Severe and Penetrating Traumatic Brain Injury in the Context of War

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■ ABSTRACT

Our data suggests that traumatic brain injury (TBI) may account for up to one third of battle-related injuries in today’s war. Although the majority of these injuries are classified as mild in severity, service members with severe or penetrating TBI can be faced with many challenges. Injuries sustained on the battlefield require a slightly different approach than the TBI care that is traditionally seen in a civilian setting. This article presents the range of care that occurs beginning on the battlefield and continuing to state-of-the-art rehabilitation within the Department of Defense and Veterans Affairs Polytrauma System of Care.

■ KEY WORDS
military, penetrating TBI, severe TBI, traumatic brain injury

Battle injuries often result in traumatic brain injury (TBI). Of the patients who required medical evacuation from theater (war zone) to Walter Reed Army Medical Center (WRAMC), 32% had TBI. Of these patients, severe and penetrating TBI comprised only 8% of the total number of TBI patients. The annual economic burden of TBI in the United States was approximately $60 billion in 2000. The average direct medical cost for severe TBI in 2002 was $65,600 per patient. Fortunately, the military population’s healthcare needs are covered by TRICARE or Department of Veterans Affairs (VA) benefits.

■ MECHANISMS OF INJURY: TBI

Traumatic brain injury is a general term and can refer to a number of different types of injuries to the brain. A TBI is sustained when any external force applied to the brain is significant enough to cause an alteration in consciousness or alter normal neurological functioning for a period of time. The nature of the external force that is exerted, the strength of that force, the area of the brain where it impacts, and individual physical and genetic variations are all factors that combine to yield highly individualized injuries. Operationally, the Defense and Veterans Brain Injury Center uses the American Congress of Rehabilitation Medicine definition of TBI. This definition is consistent with those used by the World Health Organization and the Centers for Disease Control and Prevention, with minor differences in severity classification.

In the current theaters of operation in Iraq and Afghanistan, the 4 most common mechanisms of brain injury are exposure to a blast, motor vehicle accident, fall, and gunshot wound to the head or neck. Different mechanisms of injury result in different types of injury to the brain. Blunt force trauma such as the impact from a fall or from a motor vehicle accident most often results in a coup or coup-contra-coup type of injury. If such an impact happened with a great deal of velocity or with significant torsion, such as in an aviation accident or blast exposure, there may be a diffuse axonal injury—also referred to as a shear injury. Blunt trauma results in a closed head injury, which can be further classified on a continuum of severity. Any injury which involves the penetration of matter (whether a foreign object such as a fragment of munition...
or a sliver of bone) through the dura, which covers the brain, is called a penetrating brain injury.

Because of the use of improvised explosive devices in Operation Iraqi Freedom and Operation Enduring Freedom, closed brain injuries have become a common battlefield injury. Improvised explosive devices are often planted roadside and such blast exposures often result in motor vehicle accidents, exposing a service member (SM) to 2 possible mechanisms of injury in one combat incident. Blast/explosions are the most common mechanism of injury in the current conflict. The blast itself can cause injury through multiple mechanisms. These mechanisms include direct exposure to the overpressurization wave of the explosion, which can impact the body at a velocity greater than 300 m/s, equal to the speed of sound in air. This impact may rapidly compress air-filled organs and/or displace the entire body. Secondary blast injury may then be caused by the energized (projected or falling) debris or explosive fragments that impact with the head. Tertiary blast injury may also occur as the displaced body impacts with the ground, a wall, or any other object. Finally, quaternary injury may occur through the inhalation of gases or other toxic substances. The effect of primary blast injury on the brain remains uncertain. There is a robust research program that is currently investigating the role of primary blast wave on the brain. However, the unpredictable nature of the blast, that is, how far away an SM may be from the blast, whether the blast occurs in an enclosed or open space, and the velocity of the blast wave may all contribute to the capability of producing injury, both in the brain and systemically.

When a penetrating brain injury occurs, it is not further classified by severity. A penetrating brain injury should be noted with the ICD-9 code 851.9, open intracranial wound. Unlike a penetrating brain injury, however, there is no definitive ICD-9 code for closed head injury. A closed head injury may be coded in a variety of ways. This lack of uniformity in coding is another contributing factor to the difficulty in assessing the true scope of the incidence and prevalence of TBI in our wounded SMs.

