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Combat-related blast injuries : injury types and outcomes



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# COMBAT-RELATED BLAST INJURIES:

# INJURY TYPES AND OUTCOMES

A dissertation submitted in partial satisfaction of the requirements for the degree of Doctor of Philosophy

in

Public Health (Epidemiology)

by

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2011

The dissertation of Susan Lindsay Eskridge is approved and it is acceptable in quality and form for publication on microfilm and electronically:

Chair

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2011

# DEDICATION

This dissertation is dedicated to my husband, Randy, and my girls, Katie and Brianna for all of their love and support through this long process.  It is now Katie's turn to go to college!

This dissertation is also dedicated to my parents, Alex and Winn Lindsay who instilled in me the importance of education and the confidence in myself to pursue and complete all of my goals.

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LIST OF ABBREVIATIONS

AIS, Abbreviated Injury Scale

CHAMPS, Career History Archival Medical and Personnel System

CTR-EMED, Combat Trauma Registry Expeditionary Medical Encounter Database

ICD-9, International Classification of Diseases, $9^{th}$ Revision

IED, improvised explosive device

ISS, Injury Severity Scale

LOC, loss of consciousness

MTF, medical treatment facility

mTBI, mild traumatic brain injury

NHRC, Naval Health Research Center

OEF, Operation Enduring Freedom

OIF, Operation Iraqi Freedom

PCS, post-concussive syndrome

PPE, personal protective equipment

PTA, post traumatic amnesia

PTSD, post-traumatic stress disorder

RPG, rocket propelled grenade

SOAP note, subjective, objective, assessment, plan/ clinician note

TBI, traumatic brain injury

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# ABSTRACT OF THE DISSERTATION


COMBAT-RELATED BLAST INJURIES:

INJURY TYPES AND OUTCOMES



by

Susan Lindsay Eskridge

Doctor in Philosophy in Public Health (Epidemiology)

University of California, San Diego, 2011
San Diego State University, 2011

Professor Caroline Macera, Chair



Combat-related blasts have caused the majority of injuries in Operation Iraqi Freedom with traumatic brain injury (TBI) emerging as a preeminent injury. The purpose of this dissertation is to describe the scope of combat-related blast injuries and the career performance outcomes of service personnel injured in blasts. Factors associated with career performance outcomes in service personnel injured in blasts and specifically in those with mild TBI were also explored.

The Combat Trauma Registry Expeditionary Medical Encounter Database (CTR-EMED) is a collection of datasets from frontline medical care in Iraq and subsequent hospital care. The CTR-EMED provided demographics of injured service personnel and injury episode information. Outcome variables were ascertained from the Career History Archival Medical and Personnel System, which is a database of career and medical information for service personnel.

In the 4623 blast episodes examined, mild TBI was the most frequent single injury type (10.8%) and with extremity injuries combined, the extremities was the area most commonly injured. Surface wounds of the extremities comprised 27.6% of all injuries.

When examining service discharge in 4255 personnel injured in combat-related blasts, 37.8% experienced normal attrition and 8.3% early attrition. In service personnel with a discharge code, 29.8% had a disability-related discharge. Both early attrition and disability discharge proportions were higher in those with PTSD. In those without PTSD, a dose response relationship existed between injury severity and both disability discharge and early attrition. In those with a PTSD diagnosis, injury severity was associated with these adverse outcomes but the relationship was more complex.

In the 790 service personnel diagnosed with mild TBI after a combat-related blast, 24% experienced a disability discharge. The most common acute TBI symptoms documented were headache (63.0%), loss of consciousness (37.0%) and tinnitus (31.0%). In those without PTSD, disability discharge was associated with

age, total injury severity, time to discharge and post-concussive syndrome, while disability discharge was only associated with post-concussive syndrome in those with PTSD.

These results provide important information for acute and rehabilitative care providers. The impact of PTSD on recovery after combat-related blast injuries should be explored to maximize functional outcome in these service personnel.

# CHAPTER 1

## Background and Significance

Background and Significance

Blasts effects have caused a greater percentage of injuries in Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF) than in any other large scale conflict.[1] As of December 15, 2010, over 40,000 US service members have been wounded in action and over 5,500 have been killed as a part of OEF and OIF.[2] The majority of these combat-related injuries and deaths are due to explosive blasts.[3,4] Blasts are most commonly due to improvised explosive devices (IEDs), as well as rocket and mortar shells, mines, aerial bombs and rocket-propelled grenades (RPGs).[5]

Blast injuries

Battle injuries due to blasts were first investigated during World War I when the term "shell shock" was used to describe injuries resulting in symptoms such as amnesia, headache and poor concentration without obvious evidence of a head injury.[6] In the current conflicts, common injuries due to blasts include traumatic brain injury, lung injury, ruptured tympanic membrane as well as eye injuries, penetrating injuries and lacerations from flying fragments.[7,8] While lung injuries from blasts were more common in the past, new protective gear has reduced the incidence of lung injuries. Due to the numerous mechanisms of injury that occurs with a blast, these injuries are described as polytraumatic or causing injury to multiple body systems.[7]

*Blasts: Mechanism of injury*

The five mechanisms of injury due to blasts are primary, secondary, tertiary, quaternary and quinary.[5,7,9,10] Primary injuries are caused by an overpressurization shock wave followed by an underpressurization wave which travels through the body. While the exact mechanism of how a shock wave causes damage to the brain is under investigation, theories include the direct passage of the wave into the brain causing shear forces on the tissues, the transmission of the shock wave to the brain from the thorax and secondary brain injury from damage of the pulmonary and circulatory systems.[8,11] Tympanic membrane ruptures and lung injuries are also caused by these shock waves.[7]

Secondary injuries are created by bomb fragments and other fragments from the environment that are propelled by the explosion and are considered the most common cause of blast-related injury.[9] These fragments can produce injuries at a greater distance than the shock wave. Penetrating injuries and lacerations are common injuries due to these fragments but more serious injuries such as traumatic amputations and concussions can also occur.[7]

Tertiary injuries are caused by a blast wind which can throw a victim to the ground as well as cause the collapse of buildings and other structures. Blunt and crushing injuries such as fractures, traumatic amputations and compartment syndromes are common tertiary injuries. While the blast wind will displace a whole body, it can also displace only body parts cause other injuries such as an avulsion or separation of extremities or stripping of skin.[7,9]

Quaternary blast injuries are all other injuries including burns and the inhalation of toxic substances released from the blast. Quinary injuries are specific to added elements to a bomb such as metals, fuels, radiation and bacteria.[9] It is important to remember that these injury mechanisms do not occur in isolation and have the potential to impact multiple body systems. In addition, environmental factors such as whether the blast occurs in an open or closed space and the individual's distance from a blast will affect the type and severity of injury.[7]

*Epidemiology of blast injuries and injury outcomes*

Champion et al described the need for research in the epidemiology of blast wounds as well as the consequences of the blast injuries.[7] The advances in body armor have reduced the frequency of penetrating injuries and improvements in field medical care have increased the survival rate in those experiencing combat-related blasts. These advancements create a different combination of injuries in service personnel injured in blasts than seen in past conflicts.[5,12] While there have been reports of specific injuries such as tympanic membrane injuries,[13] eye injuries,[14] burns,[15] and traumatic brain injuries,[16] there has been no comprehensive investigation into the type, location and severity of injuries due to combat-related blasts. There have been fewer studies on the functional outcome of these injuries and samples have been limited to more severely injured personnel, limited to traumatic brain injury or designed to compare blast and non-blast injury outcomes.[5,17,18]

<u>Combat blast-related traumatic brain injuries</u>

Traumatic brain injury (TBI) has frequently been described as the "signature wound" of the wars in Iraq and Afghanistan with the majority of injuries cause by blasts or explosions.[19] The Defense and Veteran's Brain Injury Center estimate that over 200,000 service personnel have been diagnosed with traumatic brain injury since the year 2000. Yet traumatic brain injury is often unrecognized and under diagnosed and it has been estimated that 360,000 or up to 20% of service members deployed as a part of OIF and OEF have experienced brain injuries.[20]

*Diagnosis of TBI*

Traumatic brain injuries are categorized into mild, moderate and severe injuries based on the length of loss of consciousness (LOC), the length of post-traumatic amnesia (PTA), the score of the Glasgow Coma Scale (GCS) as well as findings from physical and neurological examinations.[21,22] The GCS assesses the individual's eye opening, verbal responses and motor responses with a combined score that ranges from 3 to 15.[23] Mild traumatic brain injury (mTBI), also known as concussion, is defined as no more than 30 minutes of loss of consciousness (LOC), less than 24 hours of post-traumatic amnesia (PTA) and a Glascow Coma Scale (GCS) of between 13 and 15.[22] In addition, clinical symptoms are used to diagnose mTBI including headache, nausea, vomiting, dizziness, sensitivity to light, and difficulty remembering or concentrating.[24] McCrea et al. found in a sample of injured athletes that neurocognitive changes are present after injury without the occurrence of LOC or PTA.[25]

MTBI is often unrecognized due to the severity of the injuries occurring in a combat setting especially considering life-threatening injuries and obvious external injuries.[21] The investigation into the type and frequency of acute concussion symptoms could potentially assist in the diagnosis of mTBI at the initial medical examination after a blast. In addition, assessing the relation between acute symptoms and outcome could help in the identification of high risk individuals, guiding immediate disposition and future decisions on medical care.

*Functional outcome assessment after mTBI*

The majority of symptoms and neurocognitive changes present immediately after a mTBI resolve within 48 hours after the injury.[25] In those individuals who continue to have impairments after the acute period, symptoms can include memory loss, impairments in problem-solving, difficulties in concentration and attention as well as emotional and behavioral problems. These continuing impairments can create limitations in day to day activities including securing and maintaining employment. The inability to work not only influences the well being and security of the individual's dependents but also contributes to the individual's overall health and psychosocial adjustment. A study by Corrigan et al. found that employment was the greatest predictor of quality of life reported by individuals after a TBI.[26] With the importance of work to an individual after a TBI, understanding employment status and the factors influencing employment status is critical to guide patient management. In a military setting, employment status is best described as career performance outcomes which include discharge, reasons for discharge and pay grade changes.

*Outcome studies of TBI: Military population*

The majority of recent TBI outcome studies with a military population have used many outcomes including career performance, postconcussive symptoms (problems with memory, concentration, sleep and irritability), physical symptoms, medical conditions and overall health. A study by Ommaya et al. investigated the behavioral and medical reasons behind discharges comparing non-battle TBI to the total discharge population.[27] Discharge due to behavioral problems compared to the total discharge population was highest in the mTBI population (OR 1.8; 95% CI 1.4 to 2.2) and not significant in either the moderate or severe TBI populations. Discharge due to medical disability was highest in severe TBI population (OR 40.4; 95% CI 30.0 to 54.4) compared to moderate TBI (OR 25.2; 95% CI 16.2 to 39.2) and mTBI (OR 7.5; 95% CI 6.0 to 9.3).

Prospective follow-up data of battle and non-battle related TBI was described by Galarneau et al.[18] Injured military personnel were treated at Level 1 and 2 medical treatment facilities in Iraq and the diagnosis of TBI was ascertained from the records of those visits entered into the Navy-Marine Corps Combat Trauma Registry (Navy-MC CTR EMED). Follow-up information, including discharge status, hospital admissions and outpatient visits and diagnoses, was gathered from Career History Archival Medical and Personnel System (CHAMPS) database. Both total discharge and early discharge was more common in moderate-severe TBI compared to mTBI. Military personnel with a mTBI were more likely to be discharged due to the end of obligated service while all personnel with moderate-severe TBI were discharged due to disability. The number of both hospital admissions and outpatient visits was higher in moderate-severe TBI compared to mTBI. In addressing common diagnoses, post-traumatic stress disorder (PTSD) was more commonly diagnosed in personnel with mTBI compared to moderate-severe TBI.

Hoge et al. completed a post-deployment survey of 2525 U.S. Army infantry soldiers.[28] The survey included questions on injuries and the mechanism of injuries as well as injuries that produced a loss of consciousness (LOC) or an altered mental status (no memory of event, being dazed or confused after event). The soldiers also reported on overall health, days missed from work, physical symptoms and symptoms of major depressive disorder and PTSD. Of the 2525 soldiers, 4.9% reported an injury with LOC, 10.3% reported an injury with altered mental status and 17.2% reported an injury without LOC or altered mental status. Both LOC and altered mental status was associated with PTSD compared with other injuries (OR: 2.98; 95% CI: 1.70 to 5.24 and OR: 1.78; 95% CI: 1.13 to 2.81, respectively) and LOC was associated with depression compared to other injuries (OR: 3.67; 95% CI 1.65 to 8.16). When compared to other injuries, LOC was associated with poor overall health, multiple missed work days and multiple symptoms such as headaches, dizziness, sleep disturbances and memory and concentration problems. Altered mental status was associated with multiple symptoms such as headache, dizziness, sleep disturbances and balance and concentration problems when compared to other injuries. When PTSD was incorporated into the multivariate model, only the association between LOC and headache remained significant in the full model.

*Influence of PTSD on outcome*

Along with mTBI, the rising rates of PTSD among service members serving in OIF and OEF are cause for concern. Sundin et al found rates of PTSD among service members deployed to Iraq as high as 31%.[29] Hoge et al. demonstrated that PTSD plays a role in the association between a LOC event during combat and chronic symptoms after deployment.[28] After controlling for PTSD, only the association between LOC and headache remained significant. PTSD has also been found to affect functioning in combat veterans. Zatzick et al reported that individuals with combat-related PTSD demonstrated a "higher risk of diminished well-being, fair or poor physical health, currently not working and physical limitations" compared to combat veterans without PTSD.[30] These findings highlight the potential that PTSD could mediate the relationship between injury characteristics (severity, mTBI symptoms) and career performance outcomes in service members after a combat-related blast injury. It is important to consider the influence PTSD has on this relationship in service members with mTBI as well any injury from a combat-related blast.

*Summary: mTBI outcome*

Headaches, disturbances in sleep, attention and memory, mood changes, depression and diagnosis of PTSD as well as disruption in families, loss of duty time and early discharge have been attributed to blast-related TBI experienced in OIF and OEF.[18,21,28,31] The majority of current studies focus on symptoms or the occurrence of PTSD after TBI rather than functional consequences, such as career performance outcomes, of the injuries. Fewer studies use data collected within 48 hours of the injury. A better understanding of the career performance outcome and factors relating to outcome will lead to improved patient management not only for those diagnosed with mTBI but for service members diagnosed with blast-related injuries.

Purpose of studies

- Describe the nature, body region and severity of injuries caused by a combat-related blast in male service personnel.
- Describe the career performance outcomes (disability related discharge, attrition type, pay grade changes) after an injury from a combat related blast and examine the relationship between the injury severity and type of discharge from service.
- Describe the acute signs and symptoms of service personnel diagnosed with a mild traumatic brain injury (mTBI) within 48 hours after a combat-related blast, describe the career performance outcomes (disability related discharge, pay grade changes) after a mTBI and examine the relation between the symptoms, injury severity and disability related discharge from service.

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# CHAPTER 2

## Combat-related blast injuries in Iraq: Injury type, location and severity

Abstract:

*Introduction*: Combat-related blasts have caused a greater percentage of injuries in Iraq and Afghanistan than any other large-scale conflict. Improvements in body armor and field medical care have improved survival and changed the injury profile of service personnel. The objective of this study is to describe the nature, body region and severity of injuries caused by a combat-related blast in male service personnel.

*Material and Methods*: A descriptive analysis was conducted of 4623 combat-related blast episodes in Iraq between March 2004 and December 2007. The Barell matrix was used to describe the nature and body regions of injuries due to a combat-related blast.

