Head Injury (Traumatic Brain Injury)

Kevin Badgley
Paramedic, EMS I/C

Introduction to Head and Traumatic Brain Injuries

- Common major trauma
- 4 million people experience head trauma annually
  - Severe head injury is most frequent cause of trauma death
- At-risk population:
  - Males 15-24
  - Infants
  - Young children
  - Elderly

Introduction to Head and Traumatic Brain Injuries

- Injury Prevention Programs
  - Motorcycle safety
  - Helmet use decreased serious head injury by 50%
  - Bicycle safety
  - Helmet and head injury awareness programs
  - Sports
  - Football
  - Rollerblading
  - Contact sports

Anatomy and Physiology of the Head and Face

- Scalp
- Cranium
- Meninges
- Cerebrospinal fluid
- Brain
- CNS circulation
- Blood-brain barrier
- Cerebral perfusion pressure
- Cranial nerves
- Ascending reticular activating system
Anatomy and Physiology of the Head

- **Scalp**
  - Strong flexible mass of:
    - Skin
    - Fascia
    - Muscular tissue
    - Highly vascular

Anatomy and Physiology of the Head

- **Skull**
  - Facial bones
  - Cranium
    - Vault for the brain
    - Strong, light, rigid, spherical bone
    - Unyielding to increased intracranial pressure (ICP)

Anatomy and Physiology of the Head

- **Meninges**
  - Protective mechanism for the CNS
  - Dura Mater
    - Layers
      - Outer: Cranium’s inner periosteum
      - Inner: Dural layer
    - Forms partial structural divisions
      - Falx cerebri
      - Tentorium cerebelli
    - Large arteries above
      - Provide blood flow to the surface of the brain

Anatomy and Physiology of the Head

- **Meninges**
  - Arachnoid Membrane
    - “Spider-like”
    - Covers inner dura
    - Suspends brain in cranial cavity
    - Collagen and elastin fibers
    - Subarachnoid space beneath
    - CSF
    - Cushions brain
  - Pia Mater
    - Closest to brain and spinal cord
    - Covers all areas of brain and spinal cord
    - Very vascular

- **Galea aponeurotica**
  - Between scalp and skull
  - Fibrous connective sheath
  - Subaponeurotica (areolar) tissue
  - Permits venous blood flow from the dural sinuses to the venous vessels of scalp
  - Emissary veins: Potential route for infection

- **Falx cerebri**
  - Unyielding to increased intracranial pressure (ICP)

- **Fascia**
  - Vault for the brain
  - Muscular tissue
  - Inner: Dural layer
  - Fibrous connective sheath
  - Suspends brain in cranial cavity
Anatomy and Physiology of the Head

The Meninges and Skull

- Cerebrospinal Fluid
  - Clear, colorless fluid
  - Comprised of water, protein, and salts
  - Made in largest two ventricles of brain
  - Cushions CNS
  - Medium for nutrients and waste products to diffuse into and out of brain

- Brain
  - Occupies 80% of cranium
  - Comprised of 3 major structures
    - Cerebrum
    - Cerebellum
    - Brainstem
  - High metabolic rate
  - If blood supply stops:
    - Unconscious within 10 seconds
    - Irreversible damage in 4-6 minutes

- Cerebrum
  - Function
    - Center of conscious thought, personality, speech, and motor control
    - Visual, auditory, and tactile perception
    - Lobes
      - Frontal
      - Parietal
      - Occipital
      - Temporal
    - Memory and emotion
    - Motor and sensory activity
    - Hearing, speech, taste, and smell
  - Lobes
    - Frontal
    - Personality
    - Parietal
    - Motor and sensory activity
    - Occipital
    - Temporal
    - Long-term memory
    - Sensory

- Cerebrum
  - Falx Cerebri
    - Divides cerebrum into right and left hemispheres
  - Central Sulcus
    - Fissure splits cerebrum into right and left hemispheres
  - Tentorium
    - Fibrous sheet within occipital region
  - Brainstem perforates through incisura tentorii cerebelli
  - Oculomotor nerve (CN-III) travels along
    - Controls pupil size
    - Compression results in pupillary disturbances

Anatomy and Physiology of the Head

The Brain

- Cerebrum
  - Falx Cerebri
  - Central Sulcus
  - Tentorium
  - Brainstem perforates through incisura tentorii cerebelli
  - Oculomotor nerve (CN-III) travels along
Anatomy and Physiology of the Head

