Traumatic brain injury (TBI) is a common injury in wartime. The notion that combat is a risk factor for TBI was recognized long ago, as indicated by the fact that soldiers throughout the world have been using helmets since ancient times. TBI is common in war because, as Carey (1987) wrote, “the head is preferentially exposed in combat as the soldier constantly monitors his environment by means of exteroceptive neurosensory structures (eyes, ears, and nose) in order to enhance his own survival” (p. 6). Ballistics researchers estimate that the head and neck together constitute 12% of the total body area that is exposed during combat, and yet 15% to 25% of the wounds incurred during combat in World War II, Korea, and Vietnam were to the head-neck region (Carey 1987). The only body region with a higher proportion of wounds in these wars was the extremities, which accounted for 53% to 55% of injuries (Carey 1987).

There are several reasons why the military population is unique when it comes to TBI. One, obviously, is the increased TBI risk associated with combat. Another is the mechanism of injury. Although TBI in military personnel are often caused by the same mechanisms that cause TBI in civilians (e.g., motor vehicle crashes), military personnel in combat environments also face the risk of injury from explosions, which are rare in nonwar environments. Military personnel in combat environments are also at risk for a variety of comorbidities, especially injuries to other body regions and psychiatric disorders, which can delay the detection of TBI, complicate management and rehabilitation, and possibly slow recovery. The military population is unique in that it is intrinsically easier to study. Procedures such as the mandatory Post-Deployment Health Assessment (PDHA) that all U.S. service members undergo after returning to their home base make it possible to screen large numbers of returning service members. This assessment captures those with concussion who may have postponed evaluation or treatment during deployment and therefore were not identified by reviewing medical databases. This has enabled researchers to gather data about a common type of TBI—concussion—that is difficult to identify in the general civilian population.

In this chapter, we discuss TBI in the U.S. military populations with an emphasis on service members who participated in Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF). We present data about the prevalence of TBI in this population, mechanisms of injury, methods used to identify those with TBI, levels of care, management techniques, and rehabilitation strategies. We also provide data about the future direction of TBI research. The goal of this chapter is to summarize some of the knowledge and insights about TBI that have been gained by treating and studying service members injured in war. It is our hope that this knowledge will help improve understanding of traumatic brain injury in any of the contexts in which it occurs and lead to better outcomes for those who sustain TBI.

OPERATIONAL DEFINITIONS OF TBI

In 2006, a working group of the Defense and Veterans Brain Injury Center (DVBIC) developed the following operational definition of TBI in military operations:

an injury to the brain resulting from an external force and/or acceleration/deceleration mechanism from an event such as a blast, fall, direct impact, or motor vehicle accident which causes an alteration in mental status typically resulting in the temporally related onset of symptoms such as: headache, nausea, vomiting, dizziness/-balance problems, fatigue, trouble sleeping, sleep disturbances, drowsiness, sensitivity to light/noise, blurred vision, difficulty remembering, and or difficulty concentrating. (DVBIC 2006, p. 2)

This definition is consistent with those put forth by the Centers for Disease Control and Prevention, the American Academy of Neurology, and other groups with TBI interest in that it specifies an injury event with subsequent alteration in consciousness.

EPIDEMIOLOGY

The total incidence and prevalence of war-related TBI among members of the U.S. armed forces serving in OIF and OEF are not known. However, data from recently published survey-based studies of service members and veterans who served in OIF/OEF suggest that war-related TBI is common in this population (Hoge et al. 2008; Schell and Marshall 2008; Schneiderman et al. 2008; Schwab et al. 2007; Terrio et al. 2009). The most recent in-theater Mental Health Assessment Team (MHAT) found that 11.5% of soldiers surveyed in the middle of their tour endorsed having had at least one concussion at the time of the survey. Supplemental TBI postdeployment surveys of combat-exposed units demonstrate a range of 10%–20% for probable mild TBI or concussion during deployment. The MHAT studies used the Soldier-Marine Well-Being Survey, which is a lengthy questionnaire focusing predominantly on psychological health concerns, as opposed to a validated TBI screening tool. The highest reported frequency of TBI from any of these studies is 22.8%, which was obtained from an active duty army brigade combat team that was screened for TBI during the mandatory PDHA (Figure 26–
1) after spending 1 year in Iraq (Terrio et al. 2009). A telephone study of a sample of OIF/OEF veterans from all branches of the armed forces found that 19.5% screened positive for a war-related TBI (Schell and Marshall 2008). Two other studies of Army personnel found that 15.2%–15.8% screened positive for TBI (Schell and Marshall 2008; Schwab et al. 2007). The lowest frequency of TBI was 12%, which was obtained from a sample of veterans from all service branches who were mailed TBI screening questionnaires (Hoge et al. 2008). Each of these studies used the Brief Traumatic Brain Injury Screen (BTBIS) (Schwab et al. 2007) to screen for concussion. Two of the studies also used validated screening tools for posttraumatic stress disorder (PTSD) and depression, factoring these results as potential causes of symptoms. The slight variance in results across the three studies may be a reflection of method of screening (paper, telephone, face-to-face interview) and time since injury.

