PEDIATRIC ABUSE

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Why Are Infants Susceptible

- Brains of infants are larger relative to their body size.
- They have a much higher water content and a decreased amount of myelination.
- The subarachnoid space is thin so it provides limited buffering with impact.
- Neck muscles are weak and underdeveloped.
- Unfused sutures

- Patterns of abuse:
  - Physical
  - Nutritional
  - Sexual
  - Intentional drugging or poisoning
  - Neglect of medical care or safety
  - Emotional
- The vast majority of cases are either physical (70%) or sexual (25%).

Clues to Abuse

- History is not consistent with injuries and/or autopsy findings.
  - Short distance falls rarely cause fracture.
  - When fracture occurs, almost always linear fracture without underlying injury.
- Injuries in an infant.
- Evidence of recurring injury, including fractures.
- Central nervous system injuries.
- Genital trauma.
- Evidence of starvation including weight loss and decreased growth rate.

- Head injury is the leading cause of death and disability in children, of the deaths related to head injury inflicted neurotrauma is the most common cause.
- Mortality from abuse is ~3%, and is estimated to cause 2,000-3,000 deaths per year.
- Statistically divided by thirds into three age groups: less then 1, 1-6 and greater then 6.
- Premature infants are at a higher risk.

The Skin

- Bruises may be absent even with fatal internal injury.
- Concerning areas
  - Lips/ face
  - Wrists
  - Forearms
  - Buttocks
  - Fingerprint bruises to chest and abdomen
- Bruises cannot be accurately aged, however, yellow coloration indicates greater then 18hrs.

Patterned Bruise

Abuse Related Skull Fractures

- While accidental fracture and simple and linear abuse fractures tend to be complex and sometimes multiple.
- Other concerning signs include: depressed fracture, fracture greater than 3mm in width, involvement of multiple bones.
- Fractures are seen in less then half of abuse cases.

Falls

- Kids fall.
- However, kids usually don't fall far. Children falling 36 inches or less are unlikely to have life threating injuries.
- Falls from 4-6 feet generally result in contact injury to no injury at all.
- 1-3% have a skull fracture that is simple and linear and in less than 1% of the fractures there is an associated epidural or subdural.
- Diffuse injuries are extraordinarily unlikely as the point of contact is to brief.

Shaking Causing injury

- Classic triad is subdural retinal hemorrhages and anoxic encephalopathy.
- According to Matshes et al the anoxic encephalopathy comes from damage that occurs in the dorsal root ganglion on spinal levels C3-C5 (C3,4,5 keeps the diaphragm alive).

- Falls from great height are usually survived by children.
- Musemeche et al. studied falls from greater then 10 feet, half had skull fractures or brain hemorrhages but all survived.
- Barlow et al. found that all children in his study (N-61) who fell from less then 3 stories survived, falls from 5-6 story was associated with a 50% mortality rate. Of those who died most had crush like head injuries.

Diffuse vs Focal Injury

- Focal injury results from direct impact.
  - Contusions
  - Fractures
  - Some SDH
- Cause increased pressure and are symptomatic over time, lucid interval.
- Diffuse result from inertial forces.
  - Some SDH
  - DIA
- Usually, immediately symptomatic, no lucid interval.

- Head injuries are the leading cause of death in abused children.
- Most of these are the result of shaken baby (impact) syndrome.
- The outcome of shaken baby (impact) syndrome is: 7-30% die, 30-50% have defects and 30% may fully recover.
- Usually don't see external injuries, less then 50%.

Rebleeding

- The traditional thinking of acute SDH becoming chronic SDH has been challenged and it now seems that most acute SDH will resolve in a period of weeks to months.
- Lee et al.'s work seemed to show a relationship between chronic SDH and subdural hygromas (tear in arachnoid).
- Chronic SDH should not be seen as a source of significant hemorrhage from rebleeding, most is microscopic and benign.

