Protocol: Severe Traumatic Brain Injury – Management of the Adult: ≥ Age 18

Critical Care Phase of Care: Surgical/Trauma/Neuroscience Intensive Care Unit

Hennepin County **Medical Center**

Traumatic Brain Injury Center • www.hcmc.org/braininjury

This protocol is developed utilizing the Brain Trauma Foundation's 3rd Edition of the "Management of Severe Traumatic Brain Injury" (May 2007). www.braintrauma.org Any deviation from the national guidelines will be resourced.

Parameter	Goal during Resuscitation Phase (Two Hours)	Goal during Post-Resuscitation Phase (Remainder of ICU stay)	Source Document
Assessment: Glasgow Coma Score (GCS) and Vital Signs	Assess Neuro checks every 30 minutes x 2, then every hour x4, then every 2 hours or more frequently per physicians order. Vital signs are continuously monitored in the Intensive Care Unit (ICU). Should be documented with each GCS.	GCS every two hours if patient stable. More frequently as appropriate for changing condition. Vital signs are continuously monitored in the ICU. Should be documented with each GCS. GCS to be assessed at shift change with off-going and on-coming RN together. If patient stable exam to be done off of sedation. If patient unstable (Intracranial Pressure (ICP) > 20 mmHg, SBP > 160 mmHg or extremely agitated off of sedation, hypoxic or hypotensive) do not take off sedation without MD order.	HCMC protocol

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Parameter	**Goal during Resuscitation Phase (Two Hours)**	**Goal during Post-Resuscitation Phase (Remainder of ICU stay)**	**Source Document**
Oxygenation & Ventilation	Patient to be on 100% Fi02 for maximum time of two hours from initiation, then adjust to patient specific parameters Goal PaO2≥100 mmHg unless otherwise instructed Goal PaCO2 30-35 unless otherwise instructed Positive end expiratory pressure (PEEP) as needed to maintain oxygenation, minimize PEEP. Goal: is PEEP of 5. Baseline arterial blood gases (ABG)'s at admission	FIO2 – should not be set any higher than necessary to maintain goal PaO2 and O2 saturation. PaO2 - 100 PaCO2 - 35-40 ABGs every 6 hours x 24 hours, every 12 hours x 48 hours, then daily and as needed according to pulmonary status. Also check ABG one hour after a minute volume ventilator setting change.	
Ventilation for Acute Herniation	Avoid hyperventilation unless ICP > 30mmHg &/or there are signs of progressive neurological deterioration unresponsive to other measures. Hyperventilate to ICP of 25mmHg. Keep PaCO2 > 25mmHg	Avoid hyperventilation unless ICP > 30mmHg &/or there are signs of progressive neurological deterioration unresponsive to other measures. Hyperventilate to ICP of 25mmHg. Keep PaCO2 > 25mmHg	
Airway Management	Intubation	Once ICP stable, assess for a tracheostomy. If patient cannot be extubated within 7 days, patient should have tracheostomy. All medical teams involved need to discuss timing of tracheostomy, especially in patients with poor prognosis.	
Weaning of Ventilator	N/A	When patient hemodynamically stable and ICP controlled for > 48 hours, speak with ICU team about weaning protocol	

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Parameter	**Goal during Resuscitation Phase (Two Hours)**	**Goal during Post-Resuscitation Phase (Remainder of ICU stay)**	**Source Document**
Blood Pressure Management	Goal systolic blood pressure (SBP) > 100 mmHg MAP > 80mmHg until cerebral perfusion pressure (CPP) can be measured Place arterial line Maintain pressures with fluids, crystalloid (normal saline) with colloids and blood products as needed. If fluids unsuccessful begin Norepinephrine (Levophed) 0.01 - 0.3 mcg/kg/min (notify MD for dose > 0.15 mcg/kg/min) Second option is Dopamine 1 - 15 mcg/kg/min	Patient specific BP parameters to be set by MD with goal MAP for 75-90 Assess need for analgesia and/or sedation and treat those before beginning anti-hypertensive medication. Norepinephrine (Levophed) –0.01-0.15 mcg/kg/min	
CPP Management	Goal 60–70 mmHg Do not exceed 70mmHg unless otherwise instructed	Goal 60–70 mmHg Do not exceed 70mmHg unless otherwise instructed	
Intracranial Pressure Monitoring	All patients with GCS 8 or less must have an ventriculostomy (ventric preferred, may use intraparenchymal monitor if ventricles of small size) Zero at external auditory canal Keep open to drain and close momentarily q 15-30 min to read ICP and document Goal ICP <15 mmHg	Zero at external auditory canal Goal ICP <15 mmHg Monitor ICP continuously Document ICP every 30-60 minutes If open to drain, will need to close to drain momentarily to obtain accurate ICP reading	Ventriculostomy should be closed for safety during transport with frequent ICP checks. Refer to HCMC policy M4.02

