Joint Trauma System

Traumatic Brain Injury

Joint Trauma System Battlefield Trauma Trauma Educational Program
While deployed to a split Role 2 facility in Afghanistan, you receive a soldier who was injured in a dismounted blast. The patient arrives with a Glasgow Coma Score (GCS) of 8 (M4E2V2). He has a cephalohematoma and some facial lacerations. His left pupil is fixed and unreactive to light. You have no CT scanner.

1. What are the medical treatment priorities for this patient?

2. Should surgery be entertained? What if he had a penetrating head injury from a fragment?

3. Would you offer surgery to a local national?
1. Be facile with medical treatment options for traumatic brain injuries.
2. Be familiar with indications for surgical intervention.
5. Know to contact theater neurosurgeon for expert advice.
### EWS Traumatic Brain Injury

**TBI Definition**

<table>
<thead>
<tr>
<th>Motor</th>
<th>Verbal</th>
<th>Eyes</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 – Moves to command</td>
<td>5 – Converses normally, oriented</td>
<td>4 – Opens eyes spontaneously</td>
</tr>
<tr>
<td>5 – Localizes to painful stimuli</td>
<td>4 – Confused, disoriented, but organized speech</td>
<td>3 – Opens eyes in response to voice</td>
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<tr>
<td>4 – Withdraws from painful stimuli</td>
<td>3 – Disorganized words</td>
<td>2 – Opens eyes in response to pain</td>
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<tr>
<td>3 – Flexion to painful stimuli (decorticate response)</td>
<td>2 – Incomprehensible sounds</td>
<td>1 – Does not open eyes</td>
</tr>
<tr>
<td>2 – Extends to painful stimuli (decerebrate response)</td>
<td>1 – Makes no sounds</td>
<td></td>
</tr>
<tr>
<td>1 – No movement</td>
<td>1T – Intubated patient</td>
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</tbody>
</table>

*Use best available extremity and eye. If a patient moves their left arm to command, but is unable to move his other extremities, they still have a motor exam score of 6.*

**Mild TBI – GCS 13-15** (on presentation to medical treatment facility)

**Moderate TBI – GCS 9-12**

**Severe TBI – GCS 3-8**
You can’t treat primary brain injury.

Mitigated by preventative measures such as helmets and airbags

The goal of care is to prevent secondary brain injury.

- Maintain brain perfusion and oxygenation.
- SaO2 goal - 93% or greater
- PaO2 goal – 80 mmHg or greater
- Systolic Blood Pressure (SBP) – 110 mmHg or greater

**Note:** Neurosurgery and Severe Head Injury CPG recommends a goal SBP higher than most literature, which says SBP > 90 mmHg (to maintain Cerebral Perfusion Pressure (CPP) > 60 mm Hg, assuming most people’s Intracranial Pressure (ICP) is <30 mm Hg). Based on Neurocritical Care Society’s Emergency Neurologic Life Support TBI Guidelines.

**SBP < 90 mm Hg is highest single risk factor for mortality in TBI patients**
The goal of care is to prevent secondary brain injury. (continued)

- Maintain Blood Glucose 90 – 180 mg/dL
- Maintain Normocapnia - PaCO2 35-40 mm Hg
  - Routine hypercapnia (i.e. hyperventilating someone to a PaCO2 < 35 mm Hg) is no longer recommended
  - Hypercapnia remains a salvage maneuver for an acute worsening in GCS or clinical signs of impending herniation (e.g., a pupil becomes fixed and dilated).
Maintain HOB to 30% or greater

Place C-collar and maintain C-spine precautions
- High incidence of concurrent C-spine injury with TBI

Correct coagulopathy
- Goal INR ≤ 1.5
- Goal PTT ≤ 36
- Goal Platelets (≥ 50K)

Prophylaxis
- Gastric ulcer prophylaxis with PPIs or H2 blockers
- DVT prophylaxis SCD’s in all TBI patients
- Initiate DVT chemoprophylaxis as soon as it is safe
  - Do in conjunction with recommendations of theater neurosurgeon
  - No universally agreed upon timing for initiating DVT chemoprophylaxis
Minimize Brain Metabolism

■ Goals

☐ Prevent Hyperthermia
  ▪ **WARNING**: Hypothermia is dangerous too.
    In isolated TBI, it may result in ↓ brain metabolism.
  ▪ In polytrauma, hypothermia promotes coagulopathy and ↑ mortality.

