Traumatic Brain Injury: Diagnosis and Management
by the Emergency Medicine Specialist

Edward P. Sloan, MD, MPH, FACEP

Key Learning Points Regarding TBI and the Emergency Physician

1. Guidelines exist that direct the acute diagnosis and management of patients with TBI by Emergency Physicians.

2. Both the medical literature and the Internet have information that allow the Emergency Physician to learn about TBI with the use only of a home computer.

3. The diagnosis of TBI in comatose patients involves the use of the GCS score, especially the motor component. Liberal cranial CT use is also a key strategy in the diagnosis of TBI.

4. The acute management of TBI involves maintaining SBP above 90 mmHg, CPP above 70 mmHg, and the PaO2 above 60 mmHg.

5. Airway management requires RSI, using both sedative agents and paralytics that allow the airway to be secured without causing precipitous rises in ICP or aspiration.

6. Judicious hyperventilation (pCO2 30-35 mmHg) and bolus infusions of mannitol are only indicated when ICP is suspected or proven to be elevated.

7. Emergent cranial decompression is indicated when an extradural hematoma is suspected based on the presence of a fixed and dilated pupil and hemiplegia on the same side as a likely skull fracture.

8. Radiology teaching files and journal clubs can be used to teach Emergency Physicians in training about the management of TBI patients.
Case

A 58-year-old male was struck in an auto-versus pedestrian motor vehicle accident. Paramedics have immobilized the patient, established IV access, are administering oxygen at 15 L/min per NRB, and have him on a cardiac monitor. The patient monitoring responds only to painful stimuli, and is en-route to your trauma center Emergency Department.

Upon his arrival, physical exam revealed BP 100/60, P 110, RR 12, T 98.8, a large laceration over the right temporal-parietal region, several abrasions and contusions to the face, and pinpoint, equal, reactive pupils with extraocular movement intact. He exhibited non-purposeful movements on the cart. The patient’s estimated weight was 70 kg. What are the next Rx steps?
TBI and the Emergency Physician Lecture Overview

FERNE, the Foundation for the Education and Research of Neurological Emergencies, was asked by AAEM, the American Academy of Emergency Medicine, to present a lecture on state of the art traumatic brain injury (TBI) management by the Emergency Physician. The defined purpose was to utilize evidence-based medicine consensus guidelines to summarize the approach of the Emergency Physician to TBI patients in the acute setting. This lecture utilizes information available from the medical literature and from the Internet, both of which are useful in educating practitioners regarding the most current treatment strategies.

Medical Literature and Internet Search Strategies

Medical Literature Search

The information obtained from the medical literature came from the MEDLINE/PubMed search engine. The keywords utilized in the search included the terms “TBI, Guidelines, Diagnosis, therapy, and Emergency Department”. These terms provided the 1996 guidelines from the *J Neurotrauma* and the Italian guidelines from the *J Neurosurg Sci*.

Internet Search

The search of the Internet included a search using [www.google.com](http://www.google.com) and the key words TBI and head trauma. From this search, the American Association of Neurological Surgeons (AANS) website was found and the website of the Brain Trauma Foundation. Using [www.google.com](http://www.google.com), a search for the Cochrane database was made, finding the website [www.update-software.com](http://www.update-software.com). On this website, the Cochrane Library can be searched using key words in order to find abstracts of the reviews done on topics such as TBI and mannitol.

TBI Overview

Epidemiology and Pathophysiology

Each year, there are approximately 1.6 million head injuries in the United States, and 1 million patients are treated and released from an Emergency Department (ED). These injuries result in an additional 230,000 hospital admissions, cause 50,000 deaths, and result in 80,000 patients with permanent neurological disabilities per year. Over 50% of all trauma fatalities are a result of traumatic brain injury (TBI), and TBI is the leading cause of death and disability in the United States. TBI results in a lost productivity costs and annual healthcare costs of $40 billion.

In TBI patients, brain edema results from vasogenic, hydrostatic, osmotic, and cytotoxic effects. As a result of interstitial edema, brain fluid volume increases and intracranial pressure (ICP)
rises. Cerebral perfusion pressure (CPP) is the difference between the patient’s mean arterial pressure (MAP) and ICP, as is shown below:

\[
    \text{CPP} = \text{MAP} - \text{ICP}
\]

(Normal example = 80 mmHg = 90 – 10)

Both elevated ICP and decreased MAP (as in hemorrhagic shock) can cause CPP to diminish to a critical level that will increase cell death and morbidity following TBI. Cerebral blood flow (CBF) will be disturbed when ICP is above 40 mmHg, and ICP levels above 60 mmHg is uniformly lethal. In most patients, therapy for elevated ICP should begin when ICP is consistently above 20 mmHg. Once cell death begins as a result of TBI, there is secondary auto-destruction, which cause oxygen radical formation, intracellular calcium shifts, glutamate toxicity, and a cycle of ongoing cell death.

