Abusive head trauma (AHT)

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Abusive Head Trauma (AHT): Definition

- Diagnosed by presence of intracranial bleeding/cerebral edema
- Retinal hemorrhages present in about 70% of cases
- History often absent or does not explain findings
- Can have fatal intracranial injury without externally visible trauma
- Associated non-cranial injuries highly concerning for abuse

AHT: Epidemiology

- Highest incidence in children under one year of age, with peak incidence in children aged 6 weeks to 4 months
- Peak incidence of AHT corresponds to increase in infant crying, which is a normal developmental occurrence
- Can occur in children as old as five years; adult cases in literature
- Prevalence of shaking as form of discipline as high as 2% – Random digit-dial telephone survey in North Carolina
- Many adults and teenagers do not realize the dangers of shaking

Incidence of AHT

- 1000-1500 cases in the US every year
  – Misdiagnosis, underreporting are likely to make the true number higher
- Estimates of incidence reveal that 95% of serious intracranial injury occurring in children under 1 year of age, and 85% of serious intracranial injuries in children under 2 years of age, are due to inflicted trauma
- At least 2000 children die from abuse and neglect every year; AHT accounts for 10-12% of child abuse and neglect deaths

AHT: Definition of terms

- Extraaxial spaces defined by: dura mater (outermost layer), dura arachnoid, and pia arachnoid layers (adherent to brain)
- Dura is double-layered membrane; outer layer (periosteal layer) adherent to inner table of skull at sutures, and inner layer (meningeal layer) with attachments to underlying dura arachnoid

Data source:
www.shakenbabycoalition.org
Anatomy of dural layers

- Potential subdural space lies between the inner dural layer, and dura arachnoid
- Contains bridging veins which extend from brain surface, penetrate arachnoid, and cross subdural space into the intradural space to empty into the dural venous sinuses

Contact head injuries

- Skin/scalp/subgaleal contusion
- Skull fracture
- Epidural hematoma
- Focal subdural hematoma
- Cortical contusion

Inertial brain injuries

- Interhemispheric or diffuse subdural hemorrhages
- Concussion
- Gliding contusions or lacerations
- Diffuse axonal injury
- Injuries at the cranio-cervical junction
- Diffuse retinal hemorrhages or retinoschisis

AHT: Anatomy

- Shaking causes angular acceleration of brain tissue, with high peak accelerations causing damage
- Bridging veins between skull and brain are snapped, causing cerebral contusions and intracranial bleeding
- Shearing often occurs at junction of gray and white matter
- Infant brain susceptible to injury because of large head size, relatively weak neck muscles, large subarachnoid space, delicate bridging vessels
AHT: Biomechanics

- Properties of infant and mature brain differ
- Some studies have shown that shaking alone not sufficient to cause injury
- Injury thresholds have been set using primate data, or (adult) human cadavers; not known if these thresholds apply to infants
- Studies using crash-test dummies show impact of head on chest, as well as on upper back with severe shaking; this may be ample force to generate serious injury

Jenny, C. et al. Development of biofidelic 2.5 kg infant dummy. Injury Biomech Research

AHT: Mechanism

- Perpetrator often holds child by chest, compressing the chest while forcefully shaking at full arm extension
- Forces involved are much greater than those involved in normal parenting
- Usually large size differential between perpetrator and victim; adult (or adult-sized person) required
- Rib and extremity fractures can result

AHT: Symptoms

- Wide range of symptoms possible
- It is not possible to predict exactly which symptoms occur after an event, but it is possible to say that the child will not be acting normally after severe injury
- A careful history can provide specific information about symptom onset
  - This is helpful to determine timing of injury
- Symptoms may begin at any point in the range of severity, and either become progressively more severe or gradually improve
- Symptoms may begin as non-specific with mild injury; with more severe injury, symptoms more often specific to brain trauma

AHT: Symptoms

- Sleepiness, lethargy
- Irritability
- Poor feeding
- Vomiting
- Alteration in level of consciousness
- Loss of consciousness
- Seizures
- Apnea
- Coma
- Death

Subdural Hematoma

Normal CT
Subdural hematoma

Diffuse axonal injury

Biomechanics of Retinal Hemorrhages

- Most likely mechanism is through vitreous traction
  - shaking produces traction on the tightly adherent vitreous, tearing blood vessels and causing bleeding into the retina

Retinal hemorrhages

Encephalomalacia

- Softening or degeneration of brain tissue after hemorrhage, inflammation or injury
- Term can also refer to a loss of brain tissue
- Can cause death of brain tissue
- If the brain tissue dies, the tissue will disintegrate, leaving a fluid-filled space
Encephalomalacia

Case information

Infant is a 3 month old male who has been ill for the past four days
- Well Monday during day, while home with mother
- Mother went to work that evening, child vomiting when she returned home at 11 pm
- Baby up all night vomiting, feeding very little
- Gradual improvement throughout the day Tuesday
- Worse on Wednesday afternoon, vomiting and lethargy noted; had been home with father during the morning while mother at school
- Never seemed to return to normal feeding or alertness Wednesday or Thursday; was home with both parents
- Started having a seizure on Friday morning, taken to doctor’s office and referred to Emergency Department

