TACTICAL COMBAT CASUALTY CARE: TRANSITIONING BATTLEFIELD LESSONS LEARNED TO OTHER AUSTERE ENVIRONMENTS

Managing Traumatic Brain Injury: Translating Military Guidelines to the Wilderness

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Traumatic brain injury (TBI) is a common injury on the battlefield. Much of what medics do to manage these injuries on the battlefield can be translated to other austere environments, such as wilderness or disaster settings. The recognition and diagnosis of TBI can be difficult even in the hospital, but basic understanding of how to define a TBI and prevent secondary injuries can be accomplished with relatively few resources and little training. This article outlines what a TBI is and how to manage it in the field.

Keywords: traumatic brain injury, concussion, head trauma, intracranial pressure, prehospital, wilderness

Introduction

Traumatic brain injury (TBI) is the signature injury identified from the most recent conflicts in Iraq and Afghanistan.¹ While most brain injuries on the battlefield are due to blast and fragments from explosive devices, wilderness TBIs are primarily due to falls during mountaineering activities, but can also occur during cycling, snowboarding, skiing, diving, and hunting and via any other mechanisms that transmit enough force to the victim's head to cause an injury to the brain.^{2–5}

Five to 50 percent of traumatic events in the wilderness result in some form of TBI.^{2–8} The incidence in avalanche victims has been reported to be as high as 25%.^{9–13} The US Centers for Disease Control and Prevention estimated that the combined rates of TBI injuries and deaths increased from 521 per 100,000 in 2001 to 824 per 100,000 in 2010.¹⁴ This increased incidence may represent an increase in detection with the widespread use of computed tomography (CT) scan imaging and increased recognition as an entity by

medical providers. The rate of US TBI deaths during this period has remained stable at 17 to 18 per 100,000.^{14,15}

While rapid evacuation has been aggressively used by the military, especially in a mature combat theater, many wilderness injuries must be treated for hours to days before transport to a medical facility can be accomplished. Diagnostic modalities in both scenarios are similar, however, because both the battlefield and the wilderness medic must rely on a basic clinical examination and history (this examination and history, rather than CT imaging, is used to determine the mode and urgency of evacuation). In addition, many of the therapies available are the same. Prevention of secondary injury and rapid evacuation are the keystones of prehospital TBI treatment.^{16–22} While prehospital TBI management is really no different in the military and civilian arenas, other than medication use (ketamine and hypertonic saline) perhaps, the military's emphasis on immediate evacuation, early and aggressive decompression, and invasive monitoring during early postoperative care has been demonstrated to lead to improved outcomes in penetrating brain injuries.^{23,24}

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Definition

TBI has been broadly classified as either mild, moderate, or severe. Part of this definition is based on the 15-point, modified Glasgow Coma Score (GCS), which has been

Table. Glasgow Coma Score^a

	1	2	3	4	5	6
E	No eye opening	Opens eyes to painful stimuli	Opens eyes to verbal stimuli	Opens eyes spontaneously	N/A	N/A
V	Makes no sounds	Incomprehensible sounds	Incoherent words	Confused, disoriented	Oriented, converses normally	N/A
M	Makes no movements	Extension to painful stimuli (decerebrate)	Flexion to painful stimuli (decorticate)	Withdrawal to painful stimuli	Localizes to painful stimuli	Obeys commands

E, eye; V, verbal; M, motor.

^a Clinicians use this scale to rate the best eye opening response, the best verbal response, and the best motor response an individual makes. The final GCS score is the sum of these numbers.

used to assess neurologic condition after a head injury (Table). A pathoanatomic classification also helps define the underlying injury and includes subdural hematoma, epidural hematoma, subarachnoid hemorrhage, cerebral contusion, and diffuse axonal injury. Often, the more severe the anatomic injury, as documented by CT scan, the more severe the TBI.^{25,26}

Mild TBI, which accounts for over 80 to 90% of all TBIs, has been defined by the American Congress of Rehabilitation Medicine criteria as an acute condition in which the patient has sustained a trauma-induced (which includes the head being struck, the head striking an object, or the brain undergoing an acceleration/deceleration movement without direct external trauma to the head²⁷) physiologic disruption of brain function, as manifested by one of the following: 1) any period of loss of consciousness (LOC); 2) any loss of memory of events immediately before or after the accident; 3) any alteration of mental state at the time of the accident (feeling dazed, disoriented, and/or confused); and 4) focal neurologic deficits that may or may not be permanent. To meet criteria for a mild TBI (mTBI) LOC must be less than 30 minutes in duration, the initial GCS (post LOC) should be 13–15, and posttraumatic amnesia should be less than 24 hours.

Most TBIs will be mild (a concussion). The military has developed diagnostic tools for evaluating mTBI on the battlefield using the Military Acute Concussion Evaluation (MACE) and the Standardized Assessment of Concussion (SAC).^{28,29} Concussions have 3 grades of severity based on LOC and duration of altered mental status (AMS).^{30,31} Grade 1 is no LOC and less than 15 minutes of AMS; grade 2, no LOC and greater than 15 minutes of AMS; grade 3 is any LOC. The GCS ranges from 13 to 15.

