Head & Brain Trauma

- ~ 4 million head injuries in US per year
- ~ 450,000 require hospitalization
  - Most are minor injuries
  - Major head injury most common cause of trauma deaths in trauma centers (>50%)
Head & Brain Trauma

Risk Groups
- Highest: Males 15-24 yrs of age
- Very young children: 6 mos to 2 yrs of age
- Young school age children
- Elderly
Skull Anatomy Review

- Cranium
  - Frontal, occipital, temporal, parietal, mastoid, facial bones
Skull Anatomy Review

- **Middle meningeal artery**
  - lies under temporal bone
  - common source of epidural hematoma
Skull Anatomy Review

- **Foramen Magnum**
  - The large hole at the base of the skull which allows passage of the spinal cord
  - “Foramen Magnum” literally means a "large hole or opening" in Latin
  - With increased ICP the brain stem can be “pushed” through this opening with fatal consequences
Brain Anatomy Review

- Occupies 80% of intracranial space
- Divisions
  - Cerebrum
  - Cerebellum
  - Brain Stem
Brain Anatomy Review

- **Cerebrum**
  - **Cortex**
    - Voluntary skeletal movement
    - Level of awareness
  - **Frontal lobe**
    - Personality
  - **Parietal lobe**
    - Somatic sensory input
    - Memory
    - Emotions
Brain Anatomy Review

- **Cerebrum**
  - **Temporal lobe**
    - speech center
    - long term memory
    - taste
    - smell
  - **Occipital lobe**
    - origin of optic nerve
Brain Anatomy Review

- Cerebrum
  - Hypothalamus
    - center for vomiting, regulation of body temp and water
    - sleep-cycle control
    - appetite
  - Thalamus
    - emotions and alerting or arousal mechanisms
- Cerebellum
  - coordination of voluntary muscle movement
  - equilibrium and posture
Brain Anatomy Review

- Brain Stem
  - connects hemispheres and cerebellum
  - responsible for vegetative functions
  - midbrain
    - relay point for visual and auditory impulses
  - pons
    - conduction pathway between brain and other regions of body
  - medulla oblongata
    - cardiac, respiratory, and vasomotor control centers
    - control of vomiting and coughing
Brain Anatomy Review

- Brain Stem
  - Cranial Nerves
  - Reticular Activating System
    - level of arousal (level of consciousness)
      - Primary control along with cerebral cortex
  - Meninges
    - dura mater: tough outer layer, separates cerebellum from cerebral structures, landmark for lesions
    - arachnoid: web-like, venous vessels that reabsorb CSF
    - pia mater: directly attached to brain tissue
Brain Anatomy Review

- Brain Stem
  - Cerebral Spinal Fluid (CSF)
    - clear, colorless
    - circulates through brain and spinal cord
    - cushions and protects
    - ventricles
      - center of brain
      - secrete CSF by filtering blood
      - forms blood-brain barrier
Brain Metabolism & Perfusion

- **High metabolic rate**
  - consumes 20% of body’s oxygen
  - largest user of glucose
  - requires thiamine
  - does not require insulin
  - cannot store nutrients

- **Blood Supply**
  - **vertebral arteries**
    - supply posterior brain (cerebellum and brain stem)
  - **carotid arteries**
    - most of cerebrum
Brain Metabolism & Perfusion

● Perfusion
  ● Cerebral Blood Flow (CBF)
    – dependent upon CPP
    – flow requires pressure gradient
  ● Cerebral Perfusion Pressure (CPP)
    – pressure moving the blood through the cranium
    – auto-regulation allows BP change to maintain CPP
    – CPP = Mean Arterial Pressure (MAP) - Intracranial Pressure (ICP)
Brain Metabolism & Perfusion

- **Perfusion**
  - **Mean Arterial Pressure (MAP)**
    - largely dependent on cerebral vascular resistance (CVR) since diastolic is main component
    - blood volume and myocardial contractility
    - MAP = Diastolic + 1/3 Pulse Pressure
    - usually require MAP of at least 60 mm Hg to perfuse brain
  - **Intracranial Pressure (ICP)**
    - edema, hemorrhage
    - ICP usually 10-15 mm Hg
Cerebral Blood Flow

- Internal carotid artery
- Middle cerebral artery
- Circle of Willis
- Basilar artery

Bottom view of brain
Mechanisms of Injury

- Motor Vehicle Crashes
  - most common cause of head trauma
  - most common cause of subdural hematoma

- Sports Injuries

- Falls
  - common in elderly and in presence of alcohol
  - associated with subdural hematomas

- Penetrating Trauma
  - missiles more common than sharp projectiles
Categories of Injury

