

# Head Cases

Abusive and Accidental Head Injuries in Children

# Scope of the Problem

- Inflicted head injury is the leading cause of death from physical abuse.
- Leading cause of permanent physical disability from abuse.
- Most common among small infants less than 12 months old.

# A fairly typical but slightly more complicated than usual case

8 week old male infant, lives at home with mom, dad and half brother. Healthy baby from a normal pregnancy. Dad calls 911 at 5:30 am reporting that baby choked while feeding and is no longer breathing. Told to start CPR. CPR continued on route to hospital. Baby had a bradycardia throughout, but never cardiac arrest.

Arrived at local hospital intubated, breathing on his own. Normal vital signs, lethargic but responding a bit to examination and blood tests. Transferred to McMaster.

After arriving at McMaster has CT scan, MRI, bloodwork and ophthalmology exam.

CT and MRI show severe cerebral edema, acute subdural and subarachnoid hemorrhage.

Bloodwork from referring hospital and in PCCU show DIC.

No bruising seen on the skin. No oozing from skin puncture sites. Factor replacement given.

Eye exam shows severe retinal hemorrhages in both eyes.

Too sick to have a skeletal survey done.

Dad reports being up through the night a couple of times to feed baby, who seemed more irritable than usual, but not sick. During feeding at 5:30, baby choked while feeding, stopped breathing and went limp.

When told about the subarachnoid hemorrhage, he remembered bumping the baby's head against the door frame of the bathroom while carrying him that night and that he had cried a bit as a result.

Baby deteriorates to the point where brain death is declared.

Post-mortem confirms acute sub-arachnoid and subdural blood. Also reveals small area of scalp swelling/bruising with small underlying skull fracture - on the opposite side of the head from the intracranial bleeding.

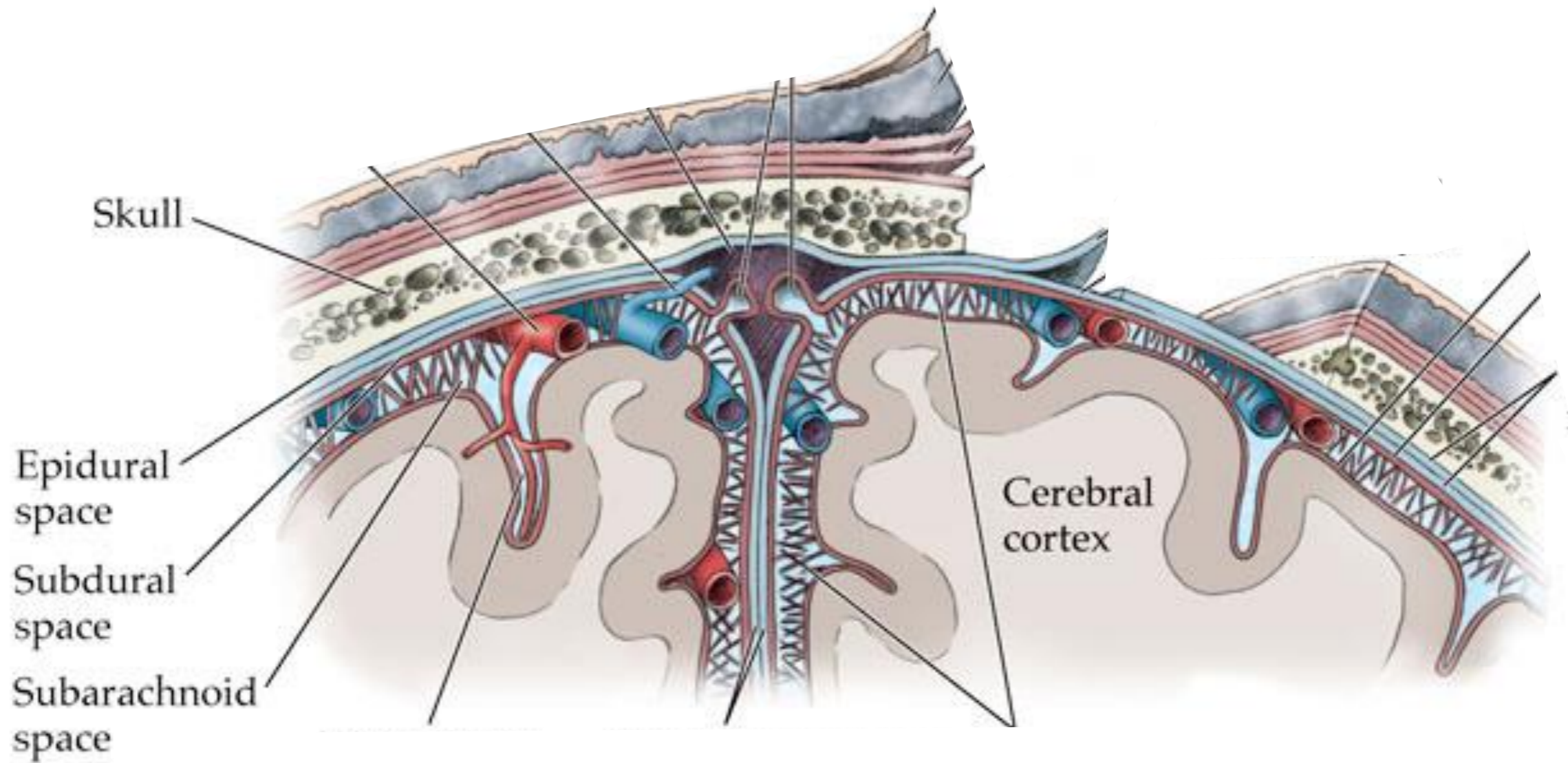
# Questions from the Case.

- What caused the DIC?
- Could DIC have caused the intracranial hemorrhage?
- Could impact with a doorknob cause a skull fracture?
- Was the cerebral edema from trauma or hypoxia or both (or something else)?
- What could have caused the retinal hemorrhages? Trauma, hypoxia, raised ICP, intracranial bleeding?



