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Prevalence and Epidemiology of Combat Blast Injuries from the Military Cohort 2001-2014

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PREFACE

Quality Enhancement Research Initiative's (QUERI) Evidence-based Synthesis Program (ESP) was established to provide timely and accurate syntheses of targeted healthcare topics of particular importance to Veterans Affairs (VA) clinicians, managers and policymakers as they work to improve the health and healthcare of Veterans. The ESP disseminates these reports throughout the VA, and some evidence syntheses inform the clinical guidelines of large professional organizations.

QUERI provides funding for four ESP Centers and each Center has an active university affiliation. The ESP Centers generate evidence syntheses on important clinical practice topics, and these reports help:

- develop clinical policies informed by evidence;
- guide the implementation of effective services to improve patient outcomes and to support VA clinical practice guidelines and performance measures; and
- set the direction for future research to address gaps in clinical knowledge.

In 2009, the ESP Coordinating Center was created to expand the capacity of HSR&D Central Office and the four ESP sites by developing and maintaining program processes. In addition, the Center established a Steering Committee comprised of QUERI field-based investigators, VA Patient Care Services, Office of Quality and Performance, and Veterans Integrated Service Networks (VISN) Clinical Management Officers. The Steering Committee provides program oversight, guides strategic planning, coordinates dissemination activities, and develops collaborations with VA leadership to identify new ESP topics of importance to Veterans and the VA healthcare system.

Comments on this evidence report are welcome and can be sent to Nicole Floyd, ESP Coordinating Center Program Manager, at Nicole.Floyd@va.gov.

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EXECUTIVE SUMMARY

INTRODUCTION

Combat blast injuries are typically categorized by the mechanism of injury. Primary blast injuries result from the over-pressurization wave and typically affect gas-filled body structures (*eg*, lungs, gastrointestinal tract, middle ear) resulting in injuries such as blast lung, tympanic membrane rupture, abdominal hemorrhage, and concussion. Secondary blast injuries result from flying debris propelled by the blast wind and may affect any body part. Blunt force or penetrating injuries are possible. Tertiary blast injuries occur when the body is accelerated by the blast wind or pressure gradients. Any body part may be affected and typical injuries include fracture and traumatic amputation, closed and open brain injuries, and crush injuries. Quaternary blast injuries are due to other products of the explosion (*eg*, heat, light) and exposure to toxins and gases. Any body part may be affected and injuries include burns, blindness, and respiratory problems from inhaled toxic gases. Quinary blast injuries include illnesses, injuries, and diseases resulting from post-explosion environmental contaminants (*eg*, bacteria, radiation).

Despite recognition of greater use of improvised and other explosive devices in the Afghanistan and Iraq War counter-insurgency operations relative to prior conflicts, the scientific literature regarding the incidence and prevalence of explosive device-induced injuries is limited. Additionally, the consequences of experiencing a traumatic brain injury (TBI) related to blast exposure versus a TBI due to other mechanisms of injury may be different. Accurate assessment of the incidence and prevalence of blast- and non-blast-related injuries as well as their long-term outcomes is a critical first step in injury prevention, treatment, and health system resource management. The purpose of this report is to systematically review the literature on 1) incidence and prevalence of combat blast injuries sustained during Operation Enduring Freedom (OEF), Operation Iraqi Freedom (OIF), and Operation New Dawn (OND) 2001 through 2014 and 2) the outcomes (*eg*, pain, vision loss, cognitive function, quality of life) following blast versus non-blast TBI.

We developed the following Key Questions with input from stakeholders and Technical Expert Panel (TEP) members:

Key Question #1: What is the incidence of combat blast injuries associated with OEF, OIF, and OND as reported in the literature or in published reports from Department of Defense (DoD) and VA databases during the period 2001-2014?

> **Key Question #1a:** What is the incidence by blast characteristics (*ie*, primary, secondary, tertiary, quaternary, and quinary), injury site, and injury outcome?