- **Coup injury**
  - directly posterior to point of impact
  - more common when front of head struck

- **Contrecoup injury**
  - directly opposite the point of impact
  - more common when back of head struck

- **Diffuse Axonal Injury (DAI)**
  - shearing, tearing or stretching of nerve fibers
  - more common with vehicle occupant and pedestrian

- **Focal Injury**
  - limited and identifiable site of injury
Head Injury

- Broad and Inclusive Term
  - Traumatic insult to the head that may result in injury to soft tissue, bony structures, and/or brain injury
  - Blunt Trauma
    - more common
    - dura intact
    - fractures, focal brain injury, DAI
  - Penetrating Trauma
    - less common (GSW most common)
    - dura and cranial contents penetrated
    - fractures, focal brain injury
Brain Injury

- “a traumatic insult to the brain capable of producing physical, intellectual, emotional, social and vocational changes”

- Three broad categories
  - **Focal injury**
    - cerebral contusion
    - intracranial hemorrhage
    - epidural hemorrhage
  - **Subarachnoid hemorrhage**
  - **Diffuse Axonal Injury**
    - concussion (mild and classic form)
Causes of Brain Injury

- Direct (Primary) Causes
  - Impact
  - Mechanical disruption of cells
  - Vascular permeability or disruption

- Indirect (Secondary or Tertiary) Causes
  - Secondary
    - edema, hemorrhage, infection, inadequate perfusion, tissue hypoxia, pressure
  - Tertiary
    - apnea, hypotension, pulmonary resistance, ECG changes
Pathophysiology of Brain Injury

- As ICP \( \uparrow \) and approaches MAP, cerebral blood flow \( \downarrow \)
  - Results in \( \downarrow \) CPP
  - Compensatory mechanisms attempt to \( \uparrow \) MAP
  - As CPP \( \downarrow \), cerebral vasodilation occurs to \( \uparrow \) blood volume
  - This leads to further \( \uparrow \) ICP, \( \downarrow \) CPP and so on
Pathophysiology of Brain Injury

- Hypercarbia causes cerebral vasodilation
  - Results in ↑ blood volume ⇒ ↑ ICP ⇒ CPP
  - Compensatory mechanisms attempt to ↑ MAP
  - As CPP ↓, cerebral vasodilation occurs to ↑ blood volume
  - And, the cycle continues

- Hypotension results in ↓ CPP ⇒ cerebral vasodilation
  - Results in ↑ blood volume ⇒ ↑ ICP ⇒ CPP
  - And, the cycle continues
Pathophysiology of Brain Injury

- Pressure exerted downward on Brain
  - cerebral cortex or RAS
    - altered level of consciousness
  - hypothalamus
    - vomiting
  - brain stem
    - ↑ BP and bradycardia 2° vagal stimulation
    - irregular respirations or tachypnea
    - unequal/unreactive pupils 2° oculomotor nerve paralysis
    - posturing
  - seizures dependent on location of injury
  - Herniation
Pathophysiology of Brain Injury

- Levels of Increasing ICP
  - Cerebral cortex and upper brain stem
    - BP rising and pulse rate slowing
    - Pupils reactive
    - Cheyne-Stokes respirations
    - Initially try to localize and remove painful stimuli
  - Middle brain stem
    - Wide pulse pressure and bradycardia
    - Pupils nonreactive or sluggish
    - Central neurogenic hyperventilation
    - Extension
Pathophysiology of Brain Injury

- Levels of Increasing ICP
  - Lower Brain Stem / Medulla
    - Pupil blown (side of injury)
    - Ataxic or absent respirations
    - Flaccid
    - Irregular or changing pulse rate
    - Decreased BP
    - Usually not survivable
Pathophysiology of Brain Injury

- Herniation
  - transtentorial herniation
    - downward displacement of the brain
  - uncal herniation
    - “downward displacement through the tentorial notch by a supratentorial mass exerting pressure on underlying structures including the brain stem”
Head Injuries

- Scalp Laceration/Avulsion
  - Most common injury
  - Vascularity = diffuse bleeding
  - Generally does not cause hypovolemia in adults
  - Can produce hypovolemia in children
Head Injuries

Depressed

Linear

Stellate

Basilar

Skull Fractures
Head Injuries

- **Linear Fracture**
  - Usually **NOT** identified in field
    - 80% of all skull fractures
  - **Suspect based on**
    - Mechanism of injury
    - Overlying soft tissue trauma
  - Usually **NOT** emergency
  - Temporal region = ~Epidural hematoma
Head Injuries

- Depressed Skull Fracture
  - Segment pushed inward
  - Pressure on brain causes brain injury
    - Neurologic signs and symptoms evident
Head Injuries