When an identified closed head injury occurs, there is a severity rating assigned on the basis of 3 indices: Glasgow Coma Scale (GCS), length of loss of consciousness (LOC) or alteration of consciousness (AOC), and length of posttraumatic amnesia (PTA). The evaluation of these variables allows for a determination of severity of injury ranging from mild to moderate to severe. Mild TBI is characterized by an LOC/AOC of less than 30 minutes, a period of PTA that resolves within 24 hours, or a GCS score of 13 to 15. Moderate TBIs are indicated by LOC/AOC that lasts between 30 minutes and 24 hours, PTA for more than 24 hours or less than 7 days, or a GCS score between 9 and 12. A severe closed brain injury is classified when there is an LOC longer than 24 hours, PTA greater than 7 days, or a GCS score of 3 to 8. When severity indicators are inconsistent, the most severe characterization is used for the rating.

When available, radiology findings from a computed tomography or magnetic resonance imaging (MRI) of the brain may be important in severity ratings as well. If an injury has been classified as a mild TBI by the above factors and radiology findings are positive, the clinician should recognize it as a “complicated mild” with the prognosis of a moderate injury. Although MRI is more sensitive for the detection of diffuse axonal injury, roughly 80% of SMs seen at the WRAMC are ineligible for MRI procedures because of the presence of metal fragments in their bodies.

Typically, TBI is classified by the severity of the initial injury. Although serial in-depth evaluations of the patient’s progress over time are a critical component of TBI care, the severity of an injury is not reclassified on the basis of a patient’s progress or rate of recovery. This can be confusing to patients, families, and command structures who may observe what is classified as a mild injury present with persistent symptoms that are debilitating and significantly impact an SM’s ability to function, whereas another SM may be diagnosed with a severe injury and may eventually recover to a higher level of functioning than his or her buddy with the “milder” injury. Again, this illustrates the individualized nature of these injuries and the complexity involved in assessing and treating them.

**TBI ACROSS MILITARY CARE ECHELONS**

Severe and penetrating TBI is easily recognized on the battlefield. Initial care is provided in the form of buddy aid. Buddy aid involves cover-fire and evacuation to the safe zone. Except in rare cases where combat medics are immediately available, medical care is limited to control of obvious hemorrhage. As soon as possible, TBI casualties are transported to the Battalion Aid Station (BAS). At this level, triage occurs, treatment is initiated, and casualty evacuation plans are formed. It is here that the “Guidelines for the Field Management of Combat-related Head Trauma” are most often implemented. Given the limited resources of the BAS, efforts are concentrated on preventing hypoxia and hypotension, 2 factors that are associated with poor outcomes in TBI. In addition, the guidelines serve as a reference for non-TBI specialists regarding airway protection, restricted use of hyperventilation, osmotic therapy, and the documentation of mental status.

Once stabilized and tactical operations allow, patients are transported to the Combat Support Hospital (CSH). These facilities offer diagnostic, surgical, and intensive care services. At this locale, emergent neurosurgical care includes evacuation of mass lesions, debridement of open wounds, and in some cases, intracranial pressure (ICP)
monitoring. Decompressive craniectomies may be performed at the CSH. Given the uncertainty of evacuation times, frequent patient transports, and limited ICP therapy that can be done in theater, decompressive craniectomies are performed at lower thresholds than in the civilian sector (Defense and Veterans Brain Injury Center, unpublished data, March 2008). As the CSH is on constant standby for incoming casualties, patient-holding capabilities are limited; therefore, patients with severe or penetrating TBI are transferred out of theater as soon as feasible.

In addition to providing primary and tertiary care to the European Command, Landstuhl Regional Medical Center receives all casualties from Iraq and Afghanistan, including the severe and penetrating TBI. Once at Landstuhl Regional Medical Center, ICP monitoring and aggressive ICP therapy are fully utilized according to the recommendations in the “Guidelines for the Management of Severe Traumatic Brain Injury,” 3rd edition, and the Guidelines for the Surgical Management of TBI. As this patient population is predicted to require long-term ICU care and rehabilitation, efforts are made to stabilize all injuries, control ICP, and further evacuate the patient stateside, usually within 36 hours.

