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Missed injuries in combat casualties: Lessons from Iraq and Afghanistan

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ABSTRACT

Introduction: Once injured in the battlefield in Iraq and Afghanistan, U.S. and NATO troops receive medical treatment through tiered echelons of care with varying resources, from austere to state-of-the-art. Similar to civilian trauma systems, the aim is to provide rapid and safe patient movement toward definitive management. A consequence of the rapid transfer of patients is the possibility of missed or delayed diagnosis of injuries. With the new injury patterns seen during these conflicts, we aimed to identify and characterize which injuries are missed and what consequences do they have on our troops' road to recovery.

Patients and Methods: A retrospective review of a PI database (established 2007) for consecutively admitted combat casualties was performed between 2007–2013. Baseline patient characteristics, injury year, admitting service, injury type, and subsequent management decisions were categorized and analyzed.

Results: There were 301 missed injuries (MI) identified in 248 patients. The annual missed injury rate was 25 per 1000 admissions. Missed injuries were associated with a penetrating mechanism (82.7% vs 58.5%, $p < 0.001$), ICU admission (58.5% vs 27.4%, $p < 0.001$), higher ISS (median 14 vs 8, $p < 0.001$), and a longer length of stay (median 3 versus 2 days, $p < 0.001$). 194 (64.5%) missed injuries led to a change in management, with 68 (22.6%) requiring a surgical procedure. 1.3% of missed injuries were life threatening, 28.2% major and 65.4% minor. The most common injuries were distal extremity fractures (23.9%), followed by spine fractures (13.3%) and traumatic tympanic membrane rupture (12.6%), There were no deaths attributed to a missed injury.

Discussion: Missed injuries during combat operations occur on a low but consistent basis. Most injuries are orthopedic in nature and typically occur in critically ill patients admitted to the ICU. It is rare that a missed injury results in a life-threatening condition.

Conclusion: As healthcare practitioners prepare for future deployments, this analysis may serve as a resource to focus on frequently missed injuries and possibly improve their detection.

Introduction

As a result of the military conflicts in Iraq and Afghanistan, there have been over fifty-two thousand injuries and over 6900 deaths among U.S. service members between 2003 and 2017 [1]. In 2004, the Joint Theater Trauma System (JTTS) was implemented to provide the best chance of survival and improved functional outcomes for every combatant [2]. This system included the development of the Joint Theater Trauma Registry (JTTR) and implementation of clinical practice guidelines [3,4]. These evidence-based guidelines, together with an improved process of information transfer have been associated with a decrease in aggregate post-injury complications by 54% [5,6].

In the JTTS, once injured in the battlefield, troops receive medical treatment through tiered echelons of care. Similar to civilian trauma systems, the aim is to provide rapid and safe patient movement toward definitive management. After initial care in limited capability military trauma centers downrange, combat casualties are admitted to a non-theater hospital in Landstuhl, Germany, at least 48 h after time of injury.

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As they progress through the system, patients may be treated by two to three different teams and up to 20 providers. At each stage, the patient has an opportunity to be re-examined by a new group of providers with the goal of identifying and, if possible, treating all injuries.

One consequence of the rapid transfer of patients to higher levels of care is the possibility of missed or delayed diagnosis of injuries. Although injury-related complications have been previously addressed in the military setting [7], missed injuries have been more difficult to capture. The aim of this study is to identify the incidence of missed injuries during combat operations and describe both the epidemiology and outcomes of missed injuries in combat casualties.

Patients and methods

Study setting

Landstuhl Regional Medical Center (LRMC) is the largest American hospital outside the United States. This hospital has 147 inpatient beds and was an American College of Surgeons Verified Trauma Center at the time of the study [8]. This study was approved by the European Regional Medical Command Research Office.

Patient population

Consecutively admitted combat casualties admitted to LRMC were identified in the JTTR between the years 2007–2013. Patients with and without missed injuries were identified. This time frame was utilized because 2007 was the first year that the registry included missed injuries as a process improvement category.

Definitions

Missed injuries were defined as newly diagnosed injuries at LRMC or at a Contiguous United States (CONUS) military treatment facility. Initial injury management pre-LRMC ('down range') typically occurred during the first 2 days after injury. New injuries were diagnosed by the primary team or by consultants. Missed injuries were classified into life threatening, major and minor, similar to Pfeifer et al. [9].

Life threatening injuries include injuries of main vessels in thorax, abdomen, hemothorax, and pneumothorax.

