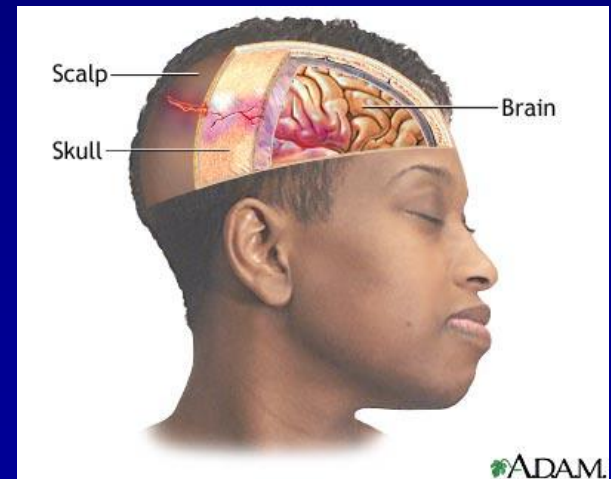


Traumatic Brain Injury (TBI)

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Epidemiology of TBI

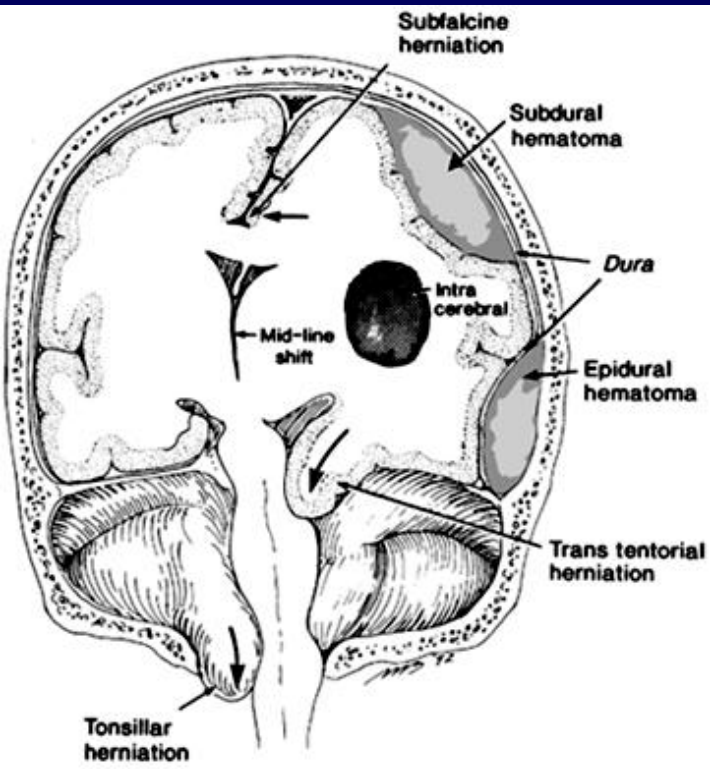
- Severe TBI → Glasgow Coma Score < 9
- In United States
 - Leading cause of death <45
 - ~100,000 deaths annually
 - ~90,000 severe disability
 - Cost > \$100 Billion (US) / yr



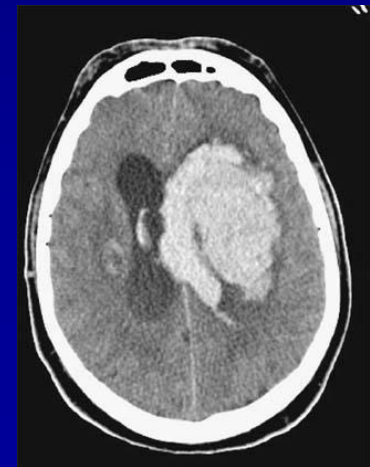
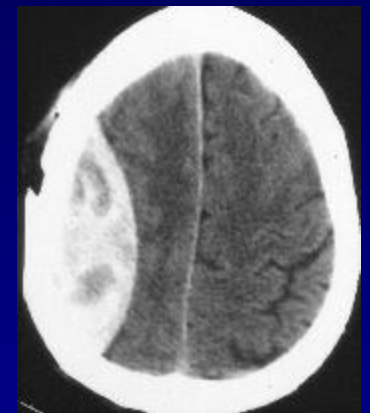
More Statistics

- 75% - other organ systems involved
- 50% mortality → 25% mortality
- Decreased GCS = Increased Mortality
- 75% non-surgical
- Alcohol involved in 40-50%