*Results*: A total of 17,637 IDC-9 codes were assigned to the 4623 blast episodes with an average of 3.8 IDC-9 codes per blast episode. The most frequent single injury type was a mild traumatic brain injury (10.8%). Other frequent injuries were open wounds in the lower extremity (8.8%) and open wounds of the face (8.2%), which includes tympanic membrane rupture. The extremities was the body region most often injured (41.3%), followed by head and neck injuries (37.4%) and torso (8.8%).

*Conclusions*: The results of this study support previous observations of traumatic brain injury as a preeminent injury of the wars in Iraq and Afghanistan with mild TBI as the most common single injury in this large cohort of blast episodes. The

extremities had the highest frequency of injuries for any one body region. The majority of the blast episodes resulted in more than one injury and the variety of injuries across nearly every body region and injury type suggests a complex nature of blast injuries. Understanding the constellation of injuries commonly caused by combat-related blasts will assist in the mitigation, treatment and rehabilitation of the effects of these injuries.

Introduction

Blast effects have caused a greater percentage of injuries in Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF) than in any other large-scale conflict.[1] As of 28 May 2010, over 37,000 US Service members have been wounded in action and over 4,000 have been killed in action as a part of OEF and OIF.[2] The majority of these combat-related injuries and deaths are due to explosive blasts,[3, 4] which can cause a wide spectrum of injuries.[5] While there have been reports of specific injuries such as tympanic membrane injuries,[6] eye injuries,[7] burns,[8] and traumatic brain injuries,[9] there has been no comprehensive investigation into the type, location, and severity of injuries due to combat-related blasts.

Five different blast injury mechanisms have been described.[5, 10-12] These injury mechanisms do not occur in isolation and have the potential to impact multiple body systems.[5] Primary injuries are caused by an overpressurization shock wave followed by an underpressurization wave which travels through the body. Traumatic brain injury, lung injury and tympanic membrane ruptures are caused by these shock waves.[5] Secondary injuries are created by bomb fragments and other fragments from the environment that are propelled by the explosion and are considered the most common cause of blast-related injury.[10] Severity of these injuries can range from lacerations to traumatic amputations. Tertiary injuries are caused by a blast wind which can throw a victim to the ground as well as cause the collapse of buildings and other structures. Blunt and crushing injuries are common tertiary injuries. Quaternary blast injuries are all other injuries including burns and the inhalation of toxic substances released from the blast. Quinary injuries are specific to added elements to a bomb such as metals, fuels, radiation and bacteria.

Champion et al described the need for research in the epidemiology of blast wounds as well as the consequences of the blast injuries.[5] The advances in body armor have reduced the frequency of penetrating injuries and improvements in field medical care have increased the survival rate in those experiencing combat-related blasts. These advancements create a different combination of injuries in service personnel injured in blasts than seen in past conflicts[12, 13] and thus a comprehensive investigation of all blast injuries is warranted to inform providers involved in trauma care and rehabilitation. The primary objective of this study is to describe the nature, body region and severity of injuries caused by a combat-related blast in male service personnel participating in Operation Iraqi Freedom (OIF) between March 2004 and December 2007. Individual demographics, injury circumstances (type of blast and use of personal protective equipment) and the disposition of the service personnel after examination will also be explored.

Material and Methods

The Combat Trauma Registry Expeditionary Medical Encounter Database (CTR-EMED) is a collection of data sets from multiple levels of care. These data sets are from primarily Navy frontline medical treatment facilities (MTF) in Iraq as well as hospitals outside of the continental United States and naval hospitals within the continental United States.[14] Data within the CTR-EMED include both data from the casualties' medical records and from clinical information for battle injuries, non-battle injures and sick-call visits. The clinical information is documented on CTR-EMED medical encounter forms at forward MTFs, which are then forwarded to the Naval Health Research Center (NHRC) where the database is maintained. The field encounter forms are reviewed by CTR-EMED clinical staff and both demographic information of the injured personnel and clinical information on the specific injury or illness are entered into the CTR-EMED database.

Clinical diagnosis codes from the International Classification of Diseases, 9th Revision (ICD-9) were assigned to each injury described on the encounter form by trained and experienced clinical staff. If there are no documented injuries recorded on the encounter form, it is documented in the CTR-EMED that there were no injuries at that clinic visit. In addition to the assigning of diagnosis codes, severity of each injury is accessed with two different standardized measures of injury severity; the Abbreviated Injury Scale (AIS) and the Injury Severity Scale (ISS).[15] The AIS is an anatomical based injury severity scale which scores each injury on a scale from 1 (minor) to 6 (unsurvivable) within six body regions (head, face, chest, abdomen, extremities and external). The ISS is derived from the AIS scores with a range of 0 to 75 and is an overall measure of injury severity. The ISS for each blast episode was documented and categorized into one of four severity levels; mild (ISS 1-3), moderate (ISS 4-8), serious (ISS 9-15) and severe (ISS 16 and higher).

Between March 2004 and December 2007, there were 5091 blast episodes in 4774 male service personnel that resulted in an examination at a Level 1 or Level 2

MTF and an encounter form entered in the Navy CTR-EMED. Female service personnel were excluded due to a low proportion of injured females. A blast episode was defined as a documented mechanism of injury of an improvised explosive device (IED), grenade, rocket propelled grenade (RPG), landmine, aerial bomb or mortar. Of these 5091 encounters at an MTF, 354 episodes resulted in no documented injury and 114 episodes resulted in the death of the service personnel either at the initial site of care or a higher level of care. The final sample size for this study was 4623 episodes of combat-related blasts which had a documented injury and an ICD-9 code assigned to that injury. This study was approved by the Institutional Review Boards at the Naval Health Research Center and San Diego State University.

Individual demographics (age, military rank, branch of service), injury circumstances (type of blast, year of blast, personal protective equipment usage) and disposition after clinic examination were ascertained for each blast episode from the CTR-EMED database. Age was reported in years and calculated by the date of injury minus the date of birth. The date of the encounter at the Level 1 or Level 2 facility was used if the date of injury was not available. Military rank was categorized as junior enlisted (E1-E3), midlevel enlisted (E4-E5), senior enlisted (E6-E9) and officers/warrant officers. Military branch of service was categorized as Air Force, Army, Navy and Marines.

The type of blast was categorized as IED, grenade, RPG, landmine, aerial bomb or mortar. The year of blast event was categorized as the year of the episode date. The year of 2004 was only from March 2004 through December 2004 and all other years (2005, 2006, 2007) were a full 12 months. Multiple blast episodes were defined as a repeat blast episode in an individual. Usage of personal protective equipment (PPE) was defined as the documented use of any single item of PPE as well as specific usage of helmet, flak jacket, ceramic plate and eye protection. Disposition after examination was categorized as return to duty (RTD), light duty/sick in quarters (LD/SIQ), admission to MTF and transfer to a higher level of care.

*Data Analysis*

Means and standard deviations were reported for age and ISS across blast episodes. Absolute numbers and percentages for the year of blast event, mechanism of blast event, the usage of PPE, multiple blast exposure and ISS severity levels were calculated. A one-way analysis of variance (ANOVA) was utilized to compare mean ISS between the different disposition statuses for the individual episodes with a value of $p>0.05$ considered significantly significant. Scheffe's correction was utilized for multiple comparisons.

The Barell injury diagnosis matrix was used to display the nature and body regions of injuries due to a combat-related blast.[16] The standard matrix uses the ICD-9 codes that describe trauma and constructs a matrix using 12 natures of injury (fractures, dislocations, sprains and strains, internal injuries, open wounds, amputations, injuries to blood vessels, contusions and superficial injuries, crush, burn and nerve injuries) and either 36, 12 or 5 body regions. The majority of the matrix cells include more than one ICD-9 code. Both the 36 body region and the 5 body region versions were used in the analysis. The 12 injury natures were collapsed into orthopedic injuries (fractures, dislocations, sprains and strains, amputations, crush injuries), internal injuries (internal, blood vessel injuries, nerve injuries) and surface injuries (open wounds, contusions and superficial injuries, burns). SAS software (version 9.2) was used for all data analysis.

Results

The study population was comprised of 4623 blast episodes which resulted in a survivable injury. Demographics of the injured personnel and blast episode characteristics for each combat-related blast episode are documented in Table 2.1. The average age of the personnel injured was 24 years with a range of 18.3 and 58.7 years. The pay grade category with the highest proportion for the episodes was junior enlisted (E1-E3) (41.7%) closely followed by midlevel enlisted (E4-E6) (39.8%). Marines had the highest percentage for episodes resulting in injury (75.9%) with the Army as the second most frequent branch of service (18.7%).

Within the study period of March 2004 and December 2007, the majority of the episodes occurred in 2006, followed by 2005. Improvised explosive device (IED) was the most common blast mechanism and was reported in 78% of the episodes. Any single other blast mechanism was found in less than 10% of the episodes. There were a total of 273 blast episodes which the service personnel had experienced a previous blast with up to four separate blast episodes per person. The usage of at least one item of PPE (helmet, flak jacket, ceramic plate, eye protection) was documented in 88.8% of the episodes (Table 2.2). In those who wore PPE, the use of helmet, flak jacket and ceramic plate was at or above 90% with 81% wearing eye protection.

A total of 17,637 IDC-9 codes were assigned to the 4623 blast episodes with an average of 3.8 IDC-9 codes per blast episode (range 1-40 codes) (Table 2.3). Seventy two percent of all episodes reported more than one IDC-9 code. An AIS code was assigned to each documented injury with a total ISS score calculated for each blast episode. The average total ISS score was 4.5 with a range of 1-75. Over 85% of the episodes resulted in mild to moderate severity as categorized by the total ISS score.

The most frequent disposition was service personnel transferred to a higher level of care after examination at the forward MTF (31.1%) followed by RTD (27.2%) and LD/SIQ (25.2%) (Table 2.4). ANOVA demonstrated a significant difference in mean total ISS between disposition status categories ($p<0.001$). Post hoc analysis using Scheffe's method found that mean ISS was highest in service personnel transferred to higher level of care compared to all other disposition categories. The mean ISS for admission to the MTF was higher than RTD and LD/SIQ which were not different than each other.

The Barell injury diagnosis matrix was used to categorize the ICD-9 codes by injury nature and body region (Table 2.5). When examining single matrix cells within the full matrix (12 natures of injuries x 36 body regions), the most frequent injury was a traumatic brain injury (TBI) Type 2 (body region) and internal injury (injury nature), which was 10.8% of all documented ICD-9 codes across all injury episodes. In the

Barell methodology, TBI Type 2 is described as an injury with “no recorded evidence of intracranial injury, and a loss of consciousness of less than one hour, or loss of consciousness of unknown duration, or unspecified level of consciousness”.[16] The ICD- codes which comprise that diagnosis matrix cell are consistent with a concussion (ICD-9 codes 850.0, 850.1, 850.5, 850.9). Other frequent injuries were open wounds in the lower extremity (8.8%), open wounds of the face (8.2%), which includes tympanic membrane rupture and unspecified other head injuries (5.8%). All other single cells were less than 5% of total number of IDC-9 codes.

Figure 2.1 summarizes the full matrix with 3 of the 5 standard rows of body regions (head and neck, torso and extremities) and combined injury nature categories (orthopedic injuries, internal injuries and surface injuries). The body region categories of spine and back and unspecified by site were not included due to the relatively low percentage of injuries in these categories. When examining the body region and combined injury nature categories, surface injuries of the extremities were the most frequent injuries and were 27.6% of all documented ICD-9 codes. The extremities was the body region most often injured (41.3%), followed by head and neck injuries (37.4%) and torso (8.8%). In terms of the nature of injury, surface injuries were most frequent (52.7%) followed by internal injuries (19.7%) and orthopedic injuries (15.1%).

Discussion

With the large proportion of injuries caused by blasts in the current military conflicts and the changing injury profiles from improved body armor and frontline medical care, the scope of blast injuries needs to be understood to improve the mitigation, treatment and rehabilitation of the effects of combat-related blasts. This comprehensive report of all injuries resulting from 4623 combat blast episodes is unique due to the use of data from Level 1 and 2 MTFs in Iraq and all levels of severity, including those who returned to duty after initial examination at these MTFs.

The results of this descriptive study support previous observations of traumatic brain injury as a preeminent injury of the wars in Iraq and Afghanistan.[17] Nearly 11% of all the documented ICD-9 codes among the injury episodes were described as TBI Type 2 internal injury, which is consistent with a mild traumatic brain injury or concussion. While civilian reports suggest that the majority of individuals with mild TBI recover within three months,[18] mild TBI has recently been associated with a vast array of negative outcomes in military personnel including mental health disorders and separation from service for behavioral reasons.[19, 20] Additionally, over 40% of the ICD-9 codes documented injuries to the extremities, which is consistent with other reports on all combat wounds as well as injuries from blast alone.[1, 21, 22] The most frequent injury to the extremities was open wounds which were over 18% of all injuries. While improved body armor has reduced injuries to the torso,[1] the extremities are still vulnerable to these surface wounds. The high rates of compliance for PPE among the study population were encouraging and likely represent strict enforcement of these safety guidelines in combat theatre.

Blast injuries are due to multiple mechanisms which are evident in the wide variety of injuries reported in these blast episodes as well as injuries across multiple body regions and organ systems.[5, 21] Injuries were present in nearly every body region and nature of injury within the Barell injury diagnosis matrix and more than one ICD-9 code was reported in over 70% of the episodes in this cohort with an average number of diagnoses of nearly four per blast episode. Polytrauma has been defined by the Veteran's Health Association as "… two or more injuries sustained in the same incident that affect multiple body parts or organ systems and result in physical, cognitive, psychological or psychosocial impairments and functional disabilities."[23] TBI is a frequent component of polytrauma and the impairments from TBI often are the focus of rehabilitation. Specific rehabilitation challenges in the treatment of polytrauma have been identified and systems of care are being established to address these challenges.[13, 23-25]

The primary limitation of this study is the potential for missing information to correctly identify ICD-9 codes. For example, nearly 6% of the ICD-9 codes fall into the "unspecified" category which is often used if there isn't enough information in the record to give a more specific code. In the presence of more serious injuries, minor injuries many not be documented in injured service personnel due to the importance of treating the serious injury. In addition, missing records can occur for various reasons including not visiting a MTF for care, rapid evacuation with limited time for documentation and incomplete coverage of all MTFs. Since the MTFs covered are primarily Navy-Marine Corps facilities, Army personnel are underrepresented in the study population. Lastly, due to the absence of autopsy data for those who were evaluated at a Level 1 or Level 2 MTF, all service personnel who subsequently died of their wounds were not included in this report.

A primary strength of the present study was the large sample of combat-related blast episodes which included data across a wide range of injury severities and from all levels of care, thus creating a unique opportunity to describe the effects of blasts. With frontline MTF data, there is better representation of minor injuries for service personnel who are returned to duty or placed on light duty after medical evaluation. The use of the Barell injury diagnosis matrix on this data goes beyond assessing a single injury type, determining a primary diagnosis or evaluating severity scores.[26] This method provides a more comprehensive approach to examine both the body region and the nature of the multiple injuries of these blast episodes although it does not provide incidence data for any single diagnosis.

## Conclusion

The most common single injury in the cohort of 4632 blast injuries was a TBI type 2 internal injury which is consistent with a concussion. When the body region and nature of injury was collapsed into broader categories, surface wounds of the extremities were the most common injuries. Understanding the nature and body region of injuries due to the effects of combat-related blast will assist in providing adequate personal protective equipment and inform clinicians who are providing care for wounded service personnel. In addition, investigations into the long term physical and psychosocial effects of these injuries are necessary to guide medical management after injury.