Cerebrum
- Hemisphere Functions
- Left side is dominant
  - Mathematical computations
  - Writing
  - Language interpretation
  - Speech
- Right
  - Non-verbal imagery

Cerebellum
- Located under tentorium
- Function
  - "Fine tunes" motor control
  - Allows smooth movement
  - Balance
  - Maintenance of muscle tone

Brainstem
- Central processing center
- Communication junction among
  - Cerebrum
  - Spinal cord
  - Cranial nerves
  - Cerebellum
- Structures
  - Midbrain
  - Pons
  - Medulla oblongata

Midbrain
- Upper portion of brainstem
- Structures
  - Hypothalamus
    - Endocrine function, vomiting reflex, hunger, thirst
    - Kidney function, body temperature, emotion
  - Thalamus
    - Switching center between pons and cerebrum
    - Critical Element in Ascending Reticular Activating System (A-RAS)
    - Major pathways for optic and olfactory nerves
  - Associated structures

Pons
- Communication interchange between cerebellum, cerebrum, midbrain, and spinal cord
- Bulb-shaped structure above medulla
- Sleeping phase of the RAS

Medulla Oblongata
- Bulge in the top of the spinal cord
- Centers
  - Respiratory Center
    - Controls depth, rate, and rhythm
  - Cardiac Center
    - Regulates rate and strength of cardiac contractions
  - Vasomotor Center
    - Distribution of blood
    - Maintains blood pressure
Anatomy and Physiology of the Head

- CNS Circulation
  - Arterial
    - Four Major Arteries
    - 2 Internal Carotid Arteries
    - 2 Vertebral Arteries
    - Circle of Willis
    - Internal Carotids and Vertebral Arteries
    - Circle the base of the brain
  - Venous
    - Venous drainage occurs through bridging veins
    - that drain surface of the cerebrum
    - Bridge with the dural sinuses
    - Drain into internal jugular veins

- Mean Arterial Pressure (MAP)
  - MAP = DBP + 1/3 Pulse Pressure

- Cerebral Perfusion Pressure
  - Pressure within cranium (ICP) resists blood flow and good perfusion to the CNS
  - Pressure usually less than 10 mmHg
  - Mean Arterial Pressure (MAP)
  - Must be at least 50 mmHg to ensure adequate perfusion
  - MAP = DBP + 1/3 Pulse Pressure
  - Cerebral Perfusion Pressure (CPP)
  - Pressure moving blood through the cranium
  - CPP = MAP – ICP

- Ascending Reticular Activation System
  - Tract of neurons in upper brainstem, pons, and midbrain
  - Responsible for sleep–wake cycle
  - Monitors input stimulation
  - Regulates body functions
  - Respiration
  - Heart rate
  - Peripheral vascular resistance

- Blood–Brain Barrier
  - Less permeable than elsewhere in body
  - Does not allow flow of interstitial proteins
  - Hormones and other circulating substances have no effect on the CNS
  - Reduced lymphatic flow
  - Very protected environment

- Cranial Nerves
  - 12 pair with distinct pathways
  - Senses, facial innervation, and body function control

- Nerves
  - Trigeminal (CN–V)
  - Facial sensation
  - Some eye motor control
  - Enables chewing process
  - Facial (CN–VII)
  - Motor control for facial muscles
  - Sensation of taste
**Anatomy and Physiology of the Face**
- Cranial Nerves
  - CN-XII (Hypoglossal)
  - CN-IX (Glossopharyngeal)
- Eye
  - Innervation
    - CN-III (Oculomotor)
    - Conjugate movement
    - CN-V (Trigeminal)
    - Movement of eyes together
    - CN-IV (Trochlear)
    - Downward and inward movement
    - CN-VI (Abducens)
    - Abduction (outward) gaze

**Anatomy and Physiology of the Neck**
- Jugular Veins
  - External
    - Superficial, lateral to the trachea
  - Internal
    - Sheath with the carotid artery and vagus nerve
- Esophagus
- Cranial Nerves
  - CN-IX (Glossopharyngeal)
    - Carotid bodies and carotid sinuses
  - CN-X
    - Speech, swallowing, cardiac, respiratory, and visceral function
- Thoracic Duct
  - Delivers lymph to the venous system