Key Question #2: What is the prevalence of combat blast injuries associated with OEF, OIF, and OND as reported in the literature or in published reports from Department of Defense (DoD) and VA databases during the period 2001-2014?

> **Key Question #2a:** What is the prevalence of blast injury by blast characteristics, injury site, and injury outcome?

Key Question #3: What are the short-term (up to 30 days), mid-term (30 days to one year) and long-term (greater than one year) injury outcomes (*ie,* pain, burns, limb loss, vision loss, hearing loss, vestibular dysfunction, mental health/PTSD, cognitive function, quality of life, functional status/employment, other-organ system-specific) among US military personnel (2001-2014) who have sustained a blast-related TBI versus a non-blast TBI or a combined blast/non-blast TBI?

> **Key Question #3a:** What are the short-term (up to 30 days), mid-term (30 days to one year) and long-term (greater than one year) injury outcomes among US military personnel (2001-2014) who have sustained a blast-related TBI according to blast characteristics?

METHODS

Data Sources and Searches

We searched MEDLINE (Ovid) for articles published in English from 2000 through April 2015 using separate search strategies for Key Questions 1 and 2 and Key Question 3. Our searches were designed to identify studies of combat injuries in US military personnel during OEF, OIF, and OND. The full search strategies are presented in Appendix A. We obtained additional articles by hand-searching the table of contents of Journal of Trauma-Injury Infection & Critical Care and reference lists of systematic reviews and other reports, and from references suggested by stakeholders, TEP members, and peer reviewers.

Study Selection

Abstracts from the MEDLINE searches were reviewed in duplicate by investigators and research associates and abstracts from the table of contents search were reviewed by a single investigator. We identified for full-text review studies of any design potentially relevant to the key questions. Two investigators or research associates independently reviewed full-text articles excluding the following:

- Studies not including US military personnel from OEF, OIF, or OND (2001-2014);
- Studies not involving combat injuries;
- Modeling studies (*eg,* mechanical/engineering models, animal studies);
- Studies not relevant to the key questions;
- Studies of treatment outcomes;
- Imaging studies or studies reporting changes in tissue (*eg,* white matter);
- Case reports;
- Studies for Key Questions 1 and 2 where the denominator was not the number deployed during the study period (*ie,* reports of injuries at a medical facility were excluded); and
- Studies for Key Question 3 that did not report outcomes of interest for blast-related TBI and non-blast TBI groups (*ie,* studies only reporting on blast-related TBI were excluded).

Data Abstraction and Risk of Bias Assessment

Study characteristics and outcomes were extracted onto evidence tables by one investigator or research associate and verified by another. We did not assess the risk of bias of the included studies although risk of bias for each study was likely moderate or high due to the study design used, selective population studied, and failure to control for potential confounding factors.

Data Synthesis and Analysis

We created summary tables for incidence and prevalence data (Key Questions 1 and 2). We organized evidence tables for Key Question 3 by outcome and time since exposure (< 30 days, 30 days to 1 year, > 1 year, or not specified). Pooled analyses were not possible due to heterogeneity of the study populations and outcome measures.

We did not formally rate the overall strength of evidence for outcomes. The typical approach to assessing strength of evidence considers consistency, precision, directness, and risk of bias of the included studies. However, because included studies were observational and there was limited reporting of outcomes of interest (*ie,* most outcomes reported in only a few studies and often using different measures), it is unlikely that strength of evidence would be anything above low. Many outcomes had insufficient evidence.

RESULTS

Results of Literature Search

Our literature searches yielded 1,146 abstracts. We identified 324 articles for full-text review and excluded 290. We identified an additional 8 articles by hand-searching, resulting in a total of 42 included articles (6 for Key Questions 1 and 2, 36 from 34 studies for Key Question 3).

