Emergency Neurological Life Support
Traumatic Brain Injury Protocol
Version 4.0

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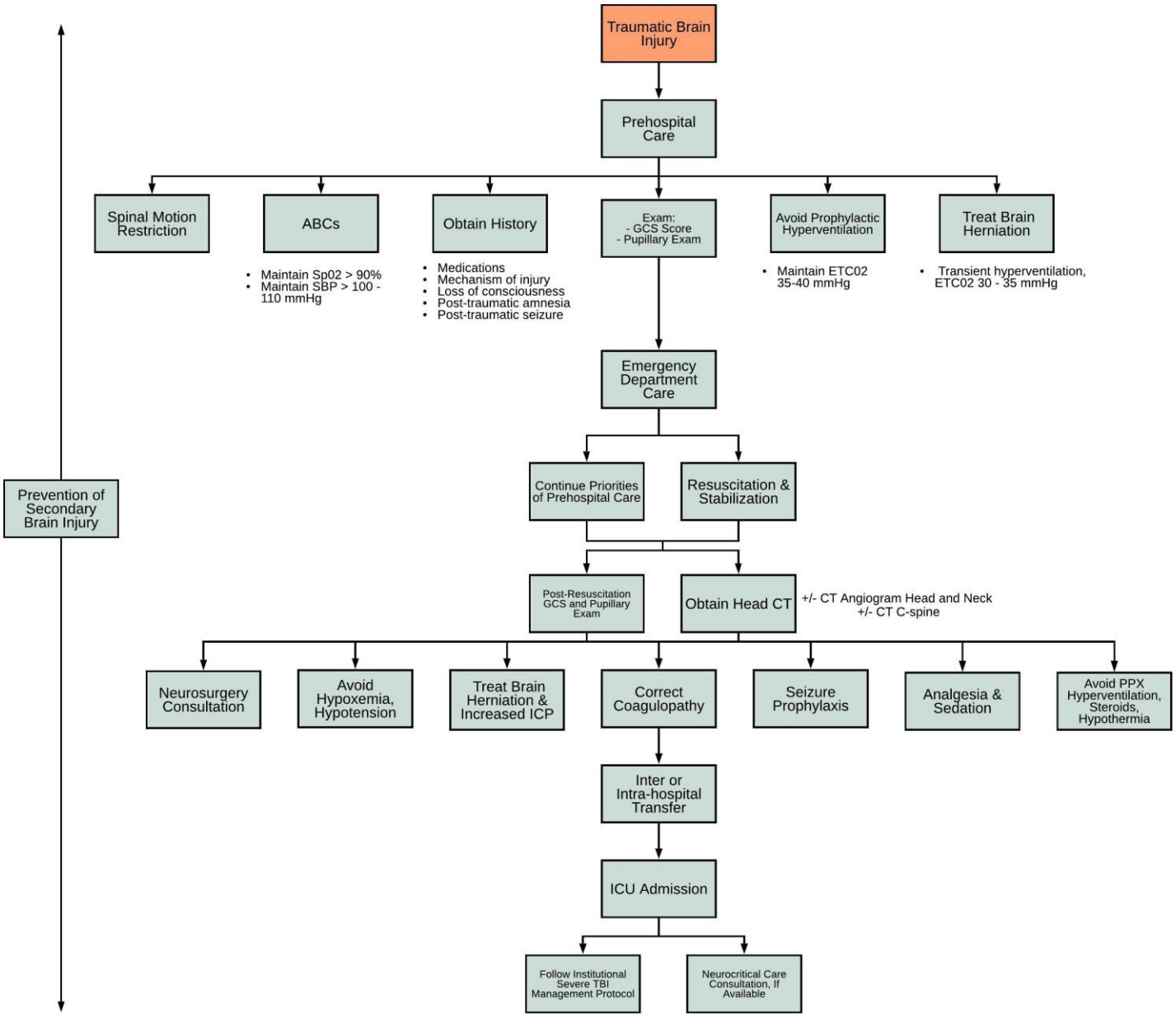
Neurocritical Care Society

ENLS

EMERGENCY NEUROLOGICAL LIFE SUPPORT

Traumatic Brain Injury Algorithm

(click each box for details)



