Emergency Neurological Life Support®
Traumatic Brain Injury Protocol
Version 6.0

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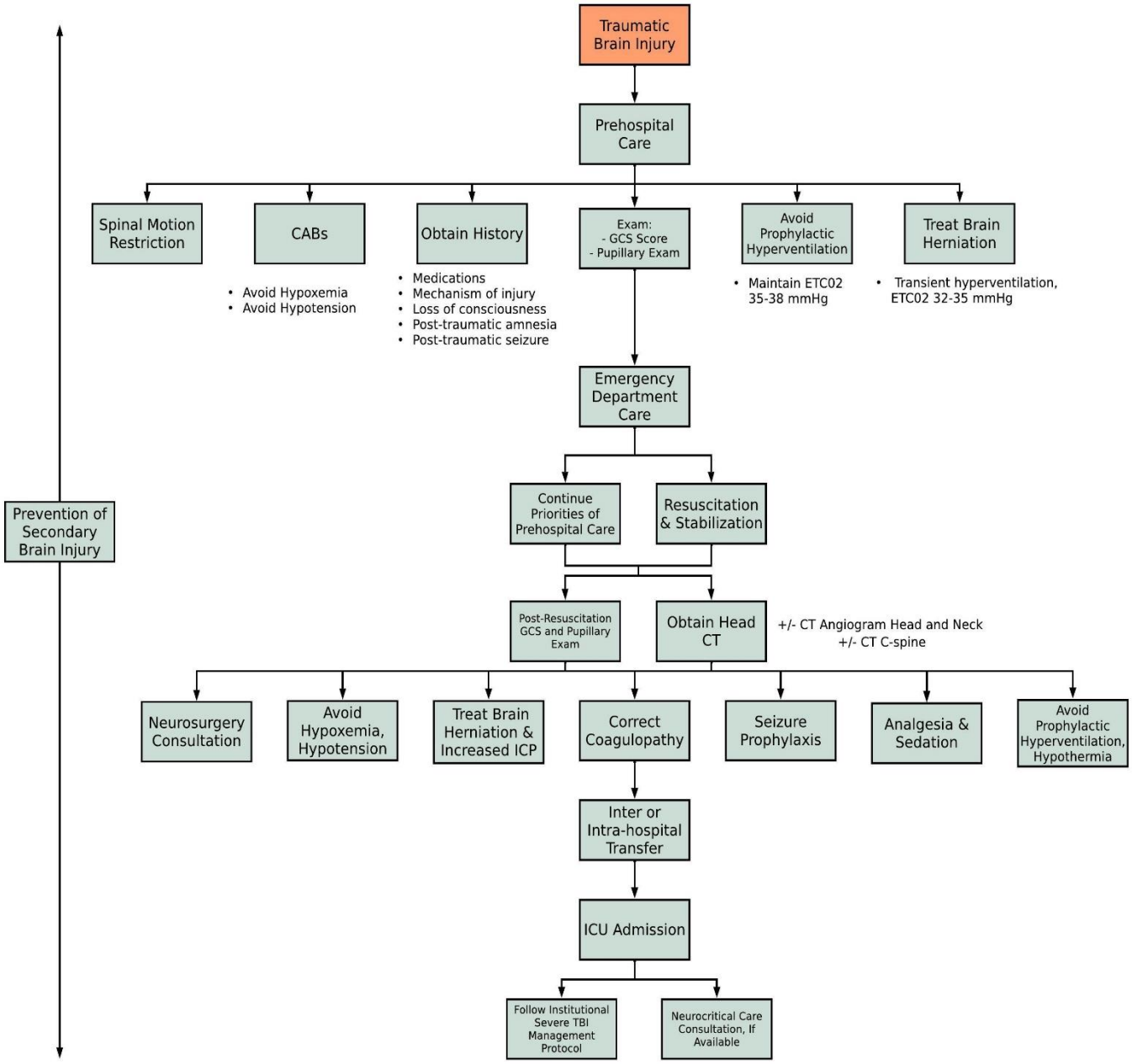
TRAUMATIC BRAIN INJURY ALGORITHM



CHECKLIST

Emergency Department and Early Hospitalization

- ☐ Secure airway and maintain normal ventilation ($PaCO_2$ 35–38 mmHg)
- ☐ Hemodynamic stabilization: maintain ≥110 mmHg for patients 15–49 or >70 years old; maintain systolic blood pressure (SBP) ≥100 mmHg for patients 50–69 years old
- ☐ Maintain SpO_2 >94%
- ☐ Restrict motion of C-spine
- ☐ Determine post-resuscitation Glasgow Coma Scale/Score (GCS); pupil size, symmetry, and light reactivity
- ☐ Treat brain herniation and increased intracranial pressure (ICP)
- ☐ Obtain non-contrast computed tomography (CT) head and C-spine
- ☐ Neurosurgical consultation
- ☐ Correct coagulopathy
- ☐ Consider seizure prophylaxis
- ☐ Q1H GCS and pupillary examination
- ☐ Coordinate safe inter- or intra-hospital transfer