Summary of Results for Key Questions

Key Questions 1 and 2

We identified 6 studies meeting inclusion criteria for Key Questions 1 or 2 (incidence and prevalence of combat blast injuries). These studies included data from 2001 to 2011; 5 used the Joint Theater Trauma Registry (JTTR) and one used Department of Defense tabular reports. Three of the JTTR studies were based on the same cohort of deployed service members (described by Belmont et al, 2012) with one reporting overall casualties, one reporting musculoskeletal casualties, and one reporting spinal injuries. The JTTR (now the Department of Defense Trauma Registry [DoDTR]) was established in 2004 and contains information on all casualties (individuals lost to the theater of operations due to illness or injury) treated at US military medical facilities in and outside the combat zone. All but one study, which focused on the troop surge in Iraq, included casualties from both Iraq and Afghanistan. The mean ages of service members in the study cohorts ranged from 26 to 30 years, and 92% to 99% were male (k = 5 reporting). In the 4 studies that reported branch of service and rank, 78% to 100% were from the Army and the large majority (up to 93%) were from enlisted ranks. None of the studies provided information on deployment details including assigned or actual duties. Additional details are presented in Appendix C, Tables 1 and 2.

Key Question 1. Incidence

The National Institute of Mental Health defines incidence as the number of new cases of a condition, symptom, death, or injury that develop during a specific time period. We included registry studies that reported incidence of combat blast injuries for the deployed population (Executive Summary Table 1).

Belmont et al (2012) reported incidence of explosion (*ie*, improvised explosive device, mortar, and rocket-propelled grenade) injuries for the years 2005 to 2009. Soldiers killed in action or sustaining non-battle injuries were not included in the analysis. The number of service members deployed and years of service were obtained through the Defense Manpower Data Center. The incidence was 4.5 blast injuries per 1,000 deployed in 2005, 3.5 per 1,000 in 2006, 4.0 per 1,000 in 2007, 1.7 per 1,000 in 2008, and 1.7 per 1,000 in 2009. The slight increase in 2007 corresponded to the troop surge.

A second report detailed all combat explosion injuries in a US Army Brigade Combat Team (n = 4,122) deployed during the 2007 troop surge in Iraq. The cohort was followed for 6 months following the 15-month deployment. The incidence of explosion injuries was 83 per 1,000 deployed soldiers.

Executive Summary Table 1. Incidence Data

Outcome	2005	2006	2007	2008	2009	2010
Explosion injuries (*any*) per 1,000 deployed (Belmont 2010)			83[a]			
Explosion injuries (*any*) per 1,000 deployed (Belmont 2012)	4.5	3.5	4.0	1.7	1.7	
Explosion-related *musculoskeletal injuries* per 1,000 deployed[b] (Belmont 2013)	3.5	2.7	3.1	1.3	1.3	
Explosion-related *spinal injuries* per 1,000 deployed[b] (Schoenfeld 2013)	0.4	0.4	0.4	0.2	0.3	
Blast-related *thoracolumbar burst* fractures per 10,000 soldier years (Freedman 2014)				0.45[c]	0.60[c]	2.08[c]

[a] All explosion injuries for a US Army Brigade Combat Team (n = 4,122) deployed during the 2007 troop surge
[b] Additional analysis of cohort described by in Belmont 2012
[c] Data from August of preceding year to August of specified year

Key Question 1a

No study reported incidence by blast characteristics (*ie,* primary, secondary, *etc*) or injury outcomes (*eg*, pain, amputations, vision loss, cognitive function, functional status, quality of life). Three reported incidence by injury site (*ie*, body location or system injured) (Executive Summary Table 1).

