Traumatic Head Injury

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Conception

Any injury to the skull, or brain, caused by external physical forces, in stead of degenerative or congenital nature

may results in an impairment of cognitive abilities, physical functioning or disturbance of behavioral or emotional functioning.
Introduction

Traumatic Brain Injury has long been recognized as an important medical entity.

- Hippocrates first commented on mechanisms of head injury and first described trephination as modality to treat head injury.

- 16th century - French military surgeon Ambrose Pare introduced term commotio cerebri to describe mild head injury to brain.

Epidemiology

United States

- 1.4 million annual incidents of TBI
- 50,000 die from TBI
- 235,000 are hospitalized
- 1.1 million are treated and released from ED
- Peak Incidence = 15–24 years old (50%)
Introduction

- 125,000 children <15yo head injured annually
- 40–60% of head injured patients have extremity injury
- 32,000–48,000 head injury survivors with orthopaedic injuries annually
Comparing TBI

Annual Incidence

- Traumatic Brain Injury: 2,000,000
- Breast Cancer: 500,000
- HIV/AIDS: 1,000
- Spinal Cord Injury: 1,500
Epidemiology

Etiology of Head Injury (U.S.)

- Falls: 28%
- Motor Vehicle Traffic: 20%
- Struck by/against: 19%
- Assault: 11%
- Other: 7%
- Unknown: 9%
- Other Transport: 2%
- Suicide: 1%
- Pedal Cycle (Non Motor Vehicle): 3%
Very Selfish Organ

The brain, 1500g, requires 20–30% of the total blood pumped by the heart.

No storage in the brain for either fuel or oxygen.

Requires constant supply of oxygen and glucose.
Main structure and function of the BRAIN

- Premotor cortex coordinates complex movements such as playing a musical instrument.
- Motor cortex sends signals to muscles to cause voluntary movements.
- Prefrontal cortex deals with behaviour and personality.
- Sensory association cortex analyses data about sensations.
- Sensory association cortex forms images once visual data have been analysed.
- Visual association cortex receives nerve impulses from the eye.
- Wernicke’s area interprets written and spoken language.
- Broca’s area is involved in the formation of speech.
- Primary auditory cortex distinguishes the particular qualities of sound.
- Auditory association cortex analyses and interprets sound data.
- Primary sensory cortex receives data about sensations in the skin, muscles, joints and organs.

Different areas of the cortex have specific functions. The symptoms of a stroke depend on which part of the brain has been damaged.
Scalp Injury
Scalp Injury

- scalp hematoma
- scalp laceration
- scalp avulsion
Scalp hematoma

- subcutaneous hematoma
- subgaleal hematoma
- subperiosteal hematoma
### Scalp hematoma

<table>
<thead>
<tr>
<th></th>
<th>subcutaneous hematoma</th>
<th>subgaleal hematoma</th>
<th>subperiosteal hematoma</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Origin</strong></td>
<td>Superficial arteries/veins</td>
<td>emissary veins in loose collective tissue</td>
<td>Skull</td>
</tr>
<tr>
<td><strong>Area</strong></td>
<td>local, limited, clear border</td>
<td>widely spread</td>
<td>with same border of suture</td>
</tr>
<tr>
<td><strong>Hardness</strong></td>
<td>Hard</td>
<td>Soft, a fluctuant boggy mass</td>
<td>Moderate</td>
</tr>
<tr>
<td><strong>Bleeding Volume</strong></td>
<td>Small</td>
<td>Great volume, hemorrhagic shock</td>
<td>Moderate</td>
</tr>
</tbody>
</table>
Scalp laceration

- sharp or blunt injury
- possible hemorrhagic shock
- press and hemostasis, debridement and suture (<24h, with good blood supply)
Scalp avulsion

- a severe scalp injury, often occurs in women with long hair
- Avulsion plane usually between subgaleal and pericranial serious
- deep pericranium, the fraudulent claims together with the forehead,
eyebrows, eyelids and ears together avulsion
- heavy bleeding, hemorrhagic shock
- Combined skull fracture and brain damage, manifested as
  unconsciousness without the pupil react to light
- complete avulsion and incomplete avulsion
Scalp avulsion

- Take active **anti-shock, anti-infection** measures
- Improve general condition
- the treatment of scalp avulsion line debridement and wound repair surgery
- vascular anastomosis avulsed scalp replantation, the avulsion organization replantation, skin graft free graft surgery
Skull Fracture

- the skull continuity damaged by strong violence
- with/without severe brain injury (related, not necessary)
- Classification: fracture of skull vault/base, liner/depressed fracture, open/closed fracture
Linear Fracture

Linear skull fractures are breaks in the bone that transverse the full thickness of the skull from the outer to inner table.