COMMUNICATION CHECKLIST

- ☐ Age
- ☐ Sex
- ☐ Pre-injury health, including home medications (antiplatelet or anticoagulation)
- ☐ Mechanism and time of injury
- ☐ Loss of consciousness, seizure, post-traumatic amnesia, helmet use
- ☐ Post-resuscitation GCS and pupil size, shape and reactivity
- ☐ Head CT findings
- ☐ C-spine status: cleared, not cleared, or documented injury
- ☐ Other injuries
- ☐ Current vital signs
- ☐ Current ventilation therapy and measurements including End-tidal carbon dioxide ($ETCO_2$) and arterial blood gas (ABG)
- ☐ Labs: Coagulation studies, complete blood count, sodium, blood urea nitrogen, creatinine, alcohol level, toxicology
- ☐ Treatments provided (reversal of anticoagulation, blood transfusions, seizure prophylaxis, etc.)
- ☐ Neurosurgical plan for surgery and/or ICP monitoring

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 made after identifying a traumatic mechanism in a patient with neurological signs or symptoms. The Glasgow Coma Scale (GCS) score should be determined in the prehospital setting and repeated upon arrival to the emergency department (ED) and following resuscitation. The severity of the injury is classified as mild, moderate, or severe by the post-resuscitation GCS score.

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

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, E3V3M4). 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 assigned. In those who are intubated, a V1T verbal score is assigned.

PREVENTION OF SECONDARY BRAIN INJURY

Applied Throughout the Continuum of Care of TBI

Primary brain injury following TBI occurs at the time of impact or acceleration-deceleration and typically results in an altered level of consciousness. With increasing severity of TBI, there is an increased risk of multicompartmental hemorrhage, 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 and prevent secondary brain injury, and to detect and treat it quickly to prevent neurological worsening.

PREHOSPITAL CARE

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 resuscitative care including maintaining a patent airway, achieving appropriate oxygenation, ventilation and circulation, and ensuring spinal motion restriction. An ABCDE or CAB system can be used during the prehospital assessment. Safe and expedient transport to the most proximate and appropriate trauma center should be provided.

Priorities in the prehospital setting include:

- Spinal motion restriction
- Maintain SpO_2 >90%, SBP ≥110 mmHg
- Obtain relevant history: mechanism of injury, medications, loss of consciousness, post-traumatic amnesia, post-traumatic seizures, helmet use, alcohol or drug use
- Determine GCS, pupillary examination and other neurologic disabilities (aphasia, facial droop, unilateral weakness, etc.)
- Avoid prophylactic hyperventilation (maintain $ETCO_2$ 35-40 mmHg)
- Identify suspected 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 can be established.

Advanced Trauma Life Support (ATLS) protocols should be followed and head 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 PREHOSPITAL ASSESSMENT

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 intensive care unit.

Airway

It is imperative to maintain oxygen saturation >90%. Hypoxia, defined as O_2 saturation <90% or a PaO_2 <60 mmHg, even for a brief period of time, is associated with increased mortality following 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 ($ETCO_2$ 32-35 or RR= 20 breaths/minute in an adult) is indicated as a temporizing measure until definitive treatment can be provided.

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 ≥110 mmHg for adults**
- **For children, SBP should be maintained > 75th percentile for age**
    - ≤ 28 days >70 mmHg
    - 1-12 months >84 mmHg
    - 1-5 years >90 mmHg
    - ≥ 6 years >100 mmHg

Disability

The GCS score should be determined in the prehospital setting and repeated upon arrival to the ED and following resuscitation. The severity of the injury is classified as mild, moderate, or severe by the *post-resuscitation* GCS score.

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

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, E3V3M4). 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 assigned. In those who are intubated, a V1T verbal score is assigned.

Exposures/Environment

Prehospital providers can provide valuable information about the trauma scene when arriving at the emergency center, including any potential exposures and observable signs of traumatic injury. An organized handoff report is necessary to communicate these details for TBI patients. During the primary assessment, the patient must be fully exposed while avoiding prolonged exposure that can result in hypothermia. Signs of traumatic injury, such as bone malalignment, soft-tissue bruising, and lacerations should be recorded. When patients are log-rolled, spinal immobilization should be maintained.

