⁷ In addition, the physical environments in Iraq and Afghanistan present challenges for safe driving, including poorly maintained roads and road signs, and unsafe driving practises by local civilians.⁸ Further, body armour required in the combat

environment may restrict motion, which may limit a driver's reactionary ability to hazards. Extra armour used to protect vehicles has also been implicated as a cause of vehicle rollovers.⁹ During the period of 2004–2005, rollovers were responsible for 66% of MVA fatalities in OIF.¹⁰

A recent review article by Krahl et al. highlighted the need for more focused studies of military MVAs, identifying an overall “paucity” of published literature on the subject.⁶ Cohen et al. studied OIF casualties referred for pain management and found that 12.3% of these individuals sustained injuries in MVAs.^{6,11} Another study that focused specifically on drowning fatalities found that 52 of 71 drowning deaths in OIF and OEF were associated with MVAs.^{6,12} A study by Schneiderman and colleagues identified more than half (18 of 28) of respondents who reported MVA as their sole injury during OIF also screened positive for mild traumatic brain injury.¹³ To date, a British study has provided the most injury-specific information regarding MVAs during OIF.⁸ In this study, Ward and Okpala examined 47 admissions resulting from MVAs at a British military medical facility near Basrah, Iraq. The analysis revealed that amongst injured personnel, 32% experienced a vehicle rollover, 28% were ejected from the vehicle, and 16% sustained an extremity fracture.⁸ The small sample size, however, precluded statistical testing, and specifics regarding injury severity were not presented.

Although MVAs are a recognised hazard amongst deployed military personnel, the literature describing these incidents is scarce. A thorough description of the nature and severity of injuries

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sustained in these incidents is warranted. The present study aimed to provide a descriptive, epidemiologic analysis of nonbattle MVAs during OIF to include injury type, site, and severity.

Methods

Sample

The study sample consisted of personnel who sustained injuries resulting from noncombat MVAs in OIF between March 2004 and June 2007 ($n = 348$). Patients were identified from the Expeditionary Medical Encounter Database (EMED), formerly the Navy-Marine Corps Combat Trauma Registry. The EMED is a deployment health database maintained by Naval Health Research Center (NHRC), in San Diego, California, and contains clinical records of injury and illness encounters of deployed US service members.¹⁴ The EMED includes data from all levels of care, following a patient from point of injury through rehabilitative outcomes, which allows for inclusion of all levels of injury severity. Clinical records are completed at or near the point of injury and copies are provided to staff at NHRC. Professional clinical coders at NHRC review the clinical record, including incident details and provider notes, and assign International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) codes, injury severities, and external cause of injury codes (E code).^{15–17} The primary inclusion criterion for the study was indication of an MVA E code (810–825). This study was approved by the NHRC Institutional Review Board.

Measures

Demographics

Demographic information, including age, sex, military rank, and branch of service, was identified from the EMED clinical record. Military rank was categorised as junior enlisted (E1–E3), non-commissioned officers (E4–E5), senior enlisted (E6–E9), and officers/warrant officers. Branch of service was categorised into Army, Marine Corps, and Navy. Missing demographic data was populated by information from the Defense Manpower Data Center, which maintains administrative and demographic data for all military personnel.

Incident-related information

Data regarding the MVA was identified from the EMED clinical record. Vehicle position group was identified for 51% of personnel ($n = 179$) and was categorised into driver, passenger, pedestrian, and gunner (i.e., the individual who operates the weapon on the top of the vehicle). Cause of MVA was identified from E code. Specific accident types were identified from provider notes and E codes, and were classified into rollover or non-rollover, and collision or non-collision.

Injury-related information

Injury severity was coded using the Abbreviated Injury Scale (AIS) and Injury Severity Score (ISS).^{16,17} The AIS is coded on a scale of 1 (minor injury) to 6 (unsurvivable) and is identified for nine body regions.¹⁶ The ISS is a composite measure of overall injury severity that is derived from the AIS and ranges from 0 to 75.¹⁷ Injuries resulting in an AIS or overall ISS of 0 were not included in this analysis since they indicated no injury. Injury type and site were identified via ICD-9-CM coding, utilising the Barell matrix.¹⁸ Injury type was classified as fracture, dislocation, sprains/strains, internal, contusion/superficial, open wounds, amputation, blood vessel, crush, burn, and nerve. Injury site was indicated as head/neck/face, extremities, torso, and spine/back. Disposition was identified as returned to duty, light duty, evacuated, and deceased.