☐ Seizure Prophylaxis
  ▪ Only beneficial for 1st 7 days post injury
  ▪ Options: phenytoin (Dilantin), fosphenytoin, or levetiracetam (Keppra)
Minimize Brain Metabolism

Goals (continued)

- Sedate
  - Intubate Severe TBI (GCS 3-8) patients to protect airway.
  - Short-acting sedatives are preferred – (e.g., Propofol or dexmedetomidine [Precedex])
  - Propofol is the recommended sedative of choice by JTS CPG
  - Short-acting narcotics (i.e. Fentanyl)
  - Intermittent blousing is preferred over continuous infusions.
  - Short-acting paralytics. Vecuronium is preferred paralytic in deployed setting.
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**Levels of Interaction**

- **Pentobarbital Load and EEG**
- **Hemicraniotomy/ Hemicraniectomy/ Duraplasty**
- **Paralysis (Vecuronium) / Hyperventilation to PaCO2 < 35 mmHg for spikes in ICP**
- **3.0% Hypertonic Saline (Possibly Mannitol for isolated TBI)**
- **ICP Monitor Placement/CSF Drainage via Ventriculostomy (if available)**
- **Adequate Sedation/Analgesia (Propofol, Midazolam, Fentanyl, Morphine)**
- **Moderate Head-up Posture (30°); Maintain SBP and SaO2; Correct Coagulopathy; C-collar**

Medical Therapy

- Hypertonic saline
  - 3% saline is preferred fluid.
  - 3% saline – 250 mL bolus followed by continuous infusion of 50-100 mL/hr
  - Goal serum Na is 150-160.
  - Central venous catheter required after 24 hours - 3% Saline is a desiccant
  - 7% and 23.4% saline may not be available in theater

- Mannitol

  WARNING: Mannitol is a potent diuretic. It can artificially mislead a provider into believing a patient is adequately resuscitated. Avoid administering in polytrauma patients except as a salvage maneuver.
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Elevated ICP

- **Mannitol** *(continued)*
  - Mannitol 1g/kg IV bolus followed by 0.25 gm/kg IV push Q4H
  - Goals serum osm is 320 mOsm/kg

- **Maintenance Fluids**
  - Use 0.9% Normal Saline
  - Colloids (e.g. albumin) associated with ↑ mortality in TBI
  - Exception: Blood and FFP are acceptable colloids
IF AVAILABLE

- Should be in most Role 3’s
- Possibly in Role 2’s, but CT scanner may not be

Consider salvageable patients with a severe head TBI and CT evidence of:

- Hematoma
- Contusion
- Swelling
- Herniation
- Compressed basal cisterns

OR Severe TBI and Normal Head CT (or no head CT) and 2 of the following:

1. Age > 40  
2. Unilateral or bilateral posturing  
3. SBP <90 mmHg
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ICP Monitors (2)

Options

- External ventricular device
- Parenchymal ICP Monitor: Only the Codman ICP Monitor is USAF approved for aeromedical evacuation.

Left: Example of a ventriculostomy ICP gauge and CSF collection bag.

Right: Description of how to place a ventriculostomy

Aim for nasion or ipsilateral medial epicanthus

Midpupillary line

Aim for tragus

Emergency War Surgery, 5th U.S. Edition, 2018
Goal ICP < 22 mmHg
Goal CPP = 60-70 mmHg
- CPP = SBP – ICP
Flight rules
- ICP monitoring recommended for patients with elevated ICP.
  - Flight stresses may increase ICP.
    - Vibration, temperature changes, noise, movement, light, hypoxia, altitude
  - Do NOT remove an ICP monitor prior to flight.
  - Do NOT remove another drain without talking with flight surgeon at Global Patient Movement Requirement Center.
    - External ventricular drains are not approved for flight
    - Subdural or epidural drains are usually Blake or JP drains: these may be okay
ICP monitoring recommended for patients with elevated ICP (continued)

- Delay evacuation – Patients at high risk for cerebral edema
  - Difficult to control ICP spikes in flight.
  - Cerebral Edema post TBI usually peaks at post-injury day 5-7.

- Pneumocephalus
  - No established treatment guidelines or flight restrictions.
  - Discuss with validating flight surgeon.
  - Be aware: Air expands at higher pressure and lower altitudes.