- **Basilar Skull Fracture**
  - Difficult to detect on x-ray
  - Signs & Symptoms depend on amount of damage
  - Diagnosis made clinically by finding:
    - CSF Otorrhea (CFS from the ears)
    - CSF Rhinorrhea (CFS from the nose)
    - Periorbital ecchymosis
    - Battle’s sign
Head Injuries

- Cerebrospinal Fluid
  - Blood clotting delayed
  - Halo sign
  - Does not crust on drying
  - Positive to Dextrostick
Head Injuries

- Basilar Skull Fracture
  - Do **NOT** pack ears
  - Let drain
  - Do **NOT** suction fluid
  - Do **NOT** instrument nose
Head Injuries

- Open Skull Fracture
  - Cranial contents exposed
  - Manage like evisceration
  - Protect exposed tissue with moist, clean dressing (if possible)
  - Neurologic signs & Symptoms evident
Brain Injuries

- Intracranial Hematomas
  - Epidural
  - Subdural
  - Intracerebral
Brain Injuries

- **Epidural Hematoma**
  - Blood between skull and dura
  - Usually arterial tear
    - middle meningeal artery
  - Causes increase in intracranial pressure
Brain Injuries

- Epidural Hematoma
  - Unconsciousness followed by lucid interval
  - Rapid deterioration
  - Decreased LOC, headache, nausea, vomiting
  - Hemiparesis, hemiplegia
  - Unequal pupils (dilated on side of clot)
  - Increase BP, decreased pulse, irregular respiratory pattern (Cushing’s Triad)
Brain Injuries

- **Subdural Hematoma**
  - Between dura mater and arachnoid
  - More common
  - Usually venous
    - bridging veins between cortex and dura
  - Causes increased intracranial pressure
Brain Injuries

- **Subdural Hematoma**
  - Slower onset
  - Increased ICP
  - Headache, decreased LOC, unequal pupils
  - Increased BP, decreased pulse
  - Hemiparesis, hemiplegia
Brain Injuries

- Intracerebral Hematoma
  - Usually due to laceration of brain
  - Bleeding into cerebral substance
  - Associated with other injuries
    - DAI
  - Neuro deficits depend on region involved and size
    - repetitive w/frontal lobe
  - Increased ICP
Brain Injuries

- Injury to Cerebrum
  - Laceration
  - Concussion
  - Contusion
Brain Injuries

- Laceration
  - Penetrating wounds
    - GSW
    - Stab
    - Depressed Fracture
  - Severe blunt trauma
  - Sudden acceleration/deceleration
Brain Injuries

- **Concussion**
  - Transient loss of consciousness
  - Retrograde amnesia, confusion
  - Perseveration – Repetitive Questioning
  - Resolves spontaneously without deficit
  - Usually due to blunt head trauma
Head Trauma

- Concussion
  - Post-concussion syndrome
    - Headaches
    - Depression
    - Personality changes
Head Trauma Assessment

The Brain Is Enclosed In A Box
Head Trauma Assessment

Early Detection and Control of Increased ICP is Critical
Cerebral Perfusion Pressure = Mean Arterial Pressure - Intracranial Pressure

CPP = MAP - ICP
Head Trauma Assessment

- LOC = Best Indicator
  - Altered LOC = Intracranial trauma UPO
  - Trauma patient unable to follow commands = 25% chance of intracranial injury needing surgery
Head Trauma Assessment

Describe LOC changes based on response to environment
Head Trauma Assessment

- AVPU Scale
  - A = Alert
  - V = Responds to Verbal stimuli
  - P = Responds to Painful stimuli
  - U = Unresponsive
Head Trauma Assessment

- Glasgow Scale
  - Eye Opening
  - Motor Response
  - Verbal Response
Head Trauma Assessment

- Glasgow Scale-Eye Opening
  - 4 = Spontaneous
  - 3 = To voice
  - 2 = To pain
  - 1 = Absent
Head Trauma Assessment

- **Glasgow Scale-Verbal**
  - 5 = Oriented
  - 4 = Confused
  - 3 = Inappropriate words
  - 2 = Moaning, Incomprehensible
  - 1 = No response
Head Trauma Assessment

- **Glasgow Scale-Motor**
  - 6 = Obeys commands
  - 5 = Localizes pain
  - 4 = Withdraws from pain
  - 3 = Decorticate (Flexion)
  - 2 = Decerebrate (Extension)
  - 1 = Flaccid
Head Trauma Assessment

A. Extension posturing (decerebrate rigidity)

B. Abnormal flexion (decorticate rigidity)
Head Trauma Assessment

- Eyes
  - Window to CNS
  - Pupil size, equality, and response to light
Head Trauma Assessment