Data analysis

Demographic information was presented for the sample of personnel involved in noncombat MVAs, as was a breakdown of MVA mechanism as indicated by E code. Injury types, sites, severity, and resulting disposition were described amongst the personnel by rollover/non-rollover, collision/non-collision, and vehicle position group. Because personnel could sustain multiple injuries per accident a separate analysis was conducted to describe all injuries suffered during the study period. All injury sites were examined for each severity group categorised as mild (AIS = 1), moderate (AIS = 2), and serious (AIS \geq 3). All fractures were analysed by body region, and mean AIS was compared. Chi-square and Fisher's exact tests were used to assess significance of categorical variables and the Mann–Whitney *U*-test was used for continuous and ordinal variables. All analyses were conducted using SAS software, version 9.2 (Cary, NC).

Results

Demographic statistics of the total sample are presented in Table 1. There were 348 service members injured in noncombat MVAs during the study period accounting for 8.3% of all noncombat events in the EMED. The median age was 22.4 years (range: 18.6–56.2). The majority of personnel were male, Marines, and junior enlisted. Table 2 provides a breakdown of MVA mechanism as indicated by E code. Approximately 30% of personnel were injured as a result of a non-collision due to loss of control. Indication of collision was present for 16% ($n = 55$) of personnel and rollover was implicated for 19% ($n = 66$). Amongst those involved in rollover accidents, 89% ($n = 59$) were injured as a result of a non-collision due to loss of control.

Injury-specific information regarding the 348 individuals involved in noncombat MVAs is provided in Table 3. Multiple injuries per accident were common and individuals could be counted multiple times in the type and/or site of injury categories, thus injury-specific results in Tables 3 and 4 are not mutually exclusive. Individuals who died were excluded from ISS analysis because autopsy information was not available for coding. The median ISS was 1 (range: 1–33). Overall, 48% of personnel sustained a contusion/superficial injury and 68% sustained an extremity injury. The majority of all personnel were either immediately returned to duty (30%) or placed on light duty (34%). Although minor injuries were predominant in both rollovers and non-rollovers, vehicle rollovers were associated with a significantly higher ISS than non-rollovers ($p < 0.001$) and a higher percent of personnel who sustained fracture injuries (23% vs. 12%, $p = 0.025$). Also when compared with non-rollovers, rollovers produced a greater proportion of personnel who

Table 1

Demographic information for military personnel injured in noncombat motor vehicle accidents, Operation Iraqi Freedom, March 2004–June 2007 ($n = 348$).

Age, years, median (range)	22.4 (18.6–56.2)
Sex, no. (%)	
Male	310 (89.1)
Female	38 (10.9)
Service, no. (%)	
Army	54 (15.5)
Marine Corps	246 (70.7)
Navy	45 (12.9)
Unknown	3 (0.9)
Rank, no. (%)	
Junior enlisted	145 (41.7)
Noncommissioned officer	110 (31.6)
Senior enlisted	68 (19.5)
Officer/warrant officer	6 (1.7)
Unknown	19 (5.5)

Table 2

Distribution of external cause of injury codes amongst personnel injured in noncombat motor vehicle accidents.

	N	%
812, 813: Traffic MVA collision w/ other vehicle	14	4.0
814: Traffic MVA collision w/ pedestrian	9	2.6
815: Traffic MVA collision w/ object on highway	13	3.7
816: Traffic MVA non-collision due to loss of control	104	29.9
817: Traffic MVA non-collision while boarding	22	6.3
818: Traffic MVA non-collision, other	65	18.7
819: Traffic MVA unspecified	37	10.6
821: Non-traffic off-road MVA, includes collision	12	3.4
822: Non-traffic MVA collision w/ other moving object	3	0.9
823: Non-traffic MVA collision w/ stationary object	4	1.1
824: Non-traffic MVA while boarding	33	9.5
825: Non-traffic MVA unspecified	32	9.2

sustained spine/back (38% vs. 18%, $p < 0.001$) or torso (27% vs. 10%, $p < 0.001$) injuries and had a higher percentage of medical evacuations (39% vs. 26%). A greater proportion of personnel involved in collision accidents sustained a head/neck/face injury compared to those involved in non-collision accidents (55% vs. 36%, $p = 0.008$).