Usually fairly straight with no bone displacement.

The common cause of injury is blunt force trauma where the impact energy transferred over a wide area of the skull.
usually of little clinical significance

unless they parallel in close proximity or transverse a suture, or they involve a venous sinus groove or vascular channel.

The resulting complications may include suture diastasis, venous sinus thrombosis, and epidural hematoma.

In young children, although rare, the possibility exists of developing a growing skull fracture especially if the fracture occurs in the parietal bone.
Depressed fracture

- a type of fracture usually resulting from blunt force trauma, such as getting struck with a hammer, rock or getting kicked in the head (with relatively small contact area)

- occur in 11% of severe head injuries

- ICP increasing, bleeding (scalp, dura, skull, brain), press and crush the delicate tissue, contamination and infection.
Management

- **Linear FX:**
- **Depressed FX:** Lift the bones off the brain

1. Combined with brain injury and large area depress, causing increasing ICP, leading to risk of herniation $$\Rightarrow$$ Emergency surgery;
2. FX occurs at the eloquent area causing neurological deficiency;
3. Non-eloquent area and small, deep $$>1\text{cm}^2$$, no ICP increasing $$\Rightarrow$$ selective surgery;
4. Across the sinus: bleeding,
5. Open comminuted fracture
fracture of skull base

- Related cranial nerve injury
- Near soft tissue delayed bruising (Raccoon eye sign/ battle’s sign)
- CSF leakage and bleed
Traumatic Brain Injury

- Open vs Closed TBI
- dural laceration, and CSF leak
- if there is an approach for pathogens to get to subdural cavity

Open ==> Closed, Contaminated ==> sterilized
## Mechanism for Closed TBI

<table>
<thead>
<tr>
<th></th>
<th>Coup TBI</th>
<th>Contre-coup TBI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Traumatic force</strong></td>
<td>contact loading</td>
<td>inertial loading</td>
</tr>
<tr>
<td><strong>Traumatic object</strong></td>
<td>Rapid moving object</td>
<td>Static/slow moving object</td>
</tr>
<tr>
<td><strong>Brain movement</strong></td>
<td>acceleration</td>
<td>deceleration</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td>Hit point</td>
<td>Contralateral to hit point</td>
</tr>
<tr>
<td><strong>Area</strong></td>
<td>Limited focal</td>
<td>diffuse</td>
</tr>
</tbody>
</table>

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**Brain Injury Diagrams**:
- **Brain Injuries Initial Impact**
- **Brain Injuries Contrecoup effect**
- **Diagram A, B, C**
- **Diagram with Arrow**
Primary and Secondary TBI

Primary TBI

- Primary TBI: the damage that occurs at the moment of trauma when tissues and blood vessels are stretched, compressed, and torn.
- Damage happens and ceases immediately at the injury, however, the direct affect decreases with time going.
- Including: Concussion, DAI, Contusion/laceration, primary brainstem injury, Hypothalamus injury.
- Disorder of consciousness, neurologic deficiency, autonomic dysfunction, intracranial hypertension and herniation.
- How badly injured: determined by the initial direct damage intensity.
Primary and Secondary TBI

Secondary TBI

- A complex set of cellular processes and biochemical cascades that occur in the minutes to days following the trauma.

- Damage effect increases with time going.

- Include damage to the BBB, release of inflammatory factors, free radical overload, excessive release of the neurotransmitter glutamate (excitotoxicity), influx of calcium and sodium ions into neurons, and dysfunction of mitochondria.

