Welcome

Pediatric Evaluation and Diagnostic Services (PEDS)
Part 2 - Abusive Head Trauma

Shaken Baby Syndrome, Shaken Impact Syndrome, Inflicted Traumatic Brain Injury, and Nonaccidental Head Injury in Infants

presented by
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Slide 2 - Goals

Goals

- Describe the anatomy and mechanism of injuries in head trauma.
- Discuss the differential diagnosis of Abusive Head Trauma.
Abusive Head Trauma

- Epidemiology
- Anatomy
- Differential diagnosis
- Medical work-up
- Forensic issues
• Described by Caffey in 1972:
  - Retinal hemorrhages.
  - Subdural or subarachnoid hemorrhages.
  - Infants with minimal signs of external trauma.
  - 1 nursemaid admitted to shaking by arms or trunk.

• More recent studies note that injuries often include evidence of impact.
  - Sometimes not seen until autopsy.
When a baby is shaken, the head - large for the body and supported by weak neck muscles - flops back and forth. A baby's brain is more watery than an adult's, and it sloshes around in the skull.
Head Trauma in Child Abuse

- Most common cause of mortality (death) and morbidity (illness) in physical child abuse.

- Intracranial injury occurs in 60% of inflicted injury deaths.

- 33%-56% of brain injuries in children less than 1 year of age are inflicted.

- More than 80% of deaths from head trauma in children under 2 years old are the result of Abusive Head Trauma.
Slide 7 - Child Characteristics

Child Characteristics

- Mean age of 5-9 months in most studies.
- Disproportionately large head and weak neck muscles.
- High water content of brain.
- Twins and siblings of twins are at higher risk.
- Colic in 35% of victims.
- Males predominate as victims.
Slide 8 - Perpetrators

Perpetrators

- Male caretakers highest risk group.
  - Mothers 13%
  - Female babysitters 17%
  - Fathers, Stepfathers and MBF's 70%

- Military families:
  - Relative Risk = 3.5.
  - 3.5 times more likely to sustain AHT.

- Substance abuse.
Slide 9 - Anatomy of the Infant Head
Brain Parenchyma

- Neurons - basic cell of CNS:
  - Cell body with nucleus.
  - Dendrites: Incoming impulses.
  - Axons: outgoing impulses.
- Gray matter - neuron cell bodies.
- White matter - nerve bundles and tracts.
- Blood vessels.
Slide 11 - Infant Brain vs. Adult Brain

Infant Brain vs. Adult Brain

- Infant brain has approximately 25% more water than the adult brain.

- Infant brain has little or no myelin.
  - Protein sheath surrounding nerves which helps provide firmness and structure.

- Result: Infant brain is much softer, more gelatinous than adult and thus more fragile.
Abusive Head Trauma

• High energy acceleration/deceleration injury.
  • Violent shaking or shaking plus a head impact against a hard or soft surface.

• Many victims have evidence of impact, but not all.

• Involves brain injury.

• May or may not be injuries elsewhere on body:
  • Retinal hemorrhages, fractures, bruises.

• Abusive Head Trauma is a subset of physical abuse.

• Not all physical abuse to the head is Abusive Head Trauma.
Effects of Shaking

- Weak neck muscles.

- Normal large head-to-body ratio.

- Violent, sustained shaking.
Slide 14 - Effects of Shaking 2

Effects of Shaking

Small veins break during shaking
Slide 15 - Effects of Shaking 3

Effects of Shaking

Bleeding around brain (Subdural Hematoma)
Effects of Shaking

- Full range of motion with shaking.
  - Impact can be chin on chest or back of head against back.
  - When the skull stops, the brain may continue to move, causing injury.
Intracranial Injuries

- Epidural hematoma.
- Subdural hematoma.
- Subarachnoid hematoma.
- Parenchymal contusion, laceration.
- Intraventricular hematoma.
Slide 19 - Infant Brain Injuries

Infant Brain Injuries

- Visible scalp hemorrhage
- Subgaleal hemorrhage
- Skull fracture
- Epidural hemorrhage
- Subarachnoid hemorrhage
- Contusion
- Invisible scalp hemorrhage
- Subdural hemorrhage