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Parameter	Goal during Resuscitation Phase (Two Hours)	Goal during Post-Resuscitation Phase (Remainder of ICU stay)	Source Document
Management of Increased ICP (Listed in order of treatment)	Dark, quiet, low stimulus environment Assure ICP monitor is calibrated HOB elevated 20-30 degrees (or reverse trendelenburg if spine films not cleared) Neck in midline position Initiate 3% Na(Cl:Al)(1:1) infusion. Cerebrospinal Fluid (CSF) Drainage Sedation with Propofol infusion 23.4% NaCl for sustained ICP > 20 mmHg (first line treatment) Bolus over 20 minutes Mannitol 0.25-1 g/kg bolus as treatment option (second line option) Paralyze with Vecuronium Hyperventilation rescue therapy for acute herniation Decompressive craniectomy Refer to other sections of this guideline for detailed management of Sedation, Pain Management, Hyperventilation and Paralytics.	Dark, quiet, low stimulus environment Assure ICP monitor is calibrated HOB elevated 20-30 degrees (or reverse trendelenburg if spine films not cleared) Neck in midline position Continue 3% Na(Cl:Al)(1:1) infusion CSF Drainage Sedation with Propofol & Fentanyl infusions Begin Ativan infusion if patient refractory to Propofol 23.4% NaCl for ICP > 20 mmHg sustained for > 20 minutes without stimuli. Bolus over 20 minutes Mannitol 0.25-1 g/kg bolus as treatment option (second line option) when ICP refractory or Na+ > 165 Paralyze with Vecuronium Hyperventilation rescue therapy for acute herniation Decompressive craniectomy Refer to other sections of this guideline for detailed management of Sedation, Pain Management, Hyperventilation and Paralytics.	HCMC protocol

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Parameter	Goal during Resuscitation Phase (Two Hours)	Goal during Post-Resuscitation Phase (Remainder of ICU stay)	Source Document
CSF Drainage	ICP ≤15 mmH2O – drain closed, monitor only. Open to drain for ICP > 15 mmHg unless otherwise instructed. ICP 15 – 19 mm Hg – drain level at 15 cm H2O. ICP ≥ 20 mm Hg – drain level at 10 cm H2O.	ICP ≤ 15 mmH2O – drain close, monitor only. Open to drain for ICP > 15 mmHg unless otherwise instructed. ICP 15 – 19 mm Hg – drain level at 15 cm H2O. ICP ≥ 20 mm Hg – drain level at 10 cm H2O.	
Brain Oxygen Monitoring	Licox insertion: -in all patients with GCS ≤ 6 regardless of Marshall score -If GCS 7 or 8 and Marshall score ≥ 3 Keep card from insertion kit MD to document placement in medical record Goal Licox (PbtO2) reading > 25 mmHg Assure Licox is reading accurately and confirm placement: Two hours after insertion, perform a 100% FiO2 challenge. The reading should triple within 10 minutes. If reading does not triple, order a CT scan STAT. If reading does triple, confirm placement on next routine CT scan Goal Licox (PbtO2) reading > 25 mmHg Refer to Appendix 3 for low PbtO2 treatment algorithm	Licox goal (PbtO2) > 25 mmHg If there is an acute drop in O2 or reading does not match the clinical picture, perform the 100% FIO2 challenge Discontinue the Licox when the ICP monitor is discontinued Refer to Appendix 3 for low PbtO2 treatment algorithm	