Figure 26–1. Post-Deployment Health Assessment (PDHA) Screening.

<table>
<thead>
<tr>
<th>Question</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.a. During this deployment, did you experience any of the following events? (Mark all that apply)</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>(1) Blast or explosion (IED, RPG, land mine, grenade, etc.)</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>(2) Vehicular accident/crash (any vehicle, including aircraft)</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>(3) Fragment wound or bullet wound above your shoulders</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>(4) Fall</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>(5) Other event (for example, a sports injury to your head). Describe.</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>9.b. Did any of the following happen to you, IMMEDIATELY after any of the event(s) you just noted in question 9.a.? (Mark all that apply)</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>(1) Lost consciousness or got “knocked out”</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>(2) Felt dazed, confused, or “saw stars”</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>(3) Didn’t remember the event</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>(4) Had a concussion</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>(5) Had a head injury</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>9.c. Did any of the following problems begin or get worse after the event(s) you noted in question 9.a.? (Mark all that apply)</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>(1) Memory problems or lapses</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>(2) Balance problems or dizziness</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>(3) Ringing in the ears</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>(4) Sensitivity to bright light</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>(5) Irritability</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>(6) Headaches</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>(7) Sleep problems</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>9.d. In the past week, have you had any of the symptoms you indicated in 9.c.? (Mark all that apply)</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>(1) Memory problems or lapses</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>(2) Balance problems or dizziness</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>(3) Ringing in the ears</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>(4) Sensitivity to bright light</td>
<td>No</td>
<td>Yes</td>
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<td>Yes</td>
<td></td>
</tr>
<tr>
<td>(7) Sleep problems</td>
<td>No</td>
<td>Yes</td>
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</table>
MECHANISMS OF INJURY

The TBI reported in these studies are almost exclusively mild traumatic brain injury (mTBI). In early evaluations of combat-related TBI, a loss of consciousness (LOC) up to 60 minutes was considered mTBI. In October 2007, a Department of Defense–wide severity of injury was published that decreased the allowable time for LOC in mTBI to 30 minutes or less (Assistant Secretary of Defense 2007). The definitions for moderate and severe remained consistent, and although time parameters for LOC and alteration in consciousness (AOC) are provided, those with more evident injury are often classified by Glasgow Coma Scale scores.

Schwab et al. (2007) found that only 2.1% of those who screened positive for war-related TBI had an injury that was greater than mild, and Hoge et al. (2008) found that only 1% of those who screened positive for TBI had an injury that was greater than mild. However, to best understand these screening results, it is important to realize that the majority of moderate and severe TBI are identified immediately and enter the trauma system of care; most are medically evacuated from the theater and are therefore not intended to be identified on routine screening measures. Furthermore, most of those with mild TBI on screening had the mildest form of mTBI. Schwab et al. (2007) found that 70% those with TBI had reported only AOC, such as being dazed or confused, "seeing stars," or having their "bell rung." Hoge et al. (2008) found that 68% of those who screened positive for TBI reported AOC, and Terrio et al. (2009) found that 63% of those with TBI reported only AOC.

Few data about those who were hospitalized for TBI from the current conflicts have been published. An analysis of data from 433 service members evacuated to the Walter Reed Army Medical Center (WRAMC) found that 88.5% had closed TBI (Warden et al. 2005). Fifty-six percent of these injuries were moderate to severe (including penetrating), and 44% were mild (Warden et al. 2005). Twenty-eight percent of those evacuated to WRAMC with combat injuries had TBI (Warden 2006). It should be noted, when interpreting the data, that WRAMC is one of only three military treatment facilities that provide care for combat-related severe and penetrating TBI. In addition, isolated mTBI patients were not included in this study because they did not require hospitalization.

Blast is a common mechanism of injury in the setting of OIF/OEF. A study of a Marine Corps mechanized battalion stationed in Iraq found that 97% of combat injuries were caused by explosive weapons such as improvised explosive devices (IEDs) and mines and just 3% were caused by direct fire, such as being shot at (Gondusky and Reiter 2005). Sixty-eight percent of those evacuated to WRAMC with a TBI were injured by a blast (Warden 2006). Among returning service members who were screened for TBI during the PDHA, 88% of those who reported being injured reported blast as a mechanism (Terrio et al. 2009). However, the screening surveys do not specify exactly which mechanism caused the TBI. Attributing combat-related TBI to a specific mechanism is often difficult because in the context of these current wars, many injuries are produced by “blast-plus,” that is, injuries by blast/explosion in conjunction with motor vehicle crashes, falls, and fragmentation. Therefore, it is difficult to discern the true mechanical force by which the TBI occurred.