CT findings

MRI findings

Eye examination

Questions

- What happened?
- When?
- Who is the likely perpetrator?
- How many events took place?
Short-term outcomes

- Mortality from abusive head trauma is high, with figures varying from 12% - 30%
- Children with injuries from non-accidental trauma have more severe injury, and worse outcomes, than children with accidental trauma
- 25% - 33% of abusive head injury victims leave the hospital without any obvious neurologic deficit

Ewing-Cobbs 1998, Starling 2004

Long-term outcomes

- Following families long-term is difficult, since families unstable; because of confidentiality restrictions, not many studies done involving long-term follow-up
- Some studies have shown that, of those who left the hospital without apparent deficits, very few remain normal

Duhaime 1996, Barlow 2004

Long-term outcomes

- Abnormalities include behavior problems, poor vision, cognitive deficits, mental retardation, hemiparesis
- Special education required for many
- Can take years for epilepsy or behavioral and neuropsychological abnormalities to be recognized

Defense theories about AHT

- Short falls cause severe injuries
- Babies are fragile
- Injuries could happen spontaneously
- Injuries are the result of a medical condition
- AHT does not exist
- It’s head injury, but my client didn’t do it

Timing of injuries

Research suggests immediate onset of symptoms after inflicted trauma events (Nashelsky et al 1995; Starling et al 2004)

- In 52/57 cases in which perpetrator confessed to head trauma, immediate symptom onset noted
- The other five cases were either not checked on for several hours after event, or caretaker did not provide information about symptom onset

Evaluating the potential effects of a fall

<table>
<thead>
<tr>
<th>Decreased risk</th>
<th>Increased risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower height</td>
<td>Greater height</td>
</tr>
<tr>
<td>No initial velocity</td>
<td>Has initial velocity</td>
</tr>
<tr>
<td>Soft impact surface</td>
<td>Hard impact surface</td>
</tr>
<tr>
<td>Lower mass</td>
<td>Greater mass</td>
</tr>
<tr>
<td>High elasticity</td>
<td>Low elasticity</td>
</tr>
<tr>
<td>Large impact area</td>
<td>Small impact area</td>
</tr>
<tr>
<td>High moment of inertia (I)</td>
<td>Low moment of inertia</td>
</tr>
<tr>
<td>Low angular velocity ((\omega))</td>
<td>High angular velocity</td>
</tr>
<tr>
<td>Low angular momentum ((I\omega))</td>
<td>High angular momentum</td>
</tr>
</tbody>
</table>
Childhood Falls

1977  Helfer  246 cases  all falls from beds, 3 linear skull fx, no deaths
1987  Nimityongskul  76 cases  all falls from bed/cribs, 97% minor injuries, 1 linear skull fx, no deaths
1988  Joffe  363 cases  all stairway falls, 92% minor injury, 6% distal fx, 1 concussion, no deaths
1991  Williams  106 cases  all witnessed falls, 77 minor injuries, 14 severe injuries (5-40 ft), no lethal injuries: <10 ft, 1 death at 70 ft
1993  Lyons  207 cases  all witnessed falls from cribs/beds, 29 minor injuries, 1 linear skull fx, no deaths
1991  Chadwick  317 cases  reported falls, 7 deaths <4 ft (all hxs felt to be false), 0 deaths 4-10 ft, 1 death >1 ft

2008  Chadwick  Meta-analysis of literature on short falls  National Electronic Injury Surveillance System (NEISS) found 3 short fall deaths among 400,000 children, calculated rate 0.825 cases per million young children per year; California Epidemiology and Prevention for Injury Control Branch (EPIC) database found 6 short fall deaths per 2.5 million children in five years, or 0.48 cases per 1 million children per year

2010  Haney  122 children who fell before age 2 years  209 short falls (bed, couch, changing table; all falls 4 ft or less); 34% of falls with injuries (bruises, bumps, scars); no serious injuries
2010  Osifo  12 children ages 3 years or less  Falls from varying heights, including from a staircase, into a pit; 2 without fall information; 2 without injuries; 4 with bruises/lacerations, 6 with moderate injuries (head injury, penetrating trauma); no deaths
2011  Shields  31264 balcony falls in children  Fall heights ranged from 5 to 87.5 feet, most falls 12.5 feet or less; 2 deaths (girls ages 6 and 11 years), with fall heights ranging from 5 to 55 feet

In summary:
• If you are given a history of serious injury with a fall from short distance, history is usually factitious
• Fall from couch, bed, crib, changing table can rarely cause a linear parietal skull fracture; there is almost never a serious or life-threatening injury from such a fall
• Falls down stairs seldom result in serious head injury

Do deaths happen as a result of short falls?
• Deaths due to short falls do occur but are extremely rare
  – 0.14 - 0.22 deaths/year/100,000 children aged 0-4 years
  – 0.056 - 0.44 deaths/1,000,000 short falls in children aged 0-4 years
• Special subtypes of short falls may have a higher mortality rate, but that rate is still very low

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