Checklist and Communication

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Checklist

☐ Secure airway and maintain normal ventilation (PaCO2 35–45)
☐ Hemodynamic stabilization: maintain ≥ 110 mmHg for patients 15–49 or > 70 years; maintain SBP ≥ 100 mmHg for patients 50–69 years
☐ Maintain SpO2 > 90%
☐ Restrict motion of C-spine
☐ Determine post-resuscitation GCS score; pupil size, symmetry, and light reactivity
☐ Treat brain herniation and increased ICP
☐ Obtain CT head and C-spine
☐ Neurosurgical consultation
☐ Correct coagulopathy
☐ Seizure prophylaxis
☐ Repeat GCS and pupillary examination hourly
☐ Coordinate safe inter- or intra-hospital transfer

Communication

☐ Age
☐ Sex
☐ Pre-injury health, including home medications (antiplatelet or anticoagulation)
☐ Mechanism and time of injury
☐ Loss of consciousness, seizure, post-traumatic amnesia, helmeted?
☐ Post-resuscitation GCS and pupil size shape and reactivity
☐ Head CT findings
☐ State of C-spine: cleared, not cleared, injury
☐ Other injuries
☐ Current vital signs
☐ Current ventilation therapy including EtCO2 and most recent ABG
☐ Labs: Coagulation parameters, CBC, sodium, BUN, Cr, alcohol level, UTOX
☐ Treatments provided (reversal of anticoagulation, blood transfusions, seizure prophylaxis, etc.)
☐ Neurosurgical plan for surgery, ICP monitoring or not

Sample sign-off narrative

“Hello there–I am signing out a 42-year-old man who presented tonight after a high-speed motorcycle accident that occurred about 11 p.m.”
“The patient was driving and lost control and was found on the road about 20 feet from his motorcycle”
“The accident was witnessed; there was positive loss of consciousness and he had one convulsive seizure lasting about 1 min witnessed by EMS”
“He was wearing a helmet”
“Initial GCS on the scene was 4. Post-resuscitation GCS here in the ED is 7 (E1, M4, V2). He was withdrawing symmetrically and moaning before intubation. Pupils are about 3 mm and briskly reactive”
“Head CT shows a 4 mm acute left SDH and bifrontal hemorrhagic contusions. CT C-spine was negative for fracture, but C-spine is not cleared”
“No other injuries were identified on his primary or secondary trauma survey”
“He is intubated and hemodynamically stable; SBP 120 mmHg and SpO2 96% on F02 60% and PEEP 8. EtCO2 35 mmHg”
“Labs coags were normal, Na 140 and platelets 240”
“He has received levetiracetam 1 g IV × 1, 1L normal saline and no blood products”
“Neurosurgery has been consulted and plans to place an external ventricular drain as soon as he gets to the ICU”
“He will be transferred to the Neurotrauma ICU, bed 4”

Traumatic Brain Injury

Diagnosis and Classification

Traumatic brain injury (TBI) is defined as an alteration in brain function or other evidence of brain pathology caused by an external force. The diagnosis of TBI is based on identifying a traumatic mechanism and/or physical signs of trauma to the brain in a patient with neurological signs or symptoms. The Glasgow Coma Scale (GCS) score ideally should be determined in the prehospital setting and repeated upon arrival to the ED and following resuscitation. The severity of the injury is classified by the *post-resuscitation* GCS score and graded as mild, moderate, or severe.

- Mild TBI: GCS 13-15
- Moderate TBI: GCS 9-12
- Severe TBI: GCS 3-8

The GCS score will be affected by hypotension, hypoxemia, sedation, and paralysis. Therefore, ideally it should be recorded in the ED following resuscitation and prior to administration of sedation or pharmacological paralysis. Scoring of the GCS should be broken down by categories for eye, motor and verbal responses in addition to the total of all values (example: GCS 10 (E3, V3, M4)). The best observed score should be recorded. For example, if a patient follows commands with the right upper extremity but only withdraws with the left upper extremity, then a GCS motor score of 6 (not 4) should be awarded.

