Detecting Traumatic Brain Injury Among Veterans of Operations Enduring and Iraqi Freedom

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Advances in battlefield medicine and protective devices used in Operation Enduring Freedom-Afghanistan (OEF), beginning in October 2001, and Operation Iraqi Freedom (OIF), beginning in March 2003, are saving the lives of many service members who would have died in other wars. While the mortality rate for injures was 30% in World War II and 24% in Vietnam, the rate in these recent wars has been constantly close to 10%.[1-3] The result is that many veterans who previously would have died are living with very serious injuries, and those who formerly would have had serious and apparent injuries now have conditions that significantly impact their lives but are not always obvious.

One of these conditions, traumatic brain injury (TBI), is considered the signature wound of the current conflicts.[4,5] It is estimated that almost 50% of soldiers injured in combat return with some form of TBI (mild, moderate, or severe).[6] This compares with 14% to 18% of combat casualties having a brain injury during the Vietnam War.[4]

What is Traumatic Brain Injury?

Traumatic brain injury is a form of brain damage resulting from a sudden jolt, blow, or penetrating head injury.[7,8] It most commonly occurs when the head is accelerated and then decelerated abruptly. The effect is that strain forces are applied to the axons (nerve fibers) in the brain. This type of closed TBI is broadly referred to as a diffuse axonal injury.[9,10] These injures may result from the head hitting an immovable object, being struck in the head, or waves of energy from an explosion. Penetrating objects such as bullets may also damage the brain. Traumatic brain injury can result in temporary to permanent cognitive, physical, or emotional dysfunction. The severity of the TBI depends on the symptoms that result from the injury, and outcomes can range from a complete recovery to permanent disability or death.[11-13] Table 1 lists common symptoms of TBI.[14-17]

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Traumatic Brain Injury Severity

In more serious cases, when blasts and other mechanisms of injury result in loss of consciousness producing a TBI, the injury may be defined as mild (≤ 30 minutes) [American

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Table 1.
Common Symptoms of Traumatic Brain Injury

General Symptoms of TBI	Symptoms of Moderate to Severe TBI
Headaches	Loss of consciousness (30 minutes or more)
Difficulty organizing daily tasks	Personality change
Mental confusion (easily confused, easily feeling overwhelmed)	Loss of coordination
Lightheadness or feeling dizzy	Weakness or numbness in the extremities
More sensitive to auditory stimuli, lights, or other distractions	Slurred speech
Behavior or mood changes (feeling sad, anxious, or listless)	Dilation of one or both pupils
Double vision, blurred vision, or tired eyes	Inability to awaken
Ringing in the ears	Seizures
Bad taste in the mouth	Repeated vomiting or nausea
Fatigue or lethargy (feeling tired all of the time)	A severe, persistent, or worsening headache
A change in sleep patterns	
Trouble with memory, concentration, or calculations	
Easily irritated or angered	
Impulsivity (lack of inhibition)	
Slowed movement, talking, reading, or thinking	
Sexual dysfunction	

TBI – traumatic brain injury
Sources: Centers for Disease Control and Prevention (May 2003);[14] DePalma et al (2005);[15] Kahn et al (2003);[16] Lew et al (2006)[17]

Congress of Rehabilitation Medicine definition], moderate (≤ 6 hours), or severe (> 6 hours).[18] Also accompanying TBI may be anterograde memory loss or posttraumatic amnesia, difficulty encoding new information following the injury. Posttraumatic amnesia may be mild (< 1 day), moderate (1 to 7 days), or severe (> 7 days).[16,19] Retrograde amnesia tends to follow the same or somewhat less of a time gradient as posttraumatic amnesia. Not all TBI victims suffer from loss of consciousness or amnesia, but those with more mild exposure to trauma may become dazed and confused, characterized by difficulties with orientation, perception, concentration, memory encoding and retrieval, and judgment.[14-16]

Because an estimated 80% of individuals sustaining TBI are classified as mild (mTBI), it is often a condition that is not readily apparent.[12] Most mTBI patients make a rapid recovery, suffer few postinjury complications, and, for these reasons, often bypass acute medical attention or hospitalization. Nevertheless, up to one-third of mTBI patients develop chronic symptoms, and delayed symptom onset is not uncommon.[11]