Major injuries include skull fractures, neurological lesions and peripheral nerve injuries, retinal detachment, pulmonary embolus, femoral, humeral, pelvic fractures and dislocations, spinal fractures other than transverse process fractures, compartment syndrome, arterial injuries, liver, spleen, and intestinal lacerations, rectal injuries, and bladder injuries.

Minor injuries include corneal abrasions, tympanic membrane perforations, testicular ruptures and scrotal punctures, simple soft tissue injuries and fractures of the hand, wrist, foot, ankle, forearm, mandible, and spinal transverse process fractures.

Changes in clinical care due to missed injuries were classified as 1) surgical intervention, or 2) non-surgical change in clinical management. A change in clinical management was defined as any intervention short of a new surgical procedure, resulting from the missed injury. For example, for a missed fracture a change in management was placement of a splint.

If there were multiple missed fractures in close proximity, they were counted as one missed injury and the highest acuity injury was identified as the region category. If there were injuries identified in separate limbs, they were counted as two missed injuries. If there was an intracranial hemorrhage and associated skull fracture, they were counted as one missed neurosurgical injury.

Some mechanism of injuries contained blunt, penetrating and/or burn components. To be able to compare groups and contrast to publish literature, three groups were created. If the injury pattern contained penetrating elements, they were assigned to the penetrating mechanism of injury. If they contained blunt but not penetrating components, they were assigned to the blunt mechanism of injury. The rest were classified according to their singular mechanism.

Data collection

Baseline patient characteristics such as age, sex, injury mechanism, injury severity score (ISS), GCS, admission year were recorded. Outcome measures such as hospital length of stay, ICU and ward length of stay, ventilator days, mortality, were collected and compared among patients with and without missed injuries. Injury type and subsequent management decisions were recorded for patients with missed injuries. Injury type was divided into ten distinct categories: orthopedic, urology, pulmonary/thorax, abdominal, vascular, maxillofacial/ophthalmology, spine fractures, neurosurgical, burn and other. Each injury category was further subdivided into regional categories, as shown in Table 3. Primary admitting services were identified and tracked for subsequent management decisions.

Statistical analysis

Patients with and without missed injuries were compared. Non-normally distributed data was analyzed using Mann-Whitney U test with significance defined as a $p < 0.05$. Categorical data was analyzed with χ^2 or Fisher's exact test. Trends in each missed injury category were studied by year for the entire patient cohort. Statistical analysis was performed with IBM SPSS statistics for Windows, Version 22.0 (IBM Corp, Armonk, NY).

Results

There were 301 missed injuries identified in 248 patients. The annual missed injury rate per patient was 25 per 1000 admissions, or 2.5%. When compared to patients admitted during the same time period without missed injuries, patients with missed injuries were a similar age, less likely to be female, more likely to be in Operation Enduring Freedom and have a penetrating mechanism (Table 1). Patients with missed injuries were also more likely admitted to the ICU and have a higher ISS (Table 2). Most missed injuries occurred in patients admitted to the trauma/general surgery service (87.4%) followed by orthopedics (10.3%).

197 (65.4%) of the missed injuries were minor, 85 (28.2%) major and 4 (1.3%) life threatening. Life threatening injuries occurred in the abdominal, vascular and pulmonary categories. Most major injuries were spine fractures (31.7%), followed by major orthopedic injuries (28.2%) and abdominal injuries (14.1%). Bowel and rectal injuries were the most common subset of abdominal injuries. The majority of the missed bowel injuries in our study were associated with improvised explosive devices (IEDs), resulting most commonly in rectal lacerations/injuries.

Most missed injuries were diagnosed at LRMC, 246 (81.7%), with a smaller fraction diagnosed at contiguous United States hospitals (CONUS), 41 (13.6%). The most commonly missed injuries were distal extremity fractures (23.9%), followed by spine fractures (13.3%), traumatic tympanic membrane rupture (12.6%), and long bone fractures (10.3%) (Table 3). Of the 301 missed injuries, 194 (64.5%) lead to a non-surgical management change, with 68 (22.6%) requiring surgical intervention (Fig. 1). Surgical necessity was highly variable by injury type (range 0–100%), with all urologic injuries requiring surgical intervention (Table 4). There were no deaths attributed to a missed injury.

Table 1
Baseline characteristics for patients with and without missed injuries between.2007–2013.

