Paediatric Traumatic Brain Injury: Clinical Insights and Medico-Legal Considerations

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Talk outline

1. TBI Pathophysiology
2. Infant TBI

Skull fractures, SDH, hypoxic-ischaemic injury

3. Clinical versus expert



1. TBI Pathophysiology

Children are not young adults

Diffuse injuries – younger children

Focal mass lesions – older children

Larger head mass

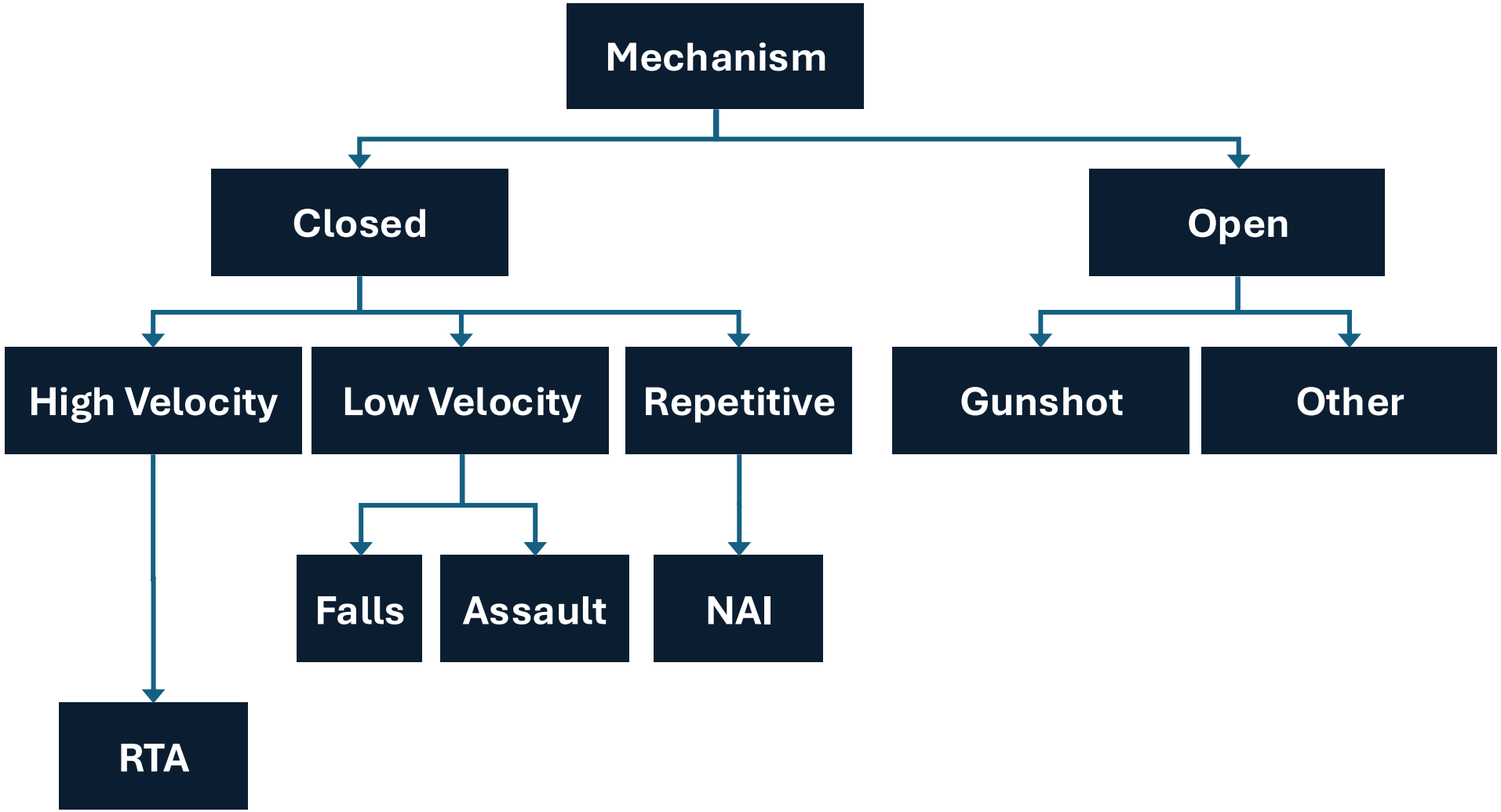
Weak cervical musculature

Pliable skull

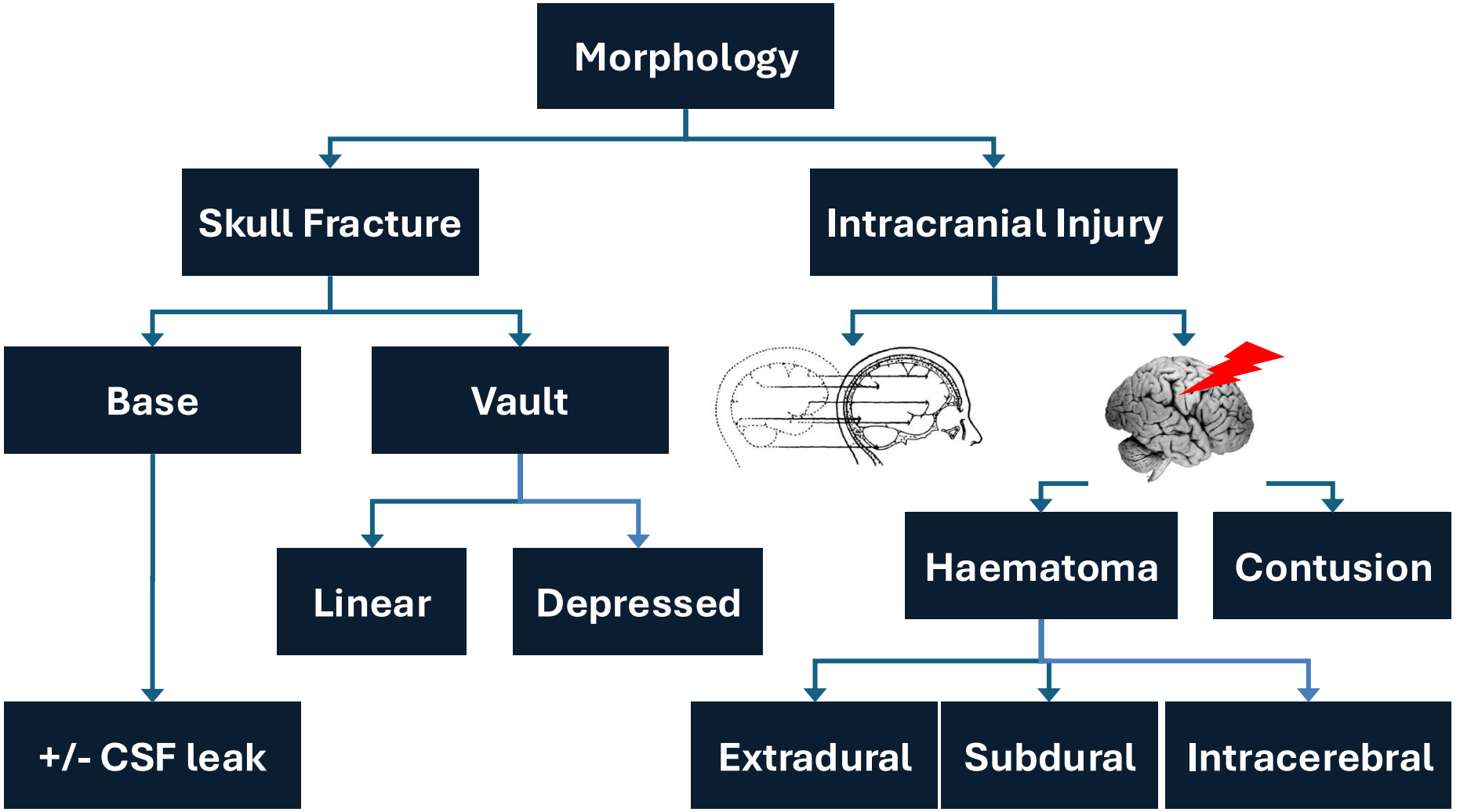