Table 2.
Common Criteria for Determining the Severity of Traumatic Brain Injury

	Loss of Consciousness	Brain Functioning	Posttraumatic Amnesia	Glasgow Coma Scale Score
Mild TBI	≤ 30 minutes	Normal MRI and CT	< 24 hours	13-15
Moderate TBI	≤ 6 hours	Abnormal MRI and CT	≤ 7 days	9-12
Severe TBI	> 6 hours	Abnormal MRI and CT	> 7 days	3-8

TBI – traumatic brain injury; MRI – magnetic resonance imaging; CT – computerized axial tomography scan
Sources: Coetzer et al (2002);[18] Kahn et al (2003);[16] Sternbach (2000)[19]

Postconcussive syndrome refers to an array of cognitive, physical, and emotional symptoms that can occur following mTBI.[20-22] Patients with postconcussive syndrome may complain of headaches, postural imbalance, insomnia, memory problems, fatigue, irritable or depressed mood, or interpersonal conflict.[17,23] Postconcussive syndrome is challenging to diagnose using a detailed physical exam or neuroimaging alone. It is often the case, unfortunately, that misattributions of underlying psychopathology prevent postconcussive syndrome patients from receiving appropriate care. The constellation of cognitive, behavioral, and social deficits common to TBI may impinge on interpersonal relationships and family support, thus complicating recovery.[24] Table 2 lists characteristics of mild, moderate, and severe TBI.[16,19]

Causes of Traumatic Brain Injury

Common causes of TBI, both civilian and military, include falls, motor-vehicle accidents, striking or being thrown against an object, or assault.[7] In the OEF and OIF war zones, however, the most common sources of TBI are explosives and blasts.[5,15,25,26] Traumatic brain injury accounts for approximately 60% of war injuries caused by blasts.[5]

Explosives can take the form of conventional bombs or enhanced-blast explosive devices.[15] Conventional bombs cause a blast wave that spreads out around its point of origin. It is initially a wave of high pressure which is followed by strong and forceful wind. Damage tends to increase as distance from the explosion decreases. Warfare in Iraq often uses explosive devices loaded with metal pieces which cause greater penetrating force, potentially causing penetrating injuries on top of closed injuries caused by blast waves. Enhanced blast-explosive devices can present greater damage than conventional bombs because the initial explosion triggers a secondary explosion, spreading out

force that lasts longer.[15]

Four basic types of injuries are caused by blasts: (1) primary—over-pressurization of "blast wave"; (2) secondary—projectiles based on proximity of primary blast; (3) tertiary—effects due to wind, which may propel the victim into walls, the ground, or other objects; and (4) quaternary—burns, asphyxia, and exposure to toxic inhalants. (See Table 3.)[14,15,25,27]

manifest psychiatric presentations predating the TBI or in response to the trauma.[22,32] However, more research is required to determine what post-TBI symptoms are due to mechanisms of brain injury versus functional psychiatric involvement either preceding or following the trauma

While extensive literature exists describing recovery from blunt-force trauma due to motor-vehicle accidents or falls,[7]

Table 3.
Types of Blast Related Injuries

Category of Injury	Source of Injury	Implications of Injury
Primary blast injury	Overpressurization of blast wave	Tympanic membrane damage; lung damage; occipital rupture; concussion
Secondary blast injury	Projectiles based on proximity of primary blast	Penetration of extremities (including the head)
Tertiary blast injury	Blast related wind impacting the speed and force with which the body hits or is hit by objects	Fracture; amputation; closed or open brain injury
Quaternary blast injury	Random circumstances such as burns, asphyxia, and exposure to toxic inhalants	Burns; closed and open brain injury; breathing problems (eg, asthma; COPD); exacerbation of cardiovascular risk factors (eg, hypertension)

COPD – chronic obstructive pulmonary disease
Sources: Centers for Disease Control and Prevention (May 2003)[14] and (December 2006)[27]; DePalma (2005)[15]; Finkel (2006)[25]