# A Quick Anatomy Review

# Cross Section of Some Important Structures in the Head



To sort out what is likely abusive head trauma, we need to know something about accidental head trauma.

# Fun Facts

- Kids hit their heads a lot.
- The younger the child, the greater the head size relative to the rest of the body.
- They have relatively weak neck muscles to support those big heads.
- Once they are mobile, they are pretty top heavy and unsteady on their feet.
- They are also nuts.

- Before they can toddle around, they can roll and crawl, so they can and do fall off things like beds, change tables, high chairs etc, usually head first.
- People carrying children often fall, resulting in a significant event for the child, especially if the adult falls on the child.
- How much injury they sustain depends on the height of the fall, how fast they are moving when they go off, what they land on and how they land.

So, just like with fractures and bruises, the frequency of accidental head injury from the child's own actions goes up exponentially as mobility increases.

# Other Ways Children Get Head Injuries

- A projectile or other object hits them in the head - it is a relatively big target.
- They become a projectile - accidentally or otherwise.
- Their heads are subjected to repetitive acceleration and deceleration forces.

# However,

The overwhelming majority of accidental head injuries, especially if the only force involved is generated by the child, are mild and superficial.

Greater degrees of injury demand greater amounts of kinetic energy and a more unusual (and therefore obvious and easily recalled) mechanism of injury.



- So, when considering a head injury, we have to try to correlate the amount of force/kinetic energy ( $\frac{1}{2}MV^2$ ) involved in the reported explanation with what is required to cause the injury observed.
- Scene assessment and photographs are extremely helpful in determining how much peril (potential energy) a child could have been exposed to.
- ie how high is the bed, couch, chandelier that the child supposedly fell from?

In other words, an exceptional injury demands an exceptional explanation; a fact which is infrequently appreciated by people that inflict head injuries on small children.

# Common accidental “explanations” for probable inflicted head injuries

- Speculations on unwitnessed events “He must have fallen.”
- Reports of short, household falls - bed, couch, jumping between furniture: “I heard a bang in the other room”
- Young sibling perpetrator: “His brother must have hit him. He’s really rough with the baby”
- No explanation; “I walked in the room and he was pale and breathing funny”

# Types of Head Injuries

# Scalp Injuries

- Most common
- Bruises, abrasions, lacerations
- For some reason that we don't understand, scalp swelling can sometimes take several days to develop and/or be noticed.

# Skull Fractures

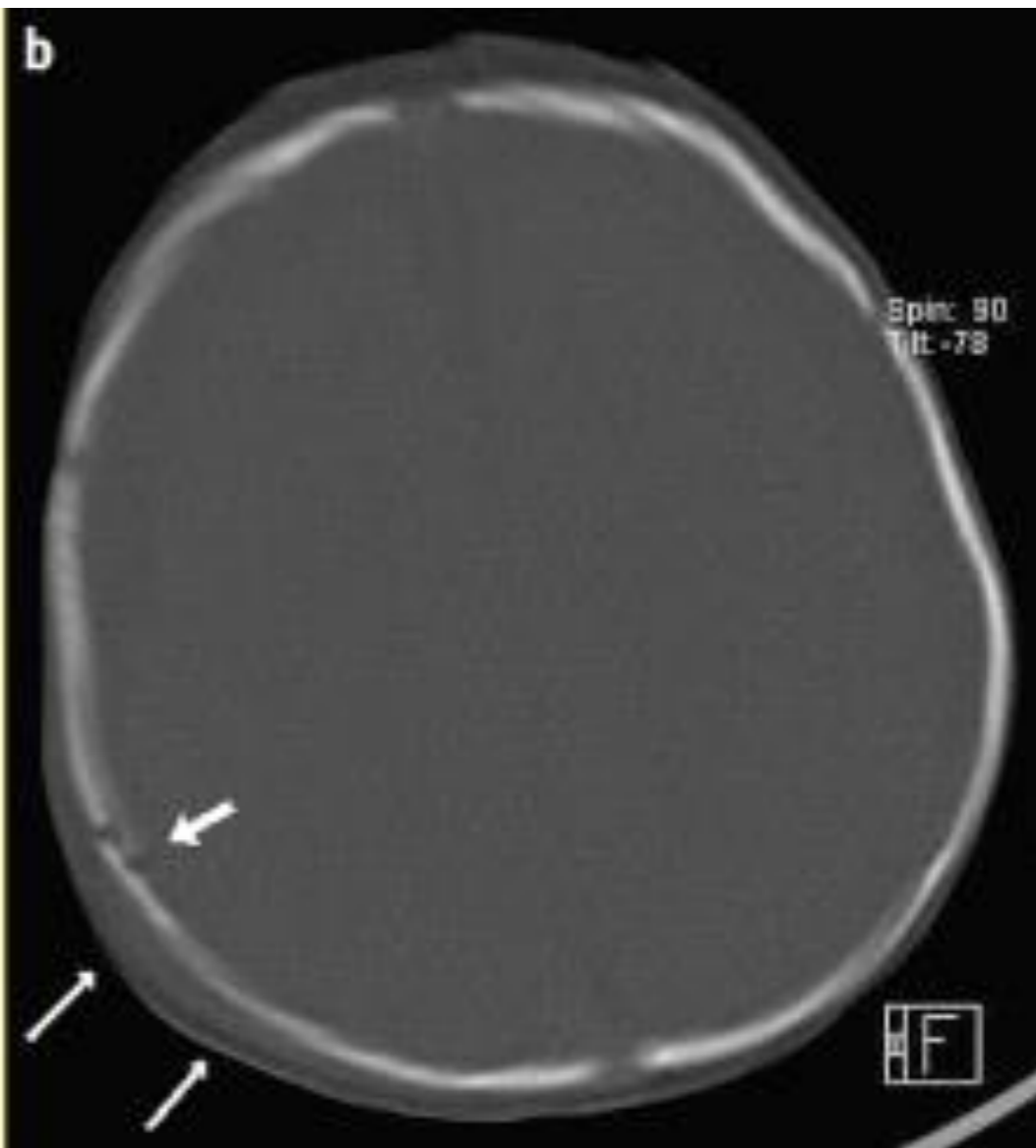
- Relatively common accidental fracture
- Age of fracture can't be determined by X-ray appearance
- Common from falls from short (<2-3 feet) height in infants, toddlers and older children
- Typically simple, linear fractures, sometimes with surprisingly little swelling/bruising.