General Injury Types



- Subdural
- Epidural
- Intracerebral
- Diffuse Axonal Injury
- Herniation



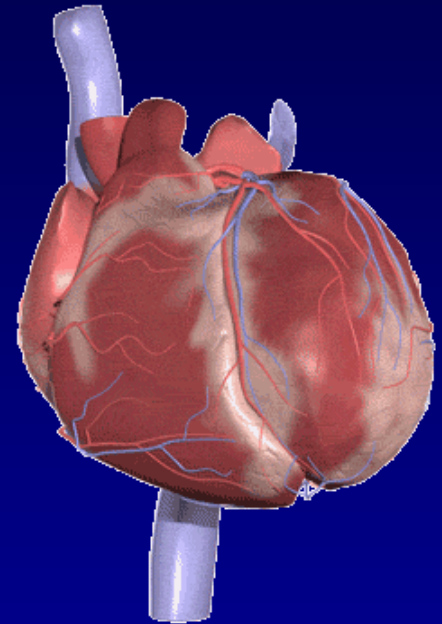
Physical Exam

- Brainstem Function
- Check Mental Status
- Glasgow Coma Scale
- Pupils (Size/Reactivity/Symmetry)
- Motor Exam
- Cranial Nerves



Brainstem Function

- Pulse
- Blood Pressure
- Respiratory Rate / Pattern
- Eye Movements



Neurologic Exam

- Mental Status
 - Awake?
 - Coherent?
 - Unresponsive?
- Glasgow Coma Scale
 - <10 → Bad
 - ≤ 8 Intubate!

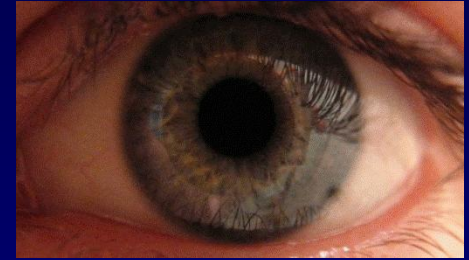
Glasgow Coma Scale	Score
Eye Opening	
Spontaneous	4
To Speech	3
To Pain	3
None	1
Verbal Score	
Oriented Conversation	5
Confused Conversation	4
Inappropriate Words	3
Incomprehensible Sounds	2
No vocal sounds	1
Motor Score	
Obeys Commands	6
Localized Pain	5
Flex/Withdraw to Pain	4
Abnormal Flexion to Pain	3
Extension to Pain	2
No Movement	1
Total Score: 3 to 15	

More Neuro

- Motor
 - Symmetrical?
 - Focal?
- Reflexes
- Cranial Nerves
 - If awake, test to establish baseline
 - If obtunded, difficult
- Test all neuro before paralyzed!

Pupils

- Pupil Shape
- Reactivity
 - Non Reactive or Fully Dilated → Severe TBI
 - Poor prognosis
- Dilation
 - $>4\text{mm}$ is “Blown” pupil
 - Anisocoria – if $>3\text{mm}$ usually abnormal
- Paralytics do not affect pupil reactivity!



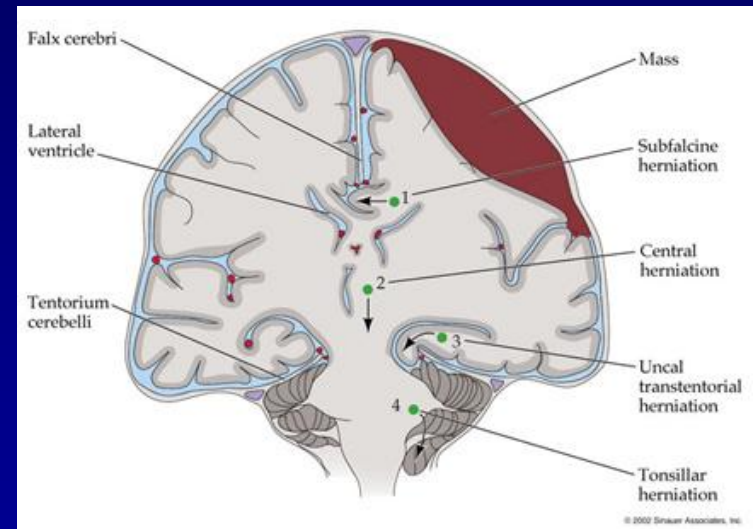
Herniation Syndromes

- Cerebellotonsillar Herniation
 - Through Foramen Magnum

- Uncal Herniation
 - Transtentorial

- Subfalcine Herniation

- Unilateral lateral herniation under Falx Cerebri



Cerebellotonsillar Herniation

- Cerebellar tonsils – herniate through Foramen Magnum
- Signs
 - Impending Respiratory / CV Collapse
 - Pinpoint Pupils
 - Flaccid Quadriplegia
 - 70% mortality