Table 4 examines injury-specific information by vehicle position group for the 179 individuals in which a vehicle position group was recorded. Contusion/superficial injuries were common amongst all vehicle position groups ranging from 50% of all passengers to 73% of all pedestrians. The proportion of persons who sustained open wounds differed significantly across groups ($p = 0.005$), with the highest percent amongst drivers (38%) and the lowest amongst pedestrians (7%). The proportion of persons who suffered an extremity injury differed significantly across position groups ($p = 0.020$), with gunners and pedestrians having the highest percents at 90% and 87%, respectively. Significant differences were also found amongst head/neck/face injuries ($p = 0.008$), with drivers having the highest percent at 58%. Injury severity did not differ significantly across vehicle position groups.

Most personnel involved in noncombat MVAs sustained more than just one injury. The 348 injured personnel sustained a total of 797 separate injuries (data not shown), an average of 2.3 injuries per service member. Overall, 80% ($n = 638$) of the injuries were mild, 15% ($n = 123$) moderate, and 5% ($n = 36$) serious. Fig. 1

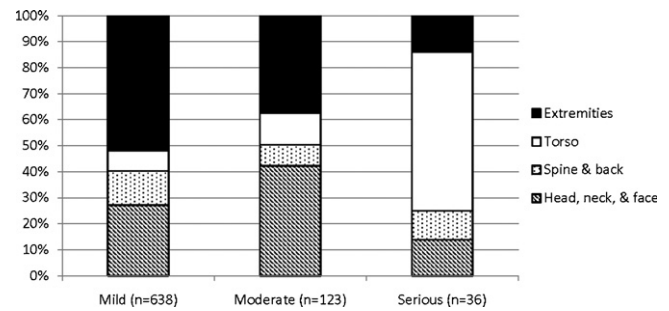


Fig. 1. Breakdown of injury site by severity amongst all injuries sustained in noncombat motor vehicle accidents, Operation Iraqi Freedom, March 2004–June 2007 ($n = 797$).

displays the breakdown of injury site stratified by severity for all 797 injuries incurred. Though torso injuries accounted for the smallest percentage of all mild injuries (8%, $n = 50$), they accounted for the largest proportion of all serious injuries (61%, $n = 22$). Extremities were the predominant injury site amongst all mild injuries (52%, $n = 331$), as were head/neck/face for all moderate injuries (42%, $n = 52$). Fig. 2 demonstrates the distribution of all fractures by site of injury, which accounted for 11% ($n = 87$) of all injuries. The most frequent fracture site was the extremities (53%, $n = 46$) and the most severe fractures were to the spine/back (mean AIS = 2.4).

Discussion

Though much research has focused on combat-related MVAs during OIF and OEF, little attention has been given to noncombat MVAs, which continue to be a significant source of morbidity amongst US military personnel.⁴ The present study conducted a thorough review of noncombat motor vehicle related accidents and subsequent injuries across severity and identified different injury patterns based on MVA mechanism and vehicle position group. The results of this descriptive analysis provide a foundation for future research, which should focus on specific accident-related information that can be used to improve vehicle safety.

Table 3

Injury-specific details by type of motor vehicle accident.