Chapter 2 is currently being prepared for the submission for the publication of the material. Eskridge, Susan L; Macera, Caroline A; Galarneau, Michael R; Holbrook, Troy L; Woodruff, Susan I; MacGregor, Andrew J; Morton, Deborah J; Shaffer, Richard A. The dissertation author was the primary investigator and author of this material.

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Table 2.1: Demographic and injury characteristics among injured male service personnel per combat-related blast episode (N=4623),
Operation Iraqi Freedom, 2004-2007

| | Mean(SD) | |
|---|---|---|
| **Age (years)** | 24.5(5.3) | |
| | **n*** | **%** |
| **Pay grade** | | |
| Junior enlisted | 1927 | 41.7 |
| Midlevel enlisted | 1842 | 39.8 |
| Senior enlisted | 409 | 8.8 |
| Officer/Warrant | 188 | 4.1 |
| **Branch of service** | | |
| Marine | 3510 | 75.9 |
| Army | 866 | 18.7 |
| Navy | 241 | 5.2 |
| Air Force | 6 | 0.1 |
| **Type of blast** | | |
| IED | 3612 | 78.1 |
| Mortar | 374 | 8.1 |
| RPG | 213 | 4.6 |
| Grenade | 190 | 4.1 |
| Landmine | 178 | 3.8 |
| Rocket | 53 | 1.1 |
| Aerial bomb | 3 | 0.1 |
| **Year of blast event** | | |
| 2004# | 904 | 19.5 |
| 2005 | 1313 | 28.4 |
| 2006 | 1784 | 38.6 |
| 2007 | 622 | 13.4 |
| **Multiple blast episodes** | 273 | 5.9 |

*Subject numbers for each variable do not add to total sample due to missing data;
#Year of 2004 includes March 2004 through December 2004;
IED=Improvised Explosive Device; RPG=Rocket Propelled Grenade

Table 2.2: Personal protective equipment (PPE) usage among injured male service personnel per combat-related blast episode (N=4623),
Operation Iraqi Freedom, 2004-2007

| | **n*** | **%** |
|---|---|---|
| **PPE documented** | 4104 | 88.8 |
| **Helmet** | | |
| Worn | 3788 | 92.3 |
| Not worn | 284 | 6.9 |
| **Flak jacket** | | |
| Worn | 3754 | 91.5 |
| Not worn | 270 | 6.6 |
| **Ceramic plate** | | |
| Worn | 3692 | 90.0 |
| Not worn | 270 | 6.6 |
| **Eye protection** | | |
| Worn | 3334 | 81.2 |
| Not worn | 613 | 14.9 |

*Subject numbers for each variable do not add to total sample due to not documented/not applicable

Table 2.3: Injury severity assessed by the number of ICD-9 codes per episode and total injury severity scale (ISS) among injured male service personnel per combat-related blast episode (N=4623), Operation Iraqi Freedom, 2004-2007

| | **Mean (SD)** | |
|---|---|---|
| **Number ICD-9/episode** | 3.8 (4.1) | |
| **Total ISS** | 4.5 (6.3) | |
| | n | % |
| **Total ISS severity categories**[*] | | |
| Mild | 2871 | 62.1 |
| Moderate | 1081 | 23.4 |
| Serious | 398 | 8.6 |
| Severe | 273 | 5.9 |

[*]Total ISS severity categories: Mild- ISS 1-3, Moderate ISS 4-8, Serious ISS 9-15, Severe ISS $\geq$16

Table 2.4: Disposition status and differences in total injury severity scale (ISS) between disposition status groups among injured male service personnel per combat-related blast episode (N=4482)*, Operation Iraqi Freedom, 2004-2007

| Discharge status | n(%) | Mean ISS (SD)# |
|---|---|---|
| **Return to duty** | 1259(27.2) | 1.7 (1.2) |
| **Light duty/Sick in quarters** | 1162(25.2) | 2.4 (1.8) |
| **Admit to MTF** | 624(13.5) | 3.7 (4.0) |
| **Transfer higher level care** | 1437(31.1) | 9.1 (9.0) |

*Missing discharge status in 147 episodes
#p>0.0001, analysis of variance. Scheffe's test showed equal means between return to duty and light duty/sick in quarters, all other mean comparisons were significantly different.
MTF= Medical treatment facility

Table 2.5: Distribution of IDC-9 codes by body region and type of injury (n (%)) among injured male service personnel due to combat-related blasts, Operation Iraqi Freedom, 2004-2007

| | Fracture | Dislocation | Sprains/ Strains | Internal | Open Wound | Amputations |
|---|---|---|---|---|---|---|
| Type 1 TBI | 94(0.53) | / | / | 297(1.69) | / | / |
| Type 2 TBI | 39(0.22) | | | 1908(10.83) | | |
| Type 3 TBI | 14(0.08) | / | / | / | / | / |
| Other Head | / | / | / | / | 198(1.12) | / |
| Face | 392(2.22) | 8(0.05) | 0 | / | 1449(8.22) | / |
| Eye | / | / | / | / | 289(1.64) | / |
| Neck | 4(0.02) | / | | / | 206(1.17) | / |
| Head/face/neck unspecified | / | / | / | / | / | / |
| Cervical SCI | 6(0.03) | / | / | 0 | / | / |
| Thoracic SCI | 7(0.04) | / | / | 0 | / | / |
| Lumbar SCI | 15(0.09) | / | / | 0 | / | / |
| Sacrum SCI | 1(0.01) | / | / | 0 | / | / |
| SCI unspecified | 0 | / | / | 0 | / | / |
| Cervical VCI | 29(0.16) | 3(0.03) | 180(1.02) | / | / | / |
| Thoracic VCI | 57(0.32) | 2(0.01) | 52(0.3) | / | / | / |
| Lumbar VCI | 106(0.60) | 6(0.03) | 153(0.87) | / | / | / |
| Sacrum VCI | 26(0.15) | / | / | / | / | / |
| VCI unspecified | 0 | 0 | / | / | / | / |
| Chest | 56(0.32) | 2(0.01) | 2(0.01) | 199(1.13) | 117(0.66) | / |
| Abdomen | / | / | / | 216(1.23) | 139(0.79) | / |
| Pelvis | 65(0.37) | 0 | 14(0.08) | 13(0.07) | 240(1.36) | / |
| Trunk | 0 | / | / | / | 18(0.10) | / |
| Back/buttocks | / | / | 2(0.01) | / | 96(0.54) | / |
| Shoulder/ Upper arm | 134(0.76) | 13(0.07) | 23(0.13) | / | 569(3.23) | 13(0.07) |
| Forearm/elbow | 234(1.33) | 12(0.07) | 8(0.05) | / | 489(2.77) | 13(0.07) |
| Wrist/hands/ fingers | 231(1.31) | 17(0.10) | 24(0.14) | / | 523(2.97) | 40(0.23) |
| UE unspecified | 4(0.02) | / | / | / | 46(0.26) | 3(0.02) |
| Hip | 11(0.06) | 1(0.01) | 11(0.06) | / | / | / |
| Upper leg/thigh | 98(0.56) | | | / | / | 25(0.14) |
| Knee | 33(0.19) | 8(0.05) | 13(0.07) | / | / | / |
| Lower leg/ankle | 488(2.77) | 20(0.11) | 47(0.27) | / | | 32(0.18) |
| Foot/toes | 275(1.56) | 33(0.19) | 7(0.04) | / | 111(0.63) | 19(0.11) |
| LE unspecified | 6(0.06) | / | 46(0.26) | / | 1555(8.82) | 28(0.16) |
| Other/multiple | 1(0.01) | / | / | / | / | / |
| Unspecified site | 5(0.03) | 0 | 5(0.03) | 1(0.03) | 3(0.02) | / |
| Systemwide/late effects | | | | | | |

TBI=Traumatic Brain Injury, SCI=Spinal Cord Injury, VCI=Vertebral Column Injury, UE=Upper Extremity, LE=Lower Extremity

Table 2.5 cont.: Distribution of IDC-9 codes by body region and type of injury (n (%)) among injured male service personnel due to combat-related blasts, Operation Iraqi Freedom, 2004-2007

| | Blood Vessels | Contusion/ superficial | Crush | Burns | Nerves | Unspecified |
|---|---|---|---|---|---|---|
| Type 1 TBI | / | / | / | / | 0 | / |
| Type 2 TBI | | | | | | |
| Type 3 TBI | / | / | / | / | / | / |
| Other Head | / | / | / | 6(0.03) | 320(1.82) | 1015(5.76) |
| Face | / | / | / | 80(0.45) | / | / |
| Eye | / | 373(2.12) | / | 18(0.10) | 10(0.06) | / |
| Neck | / | / | 0 | 37(.021) | 0 | / |
| Head/face/neck unspecified | 45(0.26) | 676(3.84) | 0 | 133(0.75) | 0 | 11(0.06) |
| Cervical SCI | / | / | / | / | / | / |
| Thoracic SCI | / | / | / | / | / | / |
| Lumbar SCI | / | / | / | / | / | / |
| Sacrum SCI | / | / | / | / | / | / |
| SCI unspecified | / | / | / | / | / | / |
| Cervical VCI | / | / | / | / | / | / |
| Thoracic VCI | / | / | / | / | / | / |
| Lumbar VCI | / | / | / | / | / | / |
| Sacrum VCI | / | / | / | / | / | / |
| VCI unspecified | / | / | / | / | / | / |
| Chest | 6(0.03) | 57(0.32) | 0 | 5(0.03) | 2(0.01) | / |
| Abdomen | 6(0.03) | 28(0.16) | / | 15(0.09) | 6(0.03) | / |
| Pelvis | 5(0.03) | 7(0.04) | 1(0.01) | 7(0.04) | 1(0.01) | / |
| Trunk | / | 112(0.64) | 0 | 4(0.02) | 0 | 0 |
| Back/buttocks | / | 74(0.42) | 0 | 38(0.22) | / | / |
| Shoulder/ Upper arm | / | 186(1.06) | 0 | 33(0.19) | / | 0 |
| Forearm/elbow | / | 83(0.47) | 0 | 60(0.34) | / | / |
| Wrist/hands/ fingers | / | 91(0.52) | 1(0.01) | 212(1.20) | / | 0 |
| UE unspecified | 89(0.50) | 129(0.50) | 0 | 30(0.17) | 177(1.00) | 0 |
| Hip | / | 25(0.14) | 0 | / | / | / |
| Upper leg/thigh | / | 83(0.47) | 2(0.01) | 31(0.18) | / | / |
| Knee | / | 110(0.62) | 1(0.01) | 12(0.07) | / | / |
| Lower leg/ankle | / | 97(0.55) | 0 | 21(0.12) | / | / |
| Foot/toes | / | 38(0.22) | 2(0.01) | 3(0.02) | / | / |
| LE unspecified | 172(0.98) | 302(1.71) | 0 | 24(0.14) | / | 0 |
| Other/multiple | 4(0.02) | | / | 80(0.45) | 66(0.37) | / |
| Unspecified site | 12(0.07) | 7(0.04) | 0 | 253(1.44) | 0 | 1(0.01) |
| Systemwide/late effects | | | | | | 92(0.52) |

TBI=Traumatic Brain Injury, SCI=Spinal Cord Injury, VCI=Vertebral Column Injury, UE=Upper Extremity, LE=Lower Extremity

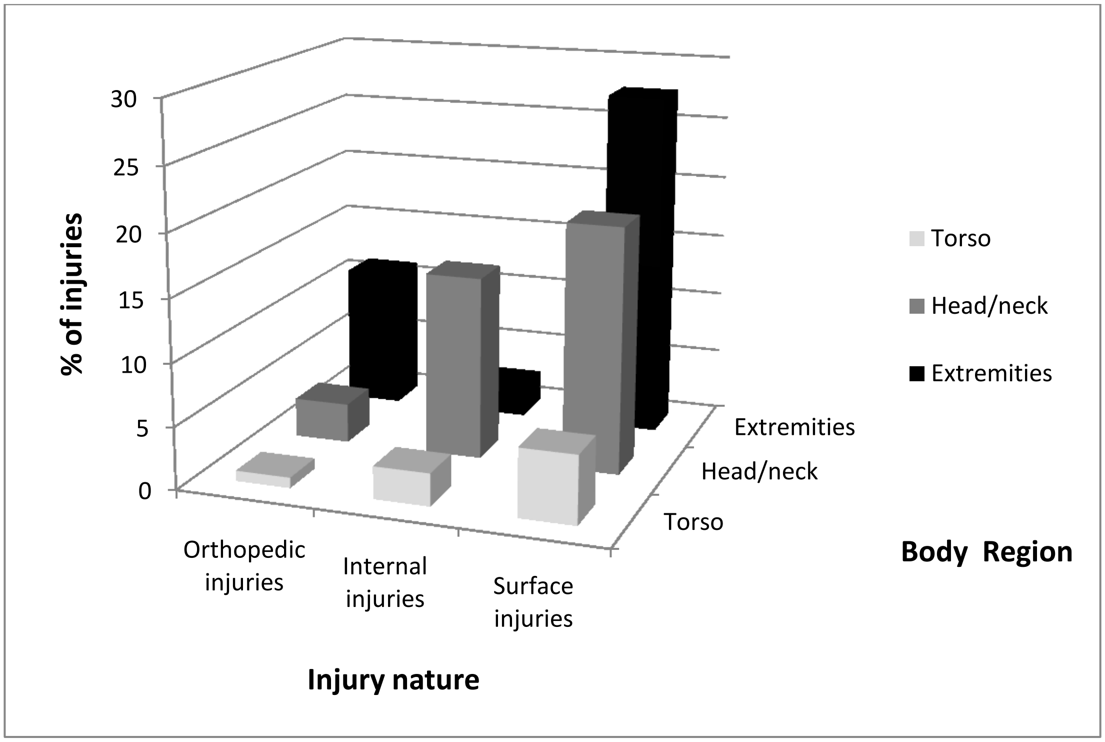


Figure 1.1: Percentage of injuries distributed by the nature of the injury and body region. Orthopedic injuries include fractures, dislocations, sprains and strains, amputations, crush injuries. Internal injuries include internal injuries, blood vessel injuries and nerve injuries. Surface injuries include open wounds, contusions and superficial injuries and burns. The body regions of spine and back and unspecified site were excluded from the figure due to low percentage of injuries.

# CHAPTER 3

## Combat-related blast injuries: The interaction of injury severity and post-traumatic stress disorder on career performance outcomes

Abstract:

*Introduction:* With combat-related blasts causing the majority of injuries in Iraq and Afghanistan, understanding the potential outcomes to these injuries is important for determining methods to support injured service personnel. The purpose of this study is to describe the career performance outcomes after an injury from a combat-related blast and examine the relationship between the injury severity and type of discharge from service.

*Materials and methods*: The career performance outcomes of 4255 service personnel injured in a combat-related blast in OIF between March 2004 and December 2007 were ascertained between 21 and 65 months after injury. The relationship between injury severity and the type of service discharge and the interaction of PTSD in this relationship was explored.

*Results*: In the total sample, 37.8% experienced a normal attrition and 8.3% had an early attrition. Out of the 2229 members who had a discharge code, 29.8% resulted in a disability discharge. Both early attrition and disability discharge proportions were higher in those with PTSD than in the no PTSD group. There was a significant interaction between PTSD and injury severity in both discharge outcome types. In those without PTSD, there was a dose response relationship between injury severity and both disability discharge and early attrition. While in those with PTSD injury severity did predict disability discharge, early attrition and normal attrition at the highest severity level, the relationship between injury severity and adverse outcomes was less clear cut than in those without PTSD.

*Conclusions*:  Initial injury severity is associated with adverse career performance outcomes and this relationship in service personnel with PTSD is more complex than in those without a PTSD diagnosis.  Career performance outcomes are an important measure of functional combat blast-related injury outcome and should be considered during the assessment of rehabilitation effectiveness.