Acute postconcussive symptoms are common in service members with war-related TBI. Ninety-one percent of those with TBI treated at WRAMC had postconcussive symptoms (Warden et al. 2005). Among those who screened positive for TBI during the PDHA at Fort Carson, Colorado, 92% reported having had postconcussive symptoms at the time of injury (Terrio et al. 2009). However, the proportion of service members who reported symptoms persisting until time of returning home was much smaller: 33% reported postconcussive symptoms during the PDHA (Terrio et al. 2009). In the Fort Carson sample, 39% of those who screened positive for TBI reported postconcussive symptoms at the time of screening after returning from theater, but only 11% of those injured without TBI reported symptoms (Terrio et al. 2009). Also of note from the Fort Carson study, the average time from date of injury to PDHA was 6.1 months. In the sample in Fort Bragg, North Carolina, 64% of those who screened positive for TBI reported three or more problematic postconcussive symptoms versus 41% of those who screened negative for TBI (Schwab et al. 2007).

Service members with war-related TBI are also at risk for psychiatric conditions. Returning service members who screened positive for TBI were more likely to have psychiatric disorders than those who were injured but did not have an associated TBI (Hoge et al. 2008). Furthermore, those who reported LOC were more likely to report a psychiatric disorder than those with AOC only (Hoge et al. 2008). In the WRAMC inpatient sample, 43% of those with TBI had a psychiatric disorder noted in their records, with depression being the most common disorder (Warden et al. 2005). Among those who were not hospitalized for their TBI and who returned with their units, PTSD was the most common psychiatric disorder (Hoge et al. 2008). PTSD is a frequent cause of postconcussive-type complaints in patients screening negative for TBI (Hoge et al. 2008; Schneiderman et al. 2008) (see also Chapter 12, Posttraumatic Stress Disorder, in this volume).

MECHANISMS OF INJURY

In the conflicts of OIF/OEF there have been an array of weapon mechanisms that lead to varying levels of TBI severity. Despite many developments in body armor and helmet technology, TBI among wounded soldiers has been estimated to be as high as 22% (Okie 2005). Of service members medically evacuated with battle-related injuries from the deployed setting to WRAMC, 31% had a TBI (DVBIC 2008). The top three primary injury agents include 55% blast (IED, rocket-propelled grenades, mortars, mines, bombs, grenades), 27% multiple mechanisms of injury, and 7% vehicular injury (DVBIC 2008). According to a report by Galarneau et al. (2008), IEDs were responsible for far more TBI diagnoses among those wounded or killed in action than any other mechanism of injury, including bullet wounds.

There is increasing awareness of another class of injury, referred to as a "blast TBI" (Ling 2008). This injury results from proximity to explosion or blast. In the current conflicts, blast injuries resulting from IEDs are extremely prevalent, but their influence on traditional biomechanical dynamics of brain injury is yet unclear (Taber et al. 2006). There is some discussion that this may be the same injury that was described as "shell shock" during World Wars I and II. Studies estimate that the rate blasts result in brain injuries is approximately 60% (Galarneau et al. 2008). Multiple mechanisms can contribute to blast brain injury. Primary blast injury to the brain is hypothesized to result from direct exposure to overpressure or negative pressure waves that follow an explosion (Mayorga 1997). Initially, primary blast injury was thought to be a rare cause of TBI, although it is a well-known cause of injuries to air-filled organs such as the lungs, gut, and ears. However, there is mounting evidence that primary blast injury affects organs with fluid interfaces that allow transfer of kinetic energy. It is hypothesized that this likely results in diffuse axonal injury in the brain and spinal cord. Preliminary results from diffusion tensor imaging studies indicate significant differences in fractional anisotropy in service members with blast TBI versus blunt TBI (C. MacDonald, “Diffusion Tensor Imaging in TBI.” Unpublished data, 2010). Secondary blast injury results when the explosive force energizes surrounding objects, setting them in motion. As these objects strike a person, injury occurs. This injury pattern is typically seen in the neck and...
person to be thrown into a stationary object. Burns and inhalation of gases or other toxic substances produce the fourth category of blast injury, quaternary injury.

Traditional acceleration/deceleration injuries also occur in combat settings. Typically resulting from motor vehicle collisions or falls, these injuries are similar to those seen in the civilian setting.

Penetrating brain injury can occur as a result of traditional gunfire or from secondary blast effects. This may result in minor to severe cerebral dysfunction. Data from Armonda et al. (2006) demonstrate that patients with penetrating injury are at increased risk for cerebral vasospasm and pseudoaneurysm compared with patients with blunt TBI.

In many patients who sustain combat-related brain injury, multiple mechanisms of injury are present. For example, the detonation of explosive devices commonly affects moving vehicles. As the explosion takes place, blast-related phenomena occur. In rapid succession, the vehicle may strike another stationary object, leading to the development of acceleration/deceleration-type injuries.

**SETTINGS OF CARE**

Combat-related TBI management is provided at different levels of care (Albertson et al. 2004). Initial TBI management in the deployed setting begins on the battlefield (Level I) in the form of buddy aid. First and foremost, this involves cover-fire and evacuation to safety and stabilization of serious injury. Special Forces (SEALS, Rangers) units are often trained in more advanced life support measures. As soon as the mission allows, the injured are evacuated from the battlefield to higher levels of care. The Battalion Aid Station (BAS), also considered Level I care, provides triage, minor treatment, and evacuation capabilities. The BAS is generally staffed by medics, physician assistants, and occasionally physicians. At this level, TBI care is limited to observation, rest, and management of noncritical symptoms (e.g., headache). In the event that more intensive evaluation or treatment is necessary, evacuation to higher echelons occurs. This evacuation does not always occur in a linear fashion but rather to the facility that allows safe and rapid transport.