Examination	Response	Score (3-15)
Eye Opening Response (E)	Eyes open spontaneously	4
	Eyes open to speech	3
	Eyes open to pain	2
	Eyes do not open	1
Motor Response (M)	Follows commands	6
	Localizes (purposeful) movement toward a painful stimulus	5
	Withdraws (normal flexion) from pain	4
	Abnormal flexion to pain (decorticate)	3
	Extension response to pain (decerebrate)	2
	None	1
Verbal Response (V)	Oriented	5
	Confused	4
	Inappropriate words	3
	Incomprehensible sounds	2
	None	1

Prevention of Secondary Brain Injury

Applied throughout continuum of care of TBI

The primary brain injury following TBI occurs at the time of impact and results in altered level of consciousness. With increasing severity of TBI, there is a risk of multicompartmental hemorrhagic injury, including acute subdural hematoma (SDH), epidural hematoma (EDH), cerebral contusion, traumatic subarachnoid hemorrhage (tSAH), diffuse axonal injury (DAI) and cerebral edema with brain compression and shift. Individuals who survive their initial trauma remain at high risk for secondary brain injury from hypoxia, ischemia, hypotension, hematoma expansion, cerebral edema, brain compression, intracranial hypertension, seizures, and fever. The role of health care providers is to anticipate secondary brain injury, detect it early and treat it quickly in order to prevent neurological worsening.

Prehospital Care

Fifty percent of all deaths from TBI occur within the first few hours of injury. Prehospital care of TBI patients by trained paramedical personnel is critical to prevent secondary brain injury and optimize neurological outcomes for children and adults. Prehospital providers must obtain a relevant history, provide best resuscitative care including maintaining a patent airway, achieve appropriate oxygenation, ventilation and circulation, ensure spinal motion restriction and provide safe and expedient transport to the most proximate and appropriate trauma center.

Priorities in the prehospital setting include:

- Spinal motion restriction
- ABCs: Maintain SpO_2 > 90%, SBP > 100 – 110 mmHg
- Obtain relevant history: mechanism of injury, medications, loss of consciousness, post-traumatic amnesia, post-traumatic seizures
- Determine GCS, pupillary examination
- Avoid prophylactic hyperventilation (maintain $ETCO_2$ 35-40 mmHg)
- Treat brain herniation

Spinal Motion Restriction

Following suspected trauma, a cervical collar and spinal motion restriction is advised to prevent iatrogenic spinal cord injury until spinal stability is established.

Advanced Trauma Life Support (ATLS) protocols should be followed and head computed tomography (CT) obtained expeditiously after the primary survey is complete and the patient is hemodynamically stable. Cervical spine CT imaging is indicated in the setting of moderate-severe TBI because C-spine injuries occur in up to 10% of patients with blunt TBI. A negative C-spine CT may not be sufficient to rule out ligamentous injuries and the C-spine should remain immobilized until it can be cleared.

Please refer to the **ENLS Protocol Traumatic Spine Injury** for a more detailed discussion of spinal precautions and clearance.

ABCDE

The ENLS TBI algorithm is designed to emphasize the importance of preventing secondary brain injury across the continuum of care from the time of initial trauma through admission to the ICU.

Airway

It is imperative to maintain oxygen saturation > 90%. Hypoxia, defined as O_2 saturation < 90% or a PaO_2 < 60mmHg, *even for a brief period of time,* is associated with increased mortality following a TBI. The combination of prehospital hypotension and hypoxia are associated with twice the risk of death than hypotension or hypoxia alone.

- **Maintain SpO_2 > 90%**

Breathing

Normal ventilation targeting a constant end-tidal CO_2 ($ETCO_2$) 35-40 mmHg should be provided. If $ETCO_2$ is not available an adult patient should receive assisted ventilation at a rate of 10 breaths/minute.

- **Maintain normal ventilation, $ETCO_2$ 35-40 mmHg**

Prophylactic hyperventilation should be avoided unless there are signs of brain herniation.

- If signs of herniation, then mild hyperventilation ($ETCO_2$ 30-35 or RR= 20 breaths/minute in an adult) is indicated

Circulation

Hypotension results in brain hypoperfusion, secondary brain injury and increased mortality. The combination of prehospital hypotension and hypoxia are associated with twice the risk of death than hypotension or hypoxia alone.