Two of the studies provided information about specific injury types for the service members deployed to Afghanistan and Iraq and included in the cohort described by Belmont et al 2012. One study identified explosion-related musculoskeletal injuries (upper and lower extremity, spine, and pelvis wounds including fractures, soft tissue injuries, joint dislocations, neurologic injuries, and traumatic amputations) during a 5-year period. The incidence values (per 1,000 deployed soldiers) were 3.5 in 2005, 2.7 in 2006, 3.1 in 2007, 1.3 in 2008, and 1.3 in 2009. The other study reported on explosion-related spinal injuries finding 0.4 per 1,000 deployed soldiers in 2005, 2006, and 2007; 0.2 per 1,000 soldiers in 2008; and 0.3 per 1,000 soldiers in 2009. The injuries included fractures, dislocations, disk displacements, nerve root injuries, and spinal cord injuries.

Another study looked specifically at combat thoracolumbar burst fractures, a pattern of injury that occurs as a result of vertical forces imparted by an explosion beneath an armored vehicle. The analysis included service members injured in Afghanistan and Iraq. The incidence of thoracolumbar burst fractures increased from 0.45 per 10,000 soldier-years in the one-year period August 2007-2008, to 0.60 per 10,000 soldier-years in August 2008-2009, and 2.08 per 10,000 soldier-years in August 2009-2010. The increase in 2009-2010 was largely among soldiers serving in Afghanistan and authors attributed this to increased use of powerful improvised explosive devices against newer, up-armored vehicles. Authors speculated that with the newer military vehicles, explosives that might have caused deaths in the past were now associated with non-fatal burst fracture injuries.

Key Question 2. Prevalence

The National Institute of Mental Health has defined prevalence as the proportion of a population who have (or had) a specific condition in a given time period regardless of when they first acquired the condition. For this review, we report cumulative data as prevalence (Executive Summary Table 2).

Explosion-related injuries over a 5-year period (2005-2009) were reported for the Belmont et al cohort. Among 1,992,232 soldiers deployed to Afghanistan or Iraq during that time period, there were 5,862 explosion injuries, or 0.29% of deployed soldiers experienced an explosion-related injury. Explosion injuries accounted for 74% of injuries.

Key Question 2a

No studies reported prevalence by blast characteristic or injury outcome.

Four studies reported specific injury sites (Executive Summary Table 2). Two studies were additional analyses of the Belmont et al cohort. The study of musculoskeletal injuries reported 4,563 soldiers with explosion-related injuries (0.23% of deployed soldiers). Of all musculoskeletal injuries, 82% were explosion-related. Another analysis reported there were 650 soldiers with explosion-related spinal injuries (0.03% of deployed soldiers). Of all spinal injuries, 75% were explosion-related. Among the 650 with explosion-related spinal injuries, 31% (n = 204) had injuries to more than one spinal region. Associated head and neck injuries were noted in 57% (n = 132) of soldiers with an explosion-related cervical spine injury.

The study of thoracolumbar burst fractures reported that over the period 2007-2010, the rate of blast-related fractures was 2.02 per 10,000 soldier-years. A Congressional Budget Office Working Paper reported major amputations (loss of a limb proximal to the wrist or ankle). The prevalence was 38 per 100,000 troop-years in OEF and OND and 88 per 100,000 troop-years in OEF.

Executive Summary Table 2. Prevalence Data

<table>
<tr><th>Outcome</th><th>2001</th><th>2002</th><th>2003</th><th>2004</th><th>2005</th><th>2006</th><th>2007</th><th>2008</th><th>2009</th><th>2010</th><th>2011</th></tr>
<tr><td>Explosion-related injuries (any) (Belmont 2012)</td><td></td><td></td><td></td><td></td><td colspan="5">74% of injuries
0.29% of 1,992,232 deployed
(30.5 per 10,000 deployed)</td><td></td><td></td></tr>
<tr><td>Blast-related thoraco-lumbar burst fractures (Freedman 2014)</td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="4">2.02 per 10,000 soldier-years</td><td></td></tr>
<tr><td>Explosion-related musculo-skeletal injuries (Belmont 2013)</td><td></td><td></td><td></td><td></td><td colspan="5">82% of musculoskeletal wounds
(14,158 wounds)
0.23% of 1,992,232 deployed
(22.9 per 10,000 deployed)</td><td></td><td></td></tr>
<tr><td>Explosion-related spinal injuries (Schoenfeld 2013)</td><td></td><td></td><td></td><td></td><td colspan="5">75% of spinal casualties
0.03% of 1,992,236 deployed
(3.3 per 10,000)</td><td></td><td></td></tr>
<tr><td>Improvised explosive device major amputations (Goldberg 2014)</td><td colspan="11">Iraq (OEF, OND): 38.3/100,000 troop-years
Afghanistan (OEF): 87.8/100,000 troop-years</td></tr>
</table>