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CT SCAN - Epidural Hematoma
CT SCAN - Subdural Hematoma & Intraventricular Hematoma

Subdural Hemorrhage

Intraventricular Hemorrhage
CT SCAN - Subdural Hematomas

Subdural Hematoma
(blood appears black indicating an older injury)

Subdural Hematoma
(blood appears white indicating a recent injury)
Slide 23 - Subdural Hematoma at Autopsy

Subdural Hematoma at Autopsy
Slide 24 - White and Grey Matter

Brain Matter

White Matter
(Axons)

Grey Matter
(Cortex)
Axonal Injury

- Blue areas of brain are most susceptible to axonal injury.
Microscopic View

- Neuron
- Axon
- Nerve Signal
Normal Axon Function

- Signals pass at a regular rate.
Axonal Injury

- Fluid entry in cell and temporary axonal swelling.

- Disruption of neurofilaments and microtubules causing interrupted axonal transport with “Retraction Ball Formation.”
Severe Diffuse Axonal Injury

- Immediate clinical symptoms:
  - Seizures;
  - Unconsciousness;
  - Difficulty breathing;
  - Vomiting;
  - Other signs of neurological damage.
Impact Injuries
Skull Fractures

- Simple:
  - Linear - not crossing suture lines.
  - Less than 2mm separation of edges of fracture.

- Complex:
  - Linear - crossing suture lines.
  - Greater than 2mm separation of edges of fracture.
  - Branching, comminuted, of stellate.
  - Depressed, compound, diastatic.
Simple Skull Fracture
Slide 33 - Complex Skull Fracture

Complex Skull Fracture
Eye Injury

- Retinal hemorrhages
- Vitreous hemorrhage
- Retinoschisis
- Papilledema
- Retinal detachment
- Disruption of eye contents
Slide 35 - Eye Anatomy
Retinal Hemorrhages

- 50% to 100% incidence in Abusive Head Trauma.

- Unilateral or bilateral.
  - Can be asymmetric.

- Classified as mild, moderate or severe.

- Described by type, location and amount.
Slide 37 - Retinal Hemorrhages Illustrated

Retinal Hemorrhages Illustrated

- Nerve Fiber Layer (Flame) Hemorrhages
- Preretinal Hemorrhages (Dot and Blot)
- Hemorrhage at the Ora Serrata
- Traumatic Retinoschisis
Slide 38 - Retinal Hemorrhages with Shaking
Slide 39 - Normal Eye
Slide 40 - Eye with Hemorrhages

Eye with Minimal Hemorrhages
Slide 41 - Eye with Significant Hemorrhages

Eye with Significant Hemorrhages
Retinal Hemorrhages

• Minor retinal hemorrhages are rarely seen in accidents.

• Diffuse, severe, multilayered that extend to the retina's edge are NOT caused by:
  ▪ CPR
  ▪ Seizures
  ▪ Coughing or vomiting
  ▪ Short falls, minor head trauma
  ▪ Elevated intracranial pressure
  ▪ Vaccination
  ▪ Most other diseases

• Retinal hemorrhages cannot be dated.
Extracranial Injuries

- Fractures
- Bruises (visible externally)
- Intra- and subcutaneous bruises (invisible)
- Lacerations/cuts
- Abrasions
Rib Fractures

- Single or multiple
- Posterior and posterolateral
- Not caused by minor trauma
- Not caused by CPR
- Caused by squeezing
Rib Fractures
Rib Fractures

Front
Rib Fractures
Multiple Rib Fractures
Basic Bone Anatomy

Cartilage (epiphysis)

Growth Plate (metaphysis)

Shaft (diaphysis)
Bone Injuries

- Sudden jerk on extremity tears metaphyseal tips.
Slide 52 - Bone Injuries 2
Bone Injuries

[Image of an X-ray showing bone injuries]

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What do the Alleged Perpetrators Say?

- Starling et al. (2004), Arch Ped Adolesc Med 158:454:
  - 81 admissions of abuse.
    - 55/81 admitted to shaking the infant.
    - 44/81 admitted shaking with no impact.
    - 12/20 with impact had skull/scalp injury vs. 4/32 with shake only.
  - 90 no admission of abuse.