- Load head first into plain with gurney at 30-45° elevation (reverse Trendelenberg)
  - Keeps head elevated during flight.
  - Backwards: Patients normally load feet first.
Exploratory Burr Holes

- Limited utility
- Indications:
  - No neurosurgical capabilities
  - No CT scanner
  - Deteriorating neurological exam that can be localized and/or
  - Unilateral pupil changes

Ventriculostomy

- Placement of catheter in the lateral ventricle that can both:
  - Monitor ICP
  - Drain CSF
- Catch 22: No ventriculostomy monitor/drain (e.g., Camino) is flight validated

*Can be placed, but must be removed prior to aeromedical evacuation (fixed wing rule)*
Craniotomy
- Removal of skull
- Evacuation of blood
- Immediate replacement of skull

Craniectomy
- Removal of skull
- Evacuation of blood
- Skull not replaced
- Delayed reconstruction

Above: Surgeon starting a craniectomy procedure.
Below: Landmarks for craniectomy incision (a) and burr hold placement for eventually craniectomy (b)
Epidural hematoma

- Accumulation of blood in the epidural space (outside of dura)
- Typically due to injury of middle meningeal artery
- Surgical indication
  - > 30 mL of blood, especially with evidence of uncal herniation.
  - Dilated, unreactive pupil with contralateral hemiparesis
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Surgical Indications (2)

Surgical Indications – Role 3 with CT scanner

- Subdural hematoma
  - Accumulation of blood underneath the dura
  - Bridging vein injury
  - Surgical indications
    - > 10 mm maximal thickness **AND/OR**
    - > 5 mm midline shift **OR**
    - Any sized SDH with decrease in GCS by ≥2, worsening pupillary exam, or ICP > 20 mmHg

*CT scan of head: Subdural hematoma with mass effect.*
Source: Borden Institute: War Surgery in Afghanistan and Iraq
Surgical Indications – Role 3 with CT scanner

- Intraparenchymal hemorrhage/contusion and subarachnoid hemorrhage
  - Surgical indications
    - GCS 6-8 AND
    - Frontal or temporal lesion > 20 mL in volume AND
    - 5 mm of midline shift OR
    - Compression of the basal cisterns

- Posterior Fossa Bleed
  - Surgical indications
    - Any mass effect on CT OR
    - Bleed with neurological dysfunction that correlates with that region of the brain

CT scan of head. Green Arrow: Intraparenchymal hemorrhage and contusion from penetrating traumatic brain injury
Surgical Indications – Role 2 without CT scanner

- **Talk to a neurosurgeon first**
- Contact info for SAMMC and WRNNMC neurosurgery at end of lecture
- Surgical indications
  - CLOSED head injury with GCS ≤8 **AND**
  - Lateralizing cortical dysfunction **AND**
    - e.g., unilateral, fixed, dilated pupil
    - e.g., hemiparesis
  - Hemodynamic dysfunction **OR**
    - e.g., hypertension, bradycardia, and respiratory variation (Cushing’s reflex)
  - Deterioration despite maximal medical management **AND**
  - Neurosurgeon not available within 4 hours transport time
Cranietectomy recommended for penetrating combat brain trauma

- Caveat: Should be performed by a neurosurgeon.
- Extremely difficult procedure.
- Bleeding is usually deep and difficult to control.

If neurosurgeon not within 4 hours transport time, call one.

If they recommend decompression:

- Do not explore below the surface.
- Control only surface bleeding with bipolar and hemostatic adjuncts.
- Rapidly close.
- DO NOT close the entry or exit wounds if bone is herniating through wound. Let wounds naturally decompress the brain.
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Craniotomy/Craniectomy

Craniotomy/Craniectomy Procedure

1. Position head slightly higher than chest.
2. Rotate patient 30°-40° off midline such that the side being operated on is highest.
   - Maintain C-Spine/Logroll precautions
3. Place burr holes over the frontal, temporal, and parietal convexities.
4. Separate dura off of the inner layer of the skull.
   - Use Penfield 1-3 instruments
5. Connect holes with a saw/drill.
   - Stay off midline in order to avoid injury to the superior sagittal sinus.

Craniecotomy with hemostatic agents placed on brain parenchyma
6. If patient has an epidural, evacuate blood and control/stop bleeding.

7. If patient has subdural or intraparenchymal hemorrhage, open dura.
   - Evacuate blood.
   - Control any visible bleeding with bipolar or hemostatic adjuncts.
   - Do not close dura for subdural hematomas.


Control of bleeding with topical fibrillar followed by tamponade with a cottonoid pad.
Source: Borden Institute: War Surgery in Afghanistan and Iraq
Absolute rules dependent on medical rules of engagement (MEDROE) in the area of responsibility at the time and can vary.

U.S. & Coalition Forces: Craniectomies only
- Blunt trauma
  - May re-implant skull subcutaneously in abdominal skin
  - May discard; skull can be alloplastically reconstructed later
- Penetrating trauma
  - Discard; will be alloplastically reconstructed in CONUS

General recommendations for host nationals
- Clean and replace
- Clean and replace via hinge craniectomy
  - Only superior aspect of skull flap is fixated
  - Allows brain to swell at inferior aspect by “hinging” outward

Computer reconstruction of skull with Poly(methyl methacrylate) implant
Source: Borden Institute: War Surgery in Afghanistan and Iraq
Evacuate the following to Role 3 facility for a head CT and/or further evaluation by a neurosurgeon.