- **Goal SBP ≥ 100 – 110 mmHg** for adults
  - SBP ≥ 110 mmHg for patients 15-49 or > 70 years
  - SBP ≥ 100 mmHg for patients 50 – 69 years old.

- For children, SBP should be maintained at least > 5th percentile for age (70 mmHg + (age x 2)).

Disability

The severity of traumatic brain injury is classified by the *post-resuscitation* Glasgow Coma Scale (GCS) score and graded as mild, moderate, or severe. The GCS score ideally should be determined in the prehospital setting and repeated upon arrival to the ED and following resuscitation.

- Mild TBI: GCS 13-15
- Moderate TBI: GCS 9-12
- Severe TBI: GCS 3-8

Examination	Response	Score (3-15)
Eye Opening Response (E)	Eyes open spontaneously	4
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	None	1
Verbal Response (V)	Oriented	5
	Confused	4
	Inappropriate words	3
	Incomprehensible sounds	2
	None	1

The GCS score will be affected by hypotension, hypoxemia, sedation, and paralysis. Therefore, ideally it should be recorded in the ED following resuscitation and prior to administration of sedation or pharmacological paralysis. Scoring of the GCS should be broken down by categories for eye, motor and verbal responses in addition to the total of all values (example: GCS 10 (E3, V3, M4)). The best observed score should be recorded. For example, if a patient follows commands with the right upper extremity but only withdraws with the left upper extremity, then a GCS motor score of 6 (not 4) should be awarded.

Expose/Environment

Prehospital providers can provide valuable information about the trauma scene and body presentation when arriving at the emergency center. A systematic way to receive report is helpful to account for these details, and severity of other injuries when caring for the TBI patient. During primary assessment the patient must be fully exposed, yet not left exposed to avoid development of hypothermia.

Obtain History

In the prehospital and emergency department setting, pertinent history includes:

- The mechanism of injury
- Presence / absences of head strike
- Helmet use
- Loss of consciousness and duration
- Post-traumatic amnesia
- Occurrence of early post-traumatic seizures
- Medications (particularly anti-platelet or anticoagulant drugs)
- Alcohol or drug use

This information can be used to activate appropriate trauma protocols and direct subsequent care.

The Essential Neuro Exam in Trauma

Traumatic brain injury severity and classification is based on the *post-resuscitation* Glasgow Coma Scale (GCS) score and graded as mild, moderate, or severe.

- Mild TBI: GCS 13-15
- Moderate TBI: GCS 9-12
- Severe TBI: GCS 3-8

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The GCS score ideally should be determined in the prehospital setting and repeated upon arrival to the ED and following resuscitation. The GCS score will be affected by hypotension, hypoxemia, sedation, and paralysis. Therefore, ideally it should be recorded in the ED following resuscitation and prior to administration of sedation or pharmacological paralysis. Scoring of the GCS should be broken down by categories for eye, motor and verbal responses in addition to the total of all values (example: GCS 10 (E3, V3, M4)). The best observed score should be recorded. For example, if a patient follows commands with the right upper extremity but only withdraws with the left upper extremity, then a GCS motor score of 6 (not 4) should be awarded.

Pupillary size, shape, and reactivity to light should be tested. These are critical pieces of information for early neurosurgical decision-making. Pupillary asymmetry, defined as a difference greater than 1mm, should be immediately recognized because it may indicate ongoing brain herniation and imminent death if not treated.

The GCS score and pupillary examination should be recorded frequently during prehospital and ED care as well as in the ICU to identify neurological worsening or improvement over time. Recognizing a decline in the GCS score ≥2 is crucial because it may indicate secondary brain injury from hematoma expansion, increasing cerebral edema, brain shift/herniation or seizures.

Avoid Prophylactic Hyperventilation

Primary TBI occurs at the time of impact. Prevention of secondary brain injury is the focus of TBI management from initial trauma through the prehospital setting, emergency department (ED), and intensive care unit (ICU) admission.