- Effects usually immediate.
Clinical Presentation

- Asymptomatic swelling/bruising
- Vomiting
- Altered mental status
  - Irritable/fussy
  - Poor feeding/not eating right
  - Unresponsive
  - Lethargic
- Seizures
- Apnea/found unresponsive
- Found dead in bed
Injuries

- Head trauma:
  - Subdural hematoma
  - Edema (swelling)
  - Subgaleal hematoma
- Contusion (bruise)
- Skull fracture

- Skeletal fractures:
  - Ribs
  - Long bones - shaft, metaphysis
  - Spine

- Bruises - external and internal.

- Blunt abdominal trauma.

- Sexual abuse injuries.
Medical Work-up

- Identifies the child’s immediate medical needs to stabilize the child, and helps develop a broad view of the child’s overall health to identify and address any other potential health concerns.
- History, if possible/available
- Full physical exam
- Labs
- Radiography:
  - X-rays
  - Head MRI
  - Bone scan
  - Head CT
  - Abdominal CT
History

- History leading up to hospitalization:
  - Last well?
- Details of accident: pre and post:
  - Exactly what happened?
  - Child’s position before and after, surfaces involved, etc.
  - How far did the child fall?
- Changes in behavior?
- Any vomiting, fever, sleepiness, lethargy?
- Care providers?
- Witnesses to child’s condition?
History

- Past history:
  - Hospitalizations, surgeries, ER visits.
  - Old injuries, fractures, significant bruising.
- Family history:
  - Fractures, bone disease, bleeding, bruising.
  - Status of siblings.
- Developmental history
  - See, hear, roll, stand, walk, talk, etc.
- Psychosocial history:
  - CPS or criminal history.
  - Family stressors and strengths.
Physical Examination

- Mental status assessment
- Skin findings
- Skeletal findings
- Abdominal findings
- Head findings
- Torn frenulum?
- Retinal hemorrhages
Lab and Radiographic Studies

- Head CT
- Skeletal survey
- Bone scan
- Head MRI
- Bleeding studies
- Chemistries - Ca, Phos, Alk phos
Why Test?

- Belfer: Less than 30 months old and suspicious of abuse:
  - 25% had unsuspected fractures.
  - 80% in children less than 12 months old.
- Ruben: Suspected abuse in children less than 2 years old with normal neuro exam:
  - 37% had occult head injury.
- Laskey: Suspected abuse:
  - 29% had AHT without any neurologic symptoms.
- AAP Guidelines:
  - Skeletal survey “mandatory” in suspected physical abuse if less than 2 years old.
  - Head CT if suspected head injury.
  - MRI best to assess head injury.
Other Studies/Consultants

- Dependent upon the differential diagnosis, and other medical conditions of each child.
  - Infection
  - Urine genetic screen
  - Copper, Vitamin D
  - Skin fibroblast culture
  - Medical genetics consult
Follow-up

- Medical and developmental
  - Retardation
  - Learning disabilities
  - Seizures
  - Hearing and/or speech impairment
  - Visual impairment or blindness
  - Behavioral disorders
- Some appear normal
- Developmental disabilities are common
- Severe brain damage
- Child deaths
CT Scans of Shaking Victim

Immediately After Shaking

3 months after shaking

Areas of Brain Loss
Case 1 - EV

- 5 week old white female.
- FTT and irritability:
  - Irritable since birth.
  - Weight less than birth weight.
  - Poor feeder.
- Normal spontaneous vaginal delivery (NSVD):
  - Home with mom, birth weight: 6 lbs. 3oz.
  - Bottle fed.
- Psychosocial history:
  - Parents married, planned pregnancy.
- Parents employed, mother still on maternity leave.
- Followed weekly:
  - Normal exams except weight and irritability.
Case 1 - EV

- Physical examination:
  - Wt <5%, Ht 25%, OFC 25%
  - Skinny, irritable but consolable
  - Anterior Fontanelle soft, pulsatile
  - Blood blister on nose
  - Red mark over right eye
  - Moving all extremities, normal tone
  - Torn frenulum

- Previous Evaluations Normal:
  - Chem 7
  - UA
  - CBC d/p
  - Feeding study
Case 1 - EV

What is your differential diagnosis?