- In abusive head trauma cases the majority will present with a subdural hematoma (~90%).
- The hemorrhage is the results of torn bridging veins brought about by motion of the brain.
- Grossly these hemorrhages appear as a thin film of blood, commonly less then 10 mL which may not be seen on CT.
- Wells et al. looked at CT of 293 children under 3 with head bleeds to determine patterns of bleeding

Other conditions with SDH

- Birth:
  - Birth trauma accounts for 1-2% of the mortality in newborns.
  - VJ Rooks et al. Found SDH in up to 46% of asymptotic infants (much higher then previous studies which were around 15%)
  - Occurring in almost half of vaginal deliveries, ~60% with instruments and less then 20% with C/S.
  - SDH was usually posterior interhemispheric fissure and along occipital lobes, occasionally posterior cranial fossa.
  - In this study, no other injury was seen (subarachnoid, fractures, contusions).
  - Most hemorrhages resolves by 4 weeks.

Computed Tomographic Finding	Intentional Injuries	Unintentional Injuries						Intent Uncertain
		All	Fall <2 m	Fall ≥2 m	MVC†	Infant Walker–Stair Fall	Struck	
Epidural hematoma (n = 80)	14 (18)	**62** (78)	28	11	5	12	6	4 (5)
Interhemispheric subdural hematoma (n = 143)	105 (73)	**21** (15)	0	3	12	4	2	17 (12)
Convexity subdural hematoma (n = 137)	99 (72)	**14** (10)	3	1	5	3	2	24 (18)
Other subdural hematoma (n = 10)	7 (70)	**3** (30)	0	0	1	1	1	0
Subarachnoid hemorrhage (n = 36)	12 (33)	**22** (61)	5	4	10	2	1	2 (6)
Intraventricular hemorrhage (n = 13)	6 (46)	**6** (46)	1	1	4	0	0	1 (8)
Petechial hemorrhage (n = 45)	15 (33)	**27** (60)	7	6	10	2	2	3 (7)
Parenchymal hematoma (n = 5)	1 (20)	**1** (20)	0	0	1	0	0	3 (60)
Hygroma (n = 43)	35 (81)	**0**	0	0	0	0	0	8 (19)
Edema (n = 85)	66 (78)	**11** (13)	0	0	8	1	2	8 (9)
Fracture (n = 140)	43 (31)	**90** (64)	33	17	14	16	10	7 (5)

R, Wells; C, Vetter; P, Laud, **Intracranial Hemorrhage in Children Younger Than 3 Years** Prediction of Intent, *Arch Pediatr Adolesc Med.* 2002;156(3):252-257. doi:10.1001/archpedi.156.3.252

- In addition, infants born via C-section after abnormal labor have higher rates of brain injury then infants born via spontaneous vaginal delivery.
- Any significant intracranial injury will present soon after birth, generally immediately, with emesis, poor feeding, seizures, etc.

- Other causes:
  - Cerebral artery aneurysms
  - Vascular malformations
  - Coagulopathy
  - Leukemia
  - Hemoglobin disorders
- To complicate matters further, patients with head trauma sometimes develop a coagulopathy.

- Hypoxia is often cited as a cause of SDH but numerous brains are autopsied with hypoxic changes without SDH.
- Cerebral venous thrombosis has also been postulated as a cause of SDH relating to increased intracranial pressure.
- McLean et al. examined 36 patients (1 day to 19 yo) who had intracranial venous thrombosis.
- No link between IVT and SDH was seen.

Weak association with SDH

- Theories exist about LPs causing intracranial hypotension leading to SDH.
- However the case reports regarding this complication are in older children and adults.
- In addition, coagulopathy is usually present when this complication occurs.

The Eyes

- Retinal hemorrhages are often seen in children with rotational brain injuries, about 85% of the time.
- Often seen with dilated fundal examination, but should be done early.
- No one is really sure why they occur theories include: increased intraocular venous pressure, retinal trauma from acceleration/deceleration, increased intracranial pressure, the most popular centers on the different densities of the vitreous and internal limiting membrane.
- The eyes of children may be more susceptible to injury due to the globes being able to move within the eye sockets due to pliability of the sclera.

