Gray and White: It MATTERS
Abusive Head Trauma in Children

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OBJECTIVES

Anatomy and Physiology

Specific Injuries

Case Studies
Heads Up

This talk is not for the faint of heart....
Gray/White matter
2 Injuries; 1 Goal

• **Primary injury** results from direct insult to brain tissue
• Goal of therapy is to reduce secondary injury

**Secondary injury**

Swelling around lesion or diffuse swelling causes decreased perfusion
INSULT

- **Parenchymal & vascular disruption and depolarization**
- **Axonal & dendritic injury**

**Ischemia**

- $K^+$
- $O_2^-$
- Glutamate
- $Ca^{2+}$
- Cytokines

**Cytotoxic edema**

- Astrocyte swelling
- Tissue osmolar load

**Neurotoxicity**

- Necrosis
- Apoptosis

**Brain Injury**

- Hematoma
- CBV

**ICP**

**Vascular dysregulation**
Your Brain

• Left Side
  – Language
  – speaking

• Right Side
  – Controls the process of how we learn
  – Nonverbal communication
  – Certain types of behavior

• Cerebellum – (lower part of brain)
  - Affects the body’s ability to coordinate movement (ataxia)
Monro-Kellie Doctrine

Intracranial compartment are fixed:

1. **Blood** (venous and arterial) – 10%
2. **Brain** – 80%
3. **CSF** – 10%

Increases in the volume of one element must be compensated by shifts in the others.
Cerebral Blood Flow

- **Goal:** ICP and preserve CBF

- CBF regulated by:
  - Dissolved gases
  - Blood volume
  - Temperature

**most at risk during first few hours after injury**
What affects CBF?

1. **PaCO2**
   - 4% increase in CBF for every 1 mm Hg increase in PaCO2
   - 4% decrease in CBF for every 1 mm HG decrease

2. **Vasoconstriction**
   - 8 – 10% from baseline

Vasodilation
   - up to 65% from baseline

*PaO2* only if < 50 mmHg
What does temp have to do with CBF?

Highly sensitive to changes in body temp:

1 C drop can decrease CBF by 6-7%
Autoregulation

• Cerebral blood flow regulated over wide variation in MAP (60-150)

  – Breaks down with brain injury

“Pressure Passive”

• Adults: low CPP - 60-70 mmHg
• Kids:
  – >40 infants, >50 children, > 60 adolescents

CPP = MAP - ICP
Case 1

4 week old brought to hospital A by mom
- not eating / stuffy nose / cough
- sibling was RSV +

Baby was lethargic / pale
- bolus given
- breathing tx/ 2 L NC
- abx IM
- RUL pneumonia

Decided to send baby to hospital B
Transport team arrived

- pt lethargic / unresponsive

- HR: 161  BP: 107/52  RR: 64  Sat: 100% on 2L

- Pt had 15 sec seizure intubated

- Second sz occurred en-route

- Hgb – 4.1; Hct – 12; other labs normal

- Secondary survey was unremarkable

Pt arrived at Hospital B and sent to the Neo ICU
CXR redone
  – RUL pneumonia

Head CT scan done

What do you think they found?
Complex stellate fracture in left parietal bone with part of fracture crossing the midline to the right parietal bone.

Subdural Hematoma

Subarachnoid Hemorrhage

Loss of gray-white delineation in occipital region

Multiple Hemorrhagic contusions
Abusive Head Trauma

• 30% of abusive head injury in patients <3y is unrecognized at 1\textsuperscript{st} presentation

• History of trauma \textbf{NOT} provided

• History of previous injuries/illnesses

• Physical signs:
  – Majority have an abnormal neurological exam
  – Retinal hemorrhages (60-85%)
  – Bruising
  – Rib fractures, long-bone fractures
Characteristics

- **Boys** account for two thirds of the children abused.
- Four fifths of the perpetrators are men (unrelated caregivers).
- More than half of the caregivers change their stories several times.
- About half of all perpetrators eventually admit to shaking the child.
- About half of all patients have a hgb level of less than 10 g/L at presentation.
- The **skeletal survey is positive** in 60% of cases.
- About 60% have evidence of present or past trauma.
- Retinal hemorrhages are present in 80%.
Patterns of Injury

- Traumatic brain injury in ~60-70% of patients
- Orthopedic injury in 11-55%
- Rib fractures have the highest specificity for abuse
- Hollow organ injury more likely than in AT
The hemorrhages will be asymmetrical
TCH Trauma Registry Abuse Cases CY2008-CY2013
Curves of Early Infant Crying
2 Weeks to 4 - 5 Months

- High Crier
- Average Crier
- Low Crier

Length of Time Crying in 24 Hours

2 weeks 2 months 4 - 5 months

20–30 Minutes
5–6 Hours
Severity of Injury for Accidental vs. Abusive Injury CY08-CY13

<table>
<thead>
<tr>
<th>Severity Level</th>
<th>Accidental</th>
<th>Abuse</th>
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</thead>
<tbody>
<tr>
<td>Minor (ISS 0-9)</td>
<td>83%</td>
<td>42%</td>
</tr>
<tr>
<td>Moderate (ISS 10-15)</td>
<td>8%</td>
<td>14%</td>
</tr>
<tr>
<td>Major (ISS 16-24)</td>
<td>7%</td>
<td>23%</td>
</tr>
<tr>
<td>Severe (ISS &gt;= 25)</td>
<td>2%</td>
<td>21%</td>
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</table>
134 closed head injuries 2012
- 75% less than a year old
- 18 deaths (13%)
- Subdural – 61
- Subarachnoid – 2
- Epidural – 2
- ICH + skull fracture - 55
30 deaths in 2013 from child abuse
Layers of the brain