It is important to avoid prophylactic hyperventilation in the first 24 hours following injury unless there are signs of brain herniation such as a dilated or non-reactive pupil, Cushing reflex (hypertension plus bradycardia) or extensor/decerebrate posturing because early prophylactic hyperventilation is associated with increased mortality. Hyperventilation, particularly within the first 24 hours after head trauma, will decrease cerebral blood flow (CBF) when the brain is hyperglycolytic and may result in cerebral ischemia.

Patients with moderate-severe TBI should be re-assessed frequently for clinical signs of intracranial hypertension or brain herniation including asymmetric, dilated or non-reactive pupils, motor exam with extensor posturing, Cushing reflex (hypertension plus bradycardia) or decline in GCS of more than 2 points. If these signs are present, then hyperventilation ($ETCO_2$ 30-35 or respiratory rate of 20 breaths/minute in an adult) may be used as a temporizing measure until definitive treatment can occur.

Treatment of Suspected Brain Herniation in the Prehospital Setting

Prehospital care of TBI patients by trained paramedical personnel is critical to prevent secondary brain injury and optimize neurological outcomes for children and adults with TBI. The severity of injury is assessed using the Glasgow Coma Scale (GCS) score and classified by GCS of 13-15 as mild TBI, 9-12 as moderate TBI, and 3-8 as severe TBI. Patients with moderate-severe TBI should be assessed frequently for clinical signs of intracranial hypertension or brain herniation including asymmetric, dilated or non-reactive pupils, motor exam with extensor posturing, Cushing reflex (hypertension plus bradycardia) or decline in GCS of more than 2 points. If these signs of brain herniation are present, then mild hyperventilation ($ETCO_2$ 30-35 or respiratory rate of 20 breaths/minute in an adult) may be used as a temporizing measure in attempt to reverse the herniation en route to an emergency department.

EMERGENCY DEPARTMENT CARE

Continue Priorities of Prehospital Care

Upon arrival to the emergency department (ED) the major priorities from the field should be maintained including spinal motion restriction, avoiding prophylactic hypoventilation, continuing resuscitation and stabilization, determining post-resuscitation GCS and pupillary examination, and treating brain herniation.

Resuscitation & Stabilization

Trauma victims should be assessed, resuscitated and stabilized per the Advanced Trauma Life Support (ATLS), Advanced Cardiac Life Support (ACLS) and Pediatric Advanced Life Support (PALS) protocols.

The priorities of resuscitation care include:

- Hemorrhage control: assessment and stabilization of circulation
- ABCs
- Obtain IV / IO access
- FAST assessment for internal bleeding
- Maintain SpO_2 > 90%, SBP ≥ 100 – 110 mmHg, $PaCO_2$ 35-40 mmHg
- Avoid hypotension/hypotensive resuscitation in the setting of TBI
- If post-resuscitation GCS score ≤ 8 → rapid sequence intubation and activate institutional severe TBI protocol.

Post-Resuscitation GCS and Pupillary Exam

TBI severity (mild, moderate or severe) is defined by the post-resuscitation Glasgow Coma Scale (GCS) score.

Examination	Response	Score (3-15)
Eye Opening Response (E)	Eyes open spontaneously	4
	Eyes open to speech	3
	Eyes open to pain	2
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	None	1
Verbal Response (V)	Oriented	5
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	Inappropriate words	3
	Incomprehensible sounds	2
	None	1

The GCS score will be affected by hypotension, hypoxemia, sedation, and paralysis. Therefore, ideally it should be recorded in the ED following resuscitation and prior to administration of sedation or pharmacological paralysis. The best observed score should be recorded. For example, if a patient follows commands with the right upper extremity but only withdraws with the left upper extremity, then a GCS motor score of 6 (not 4) should be awarded.

The size and shape of pupils, and their reactivity to light, should also be tested. Pupillary asymmetry, defined as a difference greater than 1mm, should be immediately recognized because it may indicate ongoing brain herniation and imminent death if not treated.

Obtain Head CT

In the emergency department, Advanced Trauma Life Support (ATLS) protocols should be followed first and head computed tomography (CT) obtained expeditiously after the primary survey is complete and the patient is hemodynamically stable.