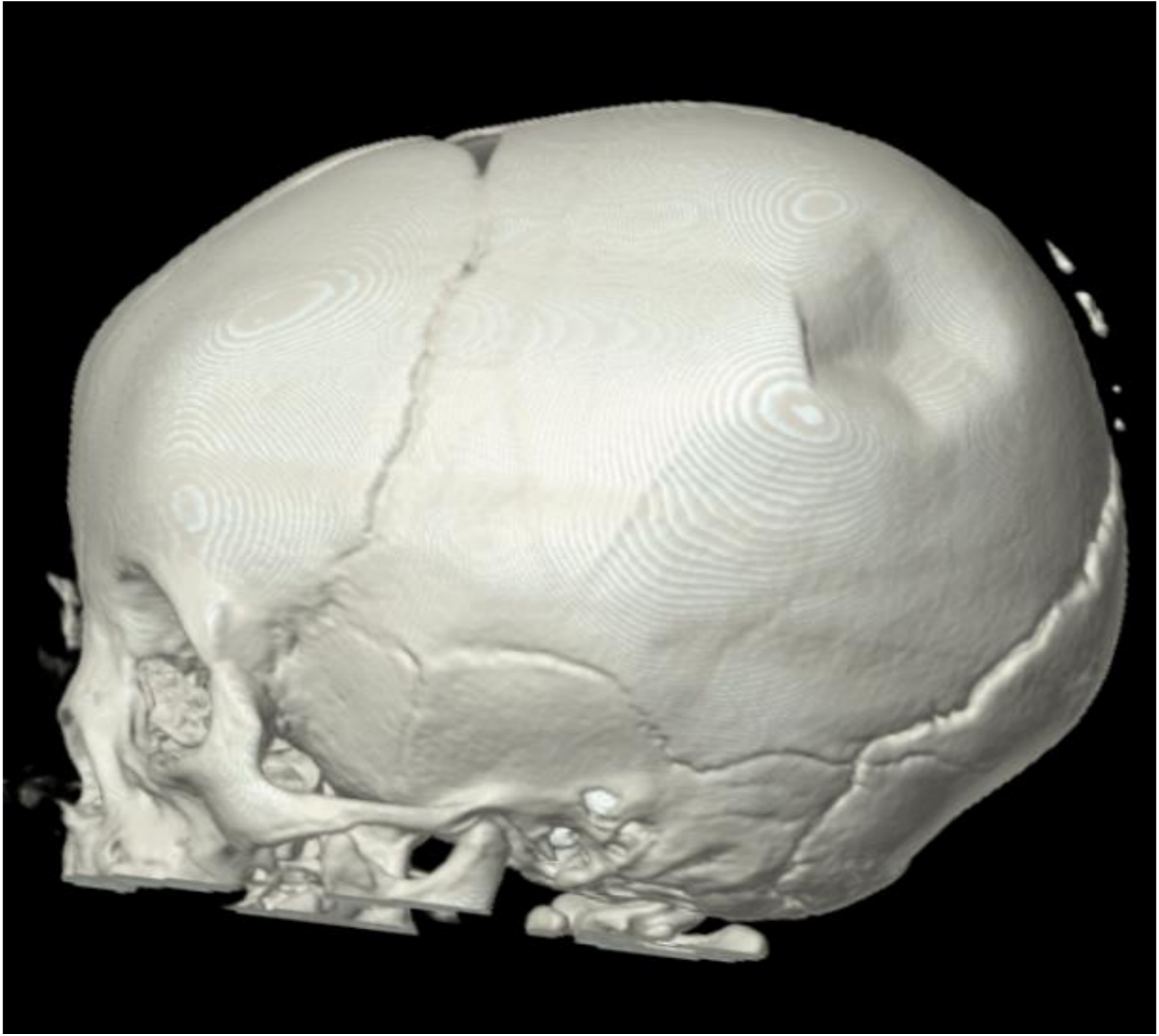
# Skull Fractures - Worrisome Features

- Unwitnessed/no explanation in a non-mobile child
- Depressed or comminuted
- Multiple sites of fracture
- Crosses suture lines









# Bleeding Inside the Head

- Epidural - usually from local impact, breaking an artery- high pressure blood- can be a big problem in a hurry
- Subarachnoid - common in significant accidental and inflicted trauma.
- Intracerebral - Requires a significant amount of trauma.

# Subdural Hemorrhage

- Collects between the arachnoid and the dura (or within the inner dura itself)
- Much more common in inflicted than accidental trauma, but still occur in accidents.
- Caused by:
  - Direct trauma to the skull over the area.
  - Rupturing of veins crossing the arachnoid and dura from rapid and/or repetitive acceleration/deceleration of the head.

# Subdural Hemorrhages

Accidental events causing diffuse/severe/multi-focal subdural hemorrhages

- motor vehicle collisions
- high/significant falls
- crush injuries
- multiple, direct impacts
- vaginal birth

# Issues to Consider With SDH

- Is there a coagulopathy?
- Is there an AVM?
- Is there an enlarged subarachnoid space?
- Is there old subdural blood/hygroma?
- Is there associated brain injury?