Introduction

Blasts are the most common mechanism of injury in Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF) with up 80% of all injuries due to blasts.[1,2] The causes of blasts include improvised explosive devices (IED), grenades, landmines, mortars, rocket propelled grenades (RPG) and aerial bombs with the majority of blasts caused by IEDs.[1-3] Blast injuries involve multiple different mechanisms and range from mild severity to fatal and can impact nearly any body system and anatomical region.[4-7] Some of the most common injuries include traumatic brain injuries (TBI), fragment wounds to extremities and torso, and tympanic membrane ruptures.[1-4]

With a greater percentage of wounded service personnel surviving battle injuries in (OEF) and (OIF) than in any other previous conflict, understanding the outcomes and the potential risk factors for adverse outcomes is important to providing support after the injury. Due to the numerous ways blasts cause injury, polytrauma is more common in blast injuries than injuries from other mechanisms and produce a multiple array of injury profiles.[4,8] Polytrauma creates a unique challenge for medical care and rehabilitation due to the variable and complex nature of these injuries.[9-11] With TBI a frequent component of polytrauma, the cognitive, psychological, emotional and behavioral impairments of TBI are often the most significant deficits to address in rehabilitation due to these impairments impact on activities of daily living as well as participation in the community and workplace.[9] Long term impairments from blast injuries can continue to impact functioning of service personnel after rehabilitation which might lead to the reduction of job performance.

The literature supports a complex relationship between post-traumatic stress disorder (PTSD) and both injury severity and functional outcome. PTSD is associated with traumatic events such as a combat-related injury.[12,13] The onset of PTSD after a combat injury has been related to severity of injury with the likelihood of a PTSD diagnosis more than three times greater in service personnel with a serious or severe injury compared to those with a minor injury.[14] Yet, in a study of battle and non-battle TBI, service personnel with mild TBI were more likely to develop PTSD than those with moderate to severe TBI.[15] In addition, combat-related PTSD has been associated with impaired functional outcome including lack of employment.[16] In a group of service personnel who had been deployed, those reporting mental health concerns were more likely to leave military service within one year than those who did not report mental health concerns.[17] PTSD has also been found to confound the association between traumatic brain injury and reported physical health problems.[12] Due to the association between PTSD and injury severity as well as PTSD and functional outcome, there is potential for PTSD to play a role in the association between injury severity and career performance outcomes.

There have been studies published on career performance outcomes in non-combat related and combat related TBI,[15,18] but none that focus specifically on combat blast-related injuries. The purpose of this retrospective cohort study is to describe the career performance outcomes (disability related discharge, time to discharge, early or normal attrition, pay grade changes) after an injury from a combat-related blast and examine the relationship between the injury severity and type of discharge from service. Service member demographics and mechanism of the blast across the injury severity groups will also be examined. Because the development of PTSD is influenced by injury severity and functional outcome by PTSD, the impact of a PTSD diagnosis on the relationship between injury severity and type of service discharge will be investigated.

Material and Methods

The study sample was identified from the Combat Trauma Registry Expeditionary Medical Encounter Database (CTR EMED), formerly the Navy-Marine Corps Combat Trauma Registry, which is maintained by the Naval Health Research Center in San Diego, California. The EMED contains information abstracted from US service members' medical records completed by military providers at forward-deployed treatment facilities in the combat zone, nearest to the point of injury. This information is merged with inpatient and outpatient medical record information and tactical, personnel, operational, and deployment-related data obtained from other US Department of Defense databases.[19] This study was approved by the Institutional Review Boards at the Naval Health Research Center and San Diego State University.

Between March 2004 and December 2007, there were 4324 male service personnel who sustained a combat-related blast injury that resulted in an encounter at a Level 1 or Level 2 medical treatment facility (MTF). Female service personnel were excluded due to a low proportion of injured females. Level 1 and Level 2 MTFs are forward or battlefield area units including immediate first aid facilities (Level 1) and units providing surgical resuscitation by mobile forward mobile surgical teams (Level 2). A blast episode was defined as a documented mechanism of injury of an improvised explosive device (IED), grenade, rocket propelled grenade (RPG), landmine, aerial bomb or mortar. Of the 4324 potential study subjects, 36 died during the follow up period and 33 did not match with the Career History Archival Medical and Personnel System (CHAMPS) database which was used for the outcome variables, which left a final sample size of 4255 male service personnel.

Clinical diagnosis codes from the International Classification of Diseases, 9th Revision (ICD-9) were assigned to each injury described on the encounter form by trained clinical staff. In addition to the assigning of diagnosis codes, severity of each injury is documented with two different standardized measures of injury severity; the Abbreviated Injury Scale (AIS) and the Injury Severity Scale (ISS).[20] The AIS is an anatomically based injury severity scale which scores each injury on a scale from 1 (relatively minor) to 6 (untreatable) within six body regions (head, face, chest, abdomen, extremities and external). The ISS is derived from the AIS scores from the three most severely injured body regions with a range of 0 to 75 and is an overall measure of injury severity.[21] The ISS for each member was documented and categorized into four severity levels; mild (ISS 1-3), moderate (ISS 4-8), serious (ISS 9-15) and severe (ISS 16 and higher).[22,23]

Individual demographics (age, military rank, branch of service) and injury circumstances (type of blast, personal protective equipment usage) were ascertained for each blast episode from the CTR-EMED database. Age was reported in years and calculated by the date of injury minus the date of birth. The date of the first recorded medical encounter at the Level 1 or Level 2 facility was used if the date of injury was not available. Military rank was categorized as junior enlisted (E1-E3), midlevel enlisted (E4-E5), senior enlisted (E6-E9) and officers/warrant officers. Military branch of service was categorized as Air Force, Army, Navy and Marine Corps. The type of blast was categorized as IED, grenade, RPG, landmine, aerial bomb or mortar.

Follow up status was ascertained through the Career History Archival Medical and Personnel System (CHAMPS). CHAMPS is a database of career and medical information for Navy and Marine Corps active duty personnel from January 1, 1965 and personnel from all services from 1988 forward and is maintained by the Naval Health Research Center (NHRC).[24] Type of discharge was determined by the examination of the discharge event codes and categorized in either a disability or non-disability discharge. Disability discharge was defined as a discharge event code with the term “disability” in the verbal description of the event code and non-disability discharge were all other event codes. Only the first discharge after the injury was utilized in the analysis if the service member re-enlisted after discharge. Time to discharge was calculated as the date of discharge minus the date of injury. A current attrition status (active duty, normal attrition, early attrition) was directly ascertained from CHAMPS for each service member. Early atrittion was defined as not completing obligated service[24] and is a broader category than disability discharge including any circumstance requiring early release from service. In addition, not all disability discharge events were defined in CHAMPS as early attrition events. Pay grade changes utilized the difference between last pay grade recorded prior to injury and the first pay grade change after injury. Diagnosis of PTSD required documentation of two separate records of the diagnosis in either inpatient or outpatient visits with a visit date greater than 30 days after the date of injury. Service personnel records were updated in CHAMPS September 30, 2009 for this data set which resulted in a range of follow up time from 1 year, 9 months to 5 years, 5 months.

*Data Analysis:*

Demographics, injury characteristics and follow up status were compared between the different categories of injury severity defined by ISS. Categorical variables were compared using chi-square and means of continuous variables were compared using a one-way analysis of variance (ANOVA). When differences in the means were found, a Bonferroni comparison was used to assess differences between the means. To examine the relationship between demographics, injury characteristics and follow up status, logistic regression was utilized for the disability discharge outcome and multinomial logistic regression for attrition status with active duty as the reference category. The independent variable was injury severity defined by the four ISS categories and mild injury was the reference category. Age at time of injury (5 year intervals) and time to discharge (1 year intervals, for disability discharge only) were reported as independent variables as well as considered as covariates, along with branch of service (Marine Corps verse other), race (Caucasian verses other) and type of blast (IED verses other). Interaction between severity and PTSD was initially assessed and when found significant in both disability discharge and attrition status outcomes; the sample was stratified by PTSD diagnosis at least 30 days after injury. Univariate and multivariate regression models appropriate for each outcome were assessed in the stratified samples. All data analysis was completed using SAS version 9.2 and level of significance was set at $p<0.05$ with interaction terms significant at $p<0.10$.

Results

A total of 4255 male service personnel were identified through the EMED with an injury from a combat related blast, survived the follow up period (range of 1 year, 9 months to 5 years, 5 months) and could be matched to a CHAMPS record for outcome status. The majority of these members (n=2588; 60.8%) had mild injuries (ISS 1-3) (Table 3.1). There were 1033 (24.3%) members with moderate injuries (ISS 4-8), 380 (8.9%) with serious injuries (ISS 9-15) and 254 (6.0%) with severe injuries (ISS $\geq$16). The average age of the service personnel was 24.6 years (SD=5.34), the majority of the personnel were Caucasian and the ISS severity levels did not vary by age or race/ethnicity. The majority of the personnel were either junior or midlevel enlisted and members of the Marine Corps. IED was the most common blast mechanism with the highest proportion in the moderate ISS injury severity.

The outcomes of type of discharge (disability, non-disability), attrition status (active duty, normal attrition, early attrition) pay grade changes (no change, increase, decrease), desertions and PTSD diagnosis per ISS severity level are presented in Table 3.2. A total of 2229 members (51.9%) had a discharge code documented in CHAMPS which were categorized as either non-disability discharge (n=1565) or disability discharge (n=664). The shortest time to discharge was in the serious ISS severity level (544.6 days for serious ISS), which was significantly different from the longest time in the mild ISS severity level (661.9 days for mild ISS). The proportion of non-disability discharge and disability discharge across the ISS severity levels trend in opposite direction with the greatest percentage of non-disability discharges in the mildest severity level and the greatest percentage of disability discharge in the severe ISS severity level. When examining attrition status, 53.9% (n=2295) of the personnel were on active duty, 37.8% (n=1608) experienced normal discharge and 8.3% (n=352) had an early discharge. The patterns in proportions across the ISS severity levels continued in attrition status with the greatest proportion of active duty and normal attrition in the mild ISS severity level and greatest proportion of early attrition in the severe ISS severity level. The greatest proportion of PTSD diagnoses were in the serious ISS severity level and moderate ISS severity level with the smallest proportion in the mild ISS severity level. The percentage of service members with PTSD who were discharged with a disability was three times larger than those without PTSD (64.6% versus 19.4%; $p<0.001$). Early attrition was also more common in those with PTSD (12.5%) than without PTSD (7.1%) ($p<0.001$) (data not shown).

Logistic regression was utilized to assess the relationship between severity level and disability discharge status with age, time to discharge, race, branch of service, type of blast and PTSD diagnosis as covariates. The interaction of PTSD and injury severity was initially assessed prior to model building. In a regression model with disability discharge as the outcome and all covariates in the model, there was a significant interaction between PTSD and severity level categories (p= 0.006). The sample was then stratified by PTSD diagnosis for all further regression analyses using disability discharge as the outcome of interest.

The results of unadjusted and adjusted models for both PTSD diagnosis and no PTSD diagnosis groups are presented in Table 3.3. In the PTSD group, the odds of a disability discharge is nearly 2 times greater (OR 1.83; 95% CI 1.20, 2.80) in those with moderate severity level compared to a mild severity level. While the odds of a disability discharge increase substantially in the serious and severe ISS severity levels (OR 14.18; 95% CI 5.50, 36.56 and OR 13.35; 95% CI 4.01, 44.46, respectively), the odds of disability discharge are not different between the two highest severity levels. This is in contrast to the no PTSD diagnosis group where the odds of disability discharge increase with each increase in ISS severity level with the odds of disability discharge over 90 times greater in those with severe ISS severity level injury compared to those with a mild injury (OR 94.91; 95% CI 50.90, 176.98). A graphical representation of these odds ratios is given in Figure 3.1.

Multinomial logistic regression was utilized to assess the relationship between severity level and attrition status using active duty as the reference level for the dependent variable. The covariates were the same as the models for disability discharge except for time to discharge was not available for this outcome. The interaction of PTSD and injury severity was assessed in this model as well and a significant interaction was found (p=0.01). The sample was stratified by PTSD diagnosis and the results of both unadjusted and adjusted multinomial logistic regression with attrition status as the dependent variable is presented in Tables 3.4 and 3.5. In the PTSD diagnosis group (Table 3.4), there are similar odds of early attrition and of normal attrition in comparison to active duty status across severity levels. Severity does influence both of these attrition status categories with the odds of both early attrition and normal attrition over 2 times greater in those with a severe ISS severity level compared to a mild ISS severity level (OR 2.64; 95% CI 1.21, 5.78 and OR 2.23; 95% 1.21, 4.10, respectively). In the no PTSD diagnosis group (Table 3.5), there is no significant increase in the odds of normal attrition compared to the active duty group at any of the severity levels. However when examining early attrition, the odds of early attrition are higher at each of the increasing severity levels compared with mild injury severity (OR 2.01 for moderate ISS level, OR 3.87 serious ISS level, OR 5.49 severe ISS level). Odds ratios from the multinomial regression are summarized graphically in Figure 3.2.

Discussion

Since blasts are the primary mechanism of injury in OIF and OEF, understanding potential career performance outcomes and injury related risk factors associated with those outcomes are important in the planning of medical and follow up care of the injured service members. This current study found an increasing proportion of both disability discharge and early attrition as severity level increased. The dose-dependent relationship of injury severity to both disability discharge and early attrition was particularly evident in the absence of concomitant PTSD. Career indicators such as promotion and retention in service should continue to be considered within the overall spectrum of blast injury functional outcomes, and should be incorporated into the evaluation and refinement of rehabilitation strategies.

To our knowledge, this study was the first that examined career performance outcomes in a large cohort of service members injured by combat-related blasts. Galarneau et al did report career performance outcomes in service members with TBI, but the mechanism of injury was broader with both battle and non-battle injury types and the sample size was limited to 69 individuals. They reported similar findings as injury severity was related to discharge status with service members diagnosed with moderate or severe TBI having a higher proportion of disability discharge and early attrition than those with mild TBI. Ommaya et al also addressed military discharge after non-combat TBI with service personnel diagnosed with mild TBI at greater risk for behavioral discharges and all those with TBI at greater risk for medical discharges compared with the total military discharge population.[18] The risk for medical discharges was higher with each increasing severity category (mild, moderate, severe) of TBI.

The prevalence of PTSD is high among this blast injured population and consistent with previous literature PTSD was associated with injury severity, early attrition and disability discharge. After stratifying the sample by PTSD diagnosis, there were clear differences between the groups in the relationship between injury severity and career performance outcomes. In the group without a PTSD diagnosis, there is a dose response relationship between injury severity and both disability discharge and early attrition with the odds of an adverse outcome increasing with a greater severity level. However, while injury severity is associated with disability discharge and early attrition in the PTSD group, the pattern is less clear cut and dramatic. These differences in the influence of injury severity on outcome may be due to the additional mental health burden associated with a PTSD diagnosis. Service personnel during injury recovery without PTSD need to overcome physical impairments to achieve the highest level of function. Yet those with PTSD must overcome both physical and psychological impairments which may lessen the influence of injury severity on eventual outcome. Additionally, PTSD can occur in mild and moderate injuries which might result in mental health related disability discharge and early attrition.

Strengths of the study include a large cohort of injured male service personnel with point of injury documentation including all levels of injury severity. Follow up time was long enough for an adequate number of discharges for analysis and outpatient diagnoses were completed by medical providers rather than self-report which reduces the influence of recall bias. The criteria for PTSD diagnosis required the documentation of PTSD diagnosis at a minimum of two separate clinic visits at least 30 days after injury which reduces the likelihood of misclassification.