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Parameter	**Goal during Resuscitation Phase (Two Hours)**	**Goal during Post-Resuscitation Phase (Remainder of ICU stay)**	**Source Document**
Timing of Craniotomy	**Acute:** Any patient who is progressively declining and/or with symptoms of uncal herniation syndrome, should be taken emergently to the operating room. For example: - midline shift > 1 cm - epidural hematoma > 30-40 ml volume - subdural hematoma with thickness > 0.5 cm extending over the hemispheres or > 30-40 ml volume - intraparenchymal hemorrhage > 30 ml in temporal lobe or cerebellum Patients who have herniated & have significant hemorrhage secondary to herniation into their brainstem should not be offered surgery.	**Acute:** Any patient who is progressively declining and/or with symptoms of uncal herniation syndrome, should be taken emergently to the operating room. For example: - midline shift > 1 cm - epidural hematoma > 30-40 ml volume - subdural hematoma with thickness > 0.5 cm extending over the hemispheres or > 30-40 ml volume - intraparenchymal hemorrhage > 30 ml in temporal lobe or cerebellum Surgery should not be offered when there are signs of significant, persistent brain stem dysfunction, when cranial nerve reflexes are absent or when there is significant brainstem hemorrhage from herniation **Delayed Craniotomy:** Evolution of hemorrhage (especially in the first 72 hours) if medical treatment fails and patient with surgical lesion progressively declines	

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Parameter	**Goal during Resuscitation Phase (Two Hours)**	**Goal during Post-Resuscitation Phase (Remainder of ICU stay)**	**Source Document**
Decompressive Craniectomy	Decompressive craniectomy should be done at the time of the initial surgery if CT scan and clinical findings in OR indicate patient will have difficulty with swelling/herniation	When ICP refractory to medical treatment, a decompressive craniectomy should be considered on patients who appear salvageable on initial exam Should be done early in the course of treatment Age is a consideration Refractory is defined as persistent, intractable ICP > 20 mmHg with no noxious stimuli & in the presence of full medical treatments.	
Maintenance IV Fluid	NS (isotonic fluids) unless otherwise instructed.	NS (isotonic fluids) unless otherwise instructed.	

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Parameter	Goal during Resuscitation Phase (Two Hours)	Goal during Post-Resuscitation Phase (Remainder of ICU stay)	Source Document
Electrolyte Management & Hyperosmolar Therapy	All patients with ICP monitor must have a central line. Begin infusion of 3% Na(Cl:AC)(1:1) in central line at 10-30 ml/hr Titrate infusion to ICP with a goal of Na+ > 150 to a maximum of 165 Baseline labs: Serum Osmo, Sodium, Potassium, BUN, Creatinine, Chloride, BiCarb Goal K+: ≥ 4 – 5, avoid hypokalemia	All patients with ICP monitor must have a central line. K+ & Na+ every 6 hours Daily labs:BUN, creat, Cl, BiCarb, Mg, Phos, serum osmo Titrate 3% Na(Cl:AC)(1:1) infusion to ICP with a goal of Na+ > 150 to a maximum of 165 For ICP < 15 mmHg keep Na+ 140-150 and serum osmolality 290-310 For ICP 15-19 mm Hg keep Na+ 145-155 and serum osmos 310-325 For ICP > 20 mmHg give 23% Na and keep Serum Na+ 155-165. Serum osmo goal: 325-340 When ICP < 15 for 48 hours, normalize sodium Mg+ goal > 2 Goal CVP 10-12 mmHg unless otherwise instructed	HCMC Protocol