Metabolism, neurobiology



TBI is a heterogenous disease

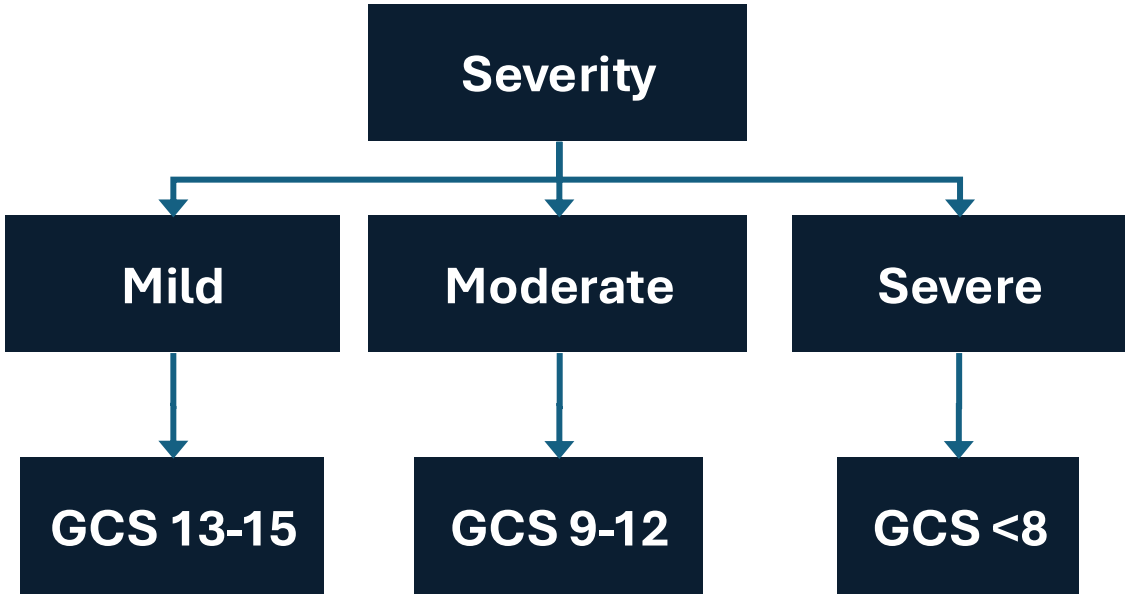


TBI is a heterogenous disease



TBI is a heterogenous disease

Feature	Score
Eyes	
Spontaneous Opening	4
Open to Speech	3
Open to Pain	2
No Response	1
Verbal	
Alert, babbles, coos, words or sentences to usual ability	5
Less than usual ability	4
Cries to pain	3
Moans to pain	2
No Response	1
Motor	
Normal spontaneous movements	6
Localising	5
Flexion	4
Abnormal Flexion	3
Extension	2
No Response	1



We can’t do anything about the primary injury.