**Pathophysiology of Head, Facial, and Neck Injury**
- Difficult to assess in the prehospital setting
- Commonly threaten life
- May expose victims to lifelong disability
**Head Injury**
- Defined as a traumatic insult to the cranial region
  - Result in injury to soft tissues, bony structures, and the brain
  - Should separate “Head Injury” from “Traumatic Brain Injury”
    - Head Injury is not specific enough term

**Scalp Injury**
- Common Injuries
  - Contusions
  - Lacerations
  - Avulsions
- Significant hemorrhage may occur
- Reconsider MOI for severe underlying problems

**Cranial Injury**
- The skull does not fracture unless trauma is extreme
- Types
  - Linear
  - Most common
  - Depressed
  - Comminuted
  - Basilar

**Cranial Injury**
- Basilar Skull Fracture
  - Common type of skull fracture
  - Signs of basilar skull fracture vary with the injury’s location
  - May permit cerebrospinal fluid to seep out

**Traumatic Brain Injury**
- “A traumatic insult to the brain capable of producing physical, intellectual, emotional, social, and vocational changes.”
  - National Head Injury Foundation
- Classification
  - Direct
  - Indirect

**Direct Brain Injury**
- Caused by the forces of trauma and can be associated with a variety of mechanisms
  - Coup
  - Contrecoup
Coup-Contrecoup Injury

Direct Brain Injury Categories
- Focal
  - Occur at a specific location in brain
    - Cerebral contusion
    - Intracranial hemorrhage
    - Epidural hematoma
    - Subdural hematoma
    - Intracerebral hemorrhage
- Diffuse
  - Concussion
  - Moderate diffuse axonal injury
  - Severe diffuse axonal injury

Focal Brain Injury
- Cerebral Contusion
  - Capillary bleeding into brain tissue
  - Common with blunt head trauma
  - May result from a coup or contrecoup mechanism
  - Localized form of the injury manifests with dysfunctions related to the site of the injury

Focal Brain Injury
- Intracranial Hemorrhage
  - Epidural Hematoma
    - Bleeding between dura mater and skull
    - Involves arteries
    - Middle meningeal artery most common
    - Rapid bleeding and reduction of oxygen to tissues
    - Herniates brain toward foramen magnum
    - Progression is both rapid and life threatening

Focal Brain Injury
- Intracranial Hemorrhage (cont.)
  - Subdural Hematoma
    - Bleeding between meninges
    - Slow bleeding
      - Superior sagittal sinus frequently injured
      - Signs progress over several days
      - Slow deterioration of mentation

Focal Brain Injury
- Intracranial Hemorrhage (cont.)
  - Intracerebral Hemorrhage
    - Ruptured blood vessel within the brain
    - Presentation similar to stroke symptoms
    - Signs and symptoms worsen over time
    - Cerebral edema
    - Inflammatory response allows fluid leakage
    - Hydrocephalus
    - May occur with hemorrhage into the subarachnoid space
**Diffuse Brain Injury**

- Due to stretching forces placed on axons
- Pathology distributed throughout brain
  - Frequently distributed throughout the brain and thus is called *diffuse axonal injury (DAI)*
- Types
  - Concussion
  - Moderate diffuse axonal injury
  - Severe diffuse axonal injury

**Diffuse Brain Injury**

- Concussion
  - Mild to moderate form of diffuse axonal injury
  - Nerve dysfunction without anatomic damage
  - Transient episode of
    - Confusion, disorientation, event amnesia
    - Suspect if patient has a momentary loss of consciousness
  - Management
    - Frequent reassessment of mentation
    - ABCs

**Diffuse Brain Injury**

- Moderate Diffuse Axonal Injury
  - Stretching and tearing of neurons with minute bruising of brain tissue
  - Unconsciousness
  - If cerebral cortex and RAS involved
  - Commonly associated with basilar skull fracture
  - Signs and Symptoms
    - Unconsciousness, persistent confusion, inability to concentrate, disorientation, and retrograde and anterograde amnesia

**Diffuse Brain Injury**

- Severe Diffuse Axonal Injury
  - Significant mechanical disruption of axons
  - Cerebral hemispheres and brainstem
  - High mortality rate
  - Signs and Symptoms
    - Prolonged unconsciousness
    - Cushing’s reflex
    - Decorticate or decerebrate posturing

**Indirect Brain Injury**

- Indirect (or secondary) injuries are the result of factors that occur because of, though after, the initial (or primary) injury
- Caused by two distinct pathological processes
  - Diminishing circulation to brain tissue due to an increasing ICP
  - Progressive pressure against, or physical displacement of, brain tissue