# Answers to some of the Issues

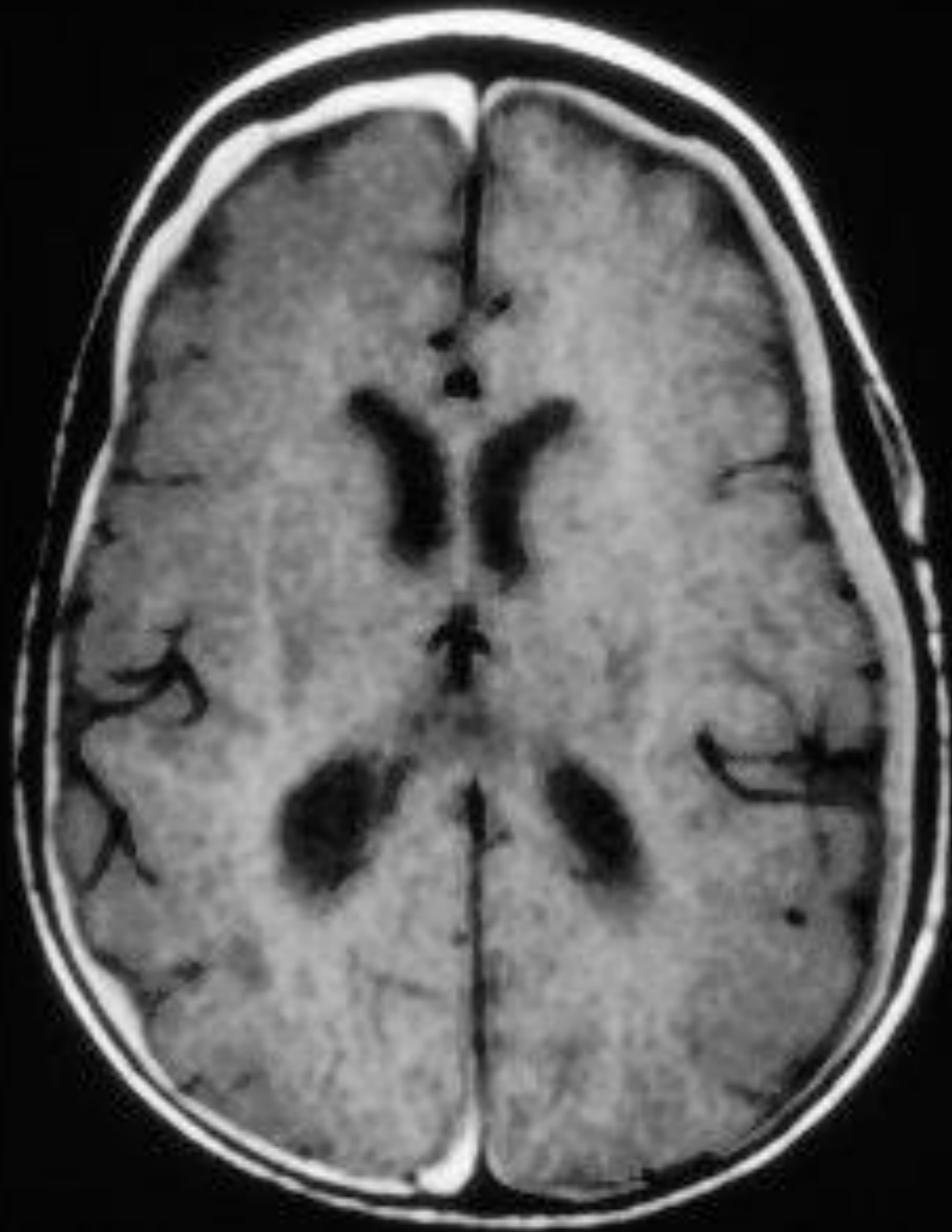
- Spontaneous SDH with no other bleeding history as a first presentation of a clotting disorder is really rare but has been documented.
- Enlargement of the sub-arachnoid space (small brain or benign enlargement of the subarachnoid space) may result in small, anterior SDH from minor or even no apparent trauma. Rarely if ever symptomatic.
- Other anatomic anomalies (arachnoid cysts, VP shunts) can be associated with occurrence of SDH

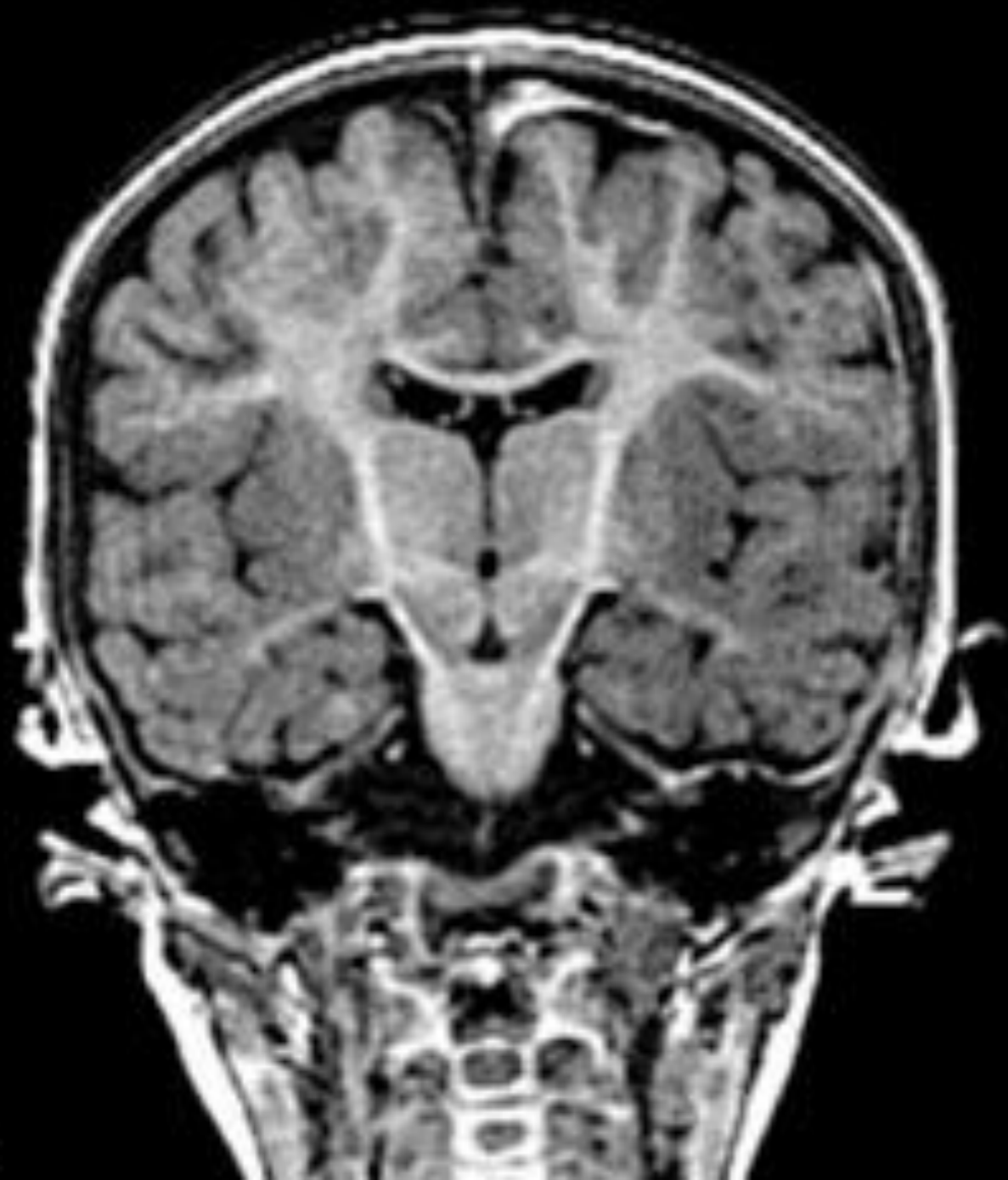
- AVMs resulting in SDH are rare. MRI can pick them up.
- SDH are not caused by hypoxia, vaccinations, vitamin deficiencies or young siblings.