Screening at the Time of Potential Traumatic Brain Injury

The most common initial screening tool is the Glasgow Coma Scale. It includes questions on motor responses (6 grades), verbal responses (5 grades), and eye-opening responses (4 grades). Lower scale scores indicate greater likelihood of more severe TBI.[28] Table 2 includes the scale cutoff scores for levels of TBI severity.[16,19] A copy of the Glasgow Coma Scale can be found on the Internet at http://www.strokecenter.org/trials/scales/glasgow_coma.pdf.[29]

The Defense and Veterans Brain Injury Center (DVBIC) at Walter Read Army Medical Center has developed a Military Acute Concussion Evaluation assessment procedure for use in warzones. The Military Acute Concussion Evaluation is based on the Standardized Assessment of Concussion[30] and includes more detailed assessments of the incident leading to potential TBI and current clinical status than occurs with administration of the Glasgow Coma Scale. While not yet validated, a description of this procedure is available on the DVBIC Web site at http://www.dvbic.org/.[31]

Course and Recovery of Traumatic Brain Injury

Recovery from brain injury varies significantly by severity group. Victims of moderate to severe TBI may suffer from residual neurocognitive deficits for the remainder of their lives. They can manifest amnesia, hyperdistractibility, and other attentional deficits, language impairment, motor slowing and incoordination, and changes in personality.[11]

Although most victims of mTBI suffering from PCS recover over a 3-month to 1-year time frame, many do not.[23] It has been argued that those who do not recover their function typically

data and studies describing blast injury are limited.[9] Whereas blunt force trauma may be somewhat more focal due to coup and contrecoup forces, blast injury may be more diffuse due to primary overpressurized waves pervasively affecting the entire brain; secondary and tertiary effects might furthermore create more multifocal effects.[15] There may also be an accumulation of effects secondary to repeated blasts. Veterans may have been exposed to multiple explosions, and while receiving only mild postconcussive effects from one blast, a second or third blast of equal force could result in more severe injury.[9]

Traumatic Brain Injury and Posttraumatic Stress Disorder Comorbidity

Posttraumatic stress disorder (PTSD) frequently follows exposure to blast and other TBI etiologies, and symptoms frequently overlap with those observed following TBI. Diagnostic discrimination between the two conditions may therefore be challenging and complicate treatment formulations. Furthermore, many brain areas typically affected in TBI such as frontal, temporal, and subcortical regions are the same as those putatively involved in PTSD symptom expression.[33]

Some authors have noted that the overlap between symptoms of PTSD and TBI calls into question current diagnostic tools for discriminating PTSD among TBI patients and thus requires the development of new measures that can differentiate the two. At a minimum, it is likely that symptoms from TBI compromise the ability to cope with the stress of PTSD (eg, through disinhibition of executive-control processes), and PTSD likewise compromises the ability to navigate the cognitive and other manifestations of TBI.[34] Those with TBI may also have more severe PTSD.[35]

Screening for Traumatic Brain Injury – Department of Defense

Because mTBI may not have obvious outward symptoms, and symptoms may overlap with other conditions,[36] extensive screening efforts are required. Starting in April 2003, all active duty, reserve, and National Guard service members and Department of Defense civilians deployed to a war zone have been required to complete an in-person post-deployment health assessment (PDHA) between 30 days before and 30 days after redeployment away from the war zone. This process includes a screening form (DD2796) that has 4 questions about potential TBI.[37] These address (1) experiences that could lead to TBI (eg, explosion); (2) condition following the event (eg, dazed, confused); (3) symptoms that began or got worse after the event (eg, memory problems); and (4) symptoms experienced in the last week. Patients indicating they were exposed to an event and have had symptoms are then referred for further evaluation.[38,39] The screening forms and specific questions mentioned in this section are available on the Department of Defense Deployment Health Clinical Center-PDHealth Web site at http://www.pdhealth.mil/.