**Intracranial Perfusion**

- Review
  - Cranial volume fixed
    - 80% = Cerebrum, cerebellum, and brainstem
    - 12% = Blood vessels and blood
    - 8% = CSF
  - Increase in size of one component diminishes size of another
    - Inability to adjust = increased ICP
Intracranial Perfusion

- Compensating for Pressure
  - Compress venous blood vessels
  - Reduction in free CSF
  - Pushed into spinal cord
- Decompensating for Pressure
  - Increase in ICP
  - Rise in systemic BP to perfuse brain
    - Further increase of ICP
    - Dangerous cycle

Intracranial Perfusion

- Role of Carbon Dioxide
  - Increase of CO₂ in CSF
    - Cerebral vasodilation
    - Contributes to > ICP
    - Causes classic symptom
      - Hyperventilation and hypertension
    - Reduced levels of CO₂ in CSF
    - Cerebral vasoconstriction
    - Results in cerebral anoxia

Factors Affecting ICP

- Vasculature Constriction
- Cerebral Edema
- Systolic Blood Pressure
  - Low BP = Poor cerebral perfusion
  - High BP = Increased ICP
- Carbon Dioxide
- Reduced respiratory efficiency

Pressure and Structural Displacement

- Increased pressure
  - Compresses brain tissue
  - Herniates brainstem
    - Compromises blood supply
  - Signs and Symptoms
    - Upper brainstem
      - Vomiting
      - Altered mental status
      - Pupillary dilation
    - Medulla oblongata
      - Respiratory
      - Cardiovascular
      - Blood pressure disturbances

Signs and Symptoms of Brain Injury

- Altered Mental Status
  - Altered orientation
  - Alteration in personality
  - Amnesia
  - Retrograde
  - Antegrade
- Cushing’s Reflex
  - Increased BP
  - Bradycardia
  - Erratic respirations
- Vomiting
  - Without nausea
  - Projectile
- Body temperature changes
- Changes in pupil reactivity
- Decorticate posturing

Signs and Symptoms of Brain Injury

- Physiological Changes
  - Frontal Lobe Injury
    - Alterations in personality
  - Occipital Lobe Injury
  - Visual disturbances
  - Cortical Disruption
    - Reduced mental status or amnesia
      - Retrograde
      - Unalbe to recall events before injury
      - Antegrade
      - Unable to recall events after trauma
      - "Repetitive questioning"
  - Focal Deficits
    - Hemiplegia, weakness, or seizures
Central Syndrome

- Progressive pressure and structural displacement are somewhat predictable
  - Known as Central Syndrome
- Physiological Changes
  - Upper Brainstem Compression
  - Increasing blood pressure
  - Reflex bradycardia
  - Vagus nerve stimulation
  - Cheyne-Stokes respirations
  - Pupils become small and reactive
  - Decorticate posturing

Central Syndrome

- Physiological Changes (cont.)
  - Middle Brainstem Compression
  - Widening pulse pressure
  - Increasing bradycardia
  - CNS hyperventilation
  - Bilateral pupil sluggishness or inactivity
  - Decerebrate posturing

Central Syndrome

- Physiological Changes (cont.)
  - Lower Brainstem Injury
  - Pupils dilated and unreactive
  - Ataxic respirations
  - Erratic with no pattern
  - Irregular and erratic pulse rate
  - ECG changes
  - Hypotension
  - Loss of response to painful stimuli

Central Syndrome

- Decerebrate posturing
  - Cushing’s Reflex
  - Increasing blood pressure
  - Decreasing pulse rate
  - Respirations that become erratic
  - Lowering level of consciousness
  - GCS <9 and dropping
  - Singular or bilaterally dilated and fixed pupils
  - Decerebrate or decorticate posturing
  - No movement with noxious stimuli

Recognition of Herniation

- Ataxic respirations

Pediatric Head Trauma

- Different pathology than older patients
  - Skull can distort due to anterior and posterior fontanelles
  - Bulging
  - Slows progression of increasing ICP
  - Intracranial hemorrhage contributes to hypovolemia
  - Decreased blood volume in pediatrics
- General Management
  - Avoid hyperextension of head
  - Tongue pushes soft palate closed
  - Ventilate through mouth and nose