Characteristics	Patients with missed injuries (n = 248)	Patients without missed injuries (n = 10,271)	P-value
Age	25 (22, 30)	25 (22, 30)	0.615
Sex M:F (%Male)	246:2 (99.2%)	9800:471 (95.4%)	0.005
Military Operation (%)			
OEF	185 (74.6%)	5988 (58.3%)	<0.001
OIF / OND	60 (23.8%)	3320 (32.3%)	0.007
Other/unknown	3 (1.2%)	963 (9.3%)	<0.001
Injury Mechanism			
Penetrating	205 (82.7%)	6010 (58.5%)	<0.001
Blunt	39 (15.7%)	3894 (37.9%)	<0.001
Burn	2 (0.8%)	291 (2.8%)	0.055
Unknown	2 (0.8%)	76 (0.7%)	0.904

OEF: Operation Enduring Freedom, OIF: Operation Iraqi Freedom, OND: Operation New Dawn.

Table 2
Clinical course for patients with and without missed injuries between.2007–2013.

	Patients with missed injuries (n = 248)	Patients without missed injuries (n = 10,271)	P-value
Admission Unit			
ICU	145 (58.5%)	2,812 (27.4%)	<0.001
Ward	103 (41.5%)	7,343 (71.5%)	<0.001
Other	0	116 (1.1%)	0.092
Admit GCS	15 (10, 15)	15 (15, 15)	<0.001
Injury Severity Score	14 (9,22)	8 (4, 13)	<0.001
ICU ISS	22 (15.5, 27)	17 (10, 24)	<0.001
Ward ISS	9 (5, 12)	5 (4, 9)	<0.001
Military ISS (combined)	18 (9, 30)	9 (4, 17)	<0.001
Ventilator Days	2 (2, 4)	2 (2, 4)	0.942
ICU Length of Stay (days)	3 (2, 4)	3 (2, 4)	0.036
Length of Stay (days)	3 (2, 4)	2 (1, 4)	<0.001

ICU: Intensive Care Unit, ISS: Injury Severity Score.

Table 3
Missed injury categories and corresponding regional categories.

Missed injury category	Regional categories	Missed injuries (percent)
Orthopedic	Long bone fractures	31 (10.3%)
	Distal extremity fractures	72 (23.9%)
	Peripheral nerve injuries	7 (2.3%)
	Sacrum/coccyx injuries	1 (0.3%)
	Pelvic injuries	3 (1.0%)
	Extremity soft tissue injuries	9 (3.0%)
	Compartment syndrome	8 (2.7%)
	Scapula/clavicle fractures	10 (3.3%)
Urology	Bladder injuries	4 (1.3%)
	Testicular injuries	10 (3.3)
	Scrotal injuries	1 (0.3%)
Pulmonary/Thorax	Lung injuries	7 (2.3%)
	Rib/sternum fractures	11 (3.7%
Abdominal	Bowel/rectal injuries	8 (2.7%)
	Liver/spleen injuries	3 (1.0%)
	Abdominal soft tissue injuries	3 (1.0%)
Vascular	Central vascular injuries	1 (0.3%)
	Cerebrovascular injuries	3 (1.0%)
	Extremity vascular injuries	2 (0.7%)
Maxillofacial/Ophthalmology	Ear injuries	38 (12.6%)
	Facial fractures	5 (1.7%)
	Soft tissue facial injuries	2 (0.7%)
	Eye injuries	2 (0.7%)
Spine fractures	C-spine fractures	7 (2.3%)
	T-spine fractures	15 (5.0%)
	L-spine fractures	11 (3.7%)
Neurosurgery	Skull fractures	3 (1.0%)
	Intracranial hemorrhage/cerebral contusions	5 (1.7%)
Burn	Burns	4 (1.3%)
Other	Anal injuries	1 (0.3%)

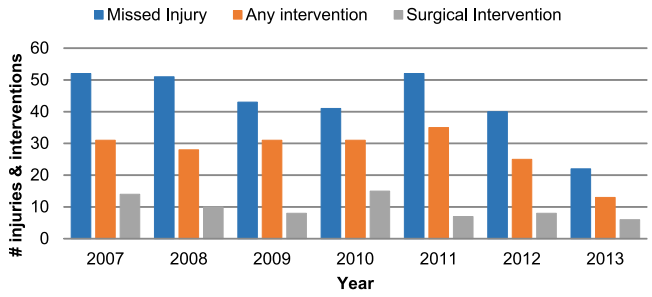

Fig. 1. Missed injury and associated management change.

Discussion

Missed injuries during combat operations occur on a consistent basis and most missed injuries in this setting lead to a change in management. Although a significant number of missed injuries ultimately require additional surgical interventions, our analysis showed a lower associated surgical intervention rate of 22.6% compared to a published civilian rate of 31.4% [10].