What do you want to do?
Case 1 - EV: Head CT
Case 1 - EV: Skull X-Ray
Slide 71 - Case 1 - EV 6

Case 1 - EV: Chest X-ray
Case 1 - EV: Leg X-Ray
Slide 73 - Case 1 - EV 8

Case 1 - EV: Eye Exam
Case 1 - EV: Summary

- Failure to Thrive (FTT) and irritability
- Torn frenulum
- Subdural hemorrhages
- Bilateral retinal hemorrhages
- Multiple fractures over space and time
  - Skull, extremities, ribs
- No evidence of a medical condition
Missed cases of AHT (<3 years)

- From C Jenny, et al; JAMA:281:621-626, 1999:
  - 173 cases in 5 years
  - 54 (31.2%) missed
    - Saw MD
    - Symptoms of head injury
    - Return and diagnosis made
  - Mean # MD visits before correct diagnosis was 2.8 (range 2-9)
  - Mean 7 days to diagnosis (range 0-189)
Erroneous Diagnoses

- 54 children, 98 other diagnoses:
  - Gastroenteritis \ 14
  - Accidental injury \ 10
  - R/O sepsis \ 9
  - Increasing head size \ 6
  - Otitis Media (ear infection) \ 5
  - Seizure disorder \ 5
  - Reflux, apnea, upper respiratory infection, urinary tract infection, unknown bruising.
Missed Radiographic Diagnoses

- 6 head CTs read as normal with subdural hematoma present
- 2 skeletal surveys
  - Missed fractures, periosteal reaction
Increased Risk of Missed Trauma

- Younger age
  - 180 days vs. 278 days
- White race
  - 37.4% white
  - 19% black
- Family
  - 2 parent: 40.2% missed
  - 1 parent: 18.7% missed

Reminder that abuse can happen to ANY children in ANY family
Remaining Vigilant

- You find only what you look for, you seek only what you know.

- All reasonable diagnoses must be considered.

- Despite best efforts, there will still be missed cases.
Case 2 - JL: Twin B

• JL: Twin B - 2 month-old (female).

• At pediatrician’s with JL: Twin A (male) being seen for diaper rash.

• MD noted knot on forehead and black eye of JL: Twin B.

• Per father: 12 month old sister hit in head with plastic radio 4 days prior.

• Since then had black eye, fussy, vomiting.
Case 2 - JL: Twin B

- Physical exam:
  - 3.5 kg (5th percentile adjusted)
  - Small, alert, vigorous suck, fussy
  - Anterior Fontanelle (soft spot) full
  - Bruises on face, eye
Case 2 - JL : Twin B
Case 2 - JL: Twin B

Significant Skull Fracture

Corner Fracture
Case 2 - JL : Twin A

- Physical exam normal

- Skeletal survey negative, but...
  - Head CT: minimal subarachnoid hemorrhage and subdural collections
  - MRI brain: bilateral subdural hematomas, multiple foci of hemorrhage various ages, parenchymal contusions
Case 2 - JL Twins Summary

- JL - Twin B:
  - Bruises to face and scalp, intracranial injuries and corner fracture.
  - Symptomatic abusive head trauma.

- JL - Twin A:
  - Appeared well.
  - Unexplained intracranial hemorrhages.
Evaluate Siblings

- Don’t forget to have siblings evaluated.
- If infants, they need a head CT and skeletal survey even if they appear well.
Differential Diagnosis - Intracranial Bleeding

- Accidental head trauma
  - Short falls and stair falls do not usually cause significant head trauma (occasional: EDH, mass effect subdural hematoma).
  - Motor vehicle crashes and falls from greater than 10 feet can cause intracranial injuries.
  - Multi-layered retinal hemorrhages are seen almost exclusively in Abusive Head Trauma.
    - Single report of TV fall on head.
Slide 88 - Frequency of Short Fall Deaths

How Frequently do Short Fall Deaths Occur in Early Childhood?

