Making it all fit: How the doctor can help sort fact from fiction in child abuse cases

San Diego International Conference
January 24, 2011

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Bruises

What does the doctor bring?

- Knowledge of biomechanics of injury
- Pattern recognition
- Analysis of injury mechanism
- Analysis of scene

Bruises

- Bruises are caused when soft tissue is compressed between 2 hard surfaces and blood vessels leak blood into tissue
- Swelling is secondary to inflammation
- Swelling resolves over first 2-3 days

Bruises in Children

- < 9 months old: 1.2% with bruises
- > 9 months old: 76.6% with skin injuries
- < 1% 15 or more injuries
- All ages:
  - < 2% bruises to thorax & abdomen
  - < 1% bruises to chin, ears, or neck
- No difference between boys and girls

Labbé J, et al. Recent skin injuries in normal children. Pediatrics 2001 108:271 - 276

Location of bruises

ACCIDENTAL	INFLICTED
Shins	Upper arms
Lower arms	Anterior thigh
Under chin	Trunk
Forehead	Genitalia
Hips	Buttocks
Elbows	Face
Ankles	Ears
Bony prominences	Neck

Accurate dating of bruises by color is not possible

- Color varies with depth of bruise and skin color
- Rate of healing varies with location on body
- Timing of bruise appearance depends on depth
  - superficial bruises appear early
  - deep bruises may take days to appear

Case Examples

Burns

What does the doctor bring?

- Knowledge of biomechanics of injury
- Pattern recognition
- Analysis of injury
- Analysis of scene

Incidence and Prevalence

- 40,000 children <15 yrs. hospitalized yearly
- >2000 children die yearly from burns
- Approximately 20% of burns are inflicted
- Scald burns - 85% of all burns in children
- Flame burns - 13%
- Electrical, chemical - 2%

Classification of Burn Injuries

Superficial	Superficial layer of the epidermis Characterized by redness only
Partial thickness	Extends into the dermis causing blistering and tissue loss
Full Thickness	Entire dermis, appendages. nerves destroyed, no pain
Fourth Degree	Extends into the muscles, bones and joints

Time required to sustain a full thickness burn from hot liquid

Degrees	Time
120	10 minutes
122	5 minutes
127	1 minute
130	30 seconds
140	5 seconds
150	2 seconds
158	1 second

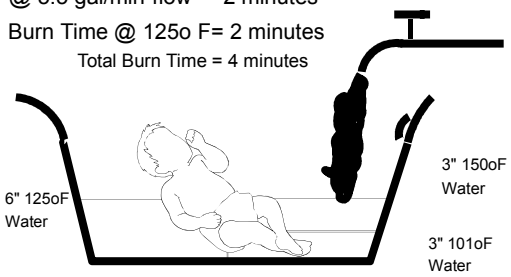
Case Examples

Child left in comfortable water.
Parent returns to find hot running, child burned.

To add 3" (11 gal)
@ 5.5 gal/min flow = 2 minutes

Burn Time @ 125o F= 2 minutes

Total Burn Time = 4 minutes



Other Types of Burns

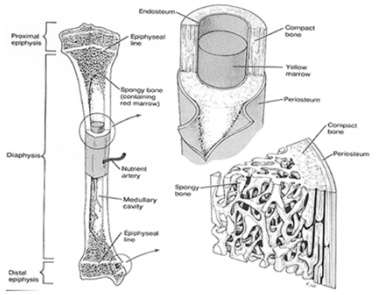
- Radiation burns – commonest is sunburn
- Chemical burns – acid, alkali, peppers, garlic
- Electrical burns – combination of heat and electrical forces
- Microwave burns

Fractures

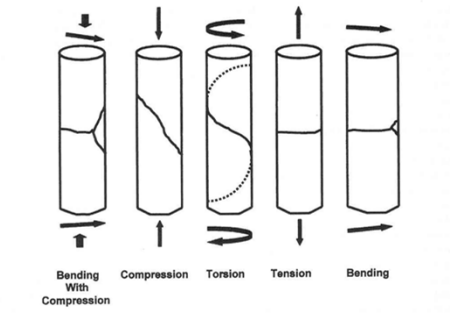
What does the doctor bring?

- Knowledge of biomechanics of injury
- Pattern recognition
- Knowledge of common injuries mistaken for abuse
- Analysis of injury
- Analysis of scene

Bone structure, illustrated



How do bones fracture?