# The work-up

- Initially CT to establish the diagnosis but MRI is always worthwhile. Include spine in MRI.
- Go straight to MRI if possible to avoid the radiation.
- Extensive coag work-up: CBC, INR, PTT, VonWillebrand profile and blood group, fibrinogen, Factors 8, 9, 11,13.
- Glutaric aciduria can generally be ruled out clinically but in young infants, specific metabolic testing is recommended.





# Subdural Hemorrhages From birth

- Typically small and do not cause symptoms
- Resolve by 4-6 weeks of age
- Location is usually different from hemorrhages due to inflicted trauma.

# Subdural Hemorrhages

- Once in the subdural space, the blood begins to break down.
- Its appearance on CT and MRI begins to change.
- How the appearance changes is highly variable, making accurate dating of the bleeding extremely difficult, if not impossible.

# Subdural Hemorrhages

- After weeks, a chronic subdural collection can remain.
- Rebleeding into these spaces can occur with minor trauma or spontaneously. Rebleeding from such minor events does not usually cause symptoms.
- Significant trauma (inflicted or otherwise) can cause symptomatic rebleeding in a chronic subdural collection.

# Subdural Hemorrhages

- Subdural blood doesn't cause symptoms unless there is so much blood that it puts pressure on the brain
- Most of the symptoms of a head trauma come from injury to the brain itself.

# Brain Injury



# Mechanisms of Brain Injury

- Direct impact to the head with transmission of energy to the brain.
- Shearing injury to brain cells from rapid and/or repetitive acceleration/deceleration forces experienced by the head.
- Pressure from blood between the brain and skull
- Penetrating trauma (rare)
- Cell damage from secondary causes

# Brain Injury

- The complicated physical and chemical events that happen when a brain cell is injured are only partially understood.
- A combination of direct injury to the brain cells, swelling around the cells and secondary injury from biochemical abnormalities arising from the original trauma all play a role.
- In inflicted head trauma, apnea is common and can result in further brain damage from lack of oxygen.
- Damaged brain cells can release large amounts of tissue factor, resulting in DIC.

# Head Injury Symptoms in Infants and Young Children

- Temporary or prolonged, depending on the severity
- Lots of cases of crying babies who stopped crying when shaken/brain injured, put to bed and seemed OK the next day, only to be subsequently shaken again.

# Symptoms

- Lethargy, reduced consciousness, coma.
- Vomiting
- Poor feeding
- Seizures
- Apnea - rare in accidental injury. Common in abusive head injury
- Expanding head size in infants - from old and enlarging subdural hemorrhage.

# Symptoms

- Because there are many medical causes of these symptoms, infants with inflicted brain injury are often seen by MDs and diagnosed with other conditions.
- Because abuse is often progressive, many of these infants have other concurrent or previously unrecognized inflicted injuries such as bruises and fractures

- Many recorded cases of death from inflicted injury after being seen by an MD and diagnosis is missed.
- Recent study of “sentinel” injuries found that 30% of babies with inflicted brain injury had previous unreported or unrecognized injuries likely due to abuse.

# Head imaging in neurologically normal infants

Greenes and Schutzman, 1998

- ❖ Retrospective review of 101 infants < 24 months admitted with imaging evidence of intracranial injury. Imaging was done due to mechanism of injury, not clinical symptoms/signs
- ❖ 19% of the infants had no clinical signs or symptoms indicative of head injury.
- ❖ 7 subdural hemorrhages, 7 cerebral contusions, 6 epidural, 3 sub-arachnoid hemorrhages
- ❖ ICIs were occult in 14 of 52 (27%) infants younger than 6 months of age, 5 of 34 (15%) infants between 6 months and 12 months of age, and none of 15 (0%) infants 12 months of age or older

# Head imaging in neurologically normal infants

Rubin et al, 2003

- ❖ 65 children < 2 y.o. with likely inflicted injuries and a normal neurological examination. Excluded if any scalp trauma present.
- ❖ 51 (78.5%) of the 65 had head CT or MRI.
- ❖ Of these, 19 (37%) had an occult head injury
- ❖ Injuries included scalp swelling (74%), skull # (74%) and intracranial injury (53%)
- ❖ All but one head injured child was <12 months old



