



Non-battle craniomaxillofacial injuries from U.S. military operations



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ABSTRACT

Introduction: Non-battle injuries (NBIs) can be a source of significant resource utilization for the armed forces in a deployed setting. While the incidence and severity of craniomaxillofacial (CMF) battle injuries (BIs) have reportedly increased in the ongoing U.S. military conflicts in Iraq and Afghanistan, the prevalence and the nature of NBIs are not well described.

Material and methods: The Joint Theater Trauma Registry was queried from October 2001 to February 2011, covering Operations Enduring Freedom and Iraqi Freedom, for both NBIs and BIs to the CMF region. Patient demographics, injury severity score, mechanism and type of injury were included in the query. Using ICD-9 diagnosis codes, CMF injuries were classified according to type (wounds, fractures, burns, vascular injuries, and nerve injuries). Statistical analysis was performed for comparative analysis.

Results: NBIs constituted 24.3% of all patients with CMF injuries evacuated to a regional combat support hospital (CMF BIs 75.4%). These injuries were characterized by blunt trauma, most commonly motor vehicle collisions (37%), and falls (20%). As compared to CMF BIs, CMF NBIs resulted in less mortality (1.3% vs. 3.1%, $p < 0.0001$), fewer injuries per patient (1.87 vs. 2.26, $p = 0.055$), and a decreased severity score (ISS) (8.38 vs. 12.98, $p < 0.0001$). However, a significant percentage of CMF NBIs still required evacuation out of theater (27.8% of NBIs vs. 42.2% of BIs, $p < 0.0001$), depleting the combat strength of the deployed forces.

Conclusions: CMF NBIs accounted for a substantial portion of total CMF injuries. Though characterized predominantly by blunt trauma with an overall better prognosis, its burden to the limited resources of a deployment can be significant. This descriptive study highlights the need to allocate appropriate resources for treatment of these injuries as well as strategies to reduce both its incidence and severity.

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1. Introduction

Non-battle injuries (NBIs) can be a source of significant resource utilization for deployed armed forces. The increasingly technological environment of the battlefield has raised the proportion of deaths of NBIs among all deaths of US troops from 3% during the Civil War to 16% in World War II (Garfield and Neugut, 1991). In the Vietnam War, NBIs were the leading type of casualty (Blood and Jolly, 1995). During the Persian Gulf War (Operations Desert Shield and Desert Storm), NBIs accounted for a high percentage of deaths (46%) and hospital admissions (25%) (Withers et al., 1994;

Writer et al., 2000; Eaton et al., 2011). Several studies have shown that most NBIs result from a variety of potentially preventable causes ranging from motor vehicle crashes, falls, physical training/sports, assault, and other accidents (Withers et al., 1994; Writer et al., 2000; Wade et al., 2007; Breeze et al., 2010).

We, amongst other investigators, have shown the incidence of craniomaxillofacial (CMF) battle injuries (BIs) have been increasing, with an incidence between 19 and 42% (Carey, 1987; Zouris et al., 2006; Wade et al., 2007; Lew et al., 2010; Chan et al., 2012; Zachar et al., 2013). The reason is that the CMF region is not adequately protected by contemporary armour technologies and is thus vulnerable on the battlefield. This is further enhanced by the evolving nature of modern combat where the primary mechanism of injury ranges from explosive devices (improvised explosive devices (IEDs), land-mines, rocket propelled grenades (RPGs), mortars) to ballistic trauma (Shuker, 1995; Lew et al., 2010; Chan et al., 2012).

CMF NBIs sustained in the deployed setting and the role they play in the overall increasing incidence of wartime CMF injuries are

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increased to 27.8% and 42.2% respectively as the care escalated to a level IV military hospital (Regional referral hospitals, such as Landstuhl Regional Medical Center in Germany) and then to 24.7% and 37.5% respectively at a level V military hospital (Tertiary care hospitals in the continental U.S.) ($p < 0.0001$). A difference was noted in the relative percentage of CMF NBI vs. BIs that advanced to higher levels of care as well. Among CMF NBI patients, 56.3% advanced from level III to IV and 39.1% from level IV to V. The advancing proportion was higher in the CMF BI group, being 78.2% and 63.6% from level III to IV and IV to V respectively ($p < 0.0001$) (Table 2).

Based on ICD-9 diagnosis codes, CMF injuries were classified into five broad categories; open wounds, fractures, burns, nerve, and vessel injuries. The relative prevalence order of each injury type was the same between both the NBI and BI groups, with open wounds being the most common CMF injury (NBI 48.4%, BI 63.9%), followed by fractures (NBI 29.5%, BI 24.9%), burns (NBI 6.2%, BI 8.8%), nerve damage (NBI 3.0%, BI 5.7%), and vessel injury (NBI 1.5%, BI 5.4%). The relative percentage of each injury type was found to be statistically different between both groups ($p < 0.0001$) (Table 3).