DURA MATER

Arachnoid Membrane

Subarachnoid space

Pia Mater

BRAIN Matter
Epidural Hematoma

Middle Meningeal Artery
Subdural
Subarachnoid

Chik, Y. et al. (2009) A case of postpartum cerebral angiopathy with subarachnoid hemorrhage
Diffuse Axonal Injury

- Result of tissue shearing at the interface of grey and white matter [12]
- Clinical symptoms are worse than the initial CT

A. Trauma causes the axon to twist and tear
B. The result is permanent death of the brain cell
Case 2

2m female arrives via EMS

HX - was feeding then suddenly became unresponsive and father began CPR

EMS arrival - HR 30, Epi given and intubated with HR to 130’s

En route to closest ER (hospital 1) - HR lost again and CPR and Epi given with return of HR

On and off again loss of pulses....
1937 - Loaded on to ambulance for transfer to level 1 pediatric hospital,  BP 61/41

1955  Unable to get BP, NaHCO3 given

2011  Improved perfusion with BP 70/34

2014  Arrival at Level 1 hospital, poss seizure activity
Physical Exam

R parietal stepoff and hematoma
Facial bruising; pupils 5mm and fixed
Abdominal bruising

Labs

WBC 12.7  H/H 6/19  Plt 112
AST 3621  ALT 1697
INR >12.4  PTT >150
ABG  7.17/30/528/-16  Lactate 16.1
1. Right horizontal parietal fracture, biparietal vertically oriented fractures, and left frontal fracture. There is extensive overlying subgaleal hematoma.

2. Diffuse brain edema with loss of gray white matter differentiation, sulcal effacement, central herniation, and tonsillar herniation.

3. There is scattered subarachnoid and intraventricular hemorrhage as well as probable small subdural hemorrhages.
Bilateral posterior rib fractures at the costovertebral junctions involving fourth through eighth ribs with left-sided posterior fractures involving first through third ribs.
Death

• Initial brain death exam was on HD#3

• Second exam on HD#4

• Pronounced brain dead at 0046 on HD#4

• Patient was turned over to Life Gift for organ donation
Deadly Triad

- Hypothermia
- Coagulopathies
- Acidosis

Halts Coag cascade
Lactic Acidosis
Myocardial Performance
Blood Pressure

• Hypotension:
  – Hypotension during the first day after injury was associated with worse cognitive outcome at 1 year.
  – The greater number of episodes of hypotension were associated with lower performance IQ.
  – These findings suggest that the initial critical care findings may affect not only mortality but long term neurocognitive outcome.

Salorio et al, 2008
Blood Pressure

- **Hypertension**: 
  - High blood pressure in the acute period did not show any changes in long term outcome.
  - However, high blood pressure throughout the entire stay did show worse cognitive outcome at 1 year.
  - Higher blood pressure may be a marker for worsening secondary injury.
Hyperventilation?

• NO !!

• A low PaCO2 is associated with increased mortality

• There is a tendency to be too aggressive in bagging
Do kids need to have ICP monitoring?

YES!

- A well known association between intracranial hypertension and poor neurologic outcome

- Improved outcomes associated with successful ICP-lowering therapies
Do kids with open fontanelles need ICP monitoring?

YES

Intracranial hypertension may be present in children with open fontanelles and sutures
IF ICP > 20

3% NS bolus 10cc/kg
• Goal 155-165 and osmo < 360

? EVD

No shift? Mannitol 1 gm/kg
If shift? 3% NS bolus 10 cc/kg
Goal – 165 -170 and osmo to 360
Increase HOB to 45 degrees

Pentobarb Coma
- Bolus then a Drip
Continuous EEG monitoring
Decompressive Craniotomy
Mannitol

Mechanism

1. Reduces blood viscosity
   - decreased blood vessel diameter = decreased cerebral blood volume
   - Immediate effect, lasts 75 minutes

2. Osmosis
   1. pulls water out of normal brain
   2. Effect develops over 25-30min, lasts 1-6h

Adverse effects

• Risk of renal failure with serum osmo > 320
• Hypovolemia with diuresis
• Can accumulate in brain and have reverse effect
Hypertonic Saline

• Similar osmotic effect to mannitol
• Other proposed benefits:
  – improved CV function
  – inhibition of inflammation
  – restores cell function
• Adverse effects: subarchnoid hemorrhage, renal failure, immune paralysis
Decompressive Craniotomy
Common Cognitive Deficits

- Largest cause of disability in Pediatric TBI population.
- Common pattern of impairments:
  - Arousal and attention
  - Memory
  - Higher executive functions

- Impairments in these skills can result in learning problems and have profound effects on the patient’s ability to function as an adult.
- One also may not see the full consequences of the injury until the patient reaches the age in which it would be expected for them to exhibit a particular skill. (i.e., a child injured at age 4 would not be expected to perform abstract reasoning until later in life)
"Justice will not be served until those who are unaffected are as outraged as those who are."

- Benjamin Franklin
Pinwheels for Prevention
What can you do???

• It is OKAY to walk away!
• Have a support system – call or to help
• The crying will end
• Accept that NORMAL babies cry
• HAVE a plan ahead of time….
Or put them in the closet.....
Take Home Points

• Keep euvolemic
• Do not tolerate
  – Hypoxia
  – Seizure
  – Hyperglycemia
  - Hypotension
  - Fever
• CPP = MAP – ICP ( >40 infants, > 50 children)
• ICP below 20 mm Hg**
For Being OUR Voice!

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