Biomechanical properties of bone

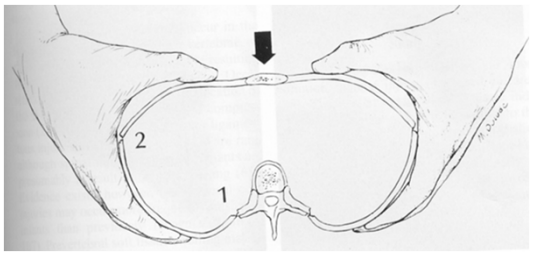
- Bone is viscoelastic- the susceptibility to injury is dependent on the rate of force application;
- Bone is less likely to fracture with sudden application of force and stress
- Bone may withstand a higher force when force is rapidly applied
  - applying a force to a bone over an extended period of time would be more likely to fracture than the same load applied rapidly

Mechanical properties of mature and immature bone

- Children's bones have lower mineral content than adult bone and are more elastic
- Children's bones can absorb relatively more energy before permanent deformation and fracture occurs
- Explains some fractures that are unique to children (i.e. greenstick and buckle fractures)

Mechanism of injury

rib fractures



Case Examples

Abusive Head Trauma (AHT)

What does the doctor bring?

- Knowledge of biomechanics of injury
- Analysis of the history provided
- Knowledge of common injuries mistaken for abuse
- Analysis of scene

What can the doctor NOT tell you?

- Exactly what happened
- Exactly when this happened

Why is there so much controversy?

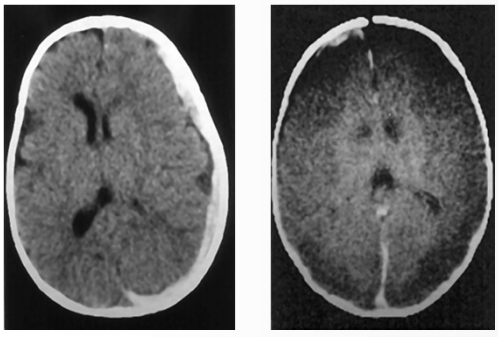
- People simply cannot believe that anyone would shake a child
- Early studies suggested shaking could not cause injury without impact - later studies have refuted this
- Articles with confessions are dismissed as flawed
- Defense authors have published some seriously flawed works to support their opinions
- The lay press primarily prints the defense cases and supports the controversy

Duhaime et al, J Neurosurg 66:409-415, 1987

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 any normal parenting activity
- Large size differential between perpetrator and victim; adult (or adult-sized person) required
- Rib and extremity fractures can result

Typical CTs in AHT



Victims of ITBI

- Radiologic evidence of intracranial injury: bleed with or without brain swelling
- Retinal hemorrhages in approx 80%
- 50% show associated non-cranial injuries
- Age range 2 weeks to several years- average age 6.6 months
- Slight predominance of male victims
- Death rates equal for males and females

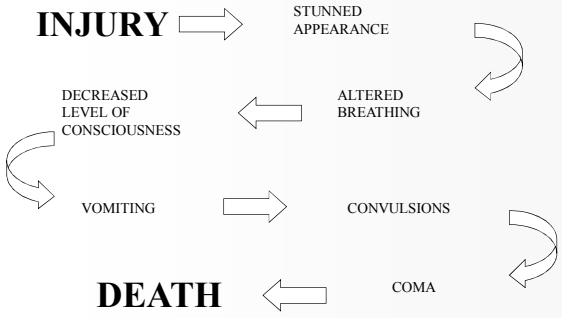
AHT Clinical presentation

Variable, depending on extent of injury:

- Sleepiness, lethargy
- Irritability
- Poor feeding
- Vomiting
- Loss or alteration of consciousness
- Seizures
- Apnea
- Coma
- Death

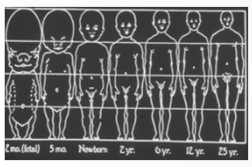
Timing of head injury

- Much debate in literature regarding how rapidly symptoms evolve
- Has important implications for prosecution of perpetrator



Pathophysiology

- Vulnerability of infant anatomy
  - large head, brain, subarachnoid spaces; weak neck muscles
  - thin, pliable skull with flat base



Forces Required

- No good experimental model exists
- *High degree of force*
  - analogous injuries are seen with…
- "…so violent that individuals observing [the shaking] would recognize it as dangerous…"

…and likely to kill the child."
-AAP 2001

Contact head injuries

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

Injuries at deeper tissue layers were caused by greater force

Hymel et al. Pediatrics 2010;125:712-720

Differential Diagnosis of AHT

- Accidents- falls, other household injury
- Bleeding disorders- factor disorders, liver disease, Vit K deficiency
- Metabolic diseases
- Infection- meningitis, encephalitis, sepsis
- Birth trauma
- Intracranial pathology- cysts, tumors, ruptured AVM