Including: Brain edema, bleeding (tSAH, all kinds of intracranial hematoma) $\Rightarrow$ ICP $\Rightarrow$ CPP $\Rightarrow$ Herniation.

- How badly injured: determined by the following damage vs treatment.
Concussion

- temporary diffuse mild brain dysfunction
- immediately unconscious (<24 hrs)
- retrograde amnesia
- autonomic dysfunction (pale, nausea, vomiting, decreased BP, etc al)
- CT(-), CSF(-), Neurological examination(-)
- conservative therapy
diffuse axonal injury

diffuse severe brain dysfunction resulting from traumatic shearing or rotational forces
immediately unconscious (relatively longer)
MRI/CT-visible small bleeds in the corpus callosum or the cerebral cortex
DAI is characterized by axonal separation under microscope
conservative therapy
Cerebral Contusion/Laceration

- a bruise of the brain tissue
- associated with multiple micro hemorrhage, small blood vessel leaks into brain tissue/pia-arachnoid membranes are torn over
- severe but focal, often following obvious secondary injury: decline in mental function in long term, brain herniation
- CT: location of the lesion, range, edema, hydrocephalus, midline structure, ICP,
Primary Brainstem Injury

- Occur immediately after trauma, no obvious ICP increasing symptoms
- Often combined with DAI
- Long time deep coma, vary-sized/asymmetry pupils, eyeball malposition, severe respiratory and circulation disorder
- CT/MRI
- Conservative treatment
Hypothalamus Injury

- Neuroendocrine system
- Hypothalamus—Anterior Pituitary—Gland axis
- Early unconsciousness, temperature disorder, diabetes insipidus, fluid and electrolyte disturbance
Intracranial Hematoma

- Epidural hematoma vs Subdural hematoma, Intracerebral hematoma

- Phase— acute <3d, subacute 3d-3w, chronic>3w
Epidural hematoma

- The majority of bleeds originate from meningeal arteries, 30% Middle MA
- mostly at impact point (weak skull parts, Temporal)
- a lucid period immediately following the trauma before symptoms become evident
- CT- lentiform/fusiform/ lens-like hematoma expansion stops at the skull’s suture
- Surgery-speed and volume
Epidural hematoma

- Tears of Bridging Veins
- ICP increasing symptoms
- CT- Crescent-shaped, with a concave surface away from the skull
- Acute- lethal 60-80%, high density, rapid decompression
- Chronic- good/complete recovery
# Differential Diagnosis

<table>
<thead>
<tr>
<th>Hematoma type</th>
<th>Epidural</th>
<th>Subdural</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location</strong></td>
<td>Between the skull and the outer endosteal layer of the dura mater</td>
<td>Within the meningeal layer of the dura mater.</td>
</tr>
<tr>
<td><strong>Involved vessel</strong></td>
<td>Temperoparietal locus (most likely) - Middle meningeal artery&lt;br&gt;Frontal locus - anterior ethmoidal artery&lt;br&gt;Occipital locus - transverse or sigmoid sinuses&lt;br&gt;Vertex locus - superior sagittal sinus</td>
<td>Bridging veins</td>
</tr>
<tr>
<td><strong>Symptoms (depend on severity)</strong>&lt;sup&gt;[10]&lt;/sup&gt;</td>
<td>Lucid interval followed by unconsciousness</td>
<td>Gradually increasing headache and confusion</td>
</tr>
<tr>
<td><strong>CT appearance</strong></td>
<td>Biconvex lens</td>
<td>Crescent-shaped</td>
</tr>
</tbody>
</table>

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**Note:**

- Lucid interval refers to a temporary period of clear consciousness that occurs before a loss of consciousness.
- Unconsciousness is a condition where a person is not aware of their environment or responsive to the environment.
- Headache is a pain or discomfort in the head.
- Confusion is a state of mental confusion.