Key Question 3

We included 34 studies (in 36 papers). Executive Summary Table 3 provides an overview of the studies. The majority of reports were clinical cohort studies with patient injury outcomes (*eg*, post-traumatic stress disorder [PTSD], pain, limb loss, vision impairment, cognitive function loss) assessed at a medical facility in the US. Many studies did not report the time from blast exposure to assessment. Of those that did, most assessments took place 30 days to one year post-exposure. Eighteen of the 34 studies included only patients with mild TBI.

Injury outcomes are summarized in Executive Summary Table 4. In studies of injury outcomes among military personnel sustaining a blast or non-blast TBI, blast and non-blast groups had similar rates of mortality, pain, vision loss, vestibular dysfunction, functional ability, depression, sleep disorders, alcohol misuse, and post-concussive symptoms. Results were consistent across studies despite the fact that the studies varied in sample size, location where assessment took place, time from exposure to assessment (< 30 days, 30 days to one year, or > one year), and level of TBI severity.

Findings were less consistent for PTSD, hearing loss, cognitive function loss, and headache, with some studies finding increased levels in the blast-related TBI groups and some finding blast and non-blast groups to be similar. Burn injuries, limb loss, and quality of life were infrequently reported (3, 2, and one study, respectively).

We found little data on outcomes according to blast characteristics. One study failed to find a difference in hearing outcomes by primary versus secondary blast injuries. Three studies that defined blast injury as due to primary blast force reported few differences between their blast injury group and non-blast injury comparator groups.

Executive Summary Table 3. Overview of Study Characteristics – Key Question 3

Number of Studies	Data Source		Sample Size	Characteristics									
				Location of Assessment[a]			Time Since Exposure[b]				TBI Severity[c]		
	Registry/ Database	Clinical Cohort		Combat Zone	After Deployment	DoD, VA or Other Medical Facility	< 30 days	30 days to 1 year	> 1 year	Any or Unclear	Mild	Moderate/ Severe	Mixed (results not reported separately)
34	6	28	18 to 12,521	3	2	26	3	10	5	14	18	1	12

[a] 2 additional studies: 1 completed in combat zone and at end of deployment; 1 unclear
[b] 2 additional studies: both with outcomes at <30 days and 30 days to 1 year post exposure
[c] 3 additional studies; 2 included mild and moderate/severe TBI with results reported separately; 1 included all severity levels reporting some results separately

Executive Summary Table 4. Overview of Outcomes According to Blast versus Non-blast TBI – Key Question 3

Number of Studies	Data Source		Outcomes Reported[a]												
	Registry/ Database	Clinical Cohort	Mortality	PTSD	Pain	Burn	Limb Loss	Vision Impairment	Hearing Impairment	Vestibular Dysfunction	Cognitive Function Loss	Quality of Life	Functional Status/ Employment	Other
34	6	28	↔2	**- 7 ↔8 1 MIXED**	**↔3**	**- 1 ↔1 ?1**	**- 1 ↔1**	**- 1 ↔5 ¯1 1 MIXED**	**- 4 ↔3 2 MIXED**	**- 1 ↔4 1 MIXED**	**- 2 ↔5 3 MIXED**	**↔1**	**↔4 ¯1**	**Depression: ↔7 Sleep: - 1, ↔3, 1 MIXED Headache: ↔2, 2 MIXED Alcohol misuse: ↔3 Post-concussive symptoms: - 1, ↔4 Injury severity: ↔1, ?1 TBI severity: - 1, ↔2, ?1**