- Approaches to estimation of mortality rates:
  - Short fall clinical studies
  - Large database information
  - Fatal fall studies
### Publicly Witnessed Short Fall Studies

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<tr>
<th>Study</th>
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<th>Head Impact</th>
<th>Skull Fractures</th>
<th>Subdural Hematoma</th>
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<td><strong>Total</strong></td>
<td>368</td>
<td>53/283</td>
<td>6 (1.6%)</td>
<td>0 (0%)*</td>
<td>0 (0%)*</td>
</tr>
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</table>

* - 95% confidence limits: 0 - 0.82%  
[Hanley’s Approximations]

- 4 separate studies:
  - 368 witnessed falls
  - 0 deaths
Plunkett (2001)

- Deaths from playground equipment falls over 11 years reported to CPSC.
- 18 deaths in over 75,000 cases reviewed.
- 6 falls unwitnessed, 2 had medical conditions.
- No formal eye exams.
- CNS bleeding mass lesions.
- Only one infant:
  - Porch swing, fell 5-6 feet onto rocks with adults nearby.
- Significant limitations in study, but death from fall is rare.
Limitations of Short Fall Studies

- Relatively small numbers (compared to national population) do not permit estimates of a very rare event.
  - It is impossible to know whether the true rate is closer to 0% or to 0.36%.
Other Causes of Intracranial Bleeding

- Coagulation defects:
  - Usual sites for bleeding are joints, soft tissue, not in brain or eyes.

- Brain tumors:
  - Not easily confused with trauma.

- Vascular malformations:
  - Rare, usually occur in brain tissue itself, not over the surfaces of the brain.

- Metabolic conditions:
  - Glutaric aciduria, methyl malonic aciduria.
Other Causes of Intracranial Bleeding

- Rebleeding:
  - Can bleed into space from previous injury.
  - No brain injury.
  - No retinal hemorrhages.

- Benign extra axial fluid collections of infancy:
  - No brain injury.
  - No retinal hemorrhages.
Birth Trauma

- Cephalohematomas (outside skull):
  - 3-10% of newborns.
  - 25% also have skull fractures.

- Subdural hemorrhages:
  - Associated with vaccuum extraction.
  - Chronic subdural collections may be associated with difficult deliveries.
  - Present within 48 hours.

- Retinal hemorrhages:
  - Gone in 2-6 weeks.
Other Theories You May Hear

- Hypoxia leads to retinal hemorrhage or subdural hemorrhage.
  - Geddes theory now rescinded.

- Vitamin C deficiency - “scurvy”.

- Immunizations.

- Cannot hurt a baby by shaking.

- Physicians say no other causes of retinal hemorrhage, subdural hemorrhage, etc.
Considering All of the Facts

“Doctor, you jumped immediately to the conclusion that the injury was intentional and never considered anything else, didn’t you?”
"So-called Shaken Baby Syndrome"

- Biomechanical data - not real children.
- Single impact adults.
- Shaking adult chimp models:
  - Measure single energy point.
- Can’t generate enough forces without impact.
- Agree that human infant data must be used, and there is none.
  - Not measuring cumulative energy.
- Dismiss confessions and epidemiologic data.
Duhaime

- Multiple articles.

- Chimp model:
  - Need impact to get forces in adult chimps causing subdural hematoma.

- 100% with autopsy evidence of impact.
  - 7/8 impact not seen until autopsy.

- Clearly abusive head trauma happens without external evidence of impact.
Final Comments

- Constellation of injuries seen are commonly associated with Abusive Head Trauma and rarely the result of accidental injury.

- Must follow the proper processes in order to reach the correct conclusions in each case.

- If children sustained lethal injury from everyday accidents, the human race would have been extinct long ago.

- 80% of deaths from head trauma in children under 2 years old are the result of Abusive Head Trauma.
Thank You

IUCPP Contact Information

**Emergencies:** Contact the IU Operator at (317) 944-5000 and ask for the child abuse pediatrician on-call.

**Non-emergencies:** Contact the IUCPP office at:
(317) 630-2617
(Monday-Friday 8am-4pm)

**Fax:** (317) 630-2587

**Email:** iucpp@iupui.edu

Download contact information sheet