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**Images:**

- **Epidural Hematoma:** Dura (peeled off skull), Skull fracture, Arterial blood, Venous blood
- **Subdural Hematoma:** Dura (still attached to skull)
# Glasgow Coma Scale

<table>
<thead>
<tr>
<th>Glasgow Coma Scale (GCS)</th>
<th></th>
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<tbody>
<tr>
<td><strong>Eye Opening</strong></td>
<td></td>
</tr>
<tr>
<td>Opens spontaneously</td>
<td>4</td>
</tr>
<tr>
<td>Responds to verbal command</td>
<td>3</td>
</tr>
<tr>
<td>Responds to pain</td>
<td>2</td>
</tr>
<tr>
<td>No eye opening</td>
<td>1</td>
</tr>
<tr>
<td><strong>Verbal</strong></td>
<td></td>
</tr>
<tr>
<td>Oriented</td>
<td>5</td>
</tr>
<tr>
<td>Disoriented</td>
<td>4</td>
</tr>
<tr>
<td>Inappropriate words</td>
<td>3</td>
</tr>
<tr>
<td>Incomprehensible speech</td>
<td>2</td>
</tr>
<tr>
<td>No verbal response</td>
<td>1</td>
</tr>
<tr>
<td><strong>Motor</strong></td>
<td></td>
</tr>
<tr>
<td>Obey commands</td>
<td>6</td>
</tr>
<tr>
<td>Localizes to pain</td>
<td>5</td>
</tr>
<tr>
<td>Withdraws to pain</td>
<td>4</td>
</tr>
<tr>
<td>Flexion to pain (Decorticate posturing)</td>
<td>3</td>
</tr>
<tr>
<td>Extension to pain (Decerebrate posturing)</td>
<td>2</td>
</tr>
<tr>
<td>No motor response</td>
<td>1</td>
</tr>
</tbody>
</table>
Glasgow Coma Scale

Developed by Teasdale and Jennett in 1974

Now, standardized to measure 30 min after injury and repetitive measurements throughout patient’s stay

Current Classification

GCS = 14–15 = Mild Head Injury
GCS = 9–13 = Moderate Head Injury
GCS < 9 = Severe Head Injury

Best prognostic indicator of outcome = CT Scan
Pupillary Size + Reactivity

Fixed Dilated Pupil = Ipsilateral Intracranial Hematoma resulting in uncal herniation
Bilateral Fixed + Dilated = Poor Brain Perfusion, bilateral uncal herniation or severe hypoxia
  Indicative of very poor neurological outcome

Neurological Posturing

Decorticate Posturing = Upper extremity flexion with lower extremity extension
  Cortical Injury above the midbrain
Decerebrate Posturing = Arm extension and internal rotation with wrist flexion
  Indicative of brainstem injury
  Very Poor predictor of outcome

Full, Complete Neurological Exam

Examine for subtle neurological deficits
Look for specific injury patterns:
  Battle’s sign, CXF Otorrhea, CSF Rhinorrhea, Hemotympanum, peri-orbital Ecchymosis is
  indicative of skull fracture and is concerning for underlying brain injury
Neuroimaging

Skull Radiography
CT Scan (Gold Standard)
Magnetic Resonance Imaging (MRI)
Experimental Modalities for Neuroimaging
  Functional MRI (fMRI)
  PET Scanning
  SPECT Scanning
  Magnetic Source Imaging (MSI)
Neuroimaging

 Skull Radiography

Prior to CT, Skull radiography used as triage tool
Can evaluate for
  Skull fractures
  Pneumocephalus
  Blood in sinus
  Penetrating foreign body

Patients with abnormal findings are at increased risk of intracranial findings
However, still misses a large number of patients with normal skull films but extensive injury
Limited utility at very rural sites without access to CT imaging
Neuroimaging

Computed Tomography (CT Scan)

Imaging modality of choice
Especially good at identifying skull fracture, extra-axial fluid collection and hemorrhagic contusion
High utilization has led to clinical decision rules to identify appropriate patients requiring evaluation
  New Orleans Criteria
  Canadian Head CT Rule
Management of TBI

Mild Head Injury
- Admission Criteria
- Discharge Criteria
- Discharge Instructions
- Return to Play Guidelines

Moderate and Severe Head Injury
- General Principles
- Airway Management
- Hemodynamic Assessment
- Seizure Prophylaxis
- Operative Management
- Intracranial Monitoring
Mild TBI Management

Symptomatic treatment and prevention of secondary injury

Appropriate management depends on assessment of risk of neurological decompensation and risk factors for intracranial hematoma