Parameter	Goal during Resuscitation Phase (Two Hours)	Goal during Post-Resuscitation Phase (Remainder of ICU stay)	Source Document
Glucose Management	Goal range: > 100 and < 140 mg/dl If serum glucose > 150 mg/dl, begin insulin drip Avoid hypoglycemia (serum glucose < 90 mg/dl)	Accucheck every 2 hours Goal range: >100 to < 140 mg/dl If serum glucose > 150 mg/dl, begin insulin drip Avoid hypoglycemia (serum glucose < 90 mg/dl) Continue during ICU stay Discuss timing of transition to long acting insulin with PharmD & Intensivist	
Hemoglobin Management	Hemoglobin ≥ 10 Transfuse as necessary	Keep Hemoglobin ≥ 10 Transfuse as necessary When ICP and Brain Tissue Oxygen are stable/normalized for 24-48 hours, the hemoglobin can be normalized	
Anti-convulsant Therapy	Phenytoin load if not done in ED Phenytoin load 18 mg/kg in normal saline at a rate of 25 mg/min in central line	Continue Phenytoin for 7 days and then discontinue. No need to taper. If patient has a seizure, refer to Neurology for further work-up. If decision is made to continue an anti-epileptic medication, then change from Dilantin to Depakote	

Parameter	Goal during Resuscitation Phase (Two Hours)	Goal during Post-Resuscitation Phase (Remainder of ICU stay)	Source Document
Sedation/Analgesia	First Option: Initiate Propofol at 5-80 mcg/kg/min if patient not adequately sedated by midazolam or other benzodiazepine.	Monitor for Propofol Infusion Syndrome. For use of Propofol > 48 hours: 1) Draw CK at initiation of Propofol & every 72 hours 2) Draw Triglycerides on Day 6 and continue every six days thereafter If there is a change in urine color to tea colored/brown or unexplained acidosis (Bicarb <20) draw at that time.	
	Lorazepam (Ativan) – Dosage 0.5- 25 mg/hr for refractory ICP	Monitor anion gap, osmolar gap Monitor for propylene glycol toxicity in patients on higher dosages or with impaired renal function. When deemed appropriate to awaken the patient you may reduce dose by 50% then further wean by 1 mg every 12 hours until off. Monitor patient withdrawal symptoms. Tachycardic, hypertensive, or elevations in ICP.	At HCMC must order Ethylene Glycol level to get a propylene glycol level
	Hydromorphone (Dilaudid) bolus 0.1 - 0.5 mg	Hydromorphone (Dilaudid) infusion 0.1 - 0.5 mg/hr Max 4 mg/hr	
	Morphine bolus 1–10 mg	Morphine infusion 1-5 mg/hr Max 30 mg/hr	

Parameter	Goal during Resuscitation Phase (Two Hours)	Goal during Post-Resuscitation Phase (Remainder of ICU stay)	Source Document
	Fentanyl continuous infusion	Initial dose 25 mcg - 100 mcg/hr IV. Max dose 500 mcg/hr	
	Patients on infusions for sedation will be monitored with the bispectral index (BIS) monitor. Titrate level of sedation to a goal of deep sedation with BIS 30-40	Patients on infusions for sedation will be monitored with the BIS. Titrate level of sedation to a goal of deep sedation with BIS 30-40	
Paralytics	Vecuronium bolus 0.1 mg/kg for procedures or ICP management	Vecuronium infusion 0.8-1.2 mcg/kg/min for ICP management Monitor with "Train of 4" and titrate to 1-2 twitches	
Temperature Management	Goal core body temperature 37.0 C Tylenol for temp > 38.6 C Cultures for temp > 37.5 C Warming blanket for temp < 35.0 C	Goal body temperature 37.0 C Tylenol for temp > 38.6 C Cultures for temp > 37.5 C If temperature remains > 37.5 C for > 4 hours consider invasive cooling device Warming blanket for temp < 35.0 C	
Anticoagulation/ DVT Prophylaxis	N/A	Discuss timing of initiation of anticoagulation medication with Neurosurgery and ICU teams. Sequential compression devices until ambulatory Consider IVC filter when unable to anti-coagulate for > 7 days	
Infection Prophylaxis	None needed unless concomitant injury necessitates treatment	None needed unless concomitant injury necessitates treatment	