Sustained Cough/ Choking

- Originates with an infant who had pertussis and was later found to have SDH, however there was a reported fall a week prior.
- Two studies looked at infants with pertussis and found not retinal hemorrhages.
- Apparent life threatening event (ALTE) characterized by choking, color change, changes in muscle tone, etc has been reportedly linked to mimicking abusive head trauma.
- Hansen et al looked at children less then 2 for ALTE associated and non associated SDH.
- They found all children with ALTE related SDH had at least one suspicious extracranial injury and were 5 times more likely to have a suspicious injury.
- They concluded ATLE is not a supported causative mechanism of AHT injuries.

Retinoschisis

- Hemorrhage, with dome shaped elevation, surrounded by macular folds below the internal limiting membrane.
- Seen in ~20% of abusive head trauma patients but high positive predictive value, however this can occur in devastating crush injury to the infant head, although rarely.
- Gnanaraj et al. looked at ocular findings in crush injury and concluded intra and preretinal hemorrhages of the posterior pole can occur in crush injury. However, if it extends out to ora serrata then the crush injury should be fatal.
- In their study (N=25) no retinoschisis was seen with crush injury. However, other studies have noted it with severe head injury and heme maligancy.

Like Everything Else, Not Specific

- Retinal hemorrhages can be seen with the birthing process.
- 33% of vaginal deliveries, 75% of vacuum assisted deliveries and 7% of C-section deliveries will have retinal hemorrhages, usually intraretinal, rarely subetinal.
- Most resolve in a few days, deeper hemorrhages may take week, almost all resolve by 6 weeks.
- However, retinal hemorrhages can be seen with coagulopathy, sepsis, subarachnoid hemorrhages, leukemia and meningitis.

Weaker association with retinal hemorrhages

Accidental trauma

- Numerous studies have looked at accidental trauma in relation to retinal hemorrhages.
- The general consensus is that retinal hemorrhages are, at best, rare in accidental trauma as opposed to abuse.
- Usually the trauma is major such as MVA.
- When retinal hemorrhages were present in accidental trauma they were mild and did not extend to the periphery of the retina.

Elevated Intracranial Pressure

- Retinal hemorrhages can be seen with optic nerve swelling however, according to Selhorst et al, papilledema was seen in ~3.5% of acute head injuries (in children, not infants).
- Morad et al. was unable to find a link between elevated ICP and significant retinal hemorrhages.
- Binenbaum et al. looked at 100 children with elevated intracranial pressure and found RH to be rare and were peripapillary and nerve fiber layer.
- Retinal hemorrhages are rare after accidental trauma even through cerebral edema is present.
- However, eye examination should be done promptly as they can fade, intraretinal clear rapidly.

- Other causes include:
  - Coagulopathy (VWD, vit K deficiency, low fibrinogen, etc.) and ECHMO.
  - OI
  - Hypertensive retinopathy
  - Meningitis, can look very similar to abuse.
  - Sepsis/ Leukemia
  - Anemia
  - Hyper/hyponatremia?

CPR

- The hypothesis has been purposed that CPR can cause retinal hemorrhages, increasing thoracic pressure increases JVP and intracranial pressure.
- Gilliland et al. studied the eyes of 169 children, and grouped them by the presence of retinal hemorrhages (99 - and 70 +).
- Of the 99 without hemorrhages 70 had resuscitation and of the 70 with hemorrhages 61 had resuscitation.
- All children with hemorrhages (70) had an injury or disease that was associated with retinal hemorrhages (head injury, CNS disease, sepsis).
- Venous valves in the jugular do a pretty good job of controlling pressure.

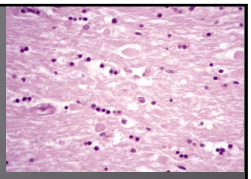
Convulsions and Valsalva

- Tyagi et al. Examined 32 children (2 years or less) after admission with convulsions and found no retinal hemorrhages.
- Herr et al. examined 100 infants with hypertrophic pyloric stenosis (forceful vomiting) and found no retinal hemorrhages.

- DAI is important to recognize because it is thought to be immediately symptomatic.
- Usually symptoms include altered level of consciousness, respiratory depression and or seizures.
- Survival time depends on the symptoms but if respiration is effected children may only survive minutes to hours if not in a hospital.