In comparing the relative percentage of CMF BI and NBI between military operations OIF and OEF, there was a statistically significant lower percentage of injuries during the more recent OEF as compared to the earlier OIF (74.6% and 77.2% respectively, $p < 0.0001$) (Table 4).

Table 2
Breakdown of patients CMF ICD-9 codes with battle vs. non-battle injuries compared to total patients injured and at different echelons of care.

	Level					
	III		IV		V	
	Number	% CMF	Number	% CMF	Number	% CMF
Total injured	26,686	25.3	13,039	37.9	11,377	34.1
Battle	17,024	29.9	9530	42.2	8637	37.5
Non-battle	9662	17.0	3322	27.8	2603	24.7

	Level					
	III		IV		V	
	Number	% Advanced	Number	% Advanced	Number	% Advanced
Total CMF injured	6740	49.45	4945	73.4	3885	57.6
Battle	5094	40.20	4020	78.2	3242	63.6
Non-battle	1643	9.25	925	56.3	643	39.1

Percent CMF values listed are relative to total, battle, and non-battle classes at each echelon of care ($p < 0.0001$). Percent advanced values depict the proportion of CMF injuries that were escalated to that of care, relative to each injury class ($p < 0.0001$). Data does not represent patients of unknown injury class which represented 0.34% of all CMF injured patients.

Table 3
Injury distribution among CMF patients with battle and non-battle injuries.

Injury type	CMF battle		CMF non-battle	
	Number	%	Number	%
Open wounds	3254	63.9	795	48.4
Fractures	1266	24.9	484	29.5
Burns	446	8.8	102	6.2
Nerves	292	5.7	49	3.0
Vessels	275	5.4	24	1.5

Percentages based on total number of patients in each injury class, Battle = 5094, Non-battle = 1643; many patients having multiple injuries. $p < 0.0001$ for all groups comparing BI vs. NBI. <1% of each injury type was of an unknown injury class, data is not represented.

Table 4
Percentages of CMF battle injury and non-battle injury per military operation.

Operation	Total	CMF BI		CMF NBI	
		Number	%	Number	%
OIF	5068	3780	74.6	1288	25.4
OEF	1669	1314	77.2	355	21.3

Data does not represent unknown class patients with CMF injuries ($n = 23$), $p = 0.0006$. Data does not represent patients of unknown injury class which represented 0.34% of all CMF injured patients.

4. Discussion

The ten years of conflict in Iraq and Afghanistan have resulted in countless deaths and even more wounded. While the majority of retrospective studies have rightly focused on battle causes, the relative attention paid to NBI is disproportionately less.

NBI probably results in a greater challenge from the standpoint of overall force readiness (Eaton et al., 2011). In this study, we have focused on NBI to the CMF region. While head and neck accounts for only 12% of the total body surface area, injury to this region results in a disproportionate amount of disability secondary to the critical senses served by the facial apparatus.

Historically, the overall rates of NBI were combined and recorded with rates of disease for specific military operations (Garfield and Neugut, 1991; Withers et al., 1994; Blood and Jolly, 1995; Writer et al., 2000). This made it difficult to draw conclusions as to the impact of NBIs on military resources, even more so to the subset of CMF NBIs. In this study, disease related admissions were not a part of study inclusion.

In this study, we found that NBIs account for one-quarter of all CMF injuries presenting to combat support hospitals. The remaining three-quarters are a result of BIs. NBIs are largely a result of blunt trauma, as opposed to BIs which are characteristically from explosive blasts. 28% of all subjects evacuated from theater due to NBI have CMF injuries, as compared to 42% of BI patients. CMF NBI patients are less critically injured with lower ISS, mortality and fewer injuries per patient. Moreover, they have a slightly lower rate of presentation and advancement to higher echelons of care for treatment of their injuries compared to BI patients.

Several differences in the demographics of the NBI group were observed. First, there were a statistically higher proportion of females with CMF NBIs. This is likely a result of the higher number of men injured in battle. Also there were proportionally fewer NBIs among U.S. marines. Again, this is consistent with the higher number of U.S. Marines involved in active combat.