Uncal Herniation

- Transtentorial
- Most common traumatic herniation
- Signs:
 - Pupil dilation
 - Contralateral hemiparesis
 - Decerebrate posturing



Cushing Response

- From increased intracranial pressure
- Signs:
 - Bradycardia
 - Hypertension
 - Irregular respirations
- Only 30% of time, but if present bad

Pathophysiology

- Initial injury (blunt/bleed)
 - Minimal immediate effect
 - Can't do anything about this!
- Secondary injury
 - Physiologic response to injury
 - This is where you can have impact

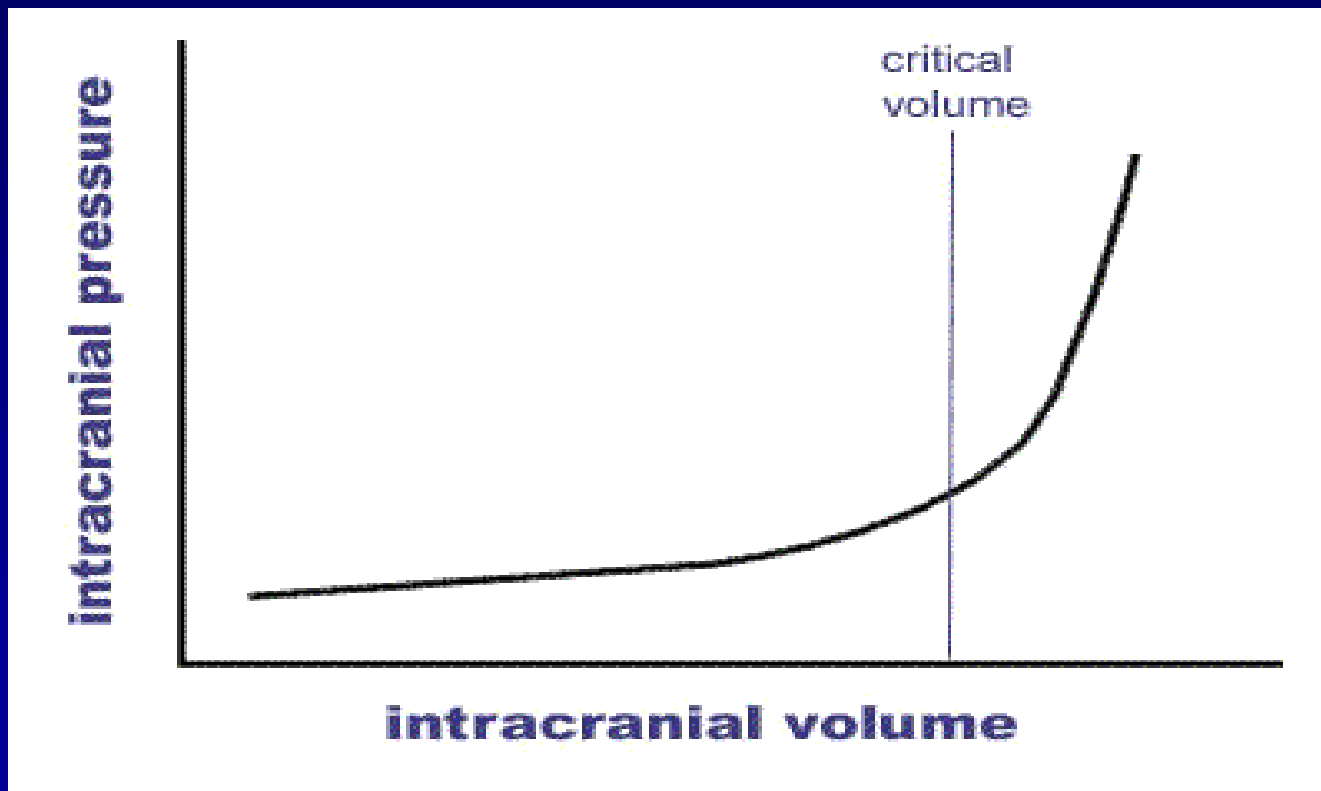
Cerebral Edema

- Two types:
 - Vasogenic
 - Interstitial process
 - Injury → Failure of Blood Brain Barrier → Leakage
 - Cytotoxic
 - Post injury ischemia
 - Intracellular pump failure
 - Intracellular edema
 - Max edema usually 48-72 hours



Munroe-Kellie Doctrine

- Cranial Volume = Brain + CSF + Blood + Mass



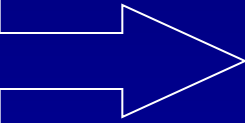
Cerebral Perfusion Pressure (CPP)

- Regulation of cerebral blood flow disrupted
 - Hard to measure
- CPP best indicator of cerebral blood flow
- $CPP = MAP - ICP$
 - Normal ICP 0-10 mm Hg
 - Normal CPP 70-100 mm Hg

How to Increase CPP?