Injury or Condition	Discussion
Accidental trauma	Few in number except in very severe trauma, Usually limited to posterior pole, Predominantly intraretinal and pre-retinal, Extremely rare (most studies <3 % incidence) after short falls except if there has been an epidural hemorrhage or occipital impact
Birth	Between 19.2 % and 37.3 % incidence in vaginal birth, 6 % incidence after C-section
Motor vehicle crash or severe crush injury	Easily determined by history
Cardiopulmonary resuscitation (CPR)	Extremely rare, few in number, posterior pole
Extracorporeal membrane oxygenation (ECMO	5 out of 37 (13 %) of ECMO patients had retinal hemorrhage.
Prematurity	Retinal hemorrhage occur at the peripheral circumferential demarcation between the vascularized and avascular retina
Intracranial hypertension or Papilledema	Small number of retinal hemorrhage on or around the optic disc
Coagulopathy/anemia	Uncommon, few in number, posterior pole severe anemia and usually thrombocytopenia required, often with cotton wool spots ++
Meningitis	More often if coagulopathy or sepsis is present. Only severe retinal hemorrhage if purulent meningitis, otherwise few in number, posterior pole
Ruptures aneurysm/arteriovenous malformation	May have severe extensive retinal hemorrhage; vascular malformation easily recognized on neuroimaging
Hypoxia	Few in posterior pole
Menkes disease	Causes blue sclera
Galactosemia	Vitreous hemorrhages reported
Glutaric aciduria	Rarely occurs and is confined to posterior pole

Taken from: Choudhary AK, Servaes S, Slovis TL, Palusci VJ, Hedlund GL, Narang SK, Moreno JA, Dias MS, Christian CW, Nelson MD Jr, Silvera VM, Palasis S, Raissaki M, Rossi A, Offiah AC. Consensus statement on abusive head trauma in infants and young children. Pediatr Radiol. 2018 Aug;48(8):1048-1065. doi: 10.1007/s00247-018-4149-1. Epub 2018 May 23. PMID: 29796797.



- Microscopically axonal spheroids may be present if the patient survived for more then 18 hours.
- However with the use of a B-amyloid precursor protein stain, injury can be detected microscopically as early as 2 hours post trauma.
- Like everything else, this is not specific for abuse, axonal spheroids may be seen anytime axons are injured including: hypoxic injury, or hemorrhage.
- It can even be seen with MS and AIDS.

Diffuse Axonal Injury (DAI)

- DAI occurs when there is severe twisting and or stretching of the brain, thereby injuring the axons.
- White matter tracts show the injury and are most common in the: rostral dorsal frontal white matter, corpus callosum, posterior limb of the internal capsule and white matter tracks in the pons.
- The nerve injury cannot be identified grossly however, punctate or linear streak hemorrhages may be seen.

Fractures and abuse

- Skeletal injuries range from 11-55% in abused children.
- Across all age groups long bones are the most commonly fractures (76%), however, in infants up to 60% of the fractures are rib fractures.

Classic Metaphyseal Lesion (bucket handle fracture)

- Fractures occurring in the distal metaphysis (no chondrocytes and less calcification).
- Usually caused by shearing forces and twisting which are usually not present in blunt trauma
  - Horizontal forces that occur when limbs are flailing.
- Highly specific for abuse but seen in 39-50%.
- Child must be small enough to be shook.

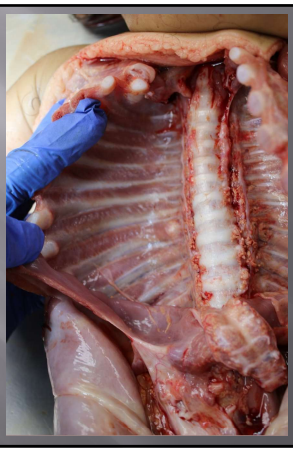
- Caused by anterior-posterior compressive force such as when the chest is encircled by adult hands.
- Usually no bruising.
- Sudden deceleration (fall) can cause a fracture but more likely in children over 2 and usually associated with bruising.
- Likelihood that rib fractures are due to abuse decreases as the child grows.
- Fractures are not always clear on radiographs.

- Have been reported with birth trauma (C-sections or trying to reposition fetus)
- Can also be seen in rickets, osteomyelitis and metabolic bone diseases.
- Kleinman et al. compared low abuse risk (42, skull fracture w/o other abnormality or history of fall) vs high abuse risk (18) infants for the prevalence of CML.
- 50% of the high risk infants had at least one CML, no one of the low risk infants.