# Head imaging in neurologically normal infants

Laskey et al, 2004

- ❖ Patients < 48 months old assessed for maltreatment with a skeletal survey and no Hx of neurologic symptoms and normal neurologic examination.
- ❖ 51 patients identified. 38 (75%) had CT and/or MRI. 35 (69%) had ophthalmology exam
- ❖ Intracranial injury was identified in 11/38 (29%) who had head imaging.
- ❖ 8/26 (31%) of studies on infants <12 were positive compared with 3/12 (25%) for patients >12 months old
- ❖ 1/35 patients examined by ophthalmology had abnormal findings

# Head imaging in neurologically normal infants

Fickenscher et al, 2009

- ❖ 58 children <20 months with head imaging as part of a physical abuse assessment.
- ❖ At presentation, 8/31 (25.8%) children with abusive injury and 15/27 (55.6%) with accidental injury were neurologically asymptomatic.
- ❖ 6/8 (75%) neurologically asymptomatic patients with inflicted injuries had abnormal brain imaging. 13/15 (86.7%) asymptomatic patients with accidental trauma had abnormal brain imaging.

# What we came up with at our national symposium

## Suggested indications for head imaging:

- Any symptoms or signs of head injury
- Facial injury and age < 2 years
- Signs of physical abuse and age < 6 months
- Injuries that may be associated with ICI
  - Skull fracture, rib fractures, multiple fractures, CML
- History of concerning mechanism even when neurologically asymptomatic

# What we came up with at our national symposium

## Consider head imaging and use your judgment if:

Concern or injuries associated with physical abuse

**AND** age 6 months – 12 months

**AND** neurologically asymptomatic

Suspected head trauma in twin or sibling

Soft tissue injury to head in infant

## Suggest head imaging may not required if:

Concern or injuries associated with physical abuse

**AND** age > 12 months

**AND** mechanism not suggestive of ICI

**AND** no signs or symptoms of ICI

# Spinal Cord Injury

- Increasingly recognized in inflicted head trauma, especially from suspected shaking episodes.
- May be the cause of some of the apnea associated with inflicted head injury.

# Is impact required or is shaking enough?

- Some well respected researchers have questioned whether shaking alone can generate sufficient force to cause the observed abnormalities of brain injury and subdural hemorrhages +/- retinal hemorrhages.
- Much evidence supports the contention that it most certainly can.
- Impact injury can be a minor or major part of the injury mechanism but does not seem to be necessary for serious injury to occur.
- Anybody who truly disputes this should be invited to be video-recorded shaking an infant as hard as he/she can for as long as he/she can. If its so harmless, why not go ahead?

# A Perpetrator Confesses

“He was feeling frustrated. The perpetrator picked up the child such that each of his hands was under one axilla (armpit). He recalls that her feet were suspended from the floor. He described being as if he was in an altered state of consciousness. He shook the child 5–15 times over between 10 and 30 s repeated in 3 bursts separated by a very short period.

He remembers her chin coming forward and touching her chest and her head going back far enough that he could see the bottom of her chin.

On multiple questions he was absolutely certain that her head did not strike anything during the shaking.

The perpetrator also remembers her whimpering during the shaking but not crying or resisting. He said he knew that shaking was wrong when he did it but just lost control. When it was over, he felt like he “snapped out of it” and realized what he had done.”

# How much force does it take to cause Inflicted brain injury and subdural hemorrhages?

The minimum amount of force isn't known but we have a very good idea of what sorts of accidental events rarely or never cause brain injury such as falling of a bed or couch, being hit with a toy by your 3 year old brother etc.

It is an amount of force which a competent observer would clearly recognize as dangerous and likely to cause harm.



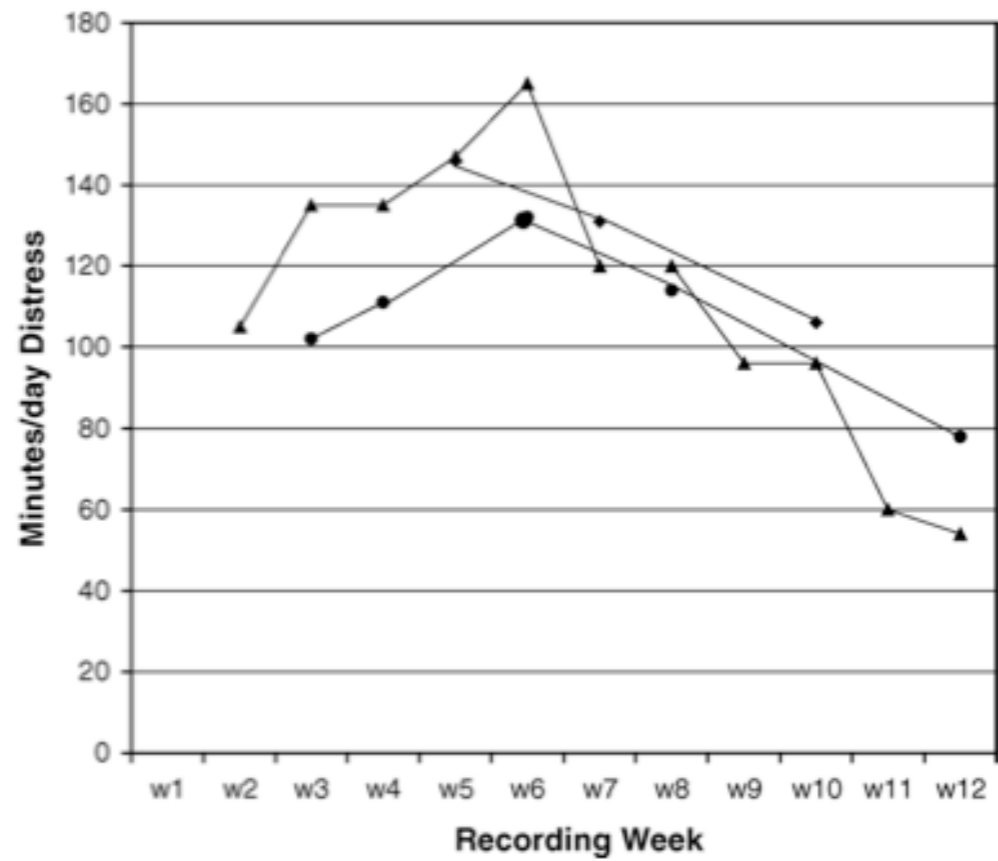
# Other injuries often seen in infants with inflicted brain trauma

- Rib fractures from forceful squeezing of the chest while shaking, throwing etc.
- Metaphyseal (growth plate) fractures of the ends of the arm and/or leg bones from flailing limbs.
- Abdominal organ trauma
- Often there are no external signs of trauma such as bruises.