Head computed tomography (CT) is the recommended neuroimaging test in trauma due to fast image acquisition and reliable detection of acute blood. The primary purpose of the initial head CT is to identify any intracranial hemorrhage that requires emergent neurosurgical intervention. Acute TBI often results in a multicompartmental intracranial hemorrhagic injury. An acute SDH appears as a homogenous hyperdense concave or crescent-shaped mass that crosses suture lines. An acute EDH is characteristically lentiform and does not cross cranial suture lines. Hemorrhagic cerebral contusions are typically seen in the frontal or anterior temporal lobes can have a “salt and pepper” appearance with mixed density acute blood. Intracranial air suggests an open skull fracture, craniofacial trauma or injury to a sinus. The location and size of the brain hemorrhage(s) should be determined as well as an estimate of the degree of mass effect, cerebral edema and brain shift by measuring the amount of midline shift of the third ventricle and evaluating if the perimesencephalic cisterns are patent, partially compressed or absent. The cranial vault and facial bones should be reviewed for fractures or penetrating objects.

General indications for neurosurgical intervention, including trauma craniotomy and/or hematoma evacuation, are described in the Neurosurgical Consultation section.

Neurosurgery Consultation

Neurosurgery should be consulted for all patients with known or suspected head trauma with abnormal neuroimaging or level of consciousness. If neurosurgical expertise is not available, every effort must be made to transfer a patient with moderate-severe TBI to an appropriate facility where such expertise is available. Adherence to the Brain Trauma Foundation Guidelines, which are based on a systematic evidence-based approach, improves neurological outcomes in both children and adults.

Indications for ICP monitoring

- Intracranial pressure (ICP) monitoring is indicated in patients with GCS score ≤ 8 and an abnormal head CT.
- Elevated ICP should also be suspected and ICP monitoring considered in the setting of an apparently "normal" head CT if the GCS score ≤ 8 with two or more of the following present:
    - Age > 40 years
    - Motor posturing
    - Systolic blood pressure (SBP) < 90mmHg

General indications for neurosurgical intervention including trauma craniotomy and/or hematoma evacuation include [28-32]:

- Acute SDH: > 10mm thickness or > 5mm midline shift; patients with an acute SDH of any size who experience a decline in GCS ≥ 2 points or have asymmetric or non-reactive pupils
- Acute EDH: > 30cm^3, > 15mm thickness, or > 5mm midline shift or GCS ≤ 8
- Cerebral contusions: comatose patients with survivable injuries and brain hemorrhage resulting in midline shift > 5mm or herniation
- Cerebellar hemorrhage resulting in mass effect, brainstem compression or hydrocephalus
- Depressed skull fracture: open fractures depressed greater than the thickness of the cranium

Neurosurgical consultation is also recommended for patients with the following injuries to determine if neurosurgical management is indicated:

- Skull fracture
- Signs of CSF leak with clear or serosanguinous fluid from ears or nares
- Lateralizing signs on neurological examination (i.e., unequal pupils, focal weakness)
- Cerebrovascular injury (refer to *ENLS Acute Ischemic Stroke* module)
- C-spine injury (refer to *ENLS Traumatic Spine Injury* module)

When consulting neurosurgery, it is important to communicate the following key information:

- Age (estimated if unknown)
- Mechanism and time of injury (if known)
- Prehospital and post-resuscitative GCS scores including best eye opening, verbal and motor components.
- Pupillary size, shape, symmetry and reactivity to light
- Head CT and C-spine results
- History of anticoagulant or antiplatelet medications and any treatments provided

Avoid Hypoxemia and Hypotension

The ENLS TBI algorithm is designed to emphasize the importance of preventing secondary brain injury across the continuum of care from the time of initial trauma through admission to the ICU.

Post-injury hypoxia and hypotension result in secondary brain injury and must therefore be prevented.

Hypoxia, defined as O_2 saturation < 90% or a PaO_2 < 60mmHg, *even for a brief period of time,* is associated with increased mortality following a TBI. Hypotension results in brain hypoperfusion, secondary brain injury and increased mortality. The combination of prehospital hypotension and hypoxia are associated with twice the risk of death than hypotension or hypoxia alone.

- **Maintain SpO_2 > 90%**
- **Maintain SBP ≥ 100 – 110 mmHg** for adults
  - SBP ≥ 110 mmHg for patients 15-49 or > 70 years
  - SBP ≥ 100 mmHg for patients 50 – 69 years old.