While the CTR-EMED has greatly improved the collection of documentation at the Level 1 and Level 2 MTF's, the coverage of all injured personnel is not complete. Missing records occur for various reasons including not visiting a MTF for care, rapid evacuation with limited time for documentation and incomplete coverage of all MTFs. Since the MTFs covered are primarily Navy-Marine Corps facilities, Army personnel are underrepresented in the study population. In addition to incomplete coverage of all injured service personnel, documentation of the medical evaluation on the encounter form may be incomplete which would reduce the accuracy of injury severity assessment.

Conclusion

With the high proportion of injuries caused by blasts in the current conflicts, long term care and career management of service personnel with blast-related injuries is currently and will continue to be a challenge. This study demonstrates that initial injury severity is associated with adverse career performance outcomes (disability discharge and early attrition) and this relationship in service personnel with PTSD is more complex than in those without a PTSD diagnosis. A model of career retention must consider the impact PTSD has on functioning beyond the influence of the injury itself.

Chapter 3 is currently being prepared for the submission for the publication of the material. Eskridge, Susan L; Macera, Caroline A; Galarneau, Michael R; Holbrook, Troy L; Woodruff, Susan I; MacGregor, Andrew J; Morton, Deborah J; Shaffer, Richard A. The dissertation author was the primary investigator and author of this material.

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Table 3.1: Demographic and injury characteristics by ISS category among male service personnel injured in a combat-related blast (N=4255), Operation Iraqi Freedom, 2004-2007

| | **Mild ISS (n=2588)** | **Moderate ISS (n=1033)** | **Serious ISS (n=380)** | **Severe ISS (n=254)** |
|---|---|---|---|---|
| | | **Mean(SD)** | | |
| **Age (years)** | 24.6 (5.4) | 24.5 (5.2) | 24.5 (4.9) | 24.8 (5.4) |
| | | **n*(%)** | | |
| **Race/Ethnicity** | | | | |
| Caucasian | 2048 (79.1) | 795 (77.0) | 300 (78.9) | 202 (79.5) |
| Hispanic | 209 (8.1) | 80 (7.7) | 37 (9.7) | 18 (7.1) |
| African-American | 152 (5.9) | 70 (6.8) | 17 (4.5) | 14 (5.5) |
| Other | 179 (6.9) | 88 (8.5) | 26 (6.8) | 20 (7.9) |
| **Pay grade[a]** | | | | |
| Junior enlisted | 1078 (41.6) | 435 (42.1) | 152 (40.0) | 91 (35.8) |
| Midlevel enlisted | 1047 (40.5) | 414 (40.1) | 147 (38.7) | 103 (40.5) |
| Senior enlisted | 230 (8.9) | 90 (8.7) | 33 (8.7) | 21 (8.3) |
| Officer/Warrant | 110 (4.2) | 36 (3.5) | 16 (4.2) | 13 (5.1) |
| **Branch of service[b]** | | | | |
| Marine | 1996 (77.1) | 769 (74.4) | 266 (70.0) | 172 (67.7) |
| Army | 457 (17.7) | 200 (19.4) | 94 (24.7) | 68 (26.8) |
| Navy | 132 (5.1) | 62 (6.0) | 19 (5.0) | 14 (5.5) |
| Air Force | 3 (0.1) | 2 (0.2) | 1 (0.3) | 0 (0.0) |
| **Type of blast[c]** | | | | |
| IED | 1975 (76.3) | 858 (83.0) | 285 (75.0) | 198 (77.9) |
| Mortar | 220 (8.5) | 67 (6.5) | 34 (8.9) | 30 (11.8) |
| RPG | 132 (5.1) | 41 (4.0) | 14 (3.7) | 9 (3.5) |
| Grenade | 123 (4.7) | 20 (1.9) | 29 (7.6) | 4 (1.6) |
| Landmine | 105 (4.1) | 36 (3.5) | 10 (2.6) | 12 (4.7) |
| Rocket | 31 (1.2) | 10 (1.0) | 8 (2.1) | 1 (0.4) |
| Aerial bomb | 2 (0.1) | 1 (0.1) | 0 (0.0) | 0 (0.0) |

a=$p \leq 0.05$ b=$p<0.01$ c=$p<0.001$; *Subject numbers for each variable do not add to total sample due to missing data;
IED=Improvised Explosive Device; RPG=Rocket Propelled Grenade;
Total ISS severity categories: Mild- ISS 1-3, Moderate- ISS 4-8, Serious- ISS 9-15, Severe -ISS $\geq$16

Table 3.2: Injury outcome follow up status by ISS category among male service personnel injured in a combat-related blast (N=4255), Operation Iraqi Freedom, 2004-2007

| | **Mild ISS (n=2615)** | **Moderate ISS (n=1038)** | **Serious ISS (n=382)** | **Severe ISS (n=256)** |
|---|---|---|---|---|
| | | **Mean(SD)** | | |
| **Days to discharge (n=2229)#** | 661.9 (368.2) | 588.1 (328.6) | 544.6 (284.3) | 611.4 (297.2) |
| | | **n (%)** | | |
| **Discharge event code (n=2229)[c]** | | | | |
| Non disability | 1125 (85.5) | 363 (66.6) | 60 (27.4) | 17 (11.4) |
| Disability | 191 (14.5) | 182 (33.4) | 159 (72.6) | 132 (88.6) |
| **Attrition status[c]** | | | | |
| Active duty | 1428 (55.2) | 560 (54.2) | 194 (51.0) | 113 (44.5) |
| Normal attrition | 1013 (39.1) | 379 (36.7) | 123 (32.4) | 93 (36.6) |
| Early attrition | 147 (5.7) | 94 (9.1) | 63 (16.6) | 48 (18.9) |
| **Pay grade changes[b]** | | | | |
| No change | 1256 (48.5) | 526 (50.9) | 211 (55.5) | 155 (61.0) |
| Initial increase | 1225 (47.3) | 470 (45.5) | 155 (40.8) | 89 (34.0) |
| Initial decrease | 107 (4.1) | 37 (3.6) | 14 (3.7) | 10 (3.9) |
| **Desertions (>1)** | 19 (0.7) | 13 (1.3) | 1 (0.3) | 0 (0.0) |
| **Diagnosis (>30 days post injury)** | | | | |
| PTSD[c] | 452 (17.5) | 296 (28.7) | 124 (32.6) | 62 (24.4) |

a=p≤0.05 b=p<0.01 c=p<0.001;
#Mild ISS severity mean different from serious ISS severity mean in Bonferroni comparison
PTSD=Post-traumatic Stress Disorder;
Total ISS severity categories: Mild- ISS 1-3, Moderate- ISS 4-8, Serious- ISS 9-15, Severe -ISS ≥16

Table 3.3: Unadjusted and adjusted odds ratios of disability discharge among male service personnel injured from a combat-related blast stratified by PTSD diagnosis >30 days after injury, (n=2229), Operation Iraqi Freedom, 2004-2007

| | PTSD Diagnosis (n=512) | | No PTSD Diagnosis (n=1717) | |
|---|---|---|---|---|
| **Independent variable** | **Unadjusted Model OR (95% CI)** | **Adjusted Model OR (95% CI)** | **Unadjusted Model OR (95% CI)** | **Adjusted Model OR (95% CI)** |
| **Age (5 year interval)** | 0.92 (0.75, 1.12) | 0.91 (0.73, 1.14) | 0.87 (0.73, 1.04) | 0.77[a] (0.63, 0.95) |
| **Mild ISS** | 1.00 | 1.00 | 1.00 | 1.00 |
| **Moderate ISS** | 1.84[c] (1.21, 2.79) | 1.83[c] (1.20, 2.80) | 3.76[c] (2.67, 5.29) | 3.76[c] (2.66, 5.31) |
| **Serious ISS** | 14.08[b] (5.49, 36.10) | 14.18[b] (5.50, 36.56) | 22.67[c] (14.98, 34.30) | 22.55[c] (14.74, 34.51) |
| **Severe ISS** | 13.22[a] (3.98, 43.91) | 13.35[a] (4.01, 44.46) | 93.11[c] (50.51, 171.64) | 94.91[c] (50.90, 176.98) |
| **Time to discharge (1yr interval)** | 0.91 (0.74, 1.11) | 1.03 (0.83, 1.28) | 0.86[a] (0.76. 0.98) | 0.99 (0.84, 1.17) |

a=p≤0.05 b=p<0.01 c=p<0.001

confounders= age, time to discharge, branch of service, race (white verses other), type of blast (IED verses other)

Total ISS severity categories: Mild- ISS 1-3, Moderate ISS 4-8, Serious ISS 9-15, Severe ISS ≥16

Table 3.4: Unadjusted and adjusted odds ratios of early attrition and normal attrition (active duty reference) among male service personnel injured from a combat-related blast with a PTSD diagnosis >30 days after injury, (n=934), Operation Iraqi Freedom, 2004-2007

| | Early attrition (n=120) | | Normal attrition (n=295) | |
|---|---|---|---|---|
| **Independent variable** | **Unadjusted Model OR (95% CI)** | **Adjusted Model OR (95% CI)** | **Unadjusted Model OR (95% CI)** | **Adjusted Model OR (95% CI)** |
| **Age (5 year interval)** | 0.54[c] (0.41, 0.71) | 0.46[c] (0.34, 0.63) | 0.55[c] (0.45, 0.66) | 0.57[c] (0.47, 0.69) |
| **Mild ISS** | 1.00 | 1.00 | 1.00 | 1.00 |
| **Moderate ISS** | 0.95 (0.58, 1.54) | 0.84 (0.51, 1.38) | 1.08 (0.78, 1.50) | 1.01 (0.72, 1.42) |
| **Serious ISS** | 1.93 (1.10, 3.40) | 1.88 (1.05, 3.36) | 1.24 (0.79, 1.95) | 1.16 (0.73, 1.85) |
| **Severe ISS** | 2.72[a] (1.28, 5.82) | 2.64[a] (1.21, 5.78) | 2.31[a] (1.28, 4.19) | 2.23[a] (1.21, 4.10) |

a=p≤0.05 c=p<0.001
confounders= age, branch of service (Marine verse other), race (white verses other), type of blast (IED verses other)
PTSD=Post-traumatic stress disorder
Total ISS severity categories: Mild- ISS 1-3, Moderate ISS 4-8, Serious ISS 9-15, Severe ISS ≥16

Table 3.5: Unadjusted and adjusted odds ratios of early attrition and normal attrition (active duty reference) among male service personnel injured from a combat-related blast without a PTSD diagnosis >30 days after injury, (n=3321), Operation Iraqi Freedom, 2004-2007

| | **Early attrition (n=268)** | | **Normal attrition (n=1313)** | |
|---|---|---|---|---|
| **Independent variable** | **Unadjusted Model OR (95% CI)** | **Adjusted Model OR (95% CI)** | **Unadjusted Model OR (95% CI)** | **Adjusted Model OR (95% CI)** |
| **Age (5 year interval)** | 0.55[c] (0.46, 0.66) | 0.55[c] (0.46, 0.66) | 0.55[c] (0.50, 0.60) | 0.59[c] (0.54, 0.64) |
| **Mild ISS** | 1.00 | 1.00 | 1.00 | 1.00 |
| **Moderate ISS** | 1.96[a] (1.40, 2.75) | 2.01[a] (1.43, 2.82) | 0.97 (0.81, 1.16) | 1.00 (0.83, 1.20) |
| **Serious ISS** | 3.67[b] (2.43, 5.53) | 3.87[b] (2.54, 5.88) | 0.84 (0.63. 1.12) | 0.94 (0.69, 1.26) |
| **Severe ISS** | 4.84[c] (3.12, 7.51) | 5.49[c] (3.48, 8.65) | 0.97 (0.70, 1.35) | 1.18 (0.83, 1.67) |

a=p≤0.05 b=p<0.01 c=p<0.001

confounders= age, branch of service (Marine verse other), race (white verses other), type of blast (IED verses other)

PTSD=Post-traumatic stress disorder

Total ISS severity categories: Mild- ISS 1-3, Moderate ISS 4-8, Serious ISS 9-15, Severe ISS ≥16

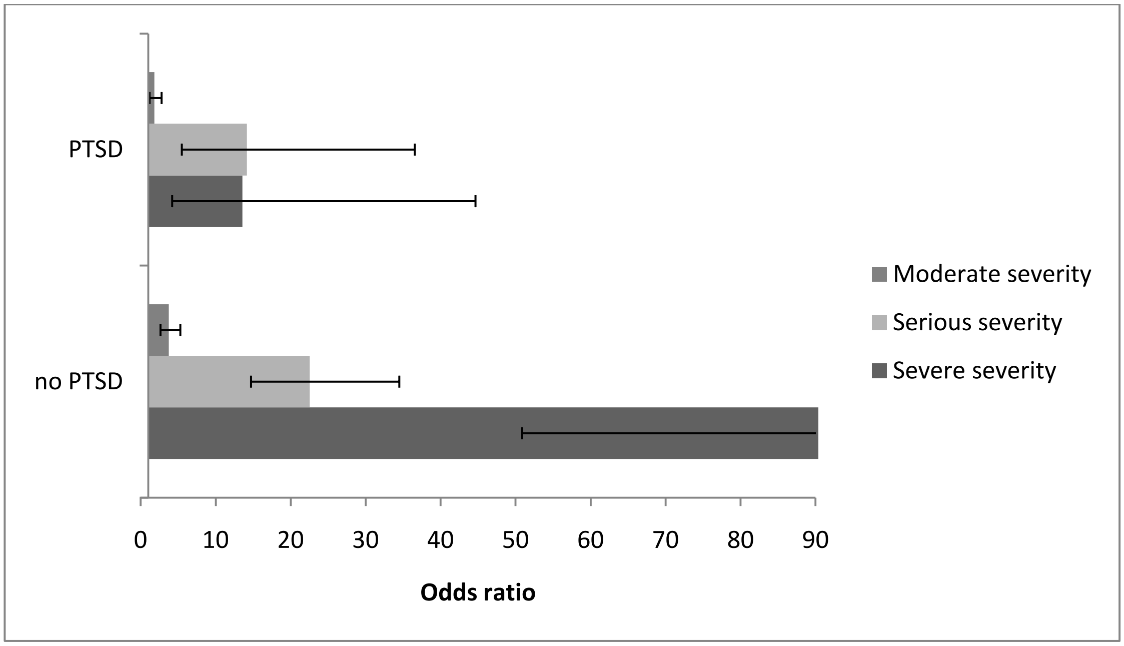


Figure 3.1 Odds of disability discharge due to severity (mild severity reference) by PTSD diagnosis

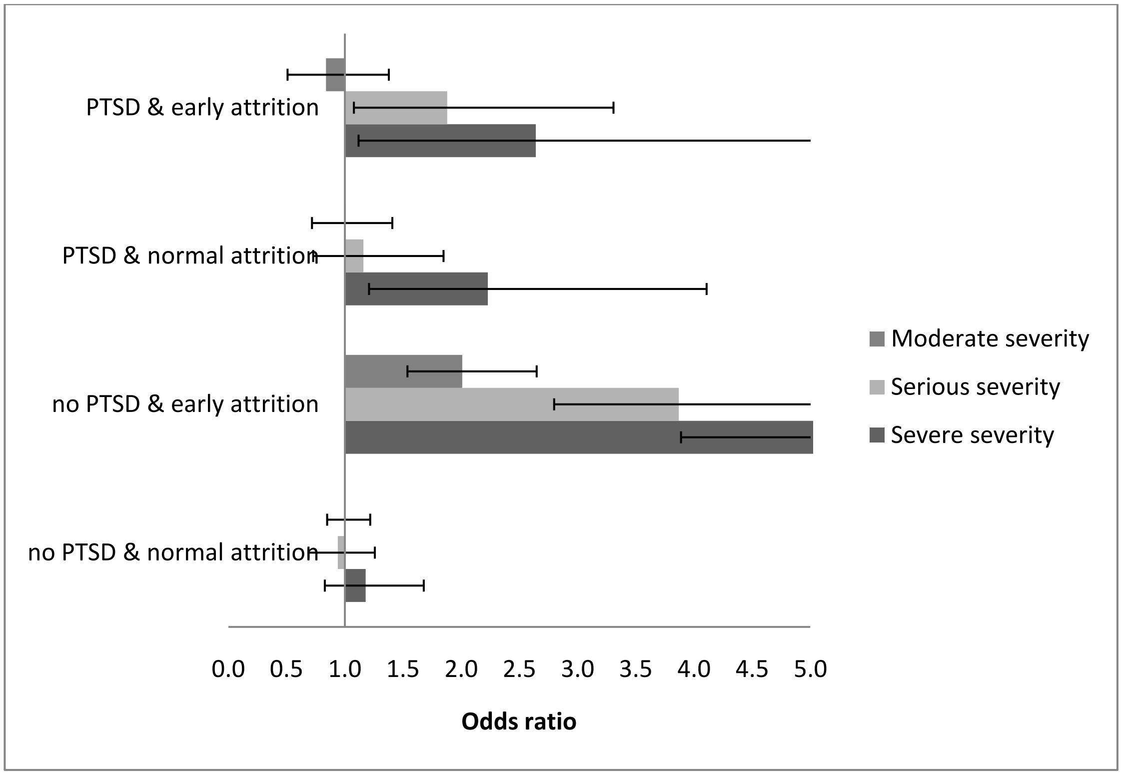


Figure 3.2 Odds of early and normal attrition (active duty reference) due to severity (mild severity reference) by PTSD diagnosis.