Level II facilities offer basic medical care, basic diagnostic capabilities, and in some cases life-saving surgery. There is limited inpatient bed space, and therefore, holding times are limited to 72 hours. These facilities are highly mobile and may relocate on the basis of operational needs.

Level III facilities represent the highest level of medical care available in deployed settings. Commonly referred to as the Combat Support Hospital, the Level III site has full surgical and intensive care capabilities. Important to TBI care, computed tomography (CT) scans and neurosurgical intervention can be performed here. Imaging techniques allow for reconstructions that can aid in forensic evaluation and ballistic trajectories, helping to ensure that no injuries are missed. Once stabilized, patients with severe or penetrating TBI are transferred out of the combat zone. Patients with less severe injury may be sent if prolonged recuperation is expected. This guarantees bed availability for the constant influx of casualties.

Definitive medical and surgical care outside the combat zone occurs at Level IV facilities. For OEF and OIF, these services are provided at Landstuhl Regional Medical Center in Germany. If indicated, aggressive management of intracranial pressure (ICP), including ICP monitoring, decompressive craniectomy, and vasopressor support, is fully implemented in accordance with the Guidelines for the Management of Severe Traumatic Brain Injury (Brain Trauma Foundation 2007). Those patients requiring ongoing care are subsequently transferred stateside to a Level V facility. These facilities are comparable with the American College of Surgeons' designated Level I trauma centers.

Transportation of critically ill TBI patients is done by critical care air transport teams on U.S. Air Force fixed wing aircraft. Moderate and severe TBI are routed to the National Naval Medical Center in Bethesda, Maryland, or WRAMC in Washington, D.C. Those with comorbid burns are treated in San Antonio, Texas. The National Naval Medical Center in Bethesda is the designated center for all penetrating injuries. While en route to the United States, complex critical care is provided by skilled critical care nurses and physicians. Altitude-approved monitors, ventilators, and other necessary medical devices are routinely used. Depending on injury patterns (e.g., pneumocephalus), flight patterns may be altered to prevent complications associated with altitude travel. In addition, those with severe brain injury and sensitive ICP may require position changes while in flight (head first, feet first) and prior to takeoff and landing to minimize effects on ICP. Those with mTBI are transported to other designated military TBI centers throughout the United States.

**SCREENING**

TBI screening is performed at many locations and at all levels of care within the military. Screening is performed in-theater as soon as possible after an injury-causing event by field medics/corpsmen as well as at higher-echelon medical facilities such as combat support hospitals. Screening is also performed in those medicinally evacuated from theater for injury (battle or nonbattle) or disease, at Landstuhl Regional Medical Center, to identify comorbid TBI that may not have been identified prior to medical evacuation from theater for other injuries. In addition, service members are screened within 30 days of returning to their home bases during the mandated PDHRA (Figure 26–1), followed by a general symptom inventory during the Post Deployment Health Reassessment (PDHRA) 3–6 months later. Finally, all OIF and OEF veterans who present to Veterans Affairs (VA) medical centers for any reason are screened for symptomatic TBI as well.

The Military Acute Concussion Evaluation (MACE) (Figure 26–2) is used to screen for acute TBI. The MACE was designed specifically for the purposes of assessing and documenting the mechanism of injury, acute characteristics, and cognitive deficits in military personnel with suspected mTBI in an austere environment (G. Grant, W. Isler, M. Baker, D. Erlanger, and T. Kaushik, "Preliminary Validation of the MACE." Unpublished data, 2008). It can be administered by any trained medical personnel including field medics/corpsmen to service members who are involved in the following events that are often associated with TBI: blasts, falls, motor vehicle crashes, direct impacts to their body, or other circumstances when TBI is suspected. The MACE includes sections for describing the injury event, guidelines for a gross neurological examination, and a brief cognitive evaluation. The neurological and cognitive assessments included in the MACE are those from the Standardized Assessment of Concussion that was introduced in the late 1990s (McCrea et al. 1997).
Military Acute Concussion Evaluation (MACE)
Defense and Veterans Brain Injury Center

Patient Name: ____________________________

SS#: ______-____-____ Unit: ____________________

Date of Injury: ______/____/____ Time of Injury: ____________

Examiner: ________________________________

Date of Evaluation: ______/____/____ Time of Evaluation: ______

History: (I – VIII)

I. Description of Incident
   Ask:
   a) What happened?
   b) Tell me what you remember.
   c) Were you dazed, confused, “saw stars”? ☐ Yes ☐ No
d) Did you hit your head? ☐ Yes ☐ No