**Brain Trauma Foundation and Cochrane Recommendations**

**Brain Trauma Foundation Guidelines**

The Brain Trauma Foundation (BTF) has both pre-hospital and in-hospital guidelines available at its website, [www.braintrauma.org](http://www.braintrauma.org). The pre-hospital guidelines can be printed from the website, but the in-hospital guidelines can only be reviewed from the website. The in-hospital guidelines, called the Management and Prognosis of Severe Traumatic Brain Injury, were developed in 2000. They are an update of the guidelines that were published in 1996. The in-hospital guidelines have been accepted by the American Association of Neurological Surgeons (AANS), the first such protocols ever accepted by the Association. These guidelines are also endorsed by the World Health Organization's (WHO) Committee on Neurotraumatology.

**Cochrane Recommendations**

The Cochrane Library has guidelines for several aspects of TBI management, including anti-epileptic drugs, barbiturates, calcium channel blockers, hyperventilation, and mannitol, dating from 1997 to 2001. (Each review is only updated when there is sufficient new information to warrant a new review.)

**Acute Management of Traumatic Brain Injury (TBI)**

The following headings provide the areas of TBI management that are addressed by the BTF or Cochrane guidelines, or are relevant to the management of TBI in the Emergency Department. The BTF guidelines utilize three classes of evidence (I-III) and three recommendation levels (standards, guidelines, and options). The Cochrane Reviews simple state a reviewer’s conclusion based on the available data from the medical literature.
Initial Resuscitation

The BTF guidelines have no firm standards or guidelines stated, instead, they offer only options that may be useful in the acute setting. These include rapid physiologic resuscitation and the use of sedation and short acting neuromuscular blockade as needed. These guidelines state that intracranial hypertension treatment should be delayed unless herniation and/or rapid neurologic deterioration are suspected clinically.

Blood Pressure and Cerebral Perfusion Pressure

Although there are no standards regarding blood pressure management, the BTF recommends that SBP should be maintained above 90 mmHg and that if possible, MAP should be maintained above 90 mmHg and CPP above 70 mmHg. These values should be achieved using judicious fluid infusion as needed.

Hypoxia

Regarding the management of hypoxia, the BTF again states no standards, but suggests that the patient’s PaO₂ should be maintained above 60 mmHg. A recommended option states that endotracheal intubation should occur when the GCS is < 9, when there is persistent hypoxia, or if the patient is unable to maintain their airway.

Hyperventilation

The BTF guidelines do provide a clear standard for hyperventilation, stating that in the face of a presumed or measured normal ICP, the pCO₂ should not be maintained below 25 mmHg even in severe TBI patients. There guidelines also state that early prophylactic hyperventilation, with pCO₂ levels below 35 mmHg, should also be avoided. Several options are provided, including the brief use of hyperventilation in the face of acute neurologic deterioration or persistent intracranial HTN that fails other medical therapies. The option to test for cerebral ischemia using jugular venous O₂ saturation monitoring is suggested if it is necessary to maintain the pCO₂ below 30 mmHg.

The Cochrane Review of this issue states that there is only one randomized controlled trial (RCT) regarding hyperventilation, and that there is still considerable uncertainty regarding its use in TBI. The reviewer concluded that although there is a possible beneficial effect on mortality with the use of hyperventilation in TBI, it is not clear that its use improves neurologic outcome.

Mannitol

The BTF guidelines state that mannitol does control increased ICP, and that it could be used in severe TBI in doses up to 1 gr per Kg body weight, although this is not a standard of care in TBI.
As with hyperventilation, the option is to use it in the face of a rapid neurologic decline and presumed herniation. The physician is guided to avoid hypovolemia with its use, and to keep the serum osmolarity above 320 mOsm. It is suggested that intermittent boluses are preferred over constant mannitol infusions.

The Cochrane Review of mannitol in TBI points out that there are few RCTs and, as such, there is uncertainty regarding its use. It may be useful, however, in the setting of measured (not presumed) increased ICP, and may be superior to pentobarbital in the setting of increased ICP.

**Barbiturates**

There are no standards regarding high dose barbiturates, but the BTF suggests that its use can control increased when all other therapies, both medical and surgical, fail to decrease ICP. It is suggested that this therapy only be used in patients who are hemodynamically stable and those for whom death is not certain.