- For children, SBP should be maintained at least > 5th percentile for age (70 mmHg + (age x 2)).

Treat Brain Herniation & Increased ICP

Signs of intracranial hypertension or brain herniation include:

- Dilated and nonreactive pupils
- Asymmetric pupils
- Motor exam that demonstrates extensor posturing
- Progressive decline in neurologic condition (decrease in GCS > 2 points) that are not associated with non-TBI causes
- Cushing reflex (hypertension, bradycardia, irregular respirations)

If signs of intracranial hypertension or herniation are present, the patient should be treated presumptively for high ICP while simultaneously facilitating the placement of an ICP monitor. Treatment of intracranial hypertension or brain herniation include medical therapies and surgical therapies.

Intracranial hypertension or "high ICP" cannot reliably be diagnosed by clinical examination or brain imaging alone. While head CT findings indicate mass effect and may suggest high ICP, a reliable relationship does not exist between the admission CT and subsequent development of high ICP in patients with severe TBI. Because intracranial hypertension leads to secondary brain injury, management of severe TBI patients using information from ICP monitoring is recommended to reduce in-hospital mortality and 2-week post-injury mortality.

Medical management of elevated ICP (ICP > 22 mmHg sustained) includes:

- Elevate HOB 30 degrees
- Drain CSF (if available)
- Hyperosmolar therapy
  - IV bolus with mannitol
  - IV bolus hypertonic saline
- Optimize cerebral perfusion (SBP > 100-110 and CPP 60-70mmHg) in adults
- Mild hyperventilation
- Optimize analgesia and sedation (see **ENLS: Pharmacotherapy**)
- Maintain normothermia
- Start continuous EEG monitoring and treat seizures

Please refer to **ENLS: Intracranial Hypertension and Herniation** module for detailed discussion of treatment of high ICP.

Please refer to **ENLS: Pharmacotherapy** module for a detailed discussion of hyperosmolar therapies, analgesia and sedation, antiseizure medications.

Correct Coagulopathy

Recognition and treatment

The incidence of coagulopathy in TBI is high. Coagulopathy associated with trauma has several possible mechanisms, but in TBI, the principal process involves tissue factor release. Studies of TXA in TBI for hemostasis in TBI are ongoing. A pharmacological cause of coagulopathy due to antiplatelet or anticoagulant medications, such as warfarin or direct oral anticoagulants is also common

Routine laboratory measures are indicated:

- PT/PTT/INR
- Platelet count
- Finbrinogen
- Thromboelastography (TEG) if available
- Factor Xa levels if DOAC suspected

Expeditious detection and correction of systemic coagulopathy in the first hour after TBI is indicated to reduce the risk of intracranial hematoma expansion and associated secondary brain injury.

See **ENLS: Pharmacotherapy** for detailed antidotes and dosing.

Seizure Prophylaxis

Posttraumatic seizures are a common complication of moderate-severe TBI and are classified as:

- Immediate seizure (within 24 hours of injury)
- Early seizure (24 hours - 7 days after injury)
- Late seizure (> 7 days after injury).

The use of prophylactic antiseizure medication is recommended for 7 days following TBI to decrease the incidence of early posttraumatic seizures.

Two commonly used antiseizure medications in the setting of moderate-severe TBI are:

- Phenytoin
- Levetiracetam

Analgesia & Sedation

Children and adults with severe TBI (GCS ≤ 8) require tracheal intubation for airway protection. Intravenous analgesia and sedation are often needed to ensure pain and agitation are adequately controlled and physiological targets for goal directed TBI care are met. In choosing sedative medications, short acting agents with minimal hemodynamic effects are preferred to allow hourly neurological examinations and rapid detection of any neurological worsening.

See the **ENLS: Airway, Ventilation and Sedation** for a more detailed discussion of Analgesia & Sedations strategies.

Avoid Prophylactic Hyperventilation, Steroids, Hypothermia

Prophylactic Hyperventilation is not recommended.

Primary TBI occurs at the time of impact. Prevention of secondary brain injury is the focus of TBI management from initial trauma through the prehospital setting, emergency department (ED), and intensive care unit (ICU) admission.