II. Cause of Injury (Circle all that apply):
   1) Explosion/Blast
   2) Blunt object
   3) Motor Vehicle Crash
   4) Fall
   5) Gunshot wound
   6) Other ____________________________

III. Was a helmet worn? ☐ Yes ☐ No Type ____________________

IV. Amnesia Before: Are there any events just BEFORE the injury that are not remembered? (Assess for continuous
    memory after the injury)
    ☐ Yes ☐ No If yes, how long ____________

V. Amnesia After: Are there any events just AFTER the injuries that are not remembered? (Assess time until
    continuous memory after the injury)
    ☐ Yes ☐ No If yes, how long ____________

VI. Does the individual report “loss of consciousness or “blacking out”? ☐ Yes ☐ No If yes, how long ____________

VII. Did anyone observe a period of “loss of consciousness or unresponsiveness”? ☐ Yes ☐ No If yes, how long ____________

VIII. Symptoms (Circle all that apply)
   1) Headache
   2) Dizziness
   3) Memory Problems
   4) Balance problems
   5) Nausea/Vomiting
   6) Difficulty Concentrating
   7) Irritability
   8) Visual Disturbances
   9) Ringing in the ears
   10) Other ____________________________

Examination: (IX – XIII)

Evaluate each domain. Total possible score is 30.

IX. Orientation: (1 point each)

<table>
<thead>
<tr>
<th>Month</th>
<th>0</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Day of Week</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Year</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
The screening tools used at other locations are variants of the Brief Traumatic Brain Injury Screen (BTBIS) (Figure 26–3). The BTBIS questions are designed to ascertain whether a service member had an injury that at least met the criteria for mTBI that were established by the American Congress of Rehabilitative Medicine (Kay et al. 1993). Service members who report having an injury event that results in one or more of the above characteristics are considered to have screened positive for a possible TBI and are referred for further evaluation. The BTBIS also asks those who had a possible TBI about problematic postconcussive symptoms they are currently experiencing. Slight variants of these questions form the basis of screening tools used at the Landstuhl Regional Medical Center, during the PDHA and PDHRA, and at the VA. The questionnaires used during the PDHA and PDHRA and at the VA ask about the presence of symptoms at the time of injury and at the present. To screen positive on the VA questionnaire (Table 26–1), a veteran must have had an injury that met mTBI criteria and resulted in postconcussive symptoms at the time of injury and must have current postconcussive symptoms as well. This captures those patients in need of TBI services but does not improve mTBI surveillance because asymptomatic patients are not recorded.

**Figure 26–3. Brief Traumatic Brain Injury Screen (BTBIS).**
3 Question DVBIC TBI Screening Tool

1. Did you have any injury(ies) during your deployment from any of the following? (check all that apply):

   A. Fragment
   B. Bullet
   C. Vehicular (any type of vehicle, including airplane)
   D. Fall
   E. Blast (Improvised Explosive Device, RPG, Land mine, Grenade, etc.)
   F. Other specify: _____________________________

2. Did any injury received while you were deployed result in any of the following? (check all that apply):

   A. Being dazed, confused or “seeing stars”
   B. Not remembering the injury
   C. Losing consciousness (knocked out) for less than a minute
   D. Losing consciousness for 1-20 minutes
   E. Losing consciousness for longer than 20 minutes

   F. Having any symptoms of concussion afterward (such as headache, dizziness, irritability, etc.)
   G. Head Injury

   H. None of the above

   NOTE: Endorsement of A-E meets criteria for positive TBI Screen

   NOTE: Confirm F and G through clinical interview

3. Are you currently experiencing any of the following problems that you think might be related to a possible head injury or concussion? (check all that apply):

   A. Headaches
   B. Dizziness
   C. Memory problems
   D. Balance problems
   E. Ringing in the ears
   F. Irritability
   G. Sleep problems
   H. Other specify: _____________________________


Studies have begun to provide preliminary evidence of the validity of the MACE and the BTBIS. In a recent study of service members with blast-related mTBI who were assessed within 24 hours of injury, the scores from the MACE's cognitive evaluation were significantly correlated with duration of LOC and the Repeatable Battery for the Assessment of Neuropsychological Status immediate memory factor (Grant et al., unpublished, 2008). Previous studies have demonstrated the validity of the Standardized Assessment of Concussion for mTBI (McCrea et al. 1997, 1998; Naunheim et al. 2008). A study of the BTBIS found that 83% of a sample of Army soldiers who screened positive for war-related TBI had their TBI confirmed by a clinical interview (Hoge et al. 2008). Clinical interview is the standard for diagnosing mTBI. The study also found that a significantly higher proportion of those who screened positive for war-related TBI (64%) had three or more problematic postconcussive symptoms after returning than those who screened negative for TBI (41%) (Hoge et al. 2008). Another study found that TBI, resulting in LOC as identified by the BTBIS, was an independent predictor of
having three or more current postconcussive symptoms when controlling for the presence of PTSD and demographic variables (Schneiderman et al. 2008). Further validation studies of the MACE, BTBIS, and the VA TBI screening tool are currently under way.