The Cochrane Review of this subject states that barbiturates work through lowering cerebral metabolism, but because there are few RCTs, that there is no evidence of improved outcome. The studies to date have shown hypotension in 25% of patient treated with this modality, and the reviewer suggests that this adverse effect might offset any of the benefit potential of this TBI treatment.

**Steroids**

The BTF guidelines state that there is no role for steroids in TBI, given that they have not been shown to decrease ICP or improve patient outcome in any studies to date.

**Calcium Channel Blockers**

The Cochrane Library includes a review of calcium channel blockers in severe TBI, pointing out that these drugs may prevent vasospasm and maintain cerebral blood flow. Despite the fact that there are four RCTs, there still is considerable uncertainty, the reviewer points out. Pooled data from two RCTs of traumatic SAH patients has shown that the use of nimodipine decreases mortality by 40% and decreases death or disability by 33%.

**Seizure Prophylaxis**

The BTF guidelines point out that there is no role for anti-epileptic drugs (AEDs) in TBI patients in order to prevent the occurrence of late post-traumatic seizures. There are guidelines that suggest that although they will not change long-term outcome, the use of phenytoin or
cabamazepine or phenytoin may reduce the risk of early seizures in high-risk patients and possible reduce the risk of ICP spikes in association with these early post-traumatic seizures.

The Cochrane Review of AEDs in TBI suggests that these drugs might be helpful in reducing the cytotoxic metabolism that causes glutamate to accumulate following seizures. In six RCTS, there use of AEDs reduces the risk of early seizures by 66%. For every 100 patients who are prophylaxed with an AED post-trauma, 10 would remain seizure-free for the first week. But, as was stated in the BTF guidelines, this early AED use has not been shown to reduce the occurrence of late seizures or alter long-term neurologic outcome.

Antibiotic Prophylaxis

Neither the BTF guidelines nor the Cochrane Library include any mention of prophylactic antibiotics in TBI. The ePocrates database (www.ePocrates.com) and the Sanford guide also have no specific recommendations regarding antibiotic use in penetrating TBI. Tintinalli’s Emergency Medicine Comprehensive Study Guide suggests that antibiotics only be given with neurosurgical consultation, and that in patients who present with a fever late following a skull fracture, that antibiotics should be given. Within 72 hours of injury, pneumococcus should be treated, and after this time interval, Staph aureus and gram negatives should be treated using vancomycin and a third generation cephalosporin such as ceftazadime.

Intracranial Pressure (ICP) Monitoring

ICP monitoring is suggested by the BTF when the TBI patient’s GCS score is < 9, or when the CT shows either space-occupying lesions or edema that compresses the basal cisterns. It is also suggested in patients with a normal CT if two of these three findings are present: age > 40 years, persistent SBP < 90 mmHG, or the presence of motor posturing. ICP monitoring is felt not to be useful in TBI patients with GCS scores > 8, unless there is a space-occupying lesion noted on CT.

Elevated ICP Management

The BTF recommends that ICP be managed using an ICP monitor, and that CPP be maintained above 70 mmHg. Ventricular drainage is encouraged, as is the use of repeat CT scans when indicated. First-line therapies include the use of hyperventilation to a pCO2 of 30-35 mmHg, or the use of mannitol in does up to 1 gr/kg. Second tier agents include the use of barbiturates and hyperventilation to a PCO2 < 30 mmHg.
Emergent Cranial Decompression

Used as far back as in the days of Hippocrates, emergent cranial decompression, or placing a Burr hole in the skull, is used to evacuate extradural hematomas in the setting of presumed tentorial herniation. When rapid, progressive neurologic deterioration occurs, with coma, a fixed and dilated pupil, hemiplegia, and a presumed skull fracture on the side of the blown pupil, a likely intracranial hematoma is present on the same side. In this situation, a temporal Burr hole is placed in proximity to the middle meningeal artery. When bilateral fixed pupils are present, this procedure can be repeated on the contra-lateral side. Although no mention is made of this procedure in the BTF guidelines, indications for this procedure are discussed in the EM Reports TBI discussion, part II.

Brain Trauma Foundation Outcome Prediction Guidelines

In its 2000 TBI guidelines, the BTF also developed standards for outcome prediction in TBI. The presence of clinical findings was correlated with mortality using available class I evidence, looking for a 70% positive predictive value (PPV) as its cutoff for being clinically useful. The clinical findings that are related to mortality, all of which can be detected in the Emergency Department, are reviewed below.

Glasgow Coma Scale (GCS) Score

As the GCS score declines, mortality increases in a step-wise manner. It is a standardized bedside test that preferably should be recorded after pulmonary and hemodynamic stabilization, and without the presence of sedatives or paralytics. The GCS score is viewed to be useful because many health care personnel, with good inter-rater reliability, can do it easily.