	Total ($n = 348$)	Rollover			Collision		
		Yes ($n = 66$)	No ($n = 282$)	<i>P</i>	Yes ($n = 55$)	No ($n = 293$)	<i>P</i>
ISS, median (range) ^a	1 (1–33)	2 (1–29)	1 (1–33)	<0.001	2 (1–33)	1 (1–29)	0.088
Type of injury, no. (%) ^{b,c}							
Fracture	49 (14.1)	15 (22.7)	34 (12.1)	0.025	11 (20.0)	38 (13.0)	0.169
Sprains/strains	132 (37.9)	31 (47.0)	101 (35.8)	0.093	15 (27.3)	117 (39.9)	0.076
Internal	106 (30.5)	22 (33.3)	84 (29.8)	0.573	22 (40.0)	84 (28.7)	0.094
Open wounds	79 (22.3)	17 (25.8)	62 (22.0)	0.510	13 (23.6)	66 (22.5)	0.857
Contusion/superficial	167 (48.0)	38 (57.6)	129 (45.7)	0.083	26 (47.3)	141 (48.1)	0.908
Site of injury, no. (%) ^b							
Head/neck/face	134 (38.5)	23 (34.9)	11 (39.4)	0.498	30 (54.6)	104 (35.5)	0.008
Spine/back	75 (21.6)	25 (37.9)	50 (17.7)	<0.001	9 (16.4)	66 (22.5)	0.308
Torso	47 (13.5)	18 (27.3)	29 (10.3)	<0.001	9 (16.4)	38 (13.0)	0.499
Extremities	236 (67.8)	48 (72.7)	188 (66.7)	0.343	32 (58.2)	204 (69.6)	0.096
Disposition, no. (%) ^d				<0.001			0.405
Deceased	4 (1.1)	3 (4.9)	1 (0.4)		0	4 (1.4)	
Evacuated	91 (26.1)	24 (39.3)	67 (26.3)		20 (36.4)	71 (24.2)	
Light duty	117 (33.6)	24 (39.3)	93 (36.5)		16 (29.1)	101 (34.5)	
RTD	104 (29.9)	10 (16.4)	94 (36.9)		17 (30.9)	87 (29.7)	

ISS, Injury Severity Score; RTD, returned to duty.

^a Excludes deceased.^b Not mutually exclusive.^c Selected injury type, five most common.^d Fisher's exact test used.

Table 4
Injury-specific details by vehicle position group (N=179).

	Driver (n=60)	Gunner (n=20)	Passenger (n=84)	Pedestrian (n=15)	P
ISS, median (range) ^a	2 (1–26)	2 (1–17)	1 (1–14)	2 (1–33)	0.397
Type of injury, no. (%) ^{b,c,d}					
Fracture	10 (16.7)	5 (25.0)	11 (13.1)	4 (26.7)	0.377
Sprains/strains	18 (30.0)	7 (35.0)	29 (34.5)	6 (40.0)	0.866
Internal	26 (43.3)	6 (30.0)	30 (35.7)	4 (26.7)	0.581
Open wounds	23 (38.3)	7 (35.0)	14 (16.7)	1 (6.7)	0.005
Contusion/superficial	31 (51.7)	14 (70.0)	42 (50.0)	11 (73.3)	0.182
Site of injury, no. (%) ^{b,d}					
Head/neck/face	35 (58.3)	7 (35.0)	35 (41.7)	2 (13.3)	0.008
Spine/back	9 (15.0)	6 (30.0)	24 (28.6)	2 (13.3)	0.180
Torso	6 (10.0)	6 (30.0)	12 (14.3)	4 (26.7)	0.095
Extremities	41 (68.3)	18 (90.0)	50 (59.5)	13 (86.7)	0.020

^a Excludes deceased.^b Not mutually exclusive.^c Selected injury type, five most common.^d Fisher's exact test used.

Vehicle rollover was the identified mechanism for approximately 1 in 5 personnel injured based on clinical record review. Consistent with previous reports on mortality following combat-related MVA,^{9,10} rollovers were generally more severe than non-rollovers. These previous reports suggested that extra armour placed on the vehicles could cause loss of control when driving at accelerated speeds or when quickly manoeuvring around road hazards. In the present analysis, rollovers were most frequently associated with the E code indicating loss of control. Future research should examine vehicle specifics (e.g., vehicle type, amount of armour) that may contribute to rollover frequency.

Other findings are of potential interest. Differential injury patterns were observed when examining the position of the person in, on, or around the vehicle at the time of the accident. We found that gunners and pedestrians had very high rates of extremity injury, which is not surprising considering that passengers and drivers have the added protection of the vehicle. In 2005, the military updated the seat restraints for gunners on the top of vehicles to address this concern.^{9,19} Interestingly, torso injuries accounted for a majority of all serious injuries. Upon further examination of the 22 serious torso injuries, approximately 40% were chest injuries (e.g., pneumothorax, lung contusion, flail chest). This finding, and whether it relates in any way to vehicle type, protective equipment worn, or MVA mechanism, needs to be explored in future studies. Further, the preponderance of personnel that sustained extremity and head/neck/face injuries, and the varying injury patterns by MVA mechanism and vehicle position group are consistent with civilian literature.^{20–23}