# CHAPTER 4

## Influence of combat blast-related mild traumatic brain injury on disability discharge

Abstract:

*Introduction*: The assessment of acute mild traumatic brain injury (TBI) symptoms after a combat-related blast could aid in diagnosis and guide follow up care and rehabilitation. The purpose of this study was to document the acute mild TBI symptoms following a combat-related blast and examine the association between acute symptoms, injury severity and disability-related discharge

*Material and Methods*: A total of 790 male service personnel experienced a mild TBI from a combat-related blast in OIF between March 2004 and December 2007 and had a documented service discharge code during follow up. Symptoms of acute TBI were ascertained from point of injury clinical medical records. The association between these symptoms, injury severity and disability-related discharge and the mediating effect of post-traumatic stress disorder (PTSD) was explored.

*Results*: Out of the 790 male service personnel, 24% had a discharge code relating to disability while 76% had a non-disability discharge. The most common acute mild TBI symptoms observed were headache (63.0%), loss of consciousness (37.0%) and tinnitus (31.0%). These symptoms, together with previous concussion, were associated with disability discharge in univariate analysis but the relationships were mitigated when controlling for overall injury severity. When the sample was stratified by PTSD diagnosis, in those without PTSD, disability discharge was associated with age (OR 0.55; 95% CI 0.31, 0.98), total injury severity (OR 1.30; 95% CI 1.19, 1.41), time to discharge (OR 1.44; 95% CI 1.04, 1.99) and post-concussive syndrome (PCS) diagnosis (OR 14.93; 95% CI 6.76, 32.97). In those diagnosed with PTSD, the odds

of these factors moved toward the null and were no longer significant, except for PCS (OR 4.64; 95% OR 2.22, 9.67). While not significant, the odds of disability discharge in the PTSD group in those with a previous concussion was 4.38 (95% CI 0.87, 22.07) compared to those without a previous concussion, and these odds were over 3 times higher in service personnel with PTSD than in those without PTSD.

*Conclusions*: Headache, loss of consciousness, tinnitus and previous concussion were associated with disability discharge, yet those relationships were mitigated by total injury severity. The predictors of disability discharge varied with the diagnosis of PTSD with no injury-related factors associated with disability discharge in service personnel diagnosed with PTSD. The impact of PTSD on the treatment and recovery from mild TBI should be explored further.

Introduction

Traumatic brain injury (TBI) has frequently been described as the "signature wound" of the wars in Iraq and Afghanistan with the majority of injuries cause by blasts or explosions.[1] Out of the 30,000 U.S. service members who have been wounded in action since March 19, 2003, approximately 9000 have been diagnosed with traumatic brain injury.[2] It has been estimated that 10%-20% of all service members deployed as a part of Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF) may have experienced a brain injury.[3,4]

Mild TBI, also known as concussion, is often unrecognized due to the severity of the other injuries occurring in a combat setting, particularly life-threatening injuries and obvious external injuries.[5] While the primary indicators for a mild TBI diagnosis are a loss of consciousness (LOC), post-traumatic amnesia (PTA) and the score on the Glasgow Coma Scale, acute clinical symptoms can include headache, nausea, vomiting, dizziness, sensitivity to light, and difficulty remembering or concentrating.[6] Due to the austere environment in which these combat blast-related mild TBI occur, it is often difficult to collect point of injury information regarding acute mild TBI symptoms. To date, the nearest assessment to the point of injury has been at the end of deployment, which can occur many months after the mild TBI.[4,7-9] Most neurocognitive sequalae are resolved within 48 hours[10] so post deployment symptoms may be influenced by other factors including experiences during deployment or post-traumatic stress disorder (PTSD).[4,7]

Long-term impairments associated with mild TBI include memory and sleep problems, headache, difficulty concentrating, and other emotional and behavioral problems. Mild TBI has also been associated with development of PTSD, which itself has been linked to poor long term functioning and quality of life. Civilian studies have highlighted the vocational outcomes of these impairments, with up to 40% of individuals diagnosed with mild TBI having not returned to work by six months post-injury.[11-13] Career performance outcomes have been examined in brain-injured military personnel as well. Service members with mild TBI were more likely to be discharged at the end of obligatory service compared to those with moderate-severe TBI. Further, all of those with moderate-severe TBI discharged were due to disability. This study was limited, however, by low sample size (mild TBI n=51) and a short follow up period (12-18 months).[14]

Acute mild TBI-related symptoms following a combat-related blast reported at the time of initial medical evaluation have not been documented. While there have been studies published on career performance outcomes in non-combat related and combat related TBI,[14,15] none focus specifically on combat blast-related TBI. The purpose of this retrospective cohort study was to document acute signs and symptoms of service personnel diagnosed with a mild TBI within 48 hours following a combat-related blast, describe the career performance outcomes (disability related discharge, pay grade changes) following a mild TBI and examine the relation between the symptoms, injury severity and disability related discharge from service. The influence of PTSD on the association between mild TBI and career performance outcomes was also explored.

Material and Methods

The study sample was identified from the Combat Trauma Registry Expeditionary Medical Encounter Database (CTR EMED), formerly the Navy-Marine Corps Combat Trauma Registry, which is maintained by the Naval Health Research Center (NHRC) in San Diego, California. The EMED contains information abstracted from US service members' medical records completed by military providers at forward-deployed treatment facilities in the combat zone, nearest to the point of injury, and is merged with inpatient and outpatient medical record information and tactical, personnel, operational, and deployment-related data obtained from other US Department of Defense databases.[16] This study was approved by the Institutional Review Boards at NHRC and San Diego State University.

Between March 2004 and December 2007, there were 1713 male service personnel who experienced a combat-related blast episode and were assigned a clinical diagnosis code consistent with a mild traumatic brain injury (mTBI) (ICD-9 codes 850.0, 850.11, 850.12, 850.5, 850.9) related to that blast episode. The study sample was restricted to males due to a low proportion of injured females. A blast episode was defined as a documented mechanism of injury of an improvised explosive device (IED), grenade, rocket propelled grenade (RPG), landmine, aerial bomb or mortar. Each subject had an encounter at a Level 1 or Level 2 medical treatment facility (MTF) within 48 hours of the injury and an encounter form entered in the CTR-

EMED. Level 1 and Level 2 MTFs are forward area units including immediate first aid facilities (Level 1) and units providing surgical resuscitation by mobile forward mobile surgical teams (Level 2). Of the 1713 injured service personnel, 1666 (97.3%) had complete records in the EMED for analysis, 1656 (96.7%) were linked to Career History Archival Medical and Personnel System (CHAMPS) and 790 (46.1%) had a documented discharge event code in CHAMPS, which constituted the final sample size for this report.

Clinical diagnosis codes from the International Classification of Diseases, 9$^{th}$ Revision (ICD-9) were assigned to each injury described on the encounter form by trained clinical staff. In addition to the assigning of diagnosis codes, severity of each injury is documented with two different standardized measures of injury severity; the Abbreviated Injury Scale (AIS) and the Injury Severity Scale (ISS).[17] The AIS is an anatomical based injury severity scale which scores each injury on a scale from 1 (relatively minor) to 6 (untreatable) within six body regions (head, face, chest, abdomen, extremities and external). The ISS is derived from the AIS scores from the three most severely injured body regions with a range of 0 to 75 and is an overall measure of injury severity[18]. The ISS for each service member was documented and categorized into four severity levels; mild (ISS 1-3), moderate (ISS 4-8), serious (ISS 9-15) and severe (ISS 16 and higher).[19,20]

All outcome variables were ascertained through CHAMPS, a database maintained at NHRC that contains career and medical information for Navy and Marine Corps active duty personnel from January 1, 1965 and personnel from all services from 1988. CHAMPS contains detailed service information such as pay grade changes, desertions, discharges and detailed medical information such as hospitalizations and outpatient visits including diagnoses made at any of these visits. The detailed service and medical events are arranged in a chronological order from the time of enlistment until the time of ending service. The discharge event status was updated in CHAMPS September 30, 2009 for this data set which resulted in a range of follow up time from 1 year, 9 months to 5 years, 5 months.

Individual demographics (age, military rank, branch of service) and injury circumstances (type of blast, personal protective equipment usage) were ascertained for each subject from the CTR-EMED database. Age was reported in years and calculated by the date of injury minus the date of birth. The date of the first recorded medical encounter at the Level 1 or Level 2 facility was used if the date of injury was not available. Military rank was categorized as junior enlisted (E1-E3), midlevel enlisted (E4-E5), senior enlisted (E6-E9) and officers/warrant officers. Military branch of service was categorized as Air Force, Army, Navy and Marine Corps. The type of blast was categorized as IED, grenade, RPG, landmine, aerial bomb or mortar. Multiple blast episodes were defined as a repeat blast episode in an individual. Usage of personal protective equipment (PPE) was defined as the documented use of any single item of PPE as well as specific usage of helmet, flak jacket, ceramic plate and eye protection.

The narrative clinician notes (SOAP note: subjective, objective, assessment, plan) on the encounter form were reviewed for 13 presenting symptoms within 48 hours of the blast. These recorded symptoms were based on the service personnel's report and the documentation of the symptoms in the clinician notes. A description of the criteria for the symptoms is provided in Table 1. A "yes" was recorded if the symptom is reported in the SOAP note and a "no" was recorded if the symptom is either denied or not documented. In addition to the symptoms, previous blast exposure and a previous combat mTBI diagnosis documented in the EMED or in the SOAP note were documented. Reliability of the data extraction was assessed with 10% of the final sample chosen randomly with a test-retest reliability of over 90% of any single recorded symptom.

Initial injury severity was reported with a total ISS score and category, an AIS head score and ICD-9 score was dichotomized into no loss of consciousness (850.0, 850.9) or loss of consciousness (850.11, 850.12, 850.5). All follow up status was ascertained from CHAMPS and only events after the injury were examined in this study. Type of discharge (disability/non-disability) was determined by the examination of the discharge event codes. Disability discharge was defined as a discharge event code with the term "disability" in the verbal description of the event code and non-disability discharge were all other event codes. Only the first discharge after the injury was utilized in the analysis if the service member re-enlisted after discharge. Time to discharge was calculated as the date of discharge minus the date of injury. Pay grade changes utilized the difference between last pay grade recorded prior to injury and the first pay grade change after injury. All medical diagnoses (ICD-9 codes) were from inpatient or outpatient visits longer than 30 days after the date of injury. Diagnoses of post-traumatic stress disorder (PTSD) and post-concussive syndrome (PCS) required documentation of two separate records of the diagnosis in either inpatient or outpatient visits.

*Data Analysis:*

Demographics, injury characteristics, initial symptoms, severity and follow up status was compared between those who were discharged with a disability event code and those who were discharged with a non-disability event code. Categorical variables were compared using chi-square and continuous variables were compared using a t-test. Since PTSD has been shown to possibly influence outcome after mild TBI,[4] the total sample was stratified by a follow up diagnosis of PTSD prior to the building of logistic regression models using disability discharge as the outcome of interest. Independent variables included total ISS score, four initial symptoms (loss of consciousness, headache, tinnitus, previous concussion) and a diagnosis of PCS. Age at time of injury (5 year intervals) and time to discharge (1 year intervals) were reported as independent variables as well as considered as covariates, along with branch of service (Marine Corps verse other), race (Caucasian verses other) and type of blast (IED verses other). All data analysis was completed using SAS version 9.2 and level of significance was set at $p \leq 0.05$ with interaction terms significant at $p \leq 0.10$.

Results

Of the 790 service personnel discharged from service after a mild traumatic brain injury from a combat related blast, 24% (190) were discharged with a disability reported in the discharge event code and the remaining 76% (600) had no report of disability in the discharge records. Depending on the date of injury, follow up time ranged from 1 year, 9 months and 5 years, 5 months. The service personnel with a disability discharge were slightly younger (22.3 years versus 23.0 years) ($p<0.05$) (Table 2). While Marines were the highest proportion in both discharge types, comparatively, there were fewer Marines and more Army personnel in the disability discharge group. Over 90% of both discharge groups reported helmet usage and of those reporting, over 90% were using a helmet at the time of injury and the usage did not differ between the groups (data not shown).

Out of the 13 symptoms recorded from the narrative clinician notes in the field encounter forms, the most common acute symptom reported in the full sample was headache (63.0%) followed by loss of consciousness (LOC) (37.0%) and tinnitus (31.0%). Four additional symptoms were reported in at least 10% of the full sample; altered mental status (14.3%), auditory symptoms (13.6%), nausea (11.8%) and dizziness (11.2%). Nearly 33% of the sample reported three or more acute symptoms (data not shown). When comparing the symptoms reported in the disability discharge group and non-disability discharge group, there was a difference in the proportion in four of the reported symptoms (Table 3). The proportion reporting a LOC and a previous combat related concussion was higher in the disability discharge group but the report of headaches and tinnitus was lower in the disability discharge group. While not all significant, the symptoms related to cognitive state (LOC, altered mental status, amnesia/memory) were reported more frequently in the disability discharge group but other concussion symptoms (headache, nausea, dizziness, vomiting, tinnitus and auditory symptoms) were reported more frequently in the non-disability discharge group. Both previous blast episode and previous combat related concussion were reported more frequently in the disability discharge group.

All measures of initially injury severity, both overall injury and specific to mild brain injury, were higher in the disability discharge group compared to the non-disability group (Table 4). Service personnel with a disability discharge had a higher total ISS (6.0 verse 3.2; $p<0.001$) and over 22% were in the serious to severe ISS categories compared to 2.3% in the non-disability group. When examining the mild TBI severity measures, the disability discharge group has a higher proportion with a head AIS of 2 (47.4% verse 35.0%; $p<0.01$) and a higher proportion of ICD-9 codes indicating LOC (46.8% verse 30.7%; $p<0.001$).