- Mild TBI with symptomatology or deficits that do not clear in 24 hours
- Any moderate or severe TBI
- Any penetrating head Injury
- Any open skull fracture

Rules for the evacuation of Host National casualties can vary significantly. It is important to understand the rules during any given deployment.

- In many cases, patients with severe TBI will not be transferred.
Mild TBI
Transfer to Role 3 facility requires approval of receiving neurosurgeon and/or chief of trauma

Moderate TBI
Transfer to Role 3 facility generally allowed

Severe TBI
Expectant Management
- Possible exception: Local national care is advanced and can provide mechanical ventilation, advanced monitoring, and neurorehabilitation
- Transfer to Role 3 by receiving neurosurgeon and hospital commander or representative (DCCS)

Note: Medical rules of engagement/eligibility may be more strict.
Defined as any brain injury that is expected to result in permanent loss of all brain function above the brain stem.

Results in profound alterations in physiology, metabolism, endocrine function, immunologic function, and clotting function.

Causes hemodynamic instability, multi-organ failure, and cardiovascular collapse in up to 60% of patients if untreated.

Associated with low levels of:
- Tri-iodothyronine (T3)
- Thyroxin (T4)
- Cortisol
- Insulin
Treatment potentially allows evacuation to LRMC to reunite with family. *Family can subsequently determine how patient would want care to proceed.*

**Catastrophic Brain Injury + Hemodynamic Instability**

1. **Control any source of bleeding**
2. **Resuscitate**
   - Use blood products for anemia (Maintain Hgb/Hct > 10/30)
   - Use crystalloids (e.g. NS, 3% NS) for hypovolemia
   - Use ½ NS if you suspect diabetes insipidus -> See next slide
3. **Add Pressors to maintain** SBP > 110 or MAP > 70 or MAP
   1) Norepinephrine is first line (Start at 0.1-0.5 mcg/kg/min)
   2) Vasopressin is second line (0.04U/min)
Catastrophic Brain Injury + Hemodynamic Instability

4. Treat diabetes insipidus if present
   - Diabetes insipidus is the inappropriate excretion of water
   - 2 types
     - Neurogenic - Insufficient ADH secretion from pituitary (seen in TBI)
     - Nephrogenic – Kidney unresponsive to ADH
   - Results in hypernatremia and profuse, dilute urine
   - Give DDAVP 1-2 mcg (if available)
   - Replete with ½ NS milliliter for milliliter for any UOP > 200 mL/hr.
   Example: Patient voids 1000 mL/hr. Give 800 mL/hr of ½ NS

5. Administer endocrine repletion regimen
   1) 1 amp IV D50W
   2) 2 gm IV solumedrol
   3) 20U IV Regular Insulin
   4) 20 mcg IV levothyroxine, followed by 10 mcg/hr IV drip (if available)
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Neurosurgery Contacts

Attempt to contact theater neurosurgeon

- 1 deployed to Baghdad Diplomatic Support Center
  BDSC is at the Baghdad International Airport and has an Army Role 3
- 1 deployed to Craig Joint Theater Hospital
  Air Force Role III at Bagram Air Base

Walter Reed National Military Medical Center (WRNMMC)

- 301-295-4000
- 312-295-4000 (DSN)
- 240-381-2528

San Antonio Military Medical Center (SAMMC)

- 210-916-2500
- 312-429-2500 (DSN)
- 210-539-0817

Ask hospital operator to contact the on call attending neurosurgeon
While deployed to a split Role 2 facility in Afghanistan, you receive a soldier who was injured in dismounted blast. The patient arrives a GCS 8 (M4E2V2). He has a cephalohematoma and some facial lacerations. His left pupil is fixed and unreactive to light. You have no CT scanner.

1. What are the medical treatment priorities for this patient?

2. Should surgery be entertained? What if he had a penetrating head injury from a fragment?

3. Would you offer surgery to a local national?
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Relevant JTS CPGs

JTS Clinical Practice Guidelines

https://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs

- Neurosurgery Severe Head Injury, 02 Mar 2017
- Emergency Cranial Procedures by Non-Neurosurgeons Deployed Setting, 23 Apr 2018
- Catastrophic Non-Survivable Brain Injury, 27 Jan 2017
- Radiology: Imaging Trauma Patients in a Deployed Setting, 13 May 2017

All photos and images are courtesy of the JTS collection unless otherwise cited.