Risk factors for intracranial hematoma

- Coagulopathy, Drug/Alcohol Intoxication, Previous neurosurgical procedures, Pre-trauma epilepsy or older age (> 60 y/o)

All patients with mild TBI should be observed for 24 hours after that injury (either inpatient or outpatient).
Mild TBI Management

Admission Criteria

Hospital Admission is required for all patients at higher risk for complications including:
- GCS < 15
- Abnormal CT Scan
- Seizure Activity
- Abnormal Bleeding Parameters (Anticoagulation or bleeding diathesis)
- Unable to be observed at home
Mild TBI Management

Discharge Criteria
Low risk patients can be discharged home with oral and written discharge instructions
Patients can be discharged if:
  GCS = 15
  Normal neurological exam
  Normal Head CT
  No predisposition for bleeding
Mild TBI Management

Discharge Instructions

- Appropriate follow-up instructions should be provided both verbally and written instructions.
- No need to awaken patient q 2 hours
- Patients who return to ED due to persistent symptoms should undergo careful repeat neurological evaluation but little data supports repeat CT Scanning

<table>
<thead>
<tr>
<th>Warning Signs after Discharge</th>
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</thead>
<tbody>
<tr>
<td>Inability to awaken the patient</td>
</tr>
<tr>
<td>Decreased/Altered mental status</td>
</tr>
<tr>
<td>Severe or worsening headache</td>
</tr>
<tr>
<td>Somnolence or confusion</td>
</tr>
<tr>
<td>Restlessness, Unsteadiness</td>
</tr>
<tr>
<td>Seizure activity</td>
</tr>
<tr>
<td>Visual difficulties</td>
</tr>
<tr>
<td>Change in behavior</td>
</tr>
<tr>
<td>Vomiting, fever, neck stiffness</td>
</tr>
<tr>
<td>Urinary or bowel incontinence</td>
</tr>
<tr>
<td>Weakness or numbness</td>
</tr>
</tbody>
</table>
Mild TBI Management

Return to Play Guidelines

✓ Patients should return to sporting activities in a step-wise fashion that emphasizes physical and cognitive rest.

✓ Patients should not return to sporting events if they are still symptomatic.

✓ There are many commonly used tools for assessing a player's ability to return to sporting events.
Mod/Severe TBI Management

General Principles

- All moderate and severe TBI patients should undergo CT imaging
- Stabilization and prevention of secondary insults is mainstay of treatment

Airway Management

- Prevention of hypoxia and hypoventilation key to preventing secondary insults
- Patients with GCS < 9, should have endotracheal airway placed
- Rapid Sequence Intubation is preferred method of intubation
- Nasotracheal Intubation contraindicated due to tendancy for ICP to increase
  2/2 cough/gag
- Lidocaine for prevention of increased ICP has not been shown to have a benefit
- Special attention should be paid to maintaining cervical spinal immobilization
Mod/Severe TBI Management

Hemodynamic Assessment

Hypotension (SBP < 90) should be aggressively treated as significant cause of worse outcome

Rarely, hypotension is due to head injury itself and other traumatic injuries should be investigated

Treatment of hypotension is directed at maintenance of cerebral perfusion

Hypotonic fluids are contraindicated
Typically isotonic fluids are used (NS)
Mod/Severe TBI Management

Operative Management

Indications

Penetrating injuries or blunt injuries with breach of the calvarium/skull
Presence of expanding intracranial hematoma

Epidural Hematoma
- If volume > 30 cm$^3$ or if comatose (GCS < 9)

Subdural Hematoma
- If size > 10 mm on CT or if 5 mm shift regardless of GCS score
- Decompression if GCS decreases by 2 points from time of injury to hospital arrival
- ICP > 20 mmHG or if pt with fixed, dilated pupils

Malignant cerebral edema

Open TBI, increased ICP
Mod/Severe TBI Management

Operative Management

Decompressive Craniotomy

- Salvage operation used to manage increasing ICP
- Removal of part of skull and underlying dura
- Decreases ICP, improves CPP, prevents ischemia
- Serves to limit secondary insults
- Literature divided on true benefit