- **Eyes**
  - Unequal Pupils + Decreased LOC =
    - Compression of oculomotor nerve
    - Probable mass lesion
  - Unequal Pupils + Alert patient =
    - Direct blow to eye, or
    - Oculomotor nerve injury, or
    - Normal inequality
Respiratory Patterns

- Cheyne Stokes
  - Diffuse injury to cerebral hemispheres
- Central neurological hyperventilation
  - Injury to mid-brain
- Apneustic
  - Injury to pons
Head Trauma Assessment

- **Respiratory Patterns**
  - Ataxic or “Boit” Respirations
    - Injury to Medulla
    - Shallow irregular breathing followed by random deep rapid respirations
Head Trauma Assessment

- **Motor Response**
  - Is patient able to move all extremities?
  - How do they move?
    - Decorticate
    - Decerebrate
    - Hemiparesis or Hemiplegia
    - Paraplegia or Quadraplegia
Head Trauma Assessment

- Motor Response
  - Lateralized/Focal Signs
    - Lateralized or Focal Deficits
  - Altered motor function may be due to fracture/dislocation
Head Trauma Assessment

- Vital Signs
  - Cushing’s Triad
    - Suggests Increased Intracranial Pressure
      - Increased BP
      - Decreased Pulse
      - Irregular respiratory pattern
Head Trauma Assessment

Vital Signs

- Isolated head injury will **NOT** cause hypotension in adult
- Look for another life threatening injury
  - Chest
  - Abdomen
  - Pelvis
  - Multiple long bone fractures
Head Trauma Assessment

Summary

- Most important sign = LOC
- Direction of changes more important than single observations
- Importance lies in continued reassessment compared with initial exam
- Altered LOC in trauma = suspect intracranial injury
Head Trauma Management

- **Airway**
  - **Open**
    - Assume C-spine Trauma
    - Jaw Thrust with C-spine Control
  - **Clear - Suction As Needed**
  - **Maintain**
    - Intubation if No Gag Reflex, or
    - RSI
    - Avoid nasal intubation
Head Trauma Management

- Breathing
  - Oxygenate - 100% O₂
  - Ventilate
  - No ROUTINE Hyperventilation
  - Hyperventilate at 20 to 24 breaths per minute IF:
    - Glasgow less than 8
    - Rapid neurologic deterioration
    - Evidence of herniation
Head Trauma Management

- Hyperventilation-Benefits
  - Decreased PaCO$_2$
  - Vasoconstriction
  - Decreased ICP
Head Trauma Management

- Hyperventilation-Risks
  - Decreased cerebral blood flow
  - Decreased oxygen delivery to tissues
  - Increased edema
Head Trauma Management

- **Circulation**
  - Maintain adequate BP and Perfusion
  - IV of NS TKO if BP normal or elevated
  - If BP decreased
    - NS bolus titrated to BP ~ 90 mm Hg
    - Consider Hetastarch (Hespan)
      - Do not use in pediatrics
  - Monitor EKG - Do **NOT** treat bradycardia beyond ventilatory management
Head Trauma Management

- Spinal motion restriction
- If BP normal or elevated, spine board head elevated $30^0$
Head Trauma Management

- Monitor for hyperthermia
  - Vasoconstriction
  - Heat retention
  - Increased cerebral $O_2$ demand
Head Trauma Management

Drug Therapy Considerations

- **Methylprednisolone (Solu-Medrol)**
  - CorticoSteroid
  - Dosage: 30mg/kg infused over 30 min
  - For use with suspected spinal cord injuries with associated paralysis
    - (Do NOT use with penetrating spinal cord injuries)
  - Limits swelling associated with spinal cord trauma
Head Trauma Management

- Drug Therapy Considerations
  - Diazepam (Valium®)
    - Anticonvulsant
    - Give if patient experiences seizures
    - May mask changes in LOC
    - May depress respirations
    - May worsen hypotension
Head Trauma Management

- Drug Therapy Considerations
  - Glucose
    - Assess blood glucose
    - Administer only if hypoglycemic
    - Consider thiamine in malnourished
Head Trauma Management

- Transport Considerations
  - Trauma Center
    - GCS $\leq 12$
      - Evidence of herniation
      - Unconscious
      - Multisystem trauma with head trauma
      - Consider comorbid factors
Head Trauma Management

- Helmet Removal
  - Immediate removal if interferes with priorities
    - access to airway or airway management
    - ventilation
    - cervical spine motion restriction
  - May only need to remove face piece to access airway
  - Consider interference with SMR
- Technique
  - requires adequate assistance
  - training in the procedure
  - padding if shoulder pads left on