OBTAIN HISTORY

In the prehospital setting, pertinent history includes:

- The mechanism of injury
- Presence or absence of head strike
- Helmet use
- Loss of consciousness and duration
- Post-traumatic amnesia
- Early post-traumatic seizures
- Medical comorbidities
- Medications (particularly antiplatelet 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

The GCS score should be determined in the prehospital setting and repeated upon arrival to the ED and following resuscitation. The severity of the injury is classified as mild, moderate, or severe by the post-resuscitation GCS score.

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

As the GCS score may be affected by hypotension, hypoxemia, sedation, paralysis, or other intoxicants, it should be recorded in the prehospital setting, 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, E3V3M4). 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 assigned. In those who are intubated, a V1T verbal score is assigned.

Pupillary size, shape, and reactivity to light are critical pieces of information for early medical and surgical decision-making. Pupillary asymmetry, defined as a difference > 1mm, should be immediately recognized because it may indicate brain herniation and irreversible injury if not emergently treated.

AVOID PROPHYLACTIC HYPERVENTILATION

Hyperventilation should be avoided in the absence of signs of brain herniation. Hyperventilation, particularly within the first 24 hours after head trauma, will decrease cerebral blood flow (CBF) when the brain is hypermetabolic and can result in cerebral ischemia. Serial neurologic assessments should be performed frequently to identify clinical signs of intracranial hypertension or brain herniation.

TREATMENT OF SUSPECTED BRAIN HERNIATION IN THE PREHOSPITAL SETTING

Serial neurologic assessments should be performed frequently to identify 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. If these signs are present, then hyperventilation (goal $ETCO_2$ of 32-35 mmHg as measured by capnography or respiratory rate of 20 breaths/minute in an adult) may be used as a temporizing measure until definitive treatment in the hospital setting can be provided.

EMERGENCY DEPARTMENT CARE

Continue Priorities of Prehospital Care

After ED arrival, clinical priorities from the field are maintained. Effective hand-off between emergency medical service personnel and ED providers should occur to ensure a safe transition of care.

Resuscitation and Stabilization

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

The priorities of resuscitation care include:

- Assessment and stabilization: Circulation, airway and breathing (CABs)
- Achieve hemorrhage control and circulation stabilization
- Obtain IV / IO access
- Focused Assessment With Sonography in Trauma (FAST) assessment for internal bleeding
- Maintain SpO_2 >94%, $PaCO_2$ 35-38 mmHg when increased ICP is suspected.
- Avoid hypotension/hypotensive resuscitation in the setting of TBI
- Maintain SBP ≥ 110 mmHg for patients 15–49 or >70 years; maintain SBP ≥100 mmHg for patients 50–69 years
- If post-resuscitation GCS score ≤8 consider rapid sequence intubation and activate institutional severe TBI protocol

OBTAIN HEAD CT IMAGING

In the emergency department, ATLS protocols should be followed first and head CT obtained expeditiously after the primary survey is complete and the patient is hemodynamically stable. The primary purpose of the initial head CT is to identify any intracranial pathology that requires emergent neurosurgical intervention.

Head CT is the first recommended imaging modality after head trauma due to fast image acquisition and reliable detection of acute blood. Acute TBI often results in multicompartmental intracranial hemorrhagic injury. When evaluating CT images, both the location and size of brain hemorrhages should be determined as well as an estimate of the degree of mass effect, cerebral edema and brain shift by measuring the amount of shift of midline structures 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.

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 CT may not be sufficient to rule out ligamentous or spinal cord injuries and the C-spine should remain immobilized until it can be cleared.

Imaging of the intracranial and extracranial vessels with CT angiography/venography or MRI angiography/venography should be considered when any of the following are present:

- Penetrating head or neck injury
- Skull fracture over a venous sinus
- A neurological deficit that is not explained by head CT findings
- Select C-spine injuries (flexion or extension injury or a fracture through the transverse foramen)
- Petrous bone fracture
- Le Fort II or III facial fractures
- A suspected vascular cause for intracranial hemorrhage such as aneurysm rupture or stroke

NEUROSURGERY CONSULTATION

Neurosurgical consultation is indicated for all patients with moderate-severe TBI. Where 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.