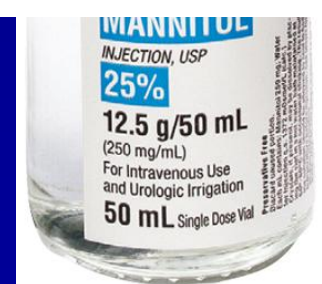
- Remember $CPP = MAP - ICP$
 - Raise MAP or lower ICP
 - Goal ICP < 20 mm Hg
- Goal is to keep CPP >50!!!
 - Greater than 65 ideal
 - Do not aggressively raise MAP however
 - Mortality ↑ 20% for every ↓10 mm Hg in CPP

Predictors of Outcome

- Age
 - Intracranial diagnosis via CT
 - GCS after resuscitation
 - Pupillary Reaction
 - Hypotension
 - Hypoxia
- 
- Double mortality!
 - Factors we can affect

Resuscitation/Management

1. Control Airway
2. CT Scan as soon as possible
3. Raise HOB
4. Avoid Hypoxia
5. Avoid Hypotension
6. Mannitol or Hypertonic Saline
7. Control PCO₂
8. Seizure prophylaxis



Airway Management

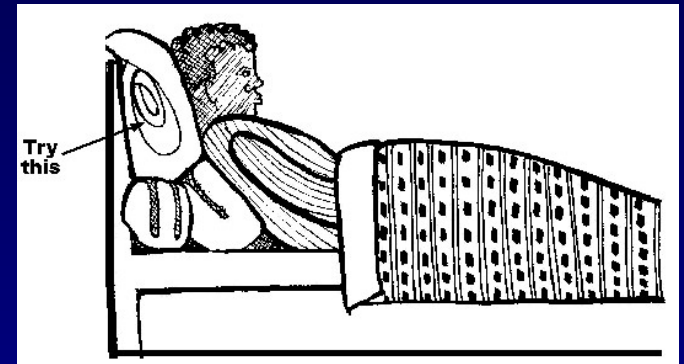
- Intubate early and often!
- Indications to intubate
 1. Inability to maintain airway
 2. Inadequate ventilation
 3. Hemodynamic instability
 4. Combative patient
 5. Patient movement precluding imaging

Airway

- RSI:
 - Consider Lidocaine (Reduce ICP?)
 - Fentanyl
 - Give slowly, cautiously
 - May cause hypotension!
 - Rapid infusions transiently increase ICP
 - Etomidate or propofol for induction
 - Succinylcholine OK
 - Should pretreat with defasciculation dose
 - Consider rocuronium/vecuronium
 - Prolonged paralysis

Elevate Head of Bed

- Head of Bed to 30 degrees
- Decreases ICP



- No effect on Cerebral Blood Flow!
- Also decreases ventilator-associated pneumonia

Post-Intubation

- Avoid Hypoxia!
- Avoid Hypoxia!
- Avoid Hypoxia!
- Maintain PaO₂ >60 mm Hg or pulse ox >90
- Goal PCO₂ 35-40 mm Hg
- Hct 30-33%



Avoid Hypotension

- Goal: SBP 110-130
- *One episode SBP < 90 → 35-50% increased mortality*
- Seek cause!
 - Isolated TBI rarely results in hypotension
 - Bleed
 - Spinal cord injury
 - Cardiogenic shock

Treating Hypotension

- Stop antihypertensives
 - Unless hypertensive emergency
- Fluids
 - Normal Saline or Lactated Ringers
 - Avoid hypotonic solutions
 - Even for maintenance fluids!
 - Increase cerebral edema

Hypotension and Pressors

- Consider if BP not responding to fluids
- Preferred agents
 - Dopamine
 - Norepinephrine
- Avoid phenylephrine
 - Increased peripheral resistance
 - Reflex bradycardia
 - Overall decrease in CO → decreased cerebral blood flow
- Remember, goal MAP >90
 - Avoid SBP <90!! This is ABSOLUTE value.