Follow up measures were compared between the disability and non-disability discharge groups (Table 4). Five different follow up diagnoses, post traumatic stress syndrome (PTSD), post concussion syndrome (PCS), dizziness, anxiety state and alcohol dependence were chosen for examination due to their higher frequency in the sample or relevance to mild TBI. The percentage of service personnel diagnosed with these conditions was significantly higher in the disability discharge group compared to the non-disability group (all $p<0.001$ except for alcohol dependence, $p<0.05$). It is important to note that the dual diagnosis of PTSD and PCS was common in the sample as a whole with 11% of the sample diagnosed with both PTSD and PCS (data not shown). There was no difference in either pay grade increases or decreased between the two disability discharge groups.

Tables 5 and 6 show the odds of discharge due to a disability by injury severity, 4 of the 13 initial symptoms (LOC, headache, tinnitus and previous concussion) and PCS diagnosis stratified by a follow up diagnosis of PTSD. Those four initial symptoms were chosen as independent variables since they were found to be significantly different between the discharge statuses in the initial univariate analysis (Table 3). As seen in the initial univariate analysis, LOC and previous concussion were predictors of disability discharge and headache and tinnitus were protective for disability discharge. While the results changed little with the addition of the confounders (age, time to discharge, race, branch of service and type of blast), the effects of these symptoms on the odds of disability discharge were mitigated when controlling for overall severity.

Despite substantial differences in odds ratios between the stratified samples, the interaction between PTSD diagnosis and previous concussion was not significant (p=0.29). In both the unadjusted and adjusted analyses, there was over a 3 fold increase in the odds of disability discharge with a previous concussion in service personnel with a diagnosis of PTSD compared to those without a PTSD diagnosis. Yet the association between previous concussion and disability discharge was significant in the univariate analysis in the sample with a PTSD diagnosis, it was no longer significant once controlling for injury severity. In addition, age, total ISS, PCS diagnosis and time to discharge provided less of a predictive influence to discharge disability in the service personnel diagnosed with PTSD compared to those without a PTSD diagnosis.

Discussion

To our knowledge, this paper is the first to describe acute symptoms (within 48 hours) of a concussion after a combat-related blast. The most common symptom reported was headache (63%) which is consistent with findings of McCrea of a sample of college athletes after a reported concussion.[21] The frequency of the symptoms in the current sample was universally lower than those reported by McCrea including headache (63% verse approximately 80%), nausea (12% verse approximately 40%) and dizziness (11% verse approximately 70%). There are numerous differences between both the subjects and study environment which could explain the discrepancy including the chaotic nature of a combat blast and the potential for additional severe injuries in a blast compared to an injury on an athletic field. Also, McCrea's study was an active surveillance of symptoms immediately after a concussion rather than information extraction from clinical notes which were written up to 48 hours after the injury.

While there was a significant difference in the proportion of service personnel reporting headaches, LOC, tinnitus and previous combat concussions between the disability and non-disability discharge groups, these differences were mitigated by total severity leaving total severity as an important injury-related factor associated with discharge disability. Total ISS was significantly higher in the disability discharge group compared to the non-disability discharge. Prior to adjustment with severity, the presence of headache or tinnitus appeared to predict non-discharge disability rather than disability discharge which may be due to the lower proportion of service personnel reporting a headache and tinnitus in the higher injury severity levels.

Since PTSD has been shown to mediate the relationship between LOC and factors such as physical health outcomes[4,7] and is related to functional outcome[22], the effect of PTSD on the relationship between the independent variables and disability discharge must be explored. Despite the lack of significance of the interaction between PTSD and multiple TBI (p=0.29), there are clear differences in the odds ratio values in the stratified samples for several of the independent variables. When examining the odds ratios of the independent variables in the fully adjusted models between the PTSD diagnosis subsample and the non-PTSD diagnosis subsample, the odds of disability discharge in relation to age, total ISS severity score, time to discharge and PCS diagnosis all move toward the null value in the PTSD subsample compared to the non-PTSD subsample. Only the relationship between PCS diagnosis and disability discharge remains significant. Previous concussion is the only independent variable for which the odds of disability discharge is higher in the subsample with PTSD compared to the subsample without PTSD. Overall, injury related factors have less of an influence on disability discharge in the sample of service personnel with PTSD than those without PTSD. This demonstrates the complex nature of the long term outcome of PTSD and suggests that the mental health burden that PTSD carries plays a larger role in eventual career performance outcomes than acute injury factors.

One benefit of the evaluation of the stratified odds ratios is to identify high risk subgroups which would have not been identified in the sample as a whole. In the subsample of service personnel with PTSD, personnel with at least one documented previous concussion have over 4 times the odds of a disability discharge than those with a single documented concussion, although this finding was not statistically significant. There is evidence that PTSD and mild TBI may have similar anatomical areas of dysfunction as well as similar neurotransmitter and neuroendocrine changes such that there is greater risk of an individual with mTBI to develop PTSD.[23] In addition, the cumulative effect of concussion has been well documented in repeat concussions occurring in sports-related injuries which include decreases in cognitive performance in jockeys[24] and mild cognitive impairment and depression in retired football players. [25,26] If cognitive abilities are hampered by repeat concussions, the effectiveness of treatment for PTSD could be diminished leading to an adverse outcome.[27]

There are limitations to the current study. Injured service personnel must be evaluated medically within 48 hours of the injury and have documentation of the injury forwarded to the CTR-EMED to be included in the study. Since the delay between the injury and the documentation of symptoms could be as long as 48 hours, symptoms could have subsided and not been reported. While reliability assessment of data extraction of the symptoms was completed, it depended on clinical notes written in forward medical treatment facilities without standardization of the information documented. A symptom was considered not present if not documented in the clinical notes which could lead to a lower overall proportion of some symptoms. In addition, there was a relatively small sample size for the PTSD group when the total sample was stratified which resulted in wide confidence intervals especially for the previous concussion variable.

The primary strength of this study is the point of injury documentation for the mild TBI diagnosis and acute mild TBI symptoms rather than from post-deployment surveys which reduces the possibility of recall bias. Follow up diagnoses of PTSD and PCS were made by medical providers rather than by self-report and required 2 separate documented diagnoses of the conditions to be considered positive for the conditions in this study.

Conclusion

The most common acute mild TBI symptoms documented after a combat-related blast were headache, tinnitus and LOC, followed by altered mental status and auditory symptoms. These symptoms are similar to those found in sports-related mild TBI but with a smaller proportion of individuals reporting symptoms. Overall injury severity was a more important predictor of disability discharge than any of the acute symptoms. It is possible that the significance of these symptoms diminishes during the long follow up period to discharge and could influence a more immediate outcome such as a diagnosis of PTSD or PCS. With the exception of previous concussion, the independent variables examined have less of an influence on disability discharge in service personnel with PTSD compared to those without PTSD. The impact of PTSD on the recovery from mild TBI and the treatment of both conditions should be further explored to maximize functional outcome in individuals with mild TBI.

Chapter 4 is currently being prepared for the submission for the publication of the material. Eskridge, Susan L; Macera, Caroline A; Galarneau, Michael R; Woodruff, Susan I; Holbrook, Troy L; MacGregor, Andrew J; Shaffer, Richard A; Morton, Deborah J. The dissertation author was the primary investigator and author of this material.

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Table 4.1: Definitions of symptoms recorded from clinician's documentation on EMED field encounter forms

| Symptom | Criteria for symptom |
|---|---|
| **Loss of consciousness** | Loss of consciousness including unsure |
| **Altered mental status** | Disruption in orientation; confused, dazed, lethargic |
| **Amnesia/Memory** | Loss of memory surrounding event, deficit detected at exam |
| **Headache** | Headache, any pain level |
| **Nausea** | Nausea, queasy feeling |
| **Vomiting** | Vomiting, emesis, dry heaves |
| **Dizzy** | Dizziness, vertigo, room spinning |
| **Lightheaded** | Lightheaded, woozy |
| **Balance deficit** | Unstable gait, sway on Romberg, ataxia, loss of stability |
| **Auditory** | Change in hearing; ear numbness, pressure; NOT tinnitus/pain |
| **Tinnitus** | Ringing/buzzing in one or both ears |
| **Visual deficit** | Visual loss, blurry not due to foreign body; light sensitivity |
| **Other symptoms** | Non-specific: shook up, fatigue, hung over, bell rung, feeling sick |
| **No documented symptoms** | No mTBI related symptoms documented in Level I or II SOAP |
| **Previous blast** | Documented in SOAP or EMED |
| **Previous combat concussion** | Combat-related, documented in SOAP or EMED |

SOAP= Clinician's documentation- Subjective, Objective, Assessment, Plan;
EMED= Expeditionary Medical Encounter Database

Table 4.2: Demographic and injury characteristics by discharge category among male service personnel diagnosed with mild traumatic brain injury due to combat-related blast (N=790), Operation Iraqi Freedom, 2004-2007

| | **Disability discharge (n=190)** | | **Non-disability discharge (n=600)** | |
|---|---|---|---|---|
| | Mean(SD) | | Mean(SD) | |
| **Age (years)**[a] | 22.2(3.0) | | 23.0(3.8) | |
| | **n***| **%** | **n*** | **%** |
| **Race/Ethnicity** | | | | |
| Caucasian | 152 | 80.0 | 490 | 81.7 |
| African-American | 13 | 6.8 | 34 | 5.7 |
| Hispanic | 8 | 4.2 | 34 | 5.7 |
| Other | 17 | 8.9 | 42 | 7.0 |
| **Pay grade** | | | | |
| Junior enlisted | 328 | 61.6 | 328 | 54.7 |
| Midlevel enlisted | 225 | 30.5 | 225 | 37.5 |
| Senior enlisted | 10 | 2.6 | 10 | 1.7 |
| Officer/Warrant | 0 | 0 | 8 | 1.3 |
| **Branch of service**[b] | | | | |
| Marine | 522 | 79.5 | 151 | 87.0 |
| Navy | 30 | 4.7 | 9 | 5.0 |
| Army | 30 | 15.8 | 46 | 7.7 |
| Air Force | 0 | 0 | 2 | 0.3 |
| **Type of blast** | | | | |
| IED | 173 | 91.0 | 525 | 87.5 |
| Landmine | 4 | 2.1 | 32 | 5.3 |
| Mortar | 5 | 2.6 | 18 | 3.0 |
| RPG | 5 | 2.6 | 14 | 2.3 |
| Rocket | 2 | 1.0 | 6 | 1.0 |
| Grenade | 1 | 0.5 | 5 | 0.8 |

a=$p \leq 0.05$, b=$p \leq 0.01$
*Subject numbers for each variable do not add to total sample due to missing data;
IED=Improvised Explosive Device; RPG=Rocket Propelled Grenade

Table 4.3: Initial symptoms by discharge category among male service personnel diagnosed with mild traumatic brain injury due to combat-related blast (N=790), Operation Iraqi Freedom, 2004-2007

| | Discharge status | |
|---|---|---|
| **Symptom** | **Disability (n=190) n (%)** | **Non-disability (n=600) n (%)** |
| **Loss of consciousness** | 90 (47.4) | 202 (33.7)[b] |
| **Altered mental status** | 28 (14.7) | 79 (13.2) |
| **Amnesia/Memory** | 16 (8.4) | 34 (5.7) |
| **Headache** | 92 (48.0) | 406 (67.0)[c] |
| **Nausea** | 17 (8.9) | 68 (11.3) |
| **Dizzy** | 19 (10.0) | 74 (12.3) |
| **Balance deficit** | 10 (5.3) | 16 (2.7) |
| **Vomiting** | 5 (2.6) | 21 (3.5) |
| **Lightheaded** | 6 (3.2) | 17 (2.8) |
| **Tinnitus** | 43 (22.6) | 202 (33.7)[b] |
| **Auditory** | 26 (13.7) | 94 (15.7) |
| **Visual deficit** | 13 (6.8) | 34 (5.7) |
| **Other symptoms** | 11 (5.8) | 20 (3.3) |
| **3 or more of above symptoms** | 59 (31.0) | 201 (33.5) |
| **No documented symptoms** | 11 (5.8) | 32 (5.3) |
| **Previous blast** | 32 (16.8) | 76 (12.7) |
| **Previous combat concussion** | 21 (11.0) | 38 (6.3)[a] |

a=$p \leq 0.05$, b=$p \leq 0.01$, c=$p \leq 0.001$

Table 4.4: Injury outcome: Initial severity and follow up status by discharge category among male service personnel diagnosed with mild traumatic brain injury due to combat-related blast (N=790), Operation Iraqi Freedom, 2004-2007

| | **Disability discharge n=190** | | **Non-disability discharge n=600** | |
|---|---|---|---|---|
| **Initial status** | | | | |
| | Mean(SD) | | Mean(SD) | |
| **Total ISS[c]** | 6.0 (6.0) | | 3.2 (2.3) | |
| | **n[*]** | **%** | **n[*]** | **%** |
| **Total ISS severity categories[c]** | | | | |
| Mild (1-3) | 79 | 41.6 | 379 | 63.2 |
| Moderate (4-8) | 69 | 36.3 | 207 | 34.5 |
| Serious (9-15) | 26 | 13.7 | 11 | 1.8 |
| Severe (>16) | 16 | 8.4 | 3 | 0.5 |
| **Head AIS= 1[b]** | 100 | 52.6 | 390 | 65.0 |
| **Head AIS= 2** | 90 | 47.4 | 210 | 35.0 |
| **LOC diagnosis (ICD-9)[c]** | 89 | 46.8 | 184 | 30.7 |
| **Follow up status** | | | | |
| | Mean(SD) | | Mean(SD) | |
| **Days to discharge[c]** | 675.0 (250.6) | | 591.8 (344.2) | |
| | **n[*]** | **%** | **n[*]** | **%** |
| **Pay grade changes** | | | | |
| Initial increase | 92 | 48.4 | 263 | 43.8 |
| Initial decrease | 5 | 2.6 | 38 | 6.3 |
| **Diagnoses >30 days post injury** | | | | |
| Postconcussion syndrome[c] | 106 | 55.8 | 63 | 10.5 |
| Post traumatic stress disorder[c] | 90 | 47.4 | 38 | 6.3 |
| Dizziness[c] | 36 | 18.9 | 17 | 2.8 |
| Anxiety state[c] | 29 | 15.3 | 31 | 5.2 |
| Alcohol dependence[a] | 18 | 9.5 | 29 | 4.8 |

a=$p \leq 0.05$, b=$p \leq 0.01$, c=$p \leq 0.001$

Table 4.5: Unadjusted and adjusted odds ratios of disability discharge among male service personnel diagnosed with mild traumatic brain injury due to combat-related blast with a PTSD diagnosis >30 days after injury (n=165), Operation Iraqi Freedom, 2004-2007

| Independent variable | Unadjusted OR (95% CI) | Adjusted by Confounders OR (95% CI) | Adjusted by Confounders + total ISS OR (95% CI) | Multivariate OR (95% CI) |
|---|---|---|---|---|
| **Age (5 year interval)** | 1.05 (0.67, 1.64) | 1.08 (0.68, 1.70) | 1.11 (0.70, 1.75) | 1.04 (0.62, 1.75) |
| **Total ISS** | 1.13[a] (1.00, 1.28) | 1.14[a] (1.00, 1.29) | ------- | 1.11 (0.96, 1.28) |
| **Report LOC** | 1.84 (0.95, 3.55) | 1.85 (0.95, 3.61) | 1.47 (0.71, 3.04) | 1.21 (0.54, 2.72) |
| **Report headache** | 0.47[a] (0.24, 0.90) | 0.44[a] (0.22, 0.87) | 0.54 (0.26, 1.12) | 0.49 (0.21, 1.14) |
| **Report tinnitus** | 0.59 (0.30, 1.19) | 0.59 (0.29, 1.19) | 0.62 (0.30, 1.28) | 0.76 (0.33, 1.75) |
| **Report previous concussion** | 4.58[a] (1.00, 21.00) | 4.62[a] (1.00, 21.34) | 4.57 (0.98, 21.30) | 4.38 (0.87, 22.07) |
| **PCS diagnosis** | 3.76[c] (1.94, 7.28) | 3.85[c] (1.96, 7.56) | 4.56[c] (2.25, 9.27) | 4.64[c] (2.22, 9.67) |
| **Time to discharge (1yr interval)** | 0.92 (0.62, 1.36) | 0.91 (0.61, 1.35) | 0.93 (0.62, 1.39) | 1.03 (0.65, 1.57) |

a=p≤0.05, b=p≤0.01, c=p≤0.001; PCS=postconcussion syndrome
confounders= age, time to discharge, branch of service (Marine verse other), race (white verses other), type of blast (IED verses other)