[a] Number is number of studies reporting that outcome; symbol provides direction of statistically significant outcomes
- Higher prevalence or more severe in blast TBI group; ¯ Higher prevalence or more severe in non-blast TBI group; **↔** Blast and non-blast groups similar; **?** P value not reported
MIXED Multiple tests with mixed results

DISCUSSION

Key Findings

Key Questions 1 and 1a - Incidence

- The published literature provides limited information about the true incidence and prevalence of blast-related injuries experienced by US military personnel. Findings are likely influenced by assessment and reporting methods.
- The reported explosion injury incidence ranged from 4.5/1,000 deployed in 2005 to 1.7/1,000 deployed in 2009.
- During the Iraq troop surge (2007) explosion injury incidence was particularly high (83/1,000 deployed in a US Army Brigade Combat Team).
- Musculoskeletal explosion injury incidence (fractures, amputations, neurological injuries, joint dislocations, and soft tissue injuries) ranged from 3.5/1,000 deployed in 2005 to 1.3/1,000 deployed in 2009.
- Spinal injury incidence (fractures, dislocations, nerve root injuries, spinal cord injuries) ranged from 0.18/1,000 deployed in 2008 to 0.40/1,000 deployed in 2005.
- Thoracolumbar burst fracture incidence was low (0.45 to 2.1 per 10,000 soldier years between 2008 and 2010) but higher in Afghanistan than Iraq and increased over the study period.
- No study reported incidence by blast characteristics.

Key Question 2 and 2a - Prevalence

- Nearly three-quarters of all combat injuries over the period from 2005 to 2009 (31 per 10,000 deployed) were due to explosions.
- A high proportion of musculoskeletal injuries (82%; 23 per 10,000 deployed) and spinal injuries (75%; 3 per 10,000 deployed) between 2005 and 2009 were due to explosions. Of the musculoskeletal injuries, 80% of axial skeletal and extremity fractures, 94% of amputations, and 85% of soft tissue injuries were explosion-related. Another study reported explosion-related amputations in 4 per 10,000 troop-years (Iraq) and 9 per 10,000 troop-years (Afghanistan) over the period from 2001 to 2011.
- No study reported prevalence by blast characteristics.

Key Question 3

- The published literature provides limited information on outcomes associated with blast versus non-blast TBI experienced by US military personnel. Definitions of blast/non-blast injury, assessment of outcomes, and reporting methods vary and often are based on small selected groups.

- Blast and non-blast TBI groups had similar rates of pain, vision loss, vestibular dysfunction, functional ability, depression, sleep disorders, alcohol misuse, and post-concussive symptoms.

- Comparative outcomes in individuals with blast versus non-blast TBI were inconsistent across studies with regard to PTSD diagnosis or symptom severity, hearing loss, cognitive function, and headache in blast and non-blast TBI groups.

- Mortality, burn injuries, limb loss, and quality of life were infrequently reported in studies comparing blast versus non-blast TBI.

- Results were consistent across studies that varied by location of assessment (combat zone, medical facility), time from exposure to assessment (< 30 days, 30 days to one year, or > one year), and level of TBI severity, although the most studies were small, clinical cohort studies, with mTBI patients evaluated at a Department of Defense or Veterans Affairs medical facility.

- There is little data on outcomes among those with TBI according to blast characteristics.

Applicability

The findings of this review are highly applicable to military personnel and organizations that provide direct acute or chronic health care services including rehabilitation as well as employment to those either currently serving or of recent Veteran status. Additionally, an understanding of the incidence, prevalence, outcomes, and causal factors of blast and non-blast injuries may be used to help reduce these injuries in future combat operations.

