BRAIN TRAUMA

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CNS: Brain & spinal cord

The CNS is enclosed in bone

*The CNS is “unforgiving” to injury*

*Intervention before CNS damage is paramount!*
There are 3 main structures that prevent damage to the brain from head injury:

- **Bone**

- **Meninges** (connective tissue elements surrounding the brain and spinal cord): dura, arachnoid and pia

- **Cerebrospinal fluid** (CSF; a fluid which is made and circulated in the brain and spinal cord)
Meninges – Dural Septa

From outer to inner:
- Dura (2 sublayers)
  - Endosteal – adherent to bone
  - Meningeal – attached to the endosteal layer, except at 4 areas (where it forms septa or partitions)
    - Dural septa will partition the brain into compartments
Meninges – Dural Venous Sinuses

- **Dura**
  - Endosteal & meningeal layers of dura also form another important structure called **dural venous sinuses**

- **Dural venous sinuses** - channels formed between layers of dura that will allow for *venous drainage of blood from the brain* and *return of CSF to the general systemic circulation*

*Tiny “bridging” veins*
Meninges – Arachnoid & Subarachnoid Space, Pia

*From outer to inner:*

- **Dura**
- **Arachnoid** – subarachnoid space contains cerebrospinal fluid which circulates around the brain
- **Pia** – pia is part of structures in the brain that make cerebrospinal fluid

CSF IS MADE WITHIN SPECIFIC CAVITIES OF THE BRAIN CALLED VENTRICLES AND CIRCULATES AROUND THE BRAIN AND SPINAL CORD IN THE “SUBARACHNOID” SPACE
PROTECTION OF THE CNS FROM TRAUMATIC INJURY

• Brain protected by
  – Bone
  – Dural Septa
  – CSF

• Head injury can cause tissue damage (neurons and/or pathways [axons]), rupture of vessels and consequent hemorrhage, and allow infection into the brain

• Disability or death can occur from a single head injury, or from repeated head injury
Brain and Spinal Cord are Entirely Encased in Bone – and are thus in a “Closed Compartment”

Elements within the “closed compartment”:

- **TISSUE** (cells, vessels, meninges, etc.)
- **BLOOD**
- **CSF**
TRAUMA CAN OCCUR TO ANY PORTION OF THE CNS (BRAIN OR SPINAL CORD)

• Here, our focus will be on Brain Trauma, which comes in two forms:

  – CLOSED HEAD INJURY: trauma to the brain \textit{without} skull fracture

  – OPEN HEAD INJURY: trauma to the brain \textit{with} skull fracture
CLOSED HEAD INJURY
HEMORRHAGE/HEMATOMA FORMATION AND CONSEQUENCES

Intracranial pressure

Equilibrium

Compensated

Uncompensated

Intracranial mass volume
DEATH CAN OCCUR FROM BRAIN HERNIATION

**Uncal or transtentorial:** ↓ level of consciousness, pupillary dilation on the side of the herniation (parasympathetic axons of CNIII); can proceed to a tonsillar herniation and death

**Tonsillar or transforaminal:** ↓ ↓ level of consciousness, change in vital signs; causes compromise of cardiovascular and respiratory centers in medulla resulting in death
DEATH CAN OCCUR FROM DESTRUCTION OF BRAIN TISSUE FOLLOWING TRAUMA

Damage to the brain following a gunshot to the head
DIFFERENT TYPES OF HEMORRHAGE INVOLVING THE MENINGES MAY OCCUR FOLLOWING HEAD INJURY – INTERVENTION MAY PREVENT DEATH

EPIDURAL SPACE (a “potential” space)
  • DURA

SUBDURAL SPACE
  • ARACHNOID

SUBARACHNOID SPACE
  • PIA
Head injury (*most commonly*, to the side of the head) can rip the dura away from the bone; bleeding of vessels occurs “epi-durally” (outside the dura)

**“Lucid” period may occur between head injury and decompensation/death**

On CT, fresh blood will appear as bright “white” - blood will collect *only* where the dura has been stripped from the inside of the skull

*Dura is still attached to bone at these two sites – which limits diffusion of blood*
Clinical Case

• A 2 ½ yr old boy (Tom) falls from his tricycle and hits the side of his head. He cries, but gets back on the tricycle. Within minutes, he is slumped over the handle bars. His parents rush him to the Emergency Department of their local hospital where the child dies.