Osmotic Therapy - Mannitol

- Very effective at reducing ICP acutely but....
- Profound diuresis → hypotension
- Use only if:
 - Signs of impending herniation
 - Unexplained neurologic deficits
 - ICP monitoring → decreased CPP
 - Pt is not dehydrated



Mannitol

- Dose: 0.25 -1.0 gm/kg IV
- Ensure foley catheter
- Watch out for:
 - Hypotension (No SBP < 90)
 - Renal Failure
 - Reverse Osmotic Effect
 - Prolonged use can open blood brain barrier

Osmotic Therapy: Hypertonic Saline

- **Benefits:**
 - Increases intravascular volume
 - Decreased cerebral edema
 - Decreases intracranial leukocytes
 - Helps prevent cerebral vasospasm
- **Risks:**
 - Central Pontine Demyelination
 - Only reported in pts with hyponatremia
 - Acute Renal Failure
 - Especially if hypovolemic
 - Pulmonary Edema
 - Preexisting cardiac disease

Hyperventilation

- Dramatically decreases ICP
but
- Also decreases cerebral blood flow
 - Overall decrease in cerebral oxygenation
- Mild hyperventilation may be helpful
 - PCO₂ 35 to 40 generally safe
 - PCO₂ < 25 dangerous
 - Use only if impending doom
- Generally avoid in first 24 hours



Post-Traumatic Seizures (PTS)

- More likely to occur
 - GCS <10
 - Cortical contusion
 - Depressed skull fracture
 - Subdural / epidural / intracerebral hematoma
 - Penetrating head wound
 - Initial seizure < 24 hours post-injury
- No association between early seizures and worse outcomes

Seizure Prevention

- May be helpful in early course
 - Do not use routinely
 - Use for pts at risk only
- Phenytoin – most effective
- Valproate – as effective but more side effects
- Benzodiazepines
 - May be helpful
 - Caution! May decrease MAP → CPP

Refractory ICP

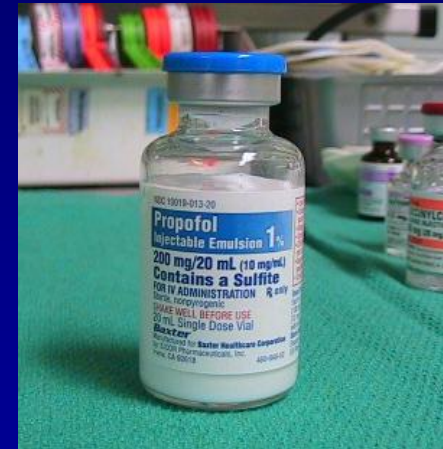
- What if remains high despite:
 - HOB > 30 degrees
 - Intubation with mild hyperventilation
 - Osmotic Therapy
 - Sedation
- Barbiturate Coma
 - May reduce ICP when all else fails

Barbiturate Coma

- Pentobarbital best studied
 - Load 10mg/kg over 30 minutes, then 5mg/kg q1h x 3
 - Maintenance 1 mg/kg/hour
- Effects:
 - Decreases cerebral metabolism and blood flow
 - Minimize cerebral oxygen demand
 - Free radical scavenger
- Indicated:
 - If all else fails (impending doom)
 - ICP > 35 mmHg
- Risk: causes hypotension in 1:4 patients

Propofol Infusion

- Effective at reducing ICP
- No effect on long term outcomes
- Dose:
 - 0.5 mg/kg initial bolus
 - Infusion at 25-75 mcg/kg/min
 - Do not exceed 5 mg/kg/hour!!
 - Associated with significant morbidity



Steroids

- Brain Trauma Foundation
 - Level One Recommendation
- “The use of steroids is not recommended”
- “In traumatic brain injury patients, high dose steroids are associated with increased mortality and are contraindicated”
- Enough said!

Review

1. Perform a good physical exam
2. Intubate
3. CT Head as soon as practical
4. Raise HOB > 30 degrees
5. Ventilate to keep PaO₂ >60 / Pulse Ox >90
6. Keep MAP > 90. Avoid any single systolic < 90!
 - Fluids! Pressors if needed
7. Use mannitol or hypertonic saline if indicated
8. Mild hyperventilation, PCO₂ no less than 35
9. Seizure prevention if warranted
10. Barbiturate coma as last resort

Pediatric Brain Injury

- GCS - <6 is same as <9 in adults
- CPP – keep between 40 and 65
 - Keep ICP less than 15
 - Keep MAP in normal to high range
- Do not use continuous propofol
- Mannitol 0.25-1.0 gm/kg
- Hypertonic Saline 5 ml/kg bolus, then 1 ml/hr

Key Points!

- Avoid Hypotension and Hypoxia
- Watch for signs of impending herniation
 - Cushings Reflex:
 - Bradycardia
 - Hypertension
 - Irregular Respirations
- Fluid resuscitate – NS / LR / Hypertonic Saline only
- No Steroids!

QUESTIONS?