Glasgow Coma Scale

- Standardized evaluation method
  - Used to measure a patient’s level of consciousness
  - Assesses the best eye opening, verbal, and motor response

<table>
<thead>
<tr>
<th>Item</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eye Opening</td>
<td>1</td>
</tr>
<tr>
<td>Motor Response</td>
<td>1</td>
</tr>
<tr>
<td>Verbal Response</td>
<td>1</td>
</tr>
<tr>
<td>Total score</td>
<td>3</td>
</tr>
</tbody>
</table>
**Eye Signs**

- Physiological Issues
  - Indicate pressure on
  - CN-II, CN-III, CN-IV, and CN-VI
  - Reduced peripheral blood flow
- Pupil Size and Reactivity
  - Reduced pupillary responsiveness
  - Depressant drugs or cerebral hypoxia
  - Fixed and dilated
  - Extreme hypoxia

**Assessment of Head and Traumatic Brain Injuries**

- Assessment follows the standard format
  - Size–up
  - Initial assessment
  - Rapid trauma assessment/focused exam and history
  - Detailed assessment
  - Pay special attention to ensuring airway patency
  - Consider the need for rapid transport

**Scene Size-Up**

- Consider the circumstances of injury
- Identify the nature and extent of forces that caused the injury
  - Spider–web windshield, deformity of the upper steering wheel, helmet use in motorcycle
- Rule out scene hazards

**Initial Assessment**

- Airway
  - Examine the face and neck for any deformity, swelling, hemorrhage, foreign bodies, or other signs of injury
  - Listen for unusual or changing voice patterns
  - Anticipate vomiting
  - Suctioning or intubation may worsen ICP

- Breathing
  - Ensure that the patient is moving an adequate volume of air
  - Head injury is likely to produce irregular breathing patterns
  - Ventilations for the serious head injury patient (GCS ≤8) are guided by capnography
  - Maintain an end–tidal CO₂ reading of between 35 and 40 mmHg
  - For patients with suspected herniation, the end–tidal CO₂ reading should range between 30 and 35 mmHg
  - Apply oxygen via nonrebreather mask to the breathing patient
**Initial Assessment**

- Circulation
  - Monitor the patient’s pulse rate and rhythm
  - Look for any hemorrhage from the head, face, and neck and control any moderate to severe bleeding
  - Maintain a blood pressure of at least 90 mmHg

**Rapid Trauma Assessment**

- A quick and directed head-to-toe examination of a patient
- Manage any life-threatening injuries and conditions as you find them during the rapid trauma assessment
  - If the patient shows any signs of pathology within the cranium, consider rapid transport

**Head, Facial, and Neck Injury Management**

- Management priorities for the patient sustaining head, face, or neck trauma include:
  - Maintaining the patient’s airway and breathing
  - Ensuring circulation through hemorrhage control
  - Taking steps to avoid hypoxia and/or hypovolemia
  - ALS—Providing appropriate medications

**Head, Facial, and Neck Injury Management**

- Airway
  - Patients may be unable to control the airway
  - Altered level of consciousness
  - Damaged airway structures
  - Sellick’s maneuver
  - Suctioning
    - May increase ICP
    - Emesis is common with head injury

**Basic Airway Management**

- Cricoid pressure
  - Helps prevent regurgitation and reduce gastric distention
  - Applies gentle pressure posteriorly on the anterior cricoid cartilage

**Apply cricoid pressure and intubate**

- Cricoid pressure
  - Helps prevent regurgitation and reduce gastric distention
  - Applies gentle pressure posteriorly on the anterior cricoid cartilage
Head, Facial, and Neck Injury Management

› Airway (cont.)
  • Patient positioning
    • Initial left-lateral recumbancy with cervical precautions, if possible
    • Approximately 30° elevation of head of spine board
  • Basic airway adjuncts
  • Oro and nasopharyngeal airways
  • Be prepared for emesis

Transport Considerations

› Limit external stimulation
  • Can increase ICP
  • Can induce seizures
› Be cautious about air transport
  • Seizures

Emotional Support

› Have friend or family provide constant reassurance
› Provide constant reorientation to environment if required
  • Keeps patient calm
  • Reduces anxiety

Special Injury Care

› Scalp Avulsion
  • Cover the open wound with bulky dressing
  • Pad under the fold of the scalp
  • Irrigate with NS to remove gross contamination
  • Bandages sometimes hard to keep on head
  • Consider triangular bandage as a “do-rag” to hold dressing in place