Since March 2005, it is required that returning service members be offered a postdeployment health reassessment (PDHRA) 90-180 days (preferably 120-150 days) following redeployment. Individuals who were hospitalized must have a PDHRA 90-180 days after discharge. This includes form DD2900, which has the same 4 TBI questions described above.[40] Information from the PDHA and PDHRA, along with the predeployment health assessment form DD2795[41] (completed within 60 days prior to deployment), is maintained in the permanent medical record and Defense Medical Surveillance System.[38,42] A recent report summarizing results of the PDHRA indicated a higher rate of self-reported mental health concerns and referrals than that observed with the PDHA, suggesting increased morbidity over time following deployment.[42]

Screening for Traumatic Brain Injury – Veterans Health Administration

On April 2, 2007, a system-wide TBI Screening Clinical Reminder was introduced into the Veterans Health Administration (VHA). On April 13, VHA directive 2007-013, *Screening and Evaluation of Possible Traumatic Brain Injury in Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF) Veterans*, was released based on the deliberations of a dedicated task force.[43] In this directive, it was noted that "currently there are no validated [TBI] screening instruments accepted for use in clinical practice." The directive furthermore cautioned that screening can lead to positive results due to other postdeployment conditions (eg, PTSD).

The TBI Screening Clinical Reminder is part of the VA Computerized Patient Record System (CPRS) and is designed to be administered to all veteran VHA patients who separated from active duty after September 11, 2001. It embodies a branching pattern of inquiry that first determines whether a previous diagnosis of TBI has been established, and, if not, whether (1) a plausible etiology for a TBI exists (eg, being near an explosion); (2) posttraumatic neurological alterations followed the etiological event; (3) postconcussive symptoms followed the posttraumatic neurological alterations; and (4) postconcussive symptoms persisted into the week preceding the evaluation. Each of these branches (sections) of the clinical reminder is evaluated only if the branch preceding it is true. Positive findings for all 4 branches result in a positive screening result. If the outcome is positive, then follow-up ensues.

A TBI Second Level Evaluation format was recently implemented by VHA. Second-level screening probes in greater detail (a) etiological variables such as number of, types of, and parameters (eg, distance from blast) relating to events predicting TBI severity; (b) neurological sequelae such as number of loss of consciousness episodes, duration of longest loss of consciousness episode, and number of episodes; (c) nondeployment TBI; (d) pain documented as to location and degree of interference with life; and (e) physical exam and medication review. The practitioner signing the related progress note must be a physiatrist, physical medicine and rehabilitation physician, or neurologist who arrives at a final TBI diagnosis.

Traumatic Brain Injury Incidence Among Veterans of Afghanistan and Iraq

Precise numbers describing the burden of TBI among OEF and OIF veterans are not available. Estimates come from a variety of sources. As of September 30, 2007 the Pentagon listed 4471 TBI diagnoses from OEF and OIF.[44] However, this number excludes cases of TBI not initially considered battle injuries. According to the founder of the Congressional Brain Injury Task force, more than 150 000 TBI instances have occurred among approximately 1.5 million OEF/OIF participants.[44]

The rate of those who screened positive on the initial VA TBI Screening Clinical Reminder is 20%.[44] That does not mean all of these patients actually had a TBI. This figure represents those who screened positive for possible TBI, requiring further diagnostic workup which may or may not indicate a TBI. This rate is similar to that seen in at least one VA hospital in North Carolina.

Many TBI sufferers, especially if untreated, may endure medical, behavioral, and social consequences for many years—perhaps even a lifetime.[4,17,24,45,46] It is essential that health care providers in the Department of Defense, VA, and private sectors do their best to identify and appropriately treat TBI among OEF and OIF veterans. **NCMJ**

Dr Jackson is supported by a Merit Review Entry Program (MREP) award from the Department of Veterans Affairs Health Services Research & Development Service (VA grant MRP 05-312). The views expressed in this article are those of the authors and do not necessarily reflect the position or policy of the Department of Veterans Affairs.