Moderate TBI is prolonged LOC greater than 30 minutes (but less than 24 hours) and a neurologic deficit with a GCS of 9 to 12.³² Severe TBI is LOC greater than 24 hours with a GCS less than 9. Moderate and severe TBI patients usually have an intracranial abnormality and significant neurologic deficits; in addition, they may be comatose, have a seizure, or have unstable vital signs.^{16,17,20}

While the GCS was originally devised to predict outcome in head injury cases, it is more complex to use than other scores, and conditions other than TBI (ie, drugs, high altitude cerebral edema, or shock) may lower the score even in the absence of brain injury. Other methods of evaluation in the acute phase may be more expedient in the field, such as the best GCS-motor score (GCS-M) or the AVPU scale, which uses 4 simple categories (Alert; Verbal response; response to Pain; Unresponsive). While not used to define the severity of TBI, the AVPU scale is simple and a practical assessment of level of consciousness for first-providers.^{17,32,33}

The “best” motor score is another less cumbersome assessment; when combined with pupillary reaction, it has been shown to be highly predictive of underlying injury and 6-month mortality.^{34,35}

While a primary injury is often caused by a mechanical insult to the brain, secondary injuries are non-mechanical damage that occur after the primary injury. Secondary injuries may be caused by hypotension, hypoxia, inadvertent hypo- or hyperventilation, and hyperthermia and can dramatically worsen the casualty's outcome. Prehospital hypotension or hypoxia have been reported to nearly double the mortality rate.^{36,37} Patients who are intubated and undergoing bag-valve-mask ventilation are especially at risk for inadvertent hyperventilation, which leads to vasoconstriction and ultimately brain ischemia if prolonged and worse outcomes.³⁸ While therapeutic hypothermia in severe TBI has not been shown to be efficacious as a treatment,³⁹ hyperthermia has been demonstrated to be harmful.⁴⁰ In addition, secondary injury may be exacerbated when the cerebral perfusion pressure (CPP) is less than 60 mm Hg. The CPP is determined by subtracting the intracranial pressure (ICP) from the mean arterial pressure (MAP), ($CPP = MAP - ICP$). When the MAP falls below 60 mm Hg and/or the ICP increases above 20 mm Hg, then the CPP decreases, likely worsening outcome. Increased ICP can be caused by bleeding in or around the brain or edema from hypoxia, ischemia, or injury. While CPP cannot be measured in the field, signs of increased ICP may be detected by a decrease in the level of consciousness or motor posturing; suspected herniation may be detected by development of asymmetric pupils or hemiparesis (a lateralizing sign). Maintaining a normal ICP, a normal MAP, and a CPP > 60 mm Hg^{18,19} is associated with improved outcomes.^{18,21,23,41}

Management

The initial evaluation of a patient with suspected TBI should be done as soon as possible after the acute injury, when it is safe to do so. For example, a climber who falls or is struck by an object and has sustained a head injury should be safely brought to the ground as soon as possible for further examination. A rescuer who puts himself or herself in danger may become a second victim and thus unable to care for the first. Many head injuries in the wilderness are associated with spine injuries, and caution should be taken to immobilize the spine, if possible, when moving a patient to a safe area. Airway, breathing, and circulation should be assessed as soon as possible, and bleeding should be controlled. Scalp bleeding may be controlled by direct pressure but may

also require a suture. The patient's level of consciousness should be assessed (using GCS, AVPU, or the “best” motor score), and a primary survey of injuries should be completed. In addition, a quick assessment for localizing signs (hemiparesis) and pupil size and reactivity is necessary to complete the primary survey. All lifesaving interventions that are necessary and possible should be implemented at this time. Positioning is the most critical factor in airway management, and airway adjuncts such as jaw thrust, nasal pharyngeal airways, supraglottic airway, endotracheal intubation, or cricothyroidotomy should be performed as indicated. Tension pneumothorax, flail chest, or open pneumothorax should be treated if present, and the patient should be positioned so that normal temperature can be maintained. Hypothermia is a far greater risk than hyperthermia in the acute phase. For example, a snowboarder with a head injury should not be placed directly on the snow while examination and treatment is carried out. If monitoring equipment is available, blood pressure, oxygen saturation, capnography, and glucose should be measured. If monitoring is unavailable, the patient's level of consciousness, mental status, pupil size, motor response, pulse, and respiration should be the minimum observed and recorded to assess for changes in the patient's status.^{21–23,28,42,43}