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
- C-spine injury

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

- Age
- Mechanism and time of injury
- Prehospital and post-resuscitative GCS scores
- Pupillary size, shape, symmetry, and reactivity to light
- Head CT and C-spine CT results
- Comorbid medical conditions
- History of anticoagulant or antiplatelet medications and any treatments provided

Indications for ICP Monitoring

- GCS score ≤8 and an abnormal head CT
- Elevated ICP should also be suspected and ICP monitoring considered for patients with a normal-appearing head CT and GCS score ≤ 8 if two or more of the following are present:
    - Age >40 years
    - Motor posturing
    - SBP <90 mmHg

General Indications for Neurosurgical Intervention

General indications for neurosurgical intervention including primary decompressive craniectomy and intracranial hematoma evacuation include:

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

AVOID HYPOXEMIA AND HYPOTENSION

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

Hypoxia, defined as O_2 saturation <94% or a PaO_2 <60 mmHg, even for a brief period of time, is associated with increased mortality following 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 ≥94%**
- **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 >75th percentile for age**
  - ≤ 28 days >70 mmHg
  - 1-12 months >84 mmHg
  - 1-5 years >90 mmHg
  - ≥ 6 years >100 mmHg

TREAT BRAIN HERNIATION & INCREASED ICP

Signs of intracranial hypertension or brain herniation include:

- Dilated and nonreactive pupils
- Asymmetric pupils
- Extensor posturing on motor exam
- Progressive decline in neurologic condition (decrease in GCS >2 points)
- Cushing reflex (hypertension, bradycardia, irregular respirations)

Intracranial hypertension cannot reliably be diagnosed by clinical examination or brain imaging alone. 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 in adults or ICP ≥20 in children) includes:

- Elevate head-of-bed to 30 degrees
- Drain CSF (if drain available)
- Hyperosmolar therapy
  - IV bolus with mannitol
  - IV bolus hypertonic saline
- Optimize cerebral perfusion (CPP 60-70 mmHg in adults; children have an age based threshold, minimum CPP 40-50 mmHg with infants on the lower end and adolescents on the higher end of the suggested spectrum)
- Temporary hyperventilation
- Optimize analgesia and sedation (see ENLS: *Pharmacotherapy* module)
- Maintain normothermia
- Continuous EEG monitoring (if available) 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, anti-seizure medications.

CORRECT COAGULOPATHY

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. 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
- Fibrinogen
- Thromboelastography or rotational thromboelastometry if available
- Thrombin time or anti-Factor Xa levels, (for oral direct thrombin inhibitors or factor Xa inhibitors and/or low-molecular weight heparin use, respectively)

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. Studies of tranexamic acid in TBI for hemostasis suggest potential use in select patients with mild-to-moderate TBI within 3 hours of injury.

See ENLS: *Pharmacotherapy* module 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 anti-seizure medication can be considered for 7 days following TBI to decrease the incidence of early post-traumatic seizures when benefits outweigh risks of treatment.

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

- Levetiracetam (preferred)
- Phenytoin
- Lacosamide

ANALGESIA & SEDATION

Children and adults with severe TBI (GCS ≤8) require endotracheal intubation for airway protection. IV 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, Breathing and Mechanical Ventilation* module for a more detailed discussion of Analgesia & Sedations strategies.

AVOID PROPHYLACTIC HYPERVENTILATION, STEROIDS, HYPOTHERMIA

Prophylactic Hyperventilation is Not Recommended

Prophylactic hyperventilation should be avoided 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), extensor/decerebrate posturing. Hyperventilation, particularly within the first 24 hours after head trauma, will decrease CBF and may result in cerebral ischemia. Early prophylactic hyperventilation is associated with increased mortality.

Steroids are Contraindicated

Administration of steroids is harmful and increases the risk of death in patients with severe TBI. Routine steroid administration after TBI is contraindicated.

Prophylactic Hypothermia is Not Recommended

Current 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 key elements are communicated between the accepting and sending physicians and nurses.

The priority during transport of a patient with TBI is to prevent secondary brain injury by prompt treatment of hypotension, oxygen desaturation, increased ICP or seizures that may occur.

ICU ADMISSION

Patients with moderate and severe TBI remain at risk for neurological decline in the first 24 hours after injury due secondary brain injury from several causes including progressive cerebral edema and expansion of intracranial hematomas causing brain herniation. 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 to rapidly detect neurological worsening. A repeat head CT should be strongly considered at 4-6 hours following the initial injury to evaluate for stable or worsening intracranial hemorrhage.

FOLLOW INSTITUTIONAL PROTOCOLS FOR THE MANAGEMENT OF SEVERE TBI

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 pressure (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 threatening acute neurologic disease, including TBI. Patients with moderate-severe TBI should be admitted to an ICU with trauma, neurosurgery and neurocritical care expertise and monitored with hourly neurological examinations.