Most common histories for AHT

	Abusive HT	Accidental HT
No explanation	51 (64%)	0
Shake to revive	3 (4%)	0
Shake intentional	2 (2.5%)	0
Unknown	1 (1.3%)	0
Fall	12 (15%)	15 (21%)
Dropped	6 (7.5%)	8 (11%)
MVC/peds	0	38 (53%)
Fall/parent	0	2 (3%)
Other	5 (6%)	4 (6%)

Characteristics of inflicted and non-inflicted traumatic brain injury. Keenan et al. *Pediatrics* 2004;114:633-639

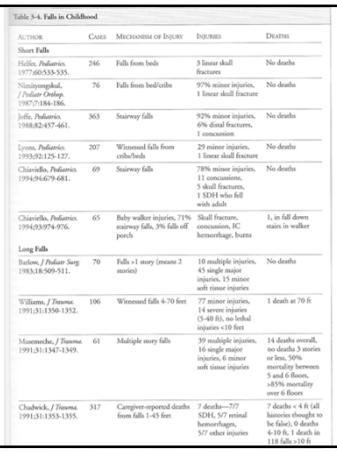


Table 3-4. Falls in Childhood

Author	Cases	Mechanism of Injury	Injuries	Deaths
Short Falls				
Helfer, *Pediatrics*. 1977;60:533-535.	246	Falls from beds	3 linear skull fractures	No deaths
Nimityongskul, *J Pediatr Orthop*. 1987;7:184-186.	76	Falls from bed/cribs	97% minor injuries, 1 linear skull fracture	No deaths
Joffe, *Pediatrics*. 1988;82:457-461.	363	Stairway falls	92% minor injuries, 6% distal fractures, 1 concussion	No deaths
Lyons, *Pediatrics*. 1993;92:125-127.	207	Witnessed falls from cribs/beds	29 minor injuries, 1 linear skull fracture	No deaths
Chiaviello, *Pediatrics*. 1994;94:679-681.	69	Stairway falls	78% minor injuries, 11 concussions, 5 skull fractures, 1 SDH who fell with adult	No deaths
Chiaviello, *Pediatrics*. 1994;93:974-976.	65	Baby walker injuries, 71% stairway falls, 3% falls off porch	Skull fracture, concussion, IC hemorrhage, burns	1, in fall down stairs in walker
Long Falls				
Barlow, *J Pediatr Surg*. 1983;18:509-511.	70	Falls >1 story (means 2 stories)	10 multiple injuries, 45 single major injuries, 15 minor soft tissue injuries	No deaths
Williams, *J Trauma*. 1991;31:1350-1352.	106	Witnessed falls 4-70 feet	77 minor injuries, 14 severe injuries (5-40 ft), no lethal injuries <10 feet	1 death at 70 ft
Muenneche, *J Trauma*. 1991;31:1347-1349.	61	Multiple story falls	39 multiple injuries, 16 single major injuries, 6 minor soft tissue injuries	14 deaths overall, no deaths 3 stories or less, 50% mortality between 5 and 6 floors, >85% mortality over 6 floors
Chadwick, *J Trauma*. 1991;31:1353-1355.	317	Caregiver-reported deaths from falls 1-45 feet	7 deaths—7/7 SDH, 5/7 retinal hemorrhages, 5/7 other injuries	7 deaths < 4 ft (all histories thought to be false), 0 deaths 6-10 ft, 1 death in 118 falls >10 ft

Childhood Falls

Starling SP. Head injury in child abuse. In: Giardino ER and Alexander R, eds. *Child Maltreatment: A clinical guide and reference*. GW Medical, 2005

Childhood Falls

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 0.625 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); 24% 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; from furniture; and 3 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 50 feet

Evaluating the Potential Effects of a Fall

Decreased Risk	Increased Risk
lower mass	greater mass
high pt. elasticity	low pt. elasticity
lower height	greater height
initial velocity 0	+ initial velocity
soft surface	hard surface
large impact area	small impact area

Characteristics of a falling person

As the mass of the falling object or person increases, impact forces will increase if all other determinants remain the same (F=ma)

The bigger you are, the harder you fall

Stairway Falls

- Most injuries resulting from stairway falls are to head and neck (Joffe & Ludwig 1988, Chiavello 1994)
- Most children with minor injuries or no injuries (90% in Joffe & Ludwig study)
- Could have focal subdural, skull fracture, focal brain injury; more severe injuries occurred if child fell with adult (Chiavello study)
- Rarely (less than 10% of time) had extremity fractures
- No life-threatening injuries or injuries involving multiple body areas

Childhood falls

- If given a history of serious injury with 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

Can a child suffer serious AHT from shaking alone or is impact required?

- "So Doctor, how much force is required to cause injuries associated with the Shaken Baby Syndrome…"
- Excessive and violent force is needed, trivial forces are not sufficient to cause the syndrome
  - bouncing
  - infant swings
  - fall from low heights
- A prospective study that will answer the question, will NEVER be done!