REFERENCES

1 Gawande A. Casualties of war—military care for the wounded from Iraq and Afghanistan. *N Engl J Med*. 2004;351(24):2471-2475.
2 Holcomb JB, Stansbury LG, Champion HR, Wade C, Bellamy RF. Understanding combat casualty care statistics. *J Trauma*. 2006;60(2):397-401.
3 US Casualty Status. http://www.defenselink.mil/news/casualty.pdf. Accessed November 30, 2007.
4 Okie S. Traumatic Brain Injury in the War Zone. *N Engl J Med*. 2005;352(20):2043-2047.
5 Keltner NL, Cooke BB. Biological perspectives: traumatic brain injury-war related. *Perspect Psychiatr Care*. 2007;43(4):223-226.
6 *Soldiers with Traumatic Brain Injury [fact sheet]*. McLean, VA: Brain Injury Association of America; February 2006.
7 Eden J, Stevens R, eds. *Evaluating the HRSA Traumatic Brain Injury Program*. Washington, DC: The National Academies Press; 2006.
8 Bigler ED. Anterior and middle cranial fossa in traumatic brain injury: relevant neuroanatomy and neuropathology in the study of neuropsychological outcome. *Neuropsychology*. 2007;21(5):515-531.
9 Taber KH, Warden DL, Hurley RA. Blast-related traumatic brain injury: what is known? *J Neuropsychiatry Clin Neurosci*. 2006;18(2):141-145.
10 Kochanek PM, Clark RSB, Jenkins LW. TBI: Pathobiology. In: Zasler ND, Katz DI, Zafonte RD, eds. *Brain Injury Medicine, Principles and Practice*. New York: Demos; 2007:81-96.
11 Rao V, Lyketsos C. Neuropsychiatric sequelae of traumatic brain injury. *Psychosomatics*. 2000;41(2):95-103.
12 Heegaard W, Biros M. Traumatic brain injury. *Emerg Med Clin North Am*. 2007;25(3):655-678, viii.
13 Moppett IK. Traumatic brain injury: assessment, resuscitation and early management. *Br J Anaesth*. 2007;99(1):18-31.
14 Explosions and Blast Injuries: A Primer for Clinicians. May 9, 2003. http://www.bt.cdc.gov/masscasualties/pdf/explosions-blast-injuries.pdf. Accessed November 5, 2007.
15 DePalma RG, Burris DG, Champion HR, Hodgson MJ. Blast injuries. *N Engl J Med*. 2005;352(13):1335-1342.
16 Khan F, Baguley IJ, Cameron ID. 4: Rehabilitation after traumatic brain injury. *Med J Aust*. 2003;178(6):290-295.
17 Lew HL, Poole JH, Guillory SB, Salerno RM, Leskin G, Sigford B. Persistent problems after traumatic brain injury: The need for long-term follow-up and coordinated care. *J Rehabil Res Dev*. 2006;43(2):vii-x.
18 Coetzer BR, Hayes NM, Du Toit PL. Long-term employment outcomes in a rural area following traumatic brain injury. *Aust J Rural Health*. 2002;10(4):229-232.
19 Sternbach GL. The Glasgow coma scale. *J Emerg Med*. 2000;19(1):67-71.
20 Bazarian JJ, Atabaki S. Predicting postconcussion syndrome after minor traumatic brain injury. *Acad Emerg Med*. 2001;8(8):788-795.
21 Lishman WA. Physiogenesis and psychogenesis in the 'post-concussional syndrome'. *Br J Psychiatry*. 1988;153:460-469.
22 Vanderploeg RD, Curtiss G, Luis CA, Salazar AM. Long-term morbidities following self-reported mild traumatic brain injury. *J Clin Exp Neuropsychol*. 2007;29(6):585-598.
23 Vanderploeg RD, Curtiss G, Belanger HG. Long-term neuropsychological outcomes following mild traumatic brain injury. *J Int Neuropsychol Soc*. 2005;11(3):228-236.
24 Draper K, Ponsford J, Schonberger M. Psychosocial and emotional outcomes 10 years following traumatic brain injury. *J Head Trauma Rehabil*. 2007;22(5):278-287.
25 Finkel MF. The neurological consequences of explosives. *J Neurol Sci*. 2006;249(1):63-67.