# The Interesting Association with Infant Crying

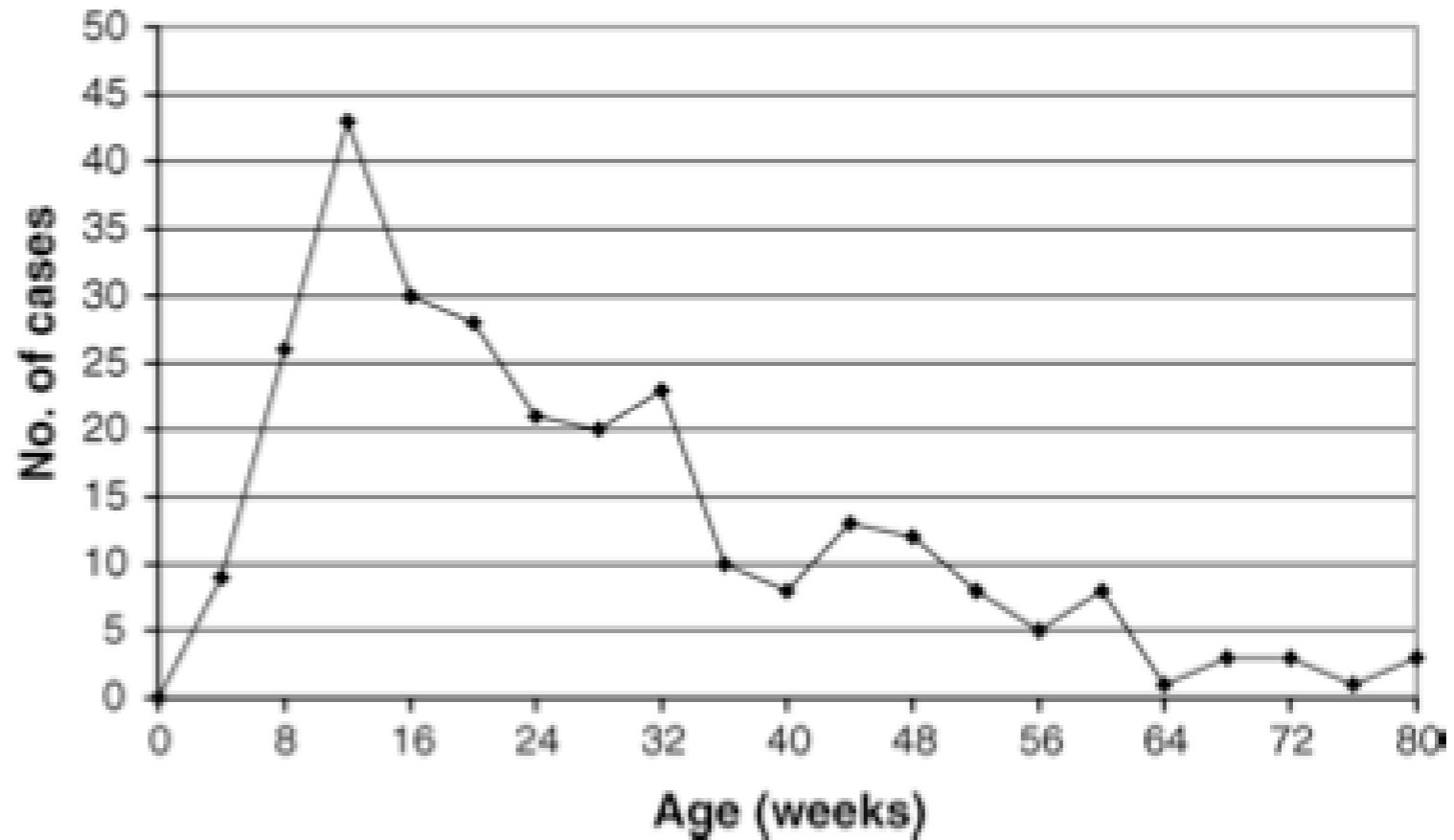
# Crying and Inflicted Brain Injury

- The peak incidence of inflicted head injury in infants mirrors the peak of the expected crying pattern in infants at about 8-10 weeks of age, otherwise known as “colic”.
- Many, many perpetrators have described “losing it” and injuring the baby when crying could not be stopped and the infant could not be soothed.
- The crying usually stops after the brain is injured.