However, many studies reported findings from individuals presenting to medical facilities and undergoing treatment for a specific combat injury. Patient and injury characteristics and subsequent health outcomes from these selected patients may differ in unknown ways from the broader group of individuals who had combat injuries. We also have little information on very long-term effects (*eg,* cognitive function decline over decades).

The Analysis of VA Health Care Utilization among Operation Enduring Freedom (OEF), Operation Iraqi Freedom (OIF), and Operation New Dawn (OND) Veterans (released June 2015) reports that 1,906,754 OEF/OIF/OND Veterans have become eligible for VA health care since fiscal year 2002 (beginning October 1, 2001) and approximately 2.7 million troops (as of December 31, 2014) have served or are serving in the 2 theaters of operation since the beginning of the conflicts in Iraq and Afghanistan. OEF/OIF/OND Veterans who present for care at a VA facility undergo a screen for TBI which includes questions about exposure to physical trauma such as explosions. Veterans who screen positive for TBI undergo a comprehensive evaluation.

Research Gaps/Future Research

Accurately recording in a standardized fashion every injury to every individual who experiences a blast (including type of blast [*eg,* primary, secondary, *etc*], distance from the blast, *etc*) and then following those individuals to assess long-term outcomes would be ideal but not realistic. However, for those who have been determined to have received blast-related injuries additional information on the circumstances surrounding the injury should include: type of blast, distance from the blast, history of blast exposure, injury severity, assigned and actual duties, and military member's physical and psychosocial characteristics. Additional information gathered would be useful to evaluate methods to reduce combat-related blast injuries. Comparisons versus deployed controls may facilitate our understanding of the mechanisms and severity of blast-related injuries and the long-term health and social consequences of those injuries. This includes not only the treatments and health outcomes specific to the blast injury but also the long-term psychosocial, employment, and economic impact of blast injuries and the role and capacity needs for health care systems and the work force as these individuals reintegrate into the civilian society. Existing databases may already contain some of this information and future analyses should incorporate blast data where possible.

Conclusions

- The published literature provides limited information about the true incidence and prevalence of blast-related injuries experienced by US military personnel and the outcomes associated with blast versus non-blast TBI. We found no reports of incidence and prevalence of blast injuries associated with different combat roles.

- Few studies of incidence of blast-related injuries or outcomes associated with blast versus non-blast TBI report important characteristics of a blast injury: type of blast, how far the individual was from the blast, whether they experienced a blast wave, whether there was loss of consciousness or altered consciousness, whether there was amnesia (and length of time), and whether there was additional trauma.

- Only 6 studies, 3 of which were derived from the same data set, provide information about the incidence and prevalence of blast-related injuries in the deployed population at risk.

- Pain, vision loss, vestibular dysfunction, functional status, depression, sleep disturbance, alcohol misuse, and post-concussive symptoms were similar in groups of patients with blast and non-blast TBI. Findings were less consistent for PTSD, hearing loss, cognitive function, and headache. Few studies reported mortality, burn outcomes, limb loss, or quality of life.

- Reporting studies were often small and involved highly selected patients and thus may not be fully representative of all individuals with blast or non-blast TBI. There are few data on very long-term outcomes that may be particularly relevant to assessment of cognitive function and quality of life.

- Blast and blast injuries (including TBI) are often defined differently. Therefore, the incidence, prevalence, and patient outcomes may vary across studies in part due to differences in how blast injury is categorized.

- To more adequately address questions about consequences of blast exposure, future research efforts should focus on comprehensive and consistent documentation at the time of and following blast exposure and more complete analyses of databases that may already have captured blast exposure information.

ABBREVIATIONS TABLE

DoD	Department of Defense
DOW	Died of wounds
KIA	Killed in action
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
OND	Operation New Dawn
PTSD	Post-traumatic Stress Disorder
RTD	Returned to duty
TBI (mTBI)	Traumatic brain injury (mild traumatic brain injury)
VA	Department of Veterans Affairs
VAMC	Veterans Affairs Medical Center
WIA	Wounded in action