Interestingly, there was a statistically significant lower percentage of CMF NBI during the more recent OEF as compared to the earlier OIF. The cause of this is not immediately evident and may require further investigation. However, we postulate that a proportion of NBI may be a result of unfamiliarity to a new environment (location and terrain, novel technologies, inexperienced troops, etc), and the later OEF have fewer of such incidents because of lessons learned from prior deployments (Table 4).

While not perhaps unexpected, one significant finding of our study is that NBIs had an overall lower mortality, fewer injuries per patient, and a better ISS when compared to the BIs. The generalization can thus be made that a NBI sustained in a deployed setting will most likely be less severe than a BI. Our evidence suggested that the reason for this difference may lie with the mechanism of injury. BIs were often caused by high energy insults predominantly from explosives and ballistics (Chan et al., 2012; Zachar et al., 2013). Explosive injuries, specifically those inflicted by IEDs, cause particularly severe injury patterns resulting in open wounds and

burns with underlying fractures (Goksel, 2005; Montgomery et al., 2005; Brennan, 2006; Salinas and Faulkner, 2010; Shuker, 2012; Zachar et al., 2013). This is in contrast to CMF NBIs, where lower energy mechanisms were found, mostly secondary to MVCs, falls and other blunt trauma. This mechanism of injury pattern more closely resembles that seen at rural civilian trauma centers (Ellis et al., 1985; Haug et al., 1990; Gassner et al., 2003; Allareddy et al., 2011; Smith et al., 2012).

Our study found the overall prevalence order of injury types to be the same within both the NBI and BI groups, with open wounds being the most common CMF injury followed by fractures, burns, nerve damage, and vessel injury. We also noted that, with the exception of CMF fractures, the percentage of each injury type was lower in the NBI group. Here again, the finding of CMF NBIs having overall fewer injuries per patient and a better ISS is supported (Table 3).

When analyzing the incidence of combat related injuries, it is important to consider whether data was limited by the echelons of care where services were rendered (Chan et al., 2012). Level I and II military treatment facilities are battalion aid stations and surgical company stations, respectively, used for triage and definitive treatment of minor injuries. Level III MTFs are combat support hospitals, and Level IV MTFs are regional referral hospitals such as Landstuhl Regional Medical Center in Germany. Finally, Level V hospitals are facilities in the continental United States where definitive care of the most serious injuries is rendered. The conclusion that NBIs tend to be less severe than BI is further supported when this data is evaluated. For instance, at level IV echelon of care, 27.8% of all NBI patients compared to 42.2% of all BI patients had CMF injuries. As one might expect, this trend is mirrored when evaluating what percentage of CMF NBI and BI were advanced from a lower to higher echelons of care. Because the CMF NBI was on average less severe in nature, definitive treatment of such injuries could more likely be rendered at lower level military hospitals.

While all the observations made in the comparisons between NBI and BI are perhaps not unexpected, the sheer numbers of NBI is what we find worthy of discussion. One out of every four CMF injured patients is a result of potentially preventable causes. It is paramount to determine whether these injuries are truly preventable and strategies implemented to prevent either its incidence or severity. In a limited review of cases presented to the military burn center, a high early rate of NBI burns were noted from a variety of preventable causes including waste burning, ammunition and gasoline handling. Feedback on NBI burn prevention was provided to the combat theater and the incidence of these injuries decreased (Kauvar et al., 2006). Many mechanisms leading to CMF NBI were potentially preventable causes and can be diminished through awareness and policy changes. Even though these injuries are less severe by all metrics than their BI counterpart (ISS, mortality, injuries/patient), more than half of them still required transport out of theater, depleting the active force and needed resources.

The military is undergoing a major systemic transformation to deal with the challenges of the 21st century modern warfare, using advances in technology and communication to improve operation efficiency. The use of smaller military units enhances the importance of each individual, meaning that reduced personal readiness may translate to a significant decrease in operational efficiency (Sanders et al., 2005). Despite advances in preventative measures, CMF NBIs are common and have a significant impact on military readiness and operational efficiency. Consequently, the adaptation of the military should include continued improvements in surveillance, prevention, and management of CMF NBIs.

5. Conclusion

The incidence and severity of CMF injuries have increased in modern combat. CMF NBIs accounted for a substantial portion of total CMF injuries. Though characterized predominantly by blunt trauma with an overall better prognosis, some of these injuries are potentially preventable and strategies to decrease both its incidence and severity are needed.

Author contribution

Andrew Q. Madson, DDS: Lead investigator, participated in all aspects of study.

David Tucker, DDS: Critical Revision.

Jay Aden, PhD: Statistical Analysis.

Robert G. Hale, DDS: Critical Revision.

Rodney K. Chan, MD, FACS: Participated in all aspects of study.

Conflict of interest

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