Age

As is seen with the GCS score, there is a step-wise increase in mortality as age increases. This is true in TBI as it is in other types of trauma patients.

Pupil Exam

The pupil exam is important to note in the acute setting, since the bilateral absence of a light reflex suggests a higher mortality than in patients who do not have this finding. Asymmetry is defined as > a 1 mm diameter difference, a dilated pupil is one that is > 4 mm in size, and a fixed pupil is one that has < a 1 mm response to light. The pupil exam should be recorded over time, and should whether the pupils are fixed, dilated, and are asymmetric at rest or to light. As with the GCS score, it is best to record the pupil exam after adequate pulmonary and hemodynamic resuscitation has taken place.
Hypotension and Hypoxia

A persistent SBP < 90 mmHg has a 67% PPV for mortality, and when seen with hypoxia, there is a 79% PPV for a bad outcome. Because these parameters are so important, it is suggested that they be recorded frequently during the resuscitation of TBI patients in the acute setting.

Cranial CT Findings

Four categories of CT findings are viewed in the BTB guidelines to have prognostic value, as are discussed below.

Basal Cisterns and Elevated ICP

The presence of compressed or absent basal cisterns suggests a three-fold increased risk of increased ICP and mortality. This finding may be associated with papillary findings, focal lesions on CT, GCS scores, and the insults that result from hypoxia and hypotension.

Subarachnoid Hemorrhage

Subarachnoid hemorrhage (SAH) occurs in up to 56% of severe TBI, and is most commonly seen over the convexity of the brain. For whatever severity of injury noted to the brain, mortality doubles in the presence of traumatic SAH. If there is blood in the basal cisterns, there is a 70% PPV of a bad outcome. The volume and extent of traumatic SAH is related to outcome, independent of the other injuries noted in TBI patients.

Midline Shift

In patients over age 45 and > a 5 mm midline shift, there is 78% PPV of a bad outcome. In any patient, if there is > a 15 mm midline shift, there is a 70% likelihood of an unfavorable outcome. Although midline shift is associated with increased ICP, the presence of other findings on CT, such as a space-occupying lesion, are more important than the shift itself. The presence or absence of a midline shift should be assessed regularly after surgical therapy is provided.

Intracranial Lesions

In all cases of coma, an intracranial lesion should be suspected. In the presence of any traumatic mass lesion, there is a 78% likelihood of a poor outcome. In a patient with a mass lesion who is over 45 years old, there is a 79% chance of death or a vegetative state. Subdural hematomas are associated with a higher mortality than are extradural
hematomas, and the hematoma volume is related to outcome. The worst outcomes are seen in subdural hematomas, diffuse axonal injury (DAI) and epidural hematomas, respectively.

**Brain Trauma Foundation Prehospital Guidelines**

The Department of Transportation National Highway Traffic Safety Administration (NHTSA) awarded the Brain Trauma Foundation a grant to develop Guidelines for emergency medical service providers and their medical directors on the prehospital assessment and treatment of traumatic brain injury. The *Guidelines for Prehospital Management of Traumatic Brain Injury*, were developed with the assistance of a national group of EMS experts, and are available to print from the Braintrauma.org website.¹⁴

**Italian Neurosurgery and Neurointensivist Guidelines**

These guidelines, developed by Italian neurosurgeons and neurointensivists, are published in three parts, covering the initial assessment and management of TBI patients, and the criteria for medical and surgical management for these patients.¹⁵⁻¹⁷

**Initial Assessment and Management**

The initial evaluation of the TBI patient using the motor component of the GCS score is discussed in patients who are comatose (eye score = 1, verbal score = 1,2). In this situation, the motor component takes on great prognostic significance, and it should be scored using the best motor response form either side of the body. The indications for cranial CT are stated, including the loss of two points on GCS, ICP above 25 mmHg, or a decrease in CPP below 70 mmHg or O₂ saturation below 50% for over 15 minutes. These guidelines recommend that intubation be achieved using rapid sequence induction (RSI) with the sedatives thiopental, midazolam, or ketamine and the paralytics succinylcholine or vecuronium.