Comparison of Animal Models to Humans

	Height	Weight	Brain Weight
Adult human	170 cm	64 kg	1,250 gm
Chimpanzee	91 cm	48 kg	425 gm
Rhesus monkey	71 cm	9 kg	85 gm
Squirrel monkey	29 cm	1.25 kg	23 gm
Infant human	50 cm	3.5 kg	375 gm

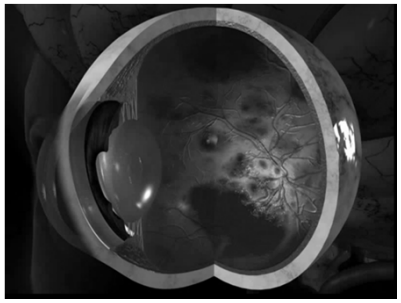
Ratio of body weight to brain weight

	Brain weight/Body weight
Adult human	1:51
Chimpanzee	1:112
Rhesus monkey	1:105
Squirrel monkey	1:54
Infant human	1:9

Other Biomechanical Issues

- Most models saying shaking is not harmful only consider a *single* shake rather than repetitive events (effects of 'tissue fatigue')
- Extrapolating injury patterns from adult to infant brains assumes that they are the same
- Unmylenated (baby) axons may be more vulnerable than mylenated (adult) axons
- Differences in adult and child skull configuration and effect of the mechanical properties of infant brain are unclear

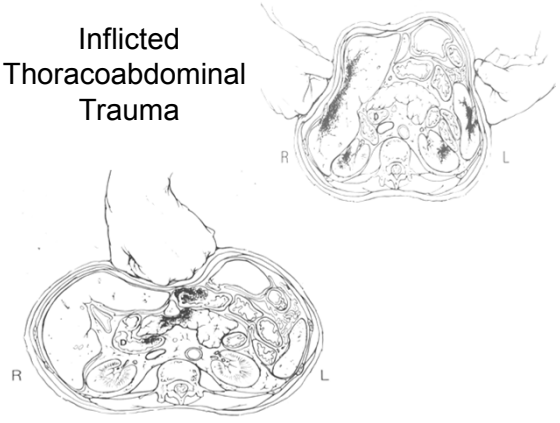
Retinal hemorrhages



Retinal Hemorrhages

- Diffuse hemorrhages generally not caused by accidental injuries, can rarely be seen when significant forces involved (i.e. MVC)
- Hemorrhages can be seen in coagulopathies, meningitis, vasculitis, sepsis, and birth
- Not caused by CPR

Inflicted Thoracoabdominal Trauma



What does the doctor bring?

- Knowledge of biomechanics of injury
- Analysis of the history provided
- Knowledge of common injuries mistaken for abuse
- Analysis of scene

What can the doctor NOT tell you?

- Exactly what happened
- Exactly when this happened
- How long the child would have been ill

Abdominal/thoracic trauma

- Results from punching or kicking child
- Tremendous force generated, especially with kicking
- Traumatic forces transmitted internally, so often no external markers of injury
- Injury often extensive, with late recognition; lethality high

Symptoms of abdominal trauma

- Lethargy
- Decreased appetite
- Vomiting
- Abdominal pain
- Increased abdominal girth
- Fever
- Shock/cardiovascular collapse
- Coma
- Death

Abdominal/thoracic trauma

- Can be slow symptom evolution
- May take hours to days to develop symptoms specific for abdominal trauma
- Child can develop hypotension (low blood pressure) and cardiovascular collapse
- Children often die before injury detection
- Thoracoabdominal trauma is an infrequent cause of pediatric trauma (<1%), but as many as 20% may be inflicted

Case Examples

Abdominal trauma causes injury by:
Direct blow – disrupts integrity of solid organs
Impingement – hollow organs forced against spine

SOLID	HOLLOW
liver spleen pancreas kidneys	stomach, duodenum, jejunum, small intestine, large intestine, bladder, ureters

*Large and small blood vessels and nerves supply all of the organs & these are subject to injury as well

Distinguishing Between Accidental and Inflicted Injuries

	Accidental	Inflicted
Median Age	7 yrs. 8 mo.	2 yrs. 6 mo.
History	Motor vehicle	Discrepant history
Medical Care	Prompt	Delayed
Organ Involved	Solid	Hollow
Mortality Rate	21%	53%

Ledbetter et al-156 children <13 yrs with abdominal injuries

Scene Investigation

- Photos of scene- beds, couches, bathtubs, floors
- Measurements of water temperature
- Measurements of heights and analysis of surface properties in falls
- Kitchen cabinets and refrigerators in cases of starvation
- Prescription, OTC, and other drugs and chemicals in cases of suspected poisoning