- Location of fracture is important.
- Posterior fractures are caused by the compressive force levering the rib over the transverse process of the vertebrae and are highly specific for abuse.
- Posterior fractures are between the 4-9 rib, usually.
- First rib fractures are highly suspicious for abuse as it takes a significant force to fracture it.

Rib fractures

- Commonly fractured bone in abuse cases.
- High PPV for abuse in children less then 3.
- Seen as the only skeletal abnormality in ~30% of cases.
- Usually seen as multiple fractures, a single fracture is more likely to be accidental.
  - Baraness et al. found an average of 5.9 fractures and Cartey and Price found single rib fractures in 20% of abuse cases.

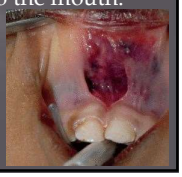


Rib Fractures and Resuscitation

- Reported in less than 1% of infant CPRs.
- Located anteriorly of anterolaterally.
- Weber et al. looked at 546 autopsies done over 10 years on infants.
  - Fractures were found in 24 cases (4%), of those 15 were healing and 10 of those were likely abuse.
  - 9 cases (2%) showed fresh fracture with no tissue reaction, all were in anterolateral chest.
- Resuscitation does not usually cause posterior fractures even with the advent of the two thumb method.
- Franke et al. examined 80 infants after CPR using chest radiographs and found no rib fractures.

Tears of Labial Frena

- Intraoral injury thought to be seen in 0.5 to 12.4% of abused children.
- Historically thought to be pathognomonic for abuse in nonambulatory children.
- Caused by blows to the mouth (slap or punch) or forceful insertion of objects into the mouth.



Birth Related Rib Fractures

- Clavicular fractures are the most common birth related fracture.
- Multiple studies have failed to reveal a high incidence of birth related rib fractures.
- However, case reports do exist and the fractures seem to be unilateral and posterior.
- Usually larger infants with shoulder dystocia and an ipsilateral clavicular fracture.
- Fractures also tend to be mid posterior instead of posterior medial.

- Not exactly as pathognomic as originally thought.
- Can be seen in about 3.5% of accidental injury with the most common mechanism being fall from standing height.
- Can also be seen with oral intubation or forceps delivery.

Other Common Injuries

(Cigarette) Burns

- Burns are present in about 5-22% of abused infants.
- Hobbs reviewed 195 burn and scalp cases (30 non-accidental and 165 accidental).
  - Scalps 81% of accident and 25% of abuse cases.
  - Contact 7% of accident and 44% of abuse cases.
  - Other 10% of accident and 3% of abuse cases.
  - Unknown 1% of accidents and 28% of abuse cases.
  - No cigarette burns in accidentals group, only 3 in abuse group
- Cigarette burns are usual circular burns of 7-10 and deep mm, elliptical orientation and superficial suggests accidental etiology.

Abdominal Injury

- Leading cause of abuse deaths after head injury.
- Blunt injuries to the abdomen are most often accidental in nature (50% mortality) but the second most common cause is inflicted trauma, which carries a worse prognosis.
- Liver is the most commonly injured organ.

- Pancreatic and duodenal injures may be seen with fall or classically "handlebar injury".
- Pancreaticoduodenal injury has not been reported from a fall under 5 years old.
- Resuscitation can reportedly cause lacerations of the liver and spleen and blood in the peritoneal cavity.
- Bush et al. retrospectively documented CPR injuries in 211 children and found one splenic hematoma and no significant visceral injury.
- There were 3% of children with a "significant injury" including retroperitoneal hemorrhage (n = 2), pneumothorax (n = 1), pulmonary hemorrhage (n = 1), epicardial hematoma (n = 1), and gastric perforation (n = 1).
- Other studies have found no difference in injury severity between abused children who have and have not undergone recucsitation.

Anogenital injuries

- Careful examination is needed to rule out postmortem artifacts as the anus can dilate postmortem.
- In cases of suspected sexual abuse swabs should be completed.
- Injury does not imply abuse.