**Criteria for Medical Therapies**

One unique concept from these guidelines relates to the use of inotropes in the TBI patient who is hypotensive. The recommendation is made that inotropes only be used once the blood volume is restored, and is indicated to maintain MAP above 90 mmHg and to achieve a CPP above 70 mmHg when the ICP is elevated. These guidelines state that the use of this these agents not be in lieu of those therapies that provide a reduction in ICP when it is elevated.
Criteria for Surgical Therapies

These guidelines state absolute and relative criteria for surgical intervention. Knowledge of these indications will help the Emergency Physician to plan for the actions for the neurosurgeon when consultation is made for the TBI patient. Absolute surgical criteria include the presence of a focal lesion that causes a midline shift > 5 mm, and a space-occupying lesion > 25 cc in volume. Relative criteria for surgical intervention include ICP > 20 mmHg or a CPP < 70 mmHg despite optimal medical therapies.


The U.S. government has put together a website that abstracts and catalogues all of the guidelines that have been developed by medical societies from around the world. On the www.guidelines.gov website, using the keywords “traumatic brain injury”, 21 guidelines are provided. Below is the description of some relevant U.S. guidelines.

American College of Radiology (ACR) Recommendations

The ACR has developed guidelines that describe which imaging techniques are indicated for several different clinical conditions seen in patients with TBI. It also goes through each imaging modality and discusses its overall utility in the TBI patient. Cranial CT is recommended as a screening tool in mild TBI in order to establish who required hospital observation, and skull x-rays are recommended if a small penetrating injury or foreign body is suspected, or when a calvarial fracture is suspected. Recommendations for the use of angiography are described, as they are in the EM Reports TBI part I monograph. These include the presence of penetrating TBI, or when vascular occlusion, dissection, or aneurysm is suspected.

Eastern Association for the Surgery of Trauma (EAST) Recommendations

The members of EAST have developed guidelines for the management of mild TBI. These include patients with a transient neurological deficit and no clear pathology on cranial CT. In patients with a GCS of 13-14 and a normal CT, only up to 3% are expected to have any type of subsequent deterioration. Neuropsychological testing is recommended at 1-2 months, since most patients recover from their mild TBI within one month. The authors state that there is limited data on those who do not recover within this time period.

Sports Concussion Guidelines

The management of concussion in sports is described in this website and in Neurology. If an athlete has mild symptoms that resolve within 15 minutes, he or she may return to the event as desired (Grade I concussion). If the symptoms last more than 15 minutes (Grade II concussion),
then there is no further participation in that event and a CT is suggested if the symptoms persist. In the presence of any loss of consciousness (LOC), a grade III concussion, Emergency Department evaluation is recommended if the symptoms persist or if the LOC is prolonged.

Radiology Teaching Files Available via the Internet

Using the website www.google.com and the keywords “radiology teaching files”, the files from many universities are available for review and downloading. These files often contain a case history, radiographs, and a description of the findings of note on these images. Two examples of content are provided from Harvard University (www.brighamrad.rad.harvard.edu/Cases/bwh) and Wayne State University (www.med.wayne.edu/diagRadiology/TF). By hitting the Print Screen button on the keyboard when an image of interest is seen, it is possible to copy the whole computer screen and paste it into PowerPoint for use during a lecture.

TBI Journal Club Articles

Several learning points were discussed at a recent journal club presented for the University of Illinois Department of Emergency Medicine. The following are some items of note from the articles:

1. Skull x-ray use in TBI is limited due to the availability of CT.  
2. Although hypertonic saline is proposed to be effective in TBI, it is not often being used in the clinical setting.  
3. The PEG-SOD TBI study is a good example of a TBI clinical trial.  
4. Patients with a normal CT and normal neurologic exam do not require in-hospital observation and can go home to be observed.  
5. In combined TBI and torso trauma with hypotension, if a patient can be stabilized, it is OK to do the cranial CT prior to performing the laparotomy.  
6. In the face of ethanol intoxication, mild TBI patients most often require cranial CT because of an 8% positive CT rate.  
7. Patients who develop come after having a lucid interval following TBI have a 75% positive intracranial hematoma rate.

Conclusions: TBI and the Emergency Physician

There are a number of sources available for the Emergency Physician to utilize in order to learn how to maximally diagnose and treat patients with TBI. The presence of authoritative texts and monographs, published guidelines, and information and radiographs on the internet make it possible to optimize our care of patients with TBI.
Reference List


**Emergency Department Management and Case Outcome**

While in the ED, the trauma service and neurosurgery were consulted. The patient had ED diagnoses of a non-depressed linear skull fracture, an epidural hematoma, severe TBI, a scalp laceration, and multiple abrasions and contusions. Transferred directly to the OR, where the epidural hematoma was evacuated. Following surgery, the patient was admitted to the ICU and remained on a ventilator for 10 days.

Twenty days following the accident, the patient was discharged to a rehabilitation facility. By six months, the patient was able to drive and function at home, but had some limitations at work. The patient also complained of persistent headaches and amnesia.