**TBI MANAGEMENT IN THE MILITARY**

As previously stated, medical management of severe and moderate TBI begins on the battlefield and in rapid triage and evacuation. Neurosurgical and critical care management varies little from that of similar civilian injuries with one exception. Decompressive craniectomies are widely used for patients with potential ICP problems. This minimizes ICP elevations that may occur during times when other intervention may be limited (i.e., during transport). Once stabilized, these patients are considered for either autologous or synthetic bone flap replacement. This typically occurs after the patient’s physical condition improves following inpatient rehabilitation at one of four designated Department of Veterans Affairs polytrauma rehabilitation centers (Table 26–2). These facilities are staffed with highly experienced personnel skilled in treating this unique population.

The greatest numbers of service members sustain concussion. Those who present for medical attention are screened and assessed for the presence of concussion-related symptoms (Figure 26–4). During the exam, if red flags are noted, patients are transferred to medical facilities that have CT capability for further evaluation. In the absence of red flags, efforts are made to manage these patients locally for up to 14 days. Service members are placed on duty restrictions for at least 24 hours, longer if symptoms persist. Once asymptomatic, exertional testing is performed. This procedure uses principles from the cardiac literature, in which patients exercise to their target heart rate. Following the exercise, a brief cognitive exam (Standardized Assessment of Concussion or similar) is given, and the patient is assessed for the recurrence of any symptoms. The presence of exercise-induced cognitive difficulties or symptom recurrence triggers ongoing duty restrictions. Absence of problems after exertional testing leads to the removal of duty restrictions. Service members with a diagnosis of concussion are given an information sheet and education in a context of expectation of recovery. Those with ongoing symptoms are screened for comorbid psychological health issues, including depression and PTSD. Those patients not showing improvement within the specified time frame are then transferred to a Level III facility where further evaluation occurs. Neuropsychological testing may be done, and the previously established treatment plan may be modified. Ongoing symptoms at this time lead to evacuation out of the theater of operations.

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**Figure 26–4. Deployed Setting Provider Algorithm.**

*Initial Management of Concussion in Deployed Setting*

**Traumatic Event Occurs: Possible Concussion**

(Blast exposure, fall, motor vehicle collision etc.)

Assess for loss of consciousness (LOC)/Alteration of consciousness (AOC) (dazed, “bell rung”, “seeing stars”, memory loss etc)

- If possible AOC/LOC after trauma, diagnose concussion and...
  1. Administer MACE
  2. Assess for red flags and symptoms

**Red Flags**

1. Progressively declining level of consciousness
2. Progressive declining neurological exam
3. Pupillary asymmetry
4. Seizures
5. Repeated vomiting
6. Clinician verified GCS < 15
7. Neurological deficit: motor or sensory
8. LOC greater than 5 minutes
9. Double vision
10. Worsening headache
11. Cannot recognize people or disoriented to place
12. Slurred speech
13. Weakness

**Symptoms**

1. Confusion (<24 hrs)
2. Unusual behavior
3. Irritability
4. Unsteady on feet
5. Vertigo/dizziness
6. Headache
7. Photophobia
8. Phonophobia

**Primary Care Management (PCM)**

1. Give educational sheet to all mTBI patients
2. Reduced stimulius environments
3. Rest
4. Aggressive headache management—use acetaminophen q 6hrs X 48hrs. After 48 hrs, may use naproxen pm
5. Avoid tramadol, narcotics
6. Consider nortriptyline or amitriptyline, 25 mg po q HS for persistent headaches (>7 days)—prescribe 10 days maximum
7. Implement duty restrictions
8. Send consult to tbi.consult@us.army.mil
9. Consider or evacuation to higher level care if clinically indicated
10. Document concussion diagnosis in EMR

**ICD-9 Codes**

850.0 Concussion w/o LOC
850.1 Concussion w/ LOC < 30 min
RETURN-TO-DUTY CRITERIA

Management at the Level IV facility often involves magnetic resonance imaging (MRI), including gradient recall echo and diffusion-weighted imaging sequences, which are more sensitive to brain injury than conventional T1- and T2-weighted sequences. In addition, the patient is evaluated by a neurologist. This prompts the decision to either return to the combat setting or, more likely, return stateside for ongoing medical care. Clinical algorithms, based on available literature and expert consensus, are used to guide the management of all patients with combat-related TBI.

Warfighters are unique individuals who may put the mission and comrades ahead of themselves. For this reason, those with concussion do not always seek immediate medical care. It is through routine PDHAs that previous concussion may be identified or ongoing symptoms are reported. In delayed presentation such as this, efforts are made at normalizing the service members’ sleep patterns. Following this, other potentially debilitating symptoms such as headaches and dizziness are addressed. Often requiring pharmacotherapy, headaches may also respond to alternative techniques such as physical therapy, occipital nerve blocks, or botulinum toxin injections (see Chapters 21 and 35, this volume). Dizziness and balance complaints (Hoffer et al. 2004), often seen without vertigo following TBI, are evaluated using isobalance testing. If indicated, canalith repositioning is performed, or for noncandidates, habituation exercises are initiated. Data from the Naval Medical Center San Diego indicate that those with blast exposure are more likely to suffer constant vestibular symptoms, whereas those with blunt trauma experience intermittent problems (Hoffer et al. 2010). A primary care model is used for early concussion management. Patients failing primary care management may be referred to one of 15 TBI specialty centers across the United States for further assessment and management.