The Crying Curve

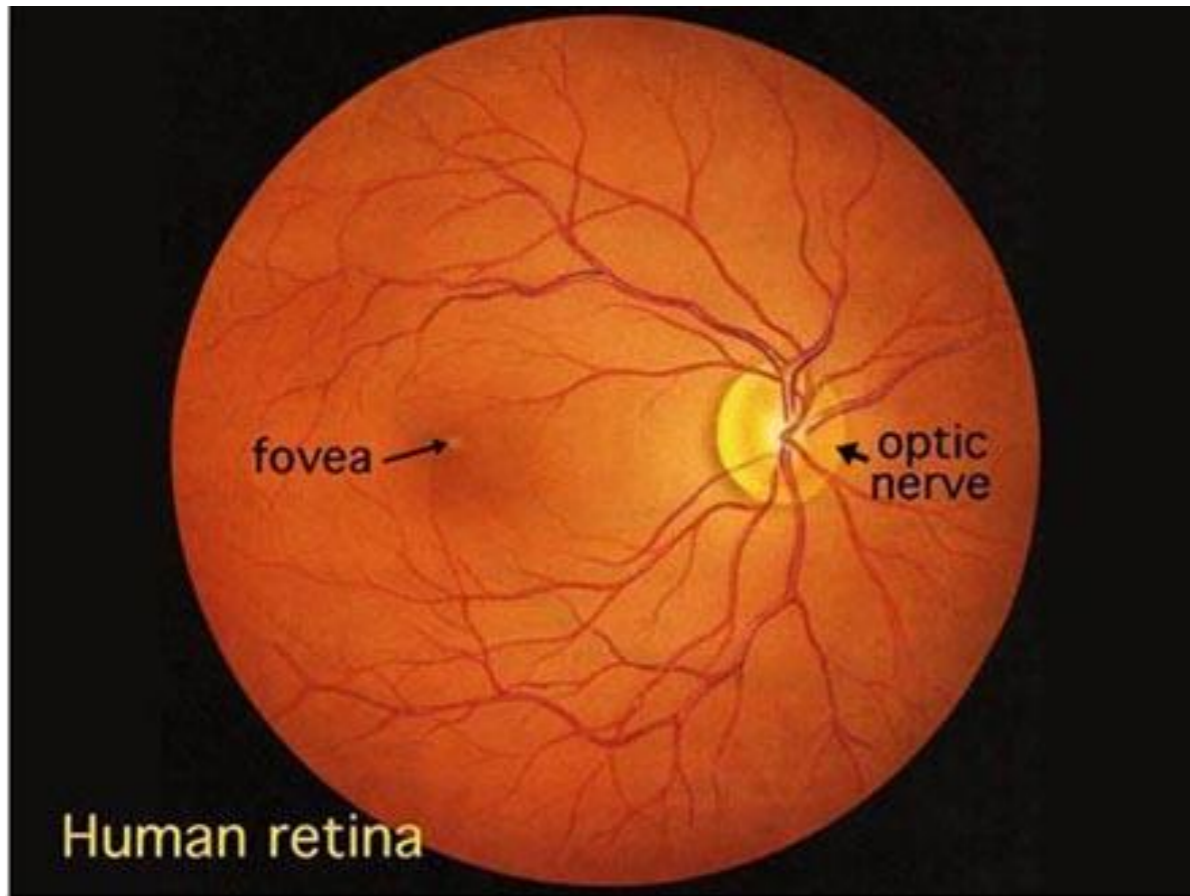
Ages of Infants Hospitalized for SBS in California (1996-2000)



# Retinal Hemorrhages

# Retinal Hemorrhages

Because the optic nerve is attached to the brain, acceleration/deceleration forces applied to the brain can be transmitted to the retina, causing damage to blood vessels in various layers of the retina.



Normal retina



Retinal hemorrhages

# Retinal Hemorrhages

- Can be caused by many different medical conditions, including minor trauma.
- Most of these conditions can be diagnosed by how the hemorrhages appear or by other symptoms the child has.
- They can begin to resolve within 12-24 hours, and continue to resolve quickly after that.



# Description of Retinal Hemorrhages

- Must include the layer in which they are seen: pre-retinal, nerve-fibre layer (flame shaped), deeper intra-retinal (dot and blot) or sub-retinal
- Number of hemorrhages, or too numerous to count
- Extent - posterior pole, equator, ora serrata
- Presence/absence of retinoschisis

# Retinal Hemorrhages

- The simple presence of any retinal hemorrhages does not imply causation by inflicted trauma.
- The extent, layers involved, number and locations, presence or absence of retinoschisis etc are all important factors.
- There are no RH findings diagnostic of inflicted injury. (Maguire et al., 2012)

# What Doesn't Cause Severe Retinal Hemorrhages?

- Hypoxia
- Raised Intracranial Pressure
- Chest compressions
- Minor trauma - although it can cause a few, scattered, posterior pole hemorrhages.

# Differential Diagnosis

Severe retinal hemorrhages, in multiple retinal layers, occurring out to the periphery of the retina have only been diagnosed in a few circumstances

- Birth - No hemorrhages visible beyond 4-6 weeks
- Leukaemia
- Severe, rollover MVC
- Crush injury to the head - ie TV falling on head
- Inflicted head injury

# When to look for them

The available evidence suggests that in a neurologically asymptomatic child with normal head imaging (or if they are too well to have had head imaging) there is virtually no chance of finding clinically relevant retinal hemorrhages. (Thackeray 2010, Greiner 2013)

**So, back to the case**

# Questions from the Case.

- What caused the DIC?
- Could DIC have caused the intracranial hemorrhage?
- Could impact with a doorknob cause a skull fracture?
- Was the cerebral edema from trauma or hypoxia or both (or something else)?
- What could have caused the retinal hemorrhages? Trauma, hypoxia, raised ICP, intracranial bleeding?

**What do you think?**



# Controversies - Real and Imagined

# Real

Much is known but much remains to be learned about this topic.

- What is the minimum amount of force needed to cause brain injury?
- How accurate is dating of blood products based on CT/MRI appearance?
- Why does landing on the back of your head seem worse than landing on another part?
- What is the role of secondary hypoxia (low oxygen) in causing brain damage?
- Lots of others - that's why we try to do good science to answer these questions.

# Imagined

- There is an entire cottage industry, especially in the US, based on raising questions about the existence of inflicted head injury in infants and children.
- Most of it is based on no actual science, misinterpretation of good science or lots of very, very bad non-science.
- A modern day version of a “Flat Earth Society”
- “Innocence” projects have taken up the issue and have succumbed to their ignorance about what is and isn’t quality scientific evidence.

# Having said that.....

We regularly come across cases which challenge our assumptions and show us unexpected possibilities.

We have to stay open minded and avoid dogmatic thinking. We must seek out dissenting opinions and honestly evaluate evidence that goes against the prevailing ideas so that we can get as close as possible to the actual truth.