Transportation of such resource-intensive patients requires the skill of critical care air transport teams. This team consists of a physician (usually intensivist or emergency medicine trained), critical care or emergency department nurses, and cardiopulmonary technicians who perform routine critical care duties while on board the US Air Force fixed wing aircraft. While en route to the United States, positioning of the patient within the aircraft may be changed to minimize the negative effects of takeoff and landing on ICP. In addition, those patients with comorbid pulmonary injury may require changes in normal flight plans so that altitude is less likely to affect tissue oxygenation. Lower altitude flights result in longer flight times and increased fuel consumption.

Casualty evacuation flights land at Andrews Air Force Base in Maryland and patients are then transferred to preselected final destinations. Those patients with severe and penetrating TBI proceed by ground ambulance to either the WRAMC or the National Naval Medical Center in the Washington, DC, area. These facilities provide care similar to that at civilian level 1 trauma centers. Ongoing ICP management, brain tissue oxygenation monitoring, and fever control occur until these issues are resolved. If indicated, additional imaging such as MRI, cerebral angiography, and transcranial Dopplers may be performed.

It is here that families are finally able to visit and participate in care decisions. The families, upon hearing the news of their loved ones’ injuries, receive travel orders to the WRAMC. When the family members arrive, a liaison receives them at the airport and brings them to the hospital. For Walter Reed, the family is brought to the Soldier Family Assistance Center (SFAC). The SFAC provides abundant resources for the families, including daycare assistance and housing—either on or off post. As families come from all over the world to be with their loved ones, the SFAC assists with the basic necessities of living for the family members.

Besides the SFAC, Red Cross, and unit liaisons, the family is also provided emotional, spiritual, and social support. Since the Global War on Terror began, the surgical intensive care unit at the WRAMC has become an open visitation unit so that the family can visit at any time with the injured loved one. The SFAC also provides the opportunity for families to come together in support groups as well as in a town hall meeting with other services to make their stay in the hospital the best it could be while they are here for their injured SM.

The staff at the WRAMC is constantly trying to better themselves in helping family members cope and assisting with all their needs in all facets of their lives while their loved one is here receiving care as long as necessary.

### Rehabilitation of the TBI Patient

The recovery from a severe TBI can take several steps. Acute rehabilitation is one of the most important steps in that recovery. As time passes, patients move from a critical health condition to a medically stable one. When that time comes, care is transferred from a military treatment facility to 1 of 4 VA Polytrauma Centers: Tampa, Florida, Palo Alto, California, Minneapolis, Minnesota, and Richmond, Virginia.

For SMs who suffer from a severe and penetrating TBI, the acute rehabilitation period can be an incredible and prosperous time as the patient returns to the highest level of independent functioning. During this rehabilitation period, as they emerge from a coma and posttraumatic amnesia, there are several phases of physical, emotional, and psychological recovery that TBI patients pass through. These phases can be described in terms of their level of responsiveness, function, or behavior. As patients emerge from a coma, they may enter a minimally conscious phase. Although the patient may still be severely disabled and dependent with care needs, the patient gradually progresses from inconsistent responses to more consistent responses.

There are several assessment tools used throughout the continuum of TBI care. Although the GCS is strongly associated with acute morbidity and mortality, it is less strongly associated with long-term functional outcome. Physical and cognitive status at discharge from hospital is associated with discharge destination. Discharge destinations include home, acute rehabilitation facility, and long-term care facility. Another assessment tool, the Rancho Los Amigos Scale, has 8 different levels of responsiveness.
and cognitive functioning. These 8 levels follow a gradual recovery from “no response” (level I) to “purposeful and appropriate response” (level VIII).10