The present study has multiple strengths compared with previous studies. It is one of the first studies to focus solely on noncombat MVAs in an operational environment, and it corrects for

one of the shortfalls identified by Krahl et al. by including specific and thorough information regarding the nature and severity of injuries.⁶ In addition, the use of clinical records completed at or near the point of injury allows for reliance on provider notes instead of patient recall (or self-report). Further, the robust EMED data allowed for assessment across all injury severities, whereas the previous study amongst British forces was only able to examine those with injuries serious enough to be admitted for care.⁸ The assessment of vehicle position group, though limited due to missing data, was a unique aspect of the study and is worthy of further examination.

The present study also has limitations that warrant mention. As indicated previously, vehicle type often was not reported in the reviewed records. Thus, our analysis homogenised tactical and nontactical vehicles of all sizes and prevented any subgroup analysis amongst different vehicle types. Medical provider notes were reviewed by clinical record specialists to determine AIS. A limitation of this is the accuracy and consistency of physician notes found therein. Further, we were unable to assess ISS in deceased individuals because autopsy information was not available for coding. In addition, little information on the use of restraints was documented on the EMED clinical records. Although the use of seatbelts is mandated amongst British and US forces, the study amongst British military personnel identified a surprisingly low rate of seatbelt compliance (15%).⁸ Finally, because the study population was identified from far-forward Navy-Marine Corps military treatment facilities, the study sample is not representative of all noncombat MVAs that occurred in the theatre of combat operations (e.g., those treated at Army facilities were not included). To our knowledge, however, this is the largest sample size ever examined of US service members who sustained injuries in noncombat MVAs.

The present study describes various aspects of injuries incurred in noncombat MVAs during OIF. It provides a thorough overview of the problem, but it needs to be supplemented with other data sources in order to guide prevention efforts. Accident reports, completed for the purposes of safety documentation, may contain more information regarding specific vehicle type and restraint use, which could clarify potential areas of education and intervention. As noncombat MVAs continue to cause significant morbidity amongst deployed military forces, intervention strategies should be adapted to current vehicle types and operational environments. Improvements in vehicle safety may contribute to a reduction in one of the primary causes of nonbattle injury in combat environments, thus reducing lost work days and maximising the efficiency of operational forces.

Conflict of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this paper.

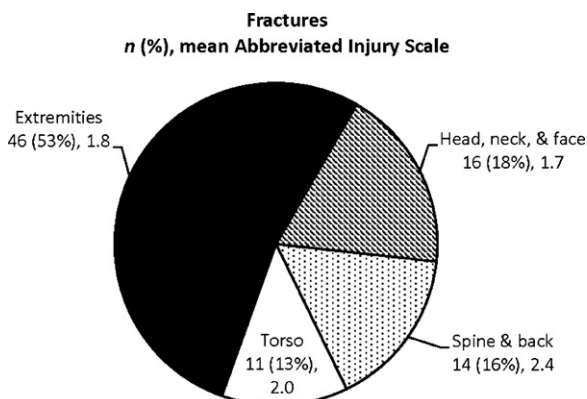


Fig. 2. All fractures sustained in noncombat motor vehicle accidents by site of injury, Operation Iraqi Freedom, March 2004–June 2007 (n = 87).

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14. ABSTRACT <p>Objective: To examine injuries sustained in noncombat motor vehicle accidents (MVAs) during Operation Iraqi Freedom by injury nature, site, and severity.</p> <p>Methods: 348 military personnel injured in noncombat MVAs were identified from clinical records completed near the point of injury.</p> <p>Results: On average, personnel suffered two injuries per incident. The most frequent mechanism of injury was non-collision due to loss of control. Overall, 16% were injured in a collision incident and 19% in a rollover incident. Rollovers were associated with more severe injuries. Drivers had a higher frequency of head/neck/face injuries, whereas gunners and pedestrians had higher rates of extremity injuries.</p> <p>Conclusions: This analysis provides a thorough overview of injuries incurred during nonbattle MVAs in the combat environment. Future research should combine injury data with accident reports to elucidate areas for improvements in vehicle safety.</p>

15. SUBJECT TERMS injury, motor vehicle accident, Operation Iraqi Freedom, military, non-combat

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