It is important to **avoid prophylactic hyperventilation** in the first 24 hours following injury unless there are signs of brain herniation such as a dilated or non-reactive pupil, Cushing reflex (hypertension plus bradycardia) or extensor/decerebrate posturing because early prophylactic hyperventilation is associated with increased mortality. Hyperventilation, particularly within the first 24 hours after head trauma, will decrease cerebral blood flow (CBF) when the brain is hyperglycolytic and may result in cerebral ischemia.

Patients with moderate-severe TBI should be re-assessed frequently for clinical signs of intracranial hypertension or brain herniation including asymmetric, dilated or non-reactive pupils, motor exam with extensor posturing, Cushing reflex (hypertension plus bradycardia) or decline in GCS of more than 2 points. If these signs are present, then **hyperventilation ($ETCO_2$ 30-35 or respiratory rate of 20 breaths/minute in an adult) may be used as a temporizing measure until definitive treatment can occur.**

Steroids Contraindicated

Administration of steroids is harmful and increases the risk of death in patients with severe TBI.

Hypothermia

Currently, the literature suggests that there is no benefit to early prophylactic hypothermia or therapeutic hypothermia for intracranial hypertension to improve neurological outcomes in TBI. However, targeted temperature management for prevention of fever is appropriate.

Inter or Intra-hospital Transfer

Patients with moderate-severe TBI should be transferred to a trauma center with neurosurgical capabilities, including the availability of pediatric neurosurgeons for pediatric patients.
It is important that the following key elements are communicated between the transferring and accepting physician. Click here to view the **TBI Communication Checklist (link).**

In the first critical hours following TBI, both inter- and intra-hospital transport for diagnostic or therapeutic procedures regularly occurs. The priority during transport of a patient with TBI is to prevent secondary brain injury by maintaining minute ventilation for a stable $PaCO_2$ and through prompt treatment of hypotension, oxygen desaturation, increased ICP or seizures that may occur. **The checklist for safe transport of patients with moderate-severe TBI, including pre-transport assessment, transport and post-transport evaluation is shown here (link).**

ICU Admission

Patients with mild, moderate, and severe TBI remain at risk for neurological decline in the first 24 hours after injury due secondary brain injury from a variety of causes including progressive cerebral edema and expansion of intracranial hematomas. Hemorrhagic expansion of traumatic cerebral contusions occurs in about 50% of cases. Patients with moderate-severe TBI should be admitted to an intensive care unit (ICU) with trauma, neurosurgery and neurocritical care expertise and monitored with hourly neurological examinations with special focus on GCS and pupillary examination in order to rapidly detect neurological worsening which occurs about 25% of the time. Recognizing a decline in the GCS score ≥ 2 is crucial because it may indicate secondary brain injury from hematoma expansion, increasing cerebral edema, brain shift/herniation or seizures. A repeat head CT should be strongly considered at 6 hours following initial injury to evaluate for stable or worsening intracranial hemorrhage

Follow Institutional Severe TBI Management Protocol

A systematic, evidence-based approach to management of TBI is recommended including adherence to institutional TBI protocols at trauma centers that follow the Brain Trauma Foundation Guidelines. A trauma patient with a post-resuscitation GCS score ≤ 8 should necessitate activation of the institutional severe TBI protocol.

A systematic evidenced-based approach to the management of pediatric TBI is equally important for children as it is for adults. The PEGASUS study assessed physician adherence to three key performance indicators [early initiation of enteral nutrition, avoidance of hypocarbia ($PaCO_2$ < 30mmHg) and adequate cerebral perfusion (CPP > 40mmHg) for 72 hours after severe TBI] and found that adherence to these performance indicators resulted in improved survival and a more favorable discharge disposition for children.

Neurocritical Care Consultation

Neurocritical care is a unique subspecialty focusing on the optimal management of children and adults with life threating brain injuries, including traumatic brain injury (TBI). Patients with moderate-severe TBI (and in some cases mild TBI when there is intracranial hemorrhage) should be admitted to an intensive care unit (ICU) with trauma, neurosurgery and neurocritical care expertise and monitored with hourly neurological examinations.