Parameter	Goal during Resuscitation Phase (Two Hours)	Goal during Post-Resuscitation Phase (Remainder of ICU stay)	Source Document
Labs	Admission Labs: electrolytes, serum osmo, CBC, coagulation panel, Mg, Phos, ABG	Na+ every 6 hours when on hypertonic saline or when Na+ > 155 Na+ every 12 hours when Na+ < 155 SICU daily order sheet CBC q day ABG q day Albumin, Coags q week Pre-albumin q week	HCMC SICU Protocol
Ventriculostomy Care	Administer Cefazolin 1 gm IV x 1 within the 30 minutes prior to insertion of ventriculostomy (use Clindamycin if allergic to Cefazolin)	Refer to HCMC policy M4.02 for ventriculostomy site care & changing CSF collection bags	
Ventriculostomy Weaning	N/A	ICP must be ≤ 15 mmHg for > 48 hours before beginning the weaning process: If ICP course has been stable at < 15 mmHg, clamp ventric for 24 hours. If ICP remains < 15 mmHg while clamped, remove the ventric If ICP course has been > 15 mmHg then wean ventric over a period of days by increasing the level of the CSF drainage bag by 5 cm H20/day. When at 20 cm H2O for 24 hours, clamp ventric If ICP remains stable with ventric clamped for 24 hours, order a CT scan If CT scan shows no hydrocephalus remove the ventric	

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Parameter	Goal during Resuscitation Phase (Two Hours)	Goal during Post-Resuscitation Phase (Remainder of ICU stay)	Source Document
Neurosurgery Clinical Coordinator	Notify Neurosurgery Clinical Coordinator of admission Meet with family	On-going support, education and discharge planning	
Social Service	Notify Neurosurgery Social Worker to meet with family	Ongoing support & discharge planning	
Chaplaincy	Notify Chaplain to be with family	Ongoing support & care conferences	
Nutrition		Consult within 24 hours of admission	
Occupational Therapy (OT)	N/A	Consult for evaluation & treatment when ICP stable for 48 hours & patient stable from respiratory & hemodynamic perspectives. Spine films must be cleared & activity level ordered before OT can assess patient. This includes activity limitations from Orthopedic service when applicable.	
Physical Therapy (PT)	N/A	Consult for evaluation & treatment when ICP stable for 48 hours & patient stable from respiratory & hemodynamic perspectives. Spine films must be cleared & activity level ordered before PT can assess patient. This includes activity limitations from Orthopedic service when applicable.	
Speech Language Pathology	N/A	For patients Rancho 3 or greater, consult for swallow assessment and communication/cognitive evaluation within 24 hours of extubation or placement of a tracheostomy	

Parameter	Goal during Resuscitation Phase (Two Hours)	Goal during Post-Resuscitation Phase (Remainder of ICU stay)	Source Document
Physical Medicine & Rehabilitation (PM&R)	N/A	Order consult when ICP stable for 48 hours & patient stable from respiratory & hemodynamic perspectives, for: - positioning - tone assessment - guidance of therapies - medication assessment for agitation - following of patient progress - rehab assessment - Rancho level - headache treatment	
Discharge from the ICU to long term acute care hospital (LTACH)	N/A	Order: PM&R, PT, OT, SLP as part of discharge orders. Patient to return to Knapp Rehab Center for acute rehab when appropriate Patient to follow-up in HCMC clinics after discharge from LTACH or Knapp	

Parameter	Goal during Resuscitation Phase (Two Hours)	Goal during Post-Resuscitation Phase (Remainder of ICU stay)	Source Document
Transport of the Critically Ill Patient	Per hospital policy	Per hospital policy: Ventriculostomy should be closed for safety during transport with frequent ICP checks. Limit transports and bundle procedures whenever the patient can tolerate, i.e.: CT and x-rays in same trip.Have adequate staff and appropriate equipment, including pulse oximeter, cardiac monitoring and ICU nurse attendant	HCMC policy

Committee reviewed December 2008:

Physicians:	Mustapha Ezzeddine, MD (Neurology Critical Care); William Heegaard, MD (Emergency Medicine); Andrew Kiragu, MD (Pediatric Critical Care); Robert Quickel, MD (SICU Intensivist); Gaylan Rockswold, MD (Chief-Division of Neurosurgery); Sarah Rockswold, MD (PM&R)
Nursing:	Susan (Suzi) Fuguet, RN (Neurosurgery); Willie Larson, RN (ED); Chris Magnuson, RN (Peds); Carol Ann Smith, RN, CNRN (TBI Center); Kelly White, RN (SICU)
PharmD:	Jon Jancik (SICU); Ellen Worlund-Voorhaar (PICU)
Resp Care:	Chris Leroux, Connie Knipp