Table 4.6: Unadjusted and adjusted odds ratios of disability discharge among male service personnel diagnosed with mild traumatic brain injury due to combat-related blast without a PTSD diagnosis >30 days after injury (n=625), Operation Iraqi Freedom, 2004-2007

| Independent variable | Unadjusted OR (95% CI) | Adjusted by Confounders OR (95% CI) | Adjusted by Confounders + total ISS OR (95% CI) | Multivariate OR (95% CI) |
|---|---|---|---|---|
| **Age (5 year interval)** | 0.52[b] (0.32, 0.85) | 0.51[b] (0.32, 0.83) | 0.51[a] (0.30, 0.88) | 0.55[a] (0.31, 0.98) |
| **Total ISS** | 1.30[c] (1.21, 1.40) | 1.31[c] (1.21, 1.42) | ---------- | 1.30[c] (1.19, 1.41) |
| **Report LOC** | 1.90[b] (1.21, 2.99) | 1.81[a] (1.13, 2.90) | 1.27 (0.75, 2.16) | 1.04 (0.59, 1.84) |
| **Report headache** | 0.38[c] (0.24, 0.60) | 0.37[c] (0.23, 0.60) | 0.74 (0.43, 1.28) | 0.64 (0.35, 1.18) |
| **Report tinnitus** | 0.54[a] (0.31, 0.92) | 0.58 (0.34, 1.01) | 0.83 (0.47, 1.49) | 1.08 (0.57, 2.04) |
| **Report previous concussion** | 1.37 (0.62, 3.06) | 1.54 (0.68, 3.50) | 1.79 (0.77, 4.19) | 1.44 (0.56, 3.66) |
| **PCS diagnosis** | 11.32[c] (5.69, 22.52) | 11.31[c] (5.53, 23.12) | 14.61[c] (6.76, 31.60) | 14.93[c] (6.76, 32.97) |
| **Time to discharge (1yr interval)** | 1.20 (0.94, 1.53) | 1.17 (0.90, 1.51) | 1.34[a] (1.00, 1.79) | 1.44[a] (1.04, 1.99) |

a=p≤0.05 b=p≤0.01 c=p≤0.001; PCS=postconcussion syndrome
confounders= age, time to discharge, branch of service(Marine verse other), race (white verses other), type of blast (IED verses other)

# CHAPTER 5

## Discussion

## Discussion

With combat-related blasts causing a higher proportion of injuries in Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF) than any other widespread conflict[1] and the changing injury profile of service personnel injured in combat,[2,3] an investigation into both the types and outcome of these injuries is important to guide clinicians involved in both acute care and rehabilitation. The goals of this dissertation were to: 1) describe the nature, body region and severity of injuries sustained in a combat-related blast, 2) describe the career performance outcomes of service personnel after a combat-related blast and examine the association of injury severity and these outcomes and 3) describe the acute signs and symptoms of blast-related mild traumatic brain injury (TBI) and examine the association of these symptoms to disability-related discharge.

## Summary of findings

### *Goal #1: The nature, body region and severity of combat-related blast injuries*

In the 4623 blast episodes examined, mild TBI was the most frequent single injury type (10.8%) and with all extremity injuries combined, the extremities was the area most commonly injured. Surface wounds of the extremities comprised 27.6% of all injuries. In addition, the injuries ranged from mild to severe with injuries across multiple body regions and organ systems.

*Goal #2: Career performance outcomes after a blast injury and the association with severity*

When examining service discharge in 4255 personnel injured in a combat-related blast, 37.8% experienced a normal attrition and 8.3% early attrition. In service personnel with a discharge code (n=2229), 29.8% had a disability-related discharge. Both early attrition and disability discharge proportions were higher in those with PTSD. In those without a PTSD diagnosis, there was a dose response relationship between injury severity and both disability discharge and early attrition. In those with a PTSD diagnosis, injury severity was associated with these adverse outcomes but the relationship was more complex. For example, in the PTSD group, the odds of a disability discharge is nearly 2 times greater (OR 1.83; 95% CI 1.20, 2.80) in those with moderate severity level compared to a mild severity level. While the odds of a disability discharge increase substantially in the serious and severe ISS severity levels (OR 14.18; 95% CI 5.50, 36.56 and OR 13.35; 95% CI 4.01, 44.46, respectively), the odds of disability discharge are not different between the two highest severity levels.

In the PTSD diagnosis group, there are similar odds of early attrition and of normal attrition in comparison to active duty status across severity levels. Severity does influence both of these attrition status categories with the odds of both early attrition and normal attrition over 2 times greater in those with a severe ISS severity level compared to a mild ISS severity level (OR 2.64; 95% CI 1.21, 5.78 and OR 2.23; 95% 1.21, 4.10, respectively). In addition, there was a significant interaction between injury severity and PTSD when examining either outcome. PTSD could be considered an effect modifier which lessens the influence that injury severity has on adverse career performance outcomes.

*Goal #3: Acute symptoms of blast-related mild TBI and disability discharge after mild TBI*

In the 790 service personnel diagnosed with a mild TBI after a combat-related blast, 190 (24%) experienced a disability discharge and 600 (76%) had a discharge that wasn't due to a disability. In the sample as a whole, headache (63.0%), loss of consciousness (37.0%) and tinnitus (31.0%) were the most common acute symptoms documented. These symptoms, in addition to a documented previous concussion, were associated with disability discharge in the univariate analysis but the relationships were mitigated when controlling for overall injury severity. In service personnel without PTSD, disability discharge was associated with age, total injury severity, time to discharge and post-concussive syndrome, while disability discharge was only associated with post-concussive syndrome in those with a PTSD diagnosis. While not significant, the odds of disability discharge in service personnel with a PTSD diagnosis and a concurrent documented previous concussion were over 3 times higher than in those without a PTSD diagnosis and a concurrent previous concussion.

<u>Implications of findings</u>

*Acute care*

While the types and percentages of certain injuries after exposure to a combat-related blast will most likely be familiar to clinicians treating these injuries daily, the systematic organization of the trauma ICD-9 codes into distinct injury nature and location categories could assist in planning the logistics of both staff and medical supplies and equipment in the frontline medical treatment facilities (MTF). It is important to note that personnel with battle and non-battle injuries as well as illnesses are evaluated and treated at these MTFs. While combat-related blast injuries are a high proportion of battle injuries, they aren't the only injury or illness seen at these facilities. Additional studies into the scope of injuries and illnesses treated at these frontline MTFs could further aid in planning of staff and supplies.

*Acute mild TBI symptoms*

The acute mild TBI symptoms described in this population of service personnel injured in blasts were similar to symptoms described in a population of collegiate athletes including headache and altered mental status. Yet, the proportions of symptoms reported were much lower in the population of injured service personnel than those injured in sports-related activities.[4] These differences could be partially explained by the active surveillance of the athletes, the circumstances surrounding the injury (battlefield versus the sports field) and the treatment of severe combat injuries which would take precedence over the question of mild TBI symptoms.

When examining the association of these symptoms to a disability-related service discharge, headache, loss of consciousness and tinnitus were all related to a disability discharge in the univariate analysis. These associations were no longer present once an adjustment for severity was made in the multivariate models. While these symptoms weren't predictive of disability discharge in this population, they might be useful in predicting more immediate outcomes such as follow up symptoms or a diagnosis of post-concussive syndrome or post-traumatic stress disorder.

In the univariate analysis, the symptoms of headache and tinnitus appeared to be protective of a disability discharge with an odds ratio below 1. While not significant, other symptoms such as nausea, dizziness and vomiting also had higher proportions in the non-disability discharge group than the disability discharge group. Since these associations were mitigated by injury severity, these symptoms may not have been documented in those with serious injuries. In addition, since all of the service personnel experienced a blast, it is unable to determine whether these symptoms are specific to mild TBI or are due to the blast itself.

An active surveillance of acute TBI symptoms in all service personnel exposed to blasts would provide a more accurate assessment of the types and proportions of acute TBI symptoms as well as differentiate symptoms which are specific to a mild TBI versus blast exposure. Yet, this type of active surveillance would be impractical in the chaotic battlefield setting and not a priority in personnel with severe injuries. A checklist of symptoms as part of documentation form may encourage a more systematic method to record these symptoms. The usage and documentation of the Military Acute Concussion Evaluation (MACE) could be a more objective method of recording acute functioning after a TBI. The MACE was released for usage in August 2006 so the evaluation was not utilized in as a variable in this dissertation due to the low frequency of documentation in this population.

*Rehabilitation from injuries*

The results of the second study with the population of service personnel who experienced an injury due to a blast show that the odds of an adverse outcome increases as severity level increases in those personnel without post-traumatic stress disorder (PTSD). Yet, in service personnel with PTSD, the relationship between injury severity and adverse outcome is less straight forward or predictable. A similar difference is observed in the third study with the population with mild TBI. Demographic and injury characteristics that were associated with discharge disability in personnel without PTSD were no longer associated with disability discharge in those with PTSD except for post-concussive syndrome (PCS).

These findings demonstrate the complex nature of recovery from injury when service personnel are coping with the impairments of PTSD while recovering from a physical injury. Service personnel without PTSD must overcome physical injury for successful rehabilitation. Yet, when personnel are faced with PTSD, they must overcome the additional mental health impairments as well as physical impairments to return to a prior level of functioning and be integrated back into the workplace. Both rehabilitation and mental health professionals should understand the potential influence PTSD impairments can have on recovery from an injury.

*PTSD as an effect modifier*

Hoge et al. demonstrated that PTSD plays a role in the association between a loss of consciousness (LOC) event during combat and chronic symptoms after deployment.[5] After controlling for PTSD, only the association between LOC and headache remained significant. With these findings, PTSD should be considered as a possible influence on the relationship between injury-related variables and outcomes in service personnel exposed to combat. A variable is defined as a confounder is it is associated with both the exposure and the outcome in question yet the variable cannot be in the causal pathway between the exposure and outcome. While not consistent, current literature suggests that the odds of PTSD increase with increasing injury severity and that PTSD has an adverse effect on functional outcome. The question is whether PTSD is in the causal pathway between injury severity and career performance outcomes. In this dataset, the diagnosis of PTSD was documented after the injury and before discharge from service yet there is lack of confirmation of an absent PTSD diagnosis prior to injury. Regardless, PTSD had a significant statistical interaction with injury severity on career performance outcomes in this dataset and has the potential to be an effect modifier between numerous injury variables, especially injury severity and career performance outcomes. Further studies are needed to investigate the role PTSD has on recovery of injury and subsequent integration back into the workplace.

While neither the interaction term nor the odds ratios reached a level of significance, in service personnel with a PTSD diagnosis and at least two documented concussions, the odds of discharge disability were over 3 times greater than in those without a PTSD diagnosis and at least two concussions. While the effect of covariates such as total injury severity and post-concussive syndrome on disability discharge seemed to lessen in personnel with PTSD, the presence of a previous concussion appeared to have a synergistic effect with PTSD on disability discharge. Further study on the role of multiple concussions play in relation to PTSD and functional outcome are needed to determine whether the difference in odds ratios between the PTSD diagnosis groups is a spurious result or a true finding.

*Personal Protective Equipment (PPE)*

The increased effectiveness of body armor used in combat has played a role in the changing injury profile observed in the conflicts in Iraq and Afghanistan with a higher proportion of survivable injuries and a reduction in thoracic injuries from 13% of injuries in Vietnam to 6% of injuries in OIF and OEF.[1] It was encouraging to note the high percentage of PPE usage in these data with over 90% compliance of helmets and thoracic armor and 80% compliance in eye protection. The challenge for PPE designers is now the high percentage of mild TBI and of surface wounds of the extremities which may be more difficult to protect.

The mechanism of mild TBI during a blast must be investigated further to aid in the design of head gear. While the number of penetrating injuries to the head has been reduced, blunt trauma could still occur either due to flying debris or from the service member being thrown from the blast. The role of the blast mechanism of pressure changes play in the etiology of mild TBI needs clarification including whether the pressure changes have a direct effect on the brain or the pressure changes are propagated through the body from other areas.[6,7] Without understanding the effects of these mechanisms of injury to the brain, developing further protective methods could prove difficult. The challenge in protecting the extremities is finding a material which is flexible, lightweight and won't contribute to overheating while protecting the limbs from flying shrapnel.

Strengths and limitations

*CTR-EMED*

The Combat Trauma Registry Expeditionary Medical Encounter Database (CTR-EMED) is a comprehensive database of frontline injury data which is combined with documentation from higher levels of care inside and outside the Continental United States.[8] The CTR-EMED is a unique database including frontline injury data including service personnel with mild injuries who were returned to duty, given light duty or admitted to the medical treatment facility (MTF). A unique aspect to these studies is the use of frontline injury data including service personnel with mild injuries who are not transferred to a higher level of care. Since only 31% of injured personnel in blast episodes were transferred to a higher level of care, 69% of the sample would be absent if data collection began with the higher levels of care.

CTR-EMED is subject to missing information from whole episodes to incomplete documentation such that the population in these studies may not be representative of all service personnel injured. For example, there isn't complete coverage of all MTFs in Iraq and those covered are Naval-Marine Corp facilities, which caused an underrepresentation of Army personnel. Injury information on service personnel who were killed in action or later died from their injuries were not included in this analysis due to the lack of autopsy data. In addition to the lack of information on the most severely injured, service personnel who have a very minor injury that requires no treatment or are treated in field would not have an encounter form for entry into the CTR-EMED. Incomplete documentation can occur if the service member was transferred rapidly to a higher level of care, as well as basic lack of documentation.

*Abbreviated Injury Scale/Injury Severity Scale*

The Abbreviated Injury Scale (AIS) was originally designed to compare injuries after automobile accidents, has been revised multiple times since its development and is currently has widespread usage in trauma research.[9,10] The AIS categorized injuries into anatomical locations and severity from 1 or minor injury to 6, which is considered to be a fatal injury. One limitation of the AIS is that the severity scoring not related to rehabilitation potential but survivability of injury such that a score of a 5 in different anatomical locations may have a different eventual outcome.[10] While an increasing score indicates increasing severity, the increase in severity between 1 and 2 is less than the increase between 3 and 4 so the AIS is not an interval scale.

The Injury Severity Scale (ISS) combines the AIS scores for the different anatomical levels to provide a summary measure of the severity of injuries from a single event.[9] The highest AIS score in the anatomical locations with the highest severity levels are squared and added together for the ISS score with a range of values between 1 and 75. Although mean ISS scores are reported and the ISS scores in study

3 are treated as a continuous variable, since the AIS is not an interval scale, it is more appropriate to categorized ISS into the four severity levels. ISS was used in study 3 in regression analysis as a continuous variable due to its use as a covariate rather than independent variable as well as concerns with sample size in the stratified sample.

## Conclusions

"There is no other wounding agent so effective at inflicting such a diverse constellation of injuries."[6] This series of studies demonstrate the impact of combat-related blast injuries on initial injuries as well as eventual career performance outcomes of the injured personnel. The results of these studies can be used to plan initial care and subsequent treatment of injured personnel, help in the design of personal protective equipment and in understanding the effects of PTSD on recovery from injury.

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