Service members with concussion who are stationed at remote bases where TBI assets are limited may be treated via primary telemedicine initiatives. Consults can be arranged via the Virtual TBI Clinic. Through video conferencing, patients at remote locations are seen by a TBI provider from an established TBI clinic. Recommendations are then made to the local clinician. Video follow-up can be scheduled as needed. A second mechanism utilizes e-mail for providers in areas that have less sophisticated conferencing capabilities. After seeing a patient with known or suspected TBI, the provider may send the de-identified history and physical to an e-mail account that is staffed by a variety of TBI experts. Recommendations are then forwarded to the provider, usually within 4 hours. This mechanism has been used successfully by providers both stateside and in the combat setting. Follow-up communication with the referring clinician is usually established within 30 days of the consult, serving as a quality assurance mechanism. With either of these mechanisms, patients exhibiting findings that raise concern can be scheduled for transfer to a more sophisticated medical facility.

The DVBIC has recently established the TBI Regional Care Coordination (RCC) program. Currently, all TBI patients evacuated from the combat setting are identified to the RCC staff. The patient is contacted immediately to confirm demographics and care needs. Patients are provided contact information for the RCC program. Additional contact with each patient is attempted at 3 months, 6 months, 1 year, and 2 years. During these telephone interviews, patients may discuss any ongoing issues and request additional guidance. Each RCC maintains a database of known TBI resources within its service region. Although referrals cannot be made directly from the RCC, the program is able to provide the patient with necessary information to facilitate care. The program interfaces with the Veterans Health Administration’s Federal Care Coordination program, which focuses on polytrauma patients. Service members may opt out of this program at any time. Maintaining contact with this patient population remains challenging given the highly mobile status of the military. Efforts to expand this program to all service members identified with TBI are likely as the program evolves.

RETURN-TO-DUTY CRITERIA

A service member’s return to duty—both restricted and unrestricted—occurs after clinical assessment, treatment, and reevaluation of progress. Cases are individually reviewed and processed according to best practices. Though patients may have the same diagnosis, symptoms and treatment response are highly variable, thereby requiring careful consideration before duty restrictions are removed. It is important to evaluate cognition before return to duty. Efforts are under way to evaluate a practical cognitive assessment for such determinations. Computer-based cognitive testing should not be done until at least 24 hours postinjury. There are a variety of tools to test cognition. The Automated Neuropsychological Assessment Metrics (ANAM) has empirical data as well as some military normative values, making this a useful tool (Vincent et al. 2008). As recommended by multiple professional societies and commissions, the Department of Defense recently mandated the use of the ANAM for baseline predeployment neurocognitive testing while other instruments are evaluated in a head-to-head study to evaluate their sensitivity and specificity for TBI. Computer-based cognitive testing can also be used following TBI to assess neurocognitive changes as part of a return-to-duty evaluation.
For settings in which computer-based cognitive testing is not available, the current military strategy for return to duty includes the MACE, which contains a validated screening tool, the Standardized Assessment of Concussion (McCrea et al. 1997), that is used to evaluate athletes for return to play. The MACE is most sensitive for use immediately postinjury but has also been used days later to screen for improvement or decline in condition. This tool has been widely distributed for use.

Vestibular testing and exertional testing are highly valued examinations that should occur prior to consideration for return to duty. Much research is currently under way looking at the mechanism of injury and vestibular complications (dizziness, balance issues), length of symptoms, and the ability to return to work (Gotshall et al. 2007). Vestibular trauma is of concern because of its ramifications of service member's stability in activity, awareness of surroundings, and overall safety of oneself and colleagues. Dizziness is often the mTBI patient's primary disability (Hoffer et al. 2004).

Exertional testing is another vital component in the assessment steps for return to duty. Research in this specialty has mostly been done in the sports medicine arena or animal models (Griesbach et al. 2008). Experts in sports-related TBI conclude that before one returns to play, he or she must be free of all postconcussive symptoms at rest and exertion (Cantu 2001) (see Chapter 27, Sports Injuries, this volume). Military exertional testing considerations include exercise to achieve 65%–85% of the target heart rate. Upon reaching the target heart rate, the patient is assessed for symptoms and cognition with an alternative version of the MACE. If the patient is asymptomatic and without cognitive dysfunction following exertion, return to duty can be considered.

**REHABILITATION AND COMMUNITY REENTRY**

Once medically stable, the small percentage of service members with severe or penetrating TBI undergo state-of-the-art rehabilitation at a VA polytrauma rehabilitation center or comparable civilian partner. These programs offer extensive multidisciplinary care for the improvement and progression of health and activities of daily living. Many return to functional status, but for those requiring ongoing care, options may include federally supported assisted-living or coma emergence programs. These programs are offered at select VA medical centers or DVBC civilian partners.