• On autopsy, he was found to have a large hematoma (a blood clot) from an epidural hemorrhage.
BRAIN HEMORRHAGE INVOLVING MENINGES

EPIDURAL SPACE (a “potential” space)
  • DURA

SUBDURAL SPACE
  • ARACHNOID

SUBARACHNOID SPACE
  • PIA

SUBDURAL HEMORRHAGE: most commonly occurs from hits to the front or back of the head, producing an anterior-posterior displacement of the brain; can also occur following whiplash injury; causes tearing of small bridging veins that empty into the superior sagittal sinus; blood collects in the subdural space
ANTERIOR-POSTERIOR DISPLACEMENT OF THE BRAIN CAN RUPTURE “BRIDGING” VEINS AS THEY ENTER THE SUPERIOR SAGITTAL SINUS (SUBDURAL HEMORRHAGE)
Hemorrhage occurs between the dura and arachnoid meninges ("subdurally"); blood spreads out because it is not confined by attachment to bone.

In this CT, the blood looks “dark” because the blood is old – this represents a “chronic” subdural hemorrhage.

Subdural hemorrhages are common in the elderly: brain shrinks with aging (and with neurodegenerative disease), placing tension on bridging veins; falls are more common.
OPEN HEAD INJURY

• In addition to damage to the brain and/or bleeding in the brain, open head injury also increases the risk of pathogens (viruses, bacteria, fungi, etc.) getting into the brain and producing inflammation/infection

• When pathogens get into the brain (regardless of mechanism), meningitis or encephalitis may occur
INFLAMMATION/INFECTION OF THE MENINGES OR BRAIN SUBSTANCE

• Inflammation of the meninges is called meningitis; meningitis can involve any of the meninges, but most commonly involves the pia and arachnoid (leptomeningitis)

  – There are 2 major types of meningitis

    • Bacterial; very dangerous; can be fatal

    • Aseptic (viral, fungal); generally self-limiting

• Inflammation of the brain substance is called encephalitis
Head Trauma and Potential Sequelae

- Intracerebral hemorrhage/hematoma formation
- Meningeal bleeding/hematoma formation
- Meningitis/encephalitis
- Contusion – bruising of brain
- White matter changes – tearing of axons
- Concussion (mild traumatic brain injury [mild TBI])
- Chronic traumatic encephalopathy (CTE)
  - Increases risk for development of neurodegenerative disease (Alzheimer’s, Parkinson’s, ALS [amyotrophic lateral sclerosis])
- Epilepsy
SHAKEN BABY SYNDROME

• Babies or infants most commonly brought into the ED because of unresponsiveness
  – Ecchymosis (bruising) of the sternum
  – Presence of retinal hemorrhage, papilledema (swelling of optic disc due to increased intracranial pressure due to bleeding between meninges or in brain), retinal detachment

• Death occurs primarily from subdural hemorrhage/subsequent brain herniation or from brainstem avulsion (tearing or separation of parts of the brainstem)

• Shaking causes anterior-posterior brain displacement (rupture of bridging veins), hypertension (which can rupture fragile vessels in brain and eyes), and tearing of unmyelinated axons; if the head is hit against something, even a pillow, direct damage to the brain can occur
SHAKEN BABY SYNDROME
(Images courtesy of M. Becher, M.D.)

Retinal hemorrhage in a baby with Shaken Baby Syndrome

Children who survive may be blind, epileptic, and intellectually or otherwise impaired because of widespread CNS damage.
“Society reaps what it sows in the way it nurtures its children”
Martin Teicher

Norma Clippard’s precious little grandchildren!
TAKE-HOME MESSAGE

CNS WITHIN A “CLOSED” COMPARTMENT – PROTECT IT!

GIVE NEW PARENTS LOTS OF SUPPORT – AND COMMUNICATE TO THEM WHAT YOU LEARNED TODAY!