While at the polytrauma center, a multidisciplinary approach is used to holistically care and aid in the progress of healing. This team approach allows particular focus from each discipline to work closely with the patient. Each professional has a valuable and particular role in stabilizing medical and rehabilitation issues, assisting in the restoration of functional abilities, as well as preventing complications that may develop along the path of healing. The following is but a very brief summary of the roles of the multidisciplinary team involved in the rehabilitation phase of the patient with a TBI. The psychiatrist coordinates and directs the multidisciplinary rehabilitation team involved in the complex care of the patient with TBI. A neuropsychologist is concerned with tracking changes in behavior and thinking processes. Therapists, both physical and occupational, focus on assisting patients in their progress in musculoskeletal function and coordination, as well as adaptation to an altered lifestyle. Speech therapists work on swallowing and speech rehabilitation. The social worker/case manager involved manages discharge planning regarding caregiver and family support, equipment, transportation, and home support. Finally, and of significant value to the rehabilitation team is the rehabilitation nurse. Many who work in rehabilitation are certified in rehabilitation nursing. This certification expresses and validates the nurse’s commitment to excellence in the specialty of rehabilitation nursing.11 The role of the nurse is comprehensive in not only focusing on nursing care (ie, bowel and bladder management, nourishment, airway management, sleep pattern management, and potential for skin integrity complications) but also implementing and assisting the family and the patient in the follow-through of the daily multidisciplinary advances. Increasingly, audiologists and vision specialists are consulted to manage the sometimes nebulous hearing and vision symptoms. As each person with a TBI has varying symptoms, recovery timing, and recovery pace, members of the rehabilitation team may vary during the recovery process.

The multidisciplinary focus of the acute rehabilitation phase of recovery is not complete without the family/caregiver support. Their participation encourages progress in cognitive recovery and physical adaptation. The involvement of family/caregivers will develop into a multifaceted role as they participate in activities of daily living.

During the SM’s stay, the VA case manager remains in contact with the patient’s military branch to keep it informed of progress and changes in the patient’s condition.12 The Department of Veterans Affairs and the Department of Defense use phone calls, secure records transfers, and meetings to ensure open communication and effective coordination. Physicians in the Polytrauma System of Care and at Military Treatment Facilities contact each other directly through teleconferencing, videoconferencing, and through VA social workers assigned to each facility.

Today’s veterans with TBIs are receiving state-of-the-art treatment and rehabilitation in the VA Polytrauma System of Care. Combat injured SMs with TBI are faring as well in their day-to-day activities as those in the private sector according to a report from the VA Inspector General. That is especially noteworthy because patients treated at VA facilities have more severe injuries than those in the private sector.12 Of interest in this military population is the outcome following severe and penetrating TBI. A report from Schwartz et al13 states that although terror victims (including suicide bombings, drive-by shootings, intrusions, knife or gun attacks, missiles or mortar attacks) suffered from more severe TBI, almost half (47%) of them succeeded to return to their previous work or education setting, similar to or better than nonterror TBI group (28.2%, \(P = .32\)). That being said, much research needs to be done particularly focusing on the military population who have vigorous duties.

### FUTURE DIRECTIONS

Research opportunities in this field of TBI are numerous. Recognizing that TBI has been labeled a signature injury of the wars in Iraq and Afghanistan,14 much research needs to be done to improve diagnostic tests and treatment of TBI as well as elucidate the pathophysiologic changes that occur with blast injury. Basic science studies are providing evidence that blast injury may cause alterations in nitric oxide production, which affects the function of the hippocampus and reticular formation.15 Biomarkers, such as S-100 proteins in serum16,17 and nitrotyrosine levels in the CSF,18 show promise in the evaluation of TBI. The implications from this research will improve the care of severe TBI in both civilian and military settings. Funding for TBI research continues at lower limits than other disease states seen with similar frequency.19 Given the number of injuries from the current conflict, the United States Congress approved a bill set forth by Senator Orrin Hatch of Utah. The Traumatic Brain Injury Act Reauthorization Bill will “extend and improve funding for a range of TBI rehabilitation programs. These programs include assistance in returning to work, finding a place to live, and obtaining needed support and appropriate rehabilitation services.”20 This bill will assist combat-injured SMs. With this bill in place, our patients, both military and civilian, can rest assured there is funding for the concerns of the TBI population and their families. According to Senator Hatch’s Web site, the federal TBI program comprises prevention and
surveillance activities at the Centers for Disease Control and Prevention, research at the National Institutes of Health, and grants to states from the Health Resources and Services Administration. This reauthorization bill expands and improves those activities, and includes provisions to look at the reintegration of war veterans returning to their communities.

**SUMMARY**

Treating the severe TBI patient requires a holistic approach with smooth transition in the continuum of care. From BAS, to the CSH, to the European Command hospital in Germany, to an air evacuation to the United States military treatment facility, the trauma nurse is found at each level of care. It is essential to remember that this patient population’s care continues into rehabilitation to return them to optimal independent function. The trauma nurse’s role is exceptionally valuable in assuring that these patients survive the critical elements of injury.

**REFERENCES**