Although it is impossible to predict which mild TBIs will progress and thus which patients will need to be evacuated, all patients with moderate or severe TBI should be evacuated as soon as possible. Maintaining vital signs and normal temperature and minimizing additional trauma is crucial.²⁸ In general, hypo- and hyperventilation should be avoided. Mild hyperventilation can be used for brief periods if the patient shows signs of impending herniation⁴⁴; these include asymmetric or nonreactive pupils (in patients without eye injuries), extensor posturing, and/or no motor response (not from spinal cord injury). Patients with signs of herniation should be given a bolus of hypertonic saline if available, temporarily hyperventilated to a P_aCO_2 of 30 to 35 mm Hg, and have their head elevated greater than 30 degrees if possible.^{45,46} A bag-valve-mask can be used to support ventilation. If capnography is not available, then a respiratory rate of 12 breaths per minute for normal ventilation, or a rate of 16 breaths per minute for hyperventilation, may be used. Blood pressure of either MAP > 60 mm Hg or systolic blood pressure > 100 mm Hg should be maintained.^{18,19} A weak or absent radial pulse may indicate a systolic blood pressure < 90 mm Hg. Raising the victim's legs may increase the venous return and blood pressure if fluids are not available. If oxygen is available, O_2 saturation should be kept at 90 to 96%, with hyperoxia avoided. The field methods for

Figure 1. Algorithm for treating increased intracranial pressure and herniation in the field. (Algorithm designed by the authors.)

treating increased intracranial pressure and herniation are temporary measures, and rapid evacuation to a medical facility with neurosurgical capability is critical (algorithm summarized in Figure 1).^{16,21–23,43,47}

The prehospital care guidelines of the military are outlined by the Committee on Tactical Combat Casualty Care (CoTCCC).⁴⁸ In making recommendations for prehospital care, this committee takes into consideration austere environments, tactical, and logistical factors. The guidelines are evidence-based, but given the environment in which they are practiced other factors may be more compelling for their adoption than the literature foundation. As an example, mannitol had been recommended for the treatment of severe TBI in the now-outdated third edition of the Brain Foundation's *Guidelines for the Management of Severe Traumatic Brain Injury*.⁴⁹ However, due to mannitol's tendency to precipitate or freeze, its fragile glass bottle storage, and the difficulty of reconstituting the medication, it was never adopted as

a viable alternative for the treatment of intracranial hypertension in the forward setting by the CoTCCC. The CoTCCC's recommended management of TBI in the field is summarized in Figure 2.

Patients with mTBI should be re-evaluated in the field, but their immediate evacuation is less critical. However, depending on the underlying pathology, they may deteriorate as any TBI case may, and all patients need ongoing monitoring and follow-up evaluation. Patients with painful injuries may be given analgesics to control pain with the understanding that it may change their examination. Ketamine (as suggested in Tactical Combat Casualty Care [TCCC]⁴⁸) may be an ideal drug in this situation because it maintains airway reflexes, ventilation, and blood pressure, but it may result in hallucinations or other altered states.⁵⁰ MACE, SAC, and other tools for mTBI evaluation can be used if available, but they do not obviate the need for further evaluation in a medical facility.^{20,31} Chronic medical conditions can

The Tactical Combat Casualty Care (TCCC) guidelines for the management of TBI in the field are:

a. Casualties with suspected TBI should be monitored for changes in level of consciousness (LOC), pupillary dilation, hypotension, and hypoxia. Any casualty with TBI and decreased LOC should have their head elevated 30 degrees above horizontal if possible. If the casualty develops hypotension (SBP < 90 mmHg or loss of radial pulse), administer sufficient Hextend to correct the hypotension. The casualty's legs may be raised to improve hypotension. Casualties with oxygen saturation below 90% should be given oxygen if available. If capnography is available, PaCO₂ should be between 35–40 mmHg.

b. Pupillary dilation and/or decreased LOC may be signs of cerebral herniation; if this occurs, hypertonic saline and hyperventilation may be used as salvage therapy. A bolus of 250 cc of hypertonic saline can be given to decrease intracerebral pressure. The PaCO₂ should be between 30–35 mmHg. If capnography is not available, use a respiratory rate of 16/min. (Routine hyperventilation in the absence of herniation is harmful and should be avoided.)

(From the current TCCC Guidelines, *PHTLS Prehospital Trauma Life Support*, 8th edition, 2016, Burlington, MA, Jones and Bartlett Learning)

Figure 2. The CoTCCC–recommended management of traumatic brain injury in the field.⁴⁸

develop after any TBI and thus require follow-up. Patients with mild TBI who have returned to baseline can walk out of the field and, if not nauseated, should maintain oral hydration and nutrition, especially if the evacuation will be lengthy.^{20,26,27,30}

Conclusions

TBI can readily present in austere environments. Once diagnosed and classified, field-expedient methods should be used to treat the primary injury and prevent any potential secondary injury that may result from hypoxia, hypotension, or increased intracerebral pressure. Prevention of hyperthermia is also important but is less critical in the acute phase of care. Depending on the severity, most casualties with a TBI will need to undergo medical evaluation, but clearly those with moderate or severe TBI should be evacuated as soon as possible for more urgent care.

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