26 Warden D. Military TBI during the Iraq and Afghanistan wars. *J Head Trauma Rehabil*. 2006;21(5):398-402.
27 *Bombing: Injury Patterns of Care, Blast Injuries Module Curriculum Guide*. Atlanta, GA: Centers for Disease Control and Prevention and American College of Emergency Physicians; December 2006.
28 Teasdale G, Jennett B. Assessment of coma and impaired consciousness. A practical scale. *Lancet*. 1974;2(7872):81-84.
29 Glasgow Coma Scale. http://www.strokecenter.org/trials/scales/glasgow_coma.pdf. Accessed December 1, 2007.
30 McCrea M, Kelly JP, Randolph C, et al. Standardized assessment of concussion (SAC): on-site mental status evaluation of the athlete. *J Head Trauma Rehabil*. 1998;13(2):27-35.
31 Military Acute Concussion Evaluation [brochure]. http://www.dvbic.org/pdfs/DVBIC_instruction_brochure.pdf. Accessed December 1, 2007.
32 Fann JR, Burington B, Leonetti A, Jaffe K, Katon WJ, Thompson RS. Psychiatric illness following traumatic brain injury in an adult health maintenance organization population. *Arch Gen Psychiatry*. 2004;61(1):53-61.
33 Gerring JP, Slomine B, Vasa RA, et al. Clinical predictors of posttraumatic stress disorder after closed head injury in children. *J Am Acad Child Adolesc Psychiatry*. 2002;41(2):157-165.
34 Bryant RA, Marosszeky JE, Crooks J, Baguley I, Gurka J. Coping style and post-traumatic stress disorder following severe traumatic brain injury. *Brain Inj*. 2000;14(2):175-180.
35 Chemtob CM, Muraoka MY, Wu-Holt P, Fairbank JA, Hamada RS, Keane TM. Head injury and combat-related posttraumatic stress disorder. *J Nerv Ment Dis*. 1998;186(11):701-708.
36 Bay E, McLean SA. Mild traumatic brain injury: an update for advanced practice nurses. *J Neurosci Nurs*. 2007;39(1):43-51.
37 Department of Defense Form DD 2796:Post-deployment health assessment (PDHA). http://www.dtic.mil/whs/directives/infomgt/forms/eforms/dd2796.pdf. Accessed December 1, 2007.
38 DOD Deployment Health Clinical Center - PDHealth.mil. http://www.pdhealth.mil/. Accessed December 1, 2007.
39 Hoge CW, Auchterlonie JL, Milliken CS. Mental health problems, use of mental health services, and attrition from military service after returning from deployment to Iraq or Afghanistan. *JAMA*. 2006;295(9):1023-1032.
40 Department of Defense Form DD 2900: Post-deployment health re-assessment (PDHRA). http://www.dtic.mil/whs/directives/infomgt/forms/eforms/dd2900.pdf. Accessed December 1, 2007.
41 Department of Defense Form DD 2795: Pre-deployment health assessment. http://www.dtic.mil/whs/directives/infomgt/forms/eforms/dd2795.pdf. Accessed December 1, 2007.
42 Milliken CS, Auchterlonie JL, Hoge CW. Longitudinal assessment of mental health problems among active and reserve component soldiers returning from the Iraq war. *JAMA*. 2007;298(18):2141-2148.
43 VHA Directive 2007-013: Screening and evaluation of possible traumatic brain injury in Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF) veterans. http://www1.va.gov/vhapublications/ViewPublication.asp?pub_ID=1556. Accessed December 1, 2007.
44 Zoroya G. 20,000 vets' brain injuries not listed in Pentagon tally. USA Today. November 23, 2007, 2007: A1.
45 Cicerone KD, Azulay J. Perceived self-efficacy and life satisfaction after traumatic brain injury. *J Head Trauma Rehabil*. 2007;22(5):257-266.
46 Shames J, Treger I, Ring H, Giaquinto S. Return to work following traumatic brain injury: trends and challenges. *Disabil Rehabil*. 2007;29(17):1387-1395.