One of the difficulties in comparing literature on missed injuries is the inconsistency in definitions used between studies. In our study, the definition of missed injury included injuries in which there was a delay in diagnosis from the initial assessment performed by surgical teams at lower echelons of care, as well as injuries that were missed at LRMC and identified in a CONUS facility. Depending on the missed injury definition used, specialty training of providers and location of the report, missed injuries in civilian trauma systems are reported to vary widely, occurring from 1.3 to 65% of patients [11]. In two European level I trauma centers, the reported missed injury rate was 8.2%(12) and 8.1%(10), while a study of military trauma patients in a Turkish hospital reported a missed injury rate of 4.8%(13). Our missed injury rate of 2.5% is on the lower spectrum for published data.

One of the tools used in an effort to minimize missed injuries is the trauma tertiary survey. In a prospective study to determine the efficacy of the tertiary survey at finding missed injuries [14], its implementation did not change the in-hospital missed injury detection rate significantly (3.8 vs 4.8%, $p > 0.05$). Our patients underwent a tertiary survey as standard of care, but missed injuries may have been identified before, during or after undergoing the survey. Previous reports from level I trauma centers show that missed injuries have an association with initial need for an emergency intervention, higher ISS or GCS ≤ 8, primary ICU admission [12] and level of training of the trauma team leader [15]. In our patients, missed injuries were associated with a penetrating mechanism, ICU admission, higher ISS, and a longer length of stay.

In our study, while the majority of missed injuries were orthopedic in nature, one area that may prompt further study by providers is the diagnosis of testicular rupture. Although rare, all missed testicular injuries led to a surgical intervention and a focused genitourinary examination at presentation in all patients may have improved time to diagnosis downrange.

Our study is not without limitations. Although we have information regarding the immediate outcome of missed injuries, we could not determine if the diagnostic time delay resulted in harm. For some injuries (e.g., extremity compartment syndrome) any time delay may be detrimental, but the significance of a two-day delay on the diagnosis of a tympanic membrane rupture is less clear. Another limitation of the study is that we were not able to determine the causative factors involved in missing the injury. Whether this was due to a limited assessment, clinician inexperience or emphasis on rapid transfer remains unknown. Imaging capabilities were sometimes limited downrange. For example, in some Forward Surgical Teams (FST), only portable x-ray machines were available, limiting the ability to diagnose some of the injuries found downrange. Another possible explanation is that obtaining definitive imaging may have been deferred until reaching a higher level of care.

The process improvement system at LRMC included weekly conferences with the trauma centers down range (Iraq and Afghanistan) where these patients were discussed and analyzed during those online meetings. Outcomes from higher levels of care were provided to sending facilities with timely constructive feedback to continuously improve care. Thirdly, in civilian trauma systems, most missed injuries are found within the index hospitalization but some will be discovered months after discharge [14]. Finally, our data reflect injuries diagnosed in-hospital at LRMC and also at the referral hospitals in the United States, which may not include all missed injuries diagnosed in a longer time frame.

Specific practice recommendations to further minimize missed injuries in the combat setting include the following:

- Strict adherence to the ATLS principles of primary, secondary and tertiary surveys and early transfer to higher level of care, if needed.
- Prompt focused distal extremity examination and imaging.
- Thorough ear examinations, especially when the injury mechanism includes an explosion, to prevent missing tympanic membrane ruptures.
- A focused genitourinary exam at presentation.

Conclusion

Although there is data of missed injuries in civilian trauma systems [10,12,14,15] and in military during peace time [13], there hasn't been a description of missed injuries in the military during active conflict. Although rare, missed injuries in the military do occur. As healthcare practitioners prepare for future deployments,

Table 4
Missed injury management.

Injury Type	n	Non-surgical Management Δ (%)	Surgical Intervention (%)
Orthopedic[a]	141	60 (42.5)	31 (22.0)
Urology	15	0	15 (100)
Pulmonary/Thorax	18	6 (33.3)	2 (11.1)
Abdominal	14	0	13 (92.9)
Vascular	4	1 (25.0)	3 (75.0)
Maxillofacial/Ophthalmology	47	33 (70.2)	3 (6.4)
Spine fractures	32	17 (53.1)	1 (3.1)
Neurosurgery	10	4 (40.0)	0
Burn	4	4 (100.0)	0
Other	2	1 (50.0)	0

[a] 14 injuries in the orthopedic category did not have treatment/management change available.

this analysis may serve as a resource to focus on frequently missed injuries, and possibly improve their detection.

Conflict of interest statement

For all authors, no conflicts were declared.

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