Appendix 1: Glasgow Coma Scale **(Source:www.cdc.gov/masstrauma/resources.gcs)**

Eye Opening Response

- ❑ Spontaneous--open with blinking at baseline **4 points**
- ❑ To verbal stimuli, command, speech **3 points**
- ❑ To pain only (not applied to face) **2 points**
- ❑ No response **1 point**

Verbal Response

- ❑ Oriented **5 points**
- ❑ Confused conversation, but able to answer questions **4 points**
- ❑ Inappropriate words **3 points**
- ❑ Incomprehensible speech **2 points**
- ❑ No response **1 point**

Motor Response

- ❑ Obeys commands for movement **6 points**
- ❑ Purposeful movement to painful stimulus **5 points**
- ❑ Withdraws in response to pain **4 points**
- ❑ Flexion in response to pain (decorticate posturing) **3 points**
- ❑ Extension response in response to pain (decerebrate posturing) **2 points**
- ❑ No response **1 point**

Appendix 2: **Marshall Score CT Classifications** (Source: Journal of Neurosurgery; Volume 75. November 1991)

Diffuse Injury I	No visible intracranial pathology
Diffuse Injury II	Cisterns present with midline shift 0-5 mm or lesion densities present but no high or mixed density lesion > 25 cc
Diffuse Injury III	Swelling, cisterns compressed or absent with midline shift 0-5 mm, no high or mixed density lesion > 25 cc
Diffuse Injury IV	Midline shift > 5 mm, high or mixed density lesion > 25 cc, or any lesion surgically evacuated

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Appendix 3: Algorithm for Low Brain Oxygen Level (Source: HCMC)

Parameter	Action
Brain PtO_2 < 20 mmHg with O_2 probe functioning properly	Assess hemoglobin Goal Hgb ≥ 10 Transfuse with PRBC's p.r.n. Hgb < 10
	Assess cerebral perfusion pressure (CPP) Goal CPP > 65 Decrease ICP (e.g., Lower ventriculostomy drainage level. Refer to section on ICP management) Increase MAP with HTS and/or pressors
	Evaluate pulmonary function for pneumonia, atelectasis, pneumothorax, mucous plug, etc. Treat accordingly. Evaluate P:F ratio (PaO_2 over FiO_2) ≥ 300 normal ≥ 250 severe pneumonia ≥ 200 ARDS
	Increase FiO_2 to achieve PtO_2 ≥ 20 only as last resort. Decrease FiO_2 as soon as possible.

Appendix 4: Rancho Los Amigos Scale **(Source: www.rancho.org)**

Level I: No response to pain, touch, sound or sight.

Level II: Generalized reflex response to pain.

Level III: Localized response. Blinks to strong light, turns toward/away from sound, responds to physical discomfort, inconsistent response to commands.

Level IV: Confused/Agitated. Alert, very active, aggressive or bizarre behaviors, performs motor activities but behavior is non-purposeful, extremely short attention span.

Level V: Confused/Non-agitated. Gross attention to environment, highly distractible, requires continual redirection, difficulty learning new tasks, agitated by too much stimulation. May engage in social conversation but with inappropriate verbalizations.

Level VI: Confused/Appropriate. Inconsistent orientation to time and place, retention span/recent memory impaired, begins to recall past, consistently follows simple directions, goal-directed behavior with assistance.

Level VII: Automatic/Appropriate. Performs daily routine in highly familiar environment in a non-confused but automatic robot-like manner. Skills noticeably deteriorate in unfamiliar environment. Lacks realistic planning for own future.

Level VIII: Purposeful/Appropriate.

Level IX: Purposeful, Appropriate: Stand-By Assistance on Request.

Level X: Purposeful, Appropriate: Modified Independent.

Original Rancho Los Amigos Cognitive Scale co-authored by Chris Hagen, Ph.D., Danese Malkmus, M.A., Patricia Durham, M.A., Rancho Los Amigos Hospital, 1972.