Families often provide in-home care for these wounded warriors. The National Defense Authorization Act of 2007, Section 744, mandated the development of a family caregiver curriculum to "train family members in the provision of care and assistance to members and former members of the Armed Forces with traumatic brain injuries." This curriculum is currently being developed by a presidentially-appointed committee of subject matter experts.

Two civilian community reentry programs within the DVBC network providing symptom management, cognitive therapy, and social skills have been instrumental in returning those patients with significant cognitive and behavioral issues to a home setting. In addition to therapy, these settings provide work trials that may increase the rate of gainful employment postdischarge.

Finally, technology is being levered to increase the independence in those service members with cognitive deficits. Pilot projects utilizing cell phones and personal assistive devices are under way. Using calendar and alarm functions, these devices are being tested as memory aids. Automated medication delivery systems that dispense only the appropriate dose and alarm at set dosing intervals are being evaluated in some care settings in an effort to increase medication safety and compliance.

**FUTURE DIRECTIONS AND CLINICAL RESEARCH OPPORTUNITIES**

In the fall of 2008, the Uniformed Services University of the Health Sciences (USUHS) opened the Center for Neuroscience and Regenerative Medicine with the goal of studying the effects and treatments of TBI and PTSD. Specifically, USUHS is establishing a consortium between Walter Reed National Military Medical Center, the National Institutes of Health, the Defense Center for Traumatic Brain Injury and Psychological Health, the Army Medical Research Command labs, and Navy labs. This network will work with USUHS as the coordinating center to accelerate regenerative medicine programs across these institutions so that fundamental studies are moved to translational laboratories and, in turn, this science will migrate quickly so as to advance development in a clinical setting.

The recently established DVBC Armed Forces Institute of Pathology TBI Research Center focuses on translational applications of biophysics and neuropathology. The lab offers advanced imaging, including 7-tesla and 9.4-tesla MRI machines with the ability to perform cutting-edge magnetic resonance microscopy. The lab has obtained a CARS microscope that will allow for in vivo studies of the effects of blast on the brain.

Numerous studies are planned or in progress to further elucidate the nature of blast-related TBI, effects of treatment, and long-term outcome. The following is a partial list of TBI research initiatives:

- Elucidation of the cellular and molecular mechanisms underlying the pathophysiological events following TBI
- Development and validation of computerized and animal model systems to explore the synergistic effects of TBI (including blast and impact) on the dynamic strains within brain tissue in combat injuries
- Drug interventions: neuroprotective/anti-inflammatory, regenerative
- Neuroimaging studies to assess or map injury as predictor of outcome
- Stem cell implantation to enhance neural regeneration
- Biomarker studies to identify and characterize TBI
- Epidemiological studies to determine incidence of mTBI and sequelae of TBI, including vestibular dysfunction and pituitary/endocrine dysfunction
- Fifteen-year longitudinal study of TBI
- Assessment of current and development of novel cognitive rehabilitation therapies
- Clinical trials to evaluate the efficacy of therapeutics to improve outcome following mild, moderate, and severe TBI
- Development of helmet-mounted sensors to quantify blast exposure
- Validation study of the use of the MACE in an austere environment; study recently funded by Congressionally Directed Medical Research Programs
- Longitudinal study of mTBI to evaluate the validity of the TBI screening tool used at large military bases, within the PDHA, and by the Department of Veterans Affairs
Driving simulation study to evaluate driving safety in patients with TBI

In the summer of 2008, the VA’s Office of Research and Development announced a request for applications for TBI-related projects, developed in part with recommendations from the State of the Art TBI conference held in May 2008 (www.research.va.gov/funding/solicitations/docs/TBI.pdf). The wide spectrum of TBI-related issues calls for an integrated research endeavor. Important efforts have begun in the VA, Department of Defense, National Institutes of Health, and DVBIC. The military and VA health care systems are committed to fully provide comprehensive programs required for optimal treatment of patients with TBI. More recently, collaborations with civilian partners (Massachusetts Institute of Technology, University of Florida, and others) has led to the development and improvement of technology that can further elucidate patterns associated with blast-induced TBI.

**KEY CLINICAL POINTS**

- Traumatic brain injury (TBI) is a common war-related injury.
- Explosions are a prevalent mechanism of combat-related injury, although primary blast brain injury appears to be a rare phenomenon.
- TBI screening occurs at multiple time points during active duty and in veteran medical care.
- Treatment algorithms that consider resource availability and tactical limitations drive TBI care in the combat setting.
- Current research efforts are focused on identifying and mitigating blast-related brain injury.

**RECOMMENDED READINGS**


**REFERENCES**


Assistant Secretary of Defense, Health Affairs Memorandum: Traumatic brain injury definitions and reporting. October 1, 2007


Gotshall KR, Gray NL, Drake AI: To investigate the influence of acute vestibular impairment following traumatic brain injury on subsequent ability to remain on active duty 12 months later. Mil Med 172:852–857, 2007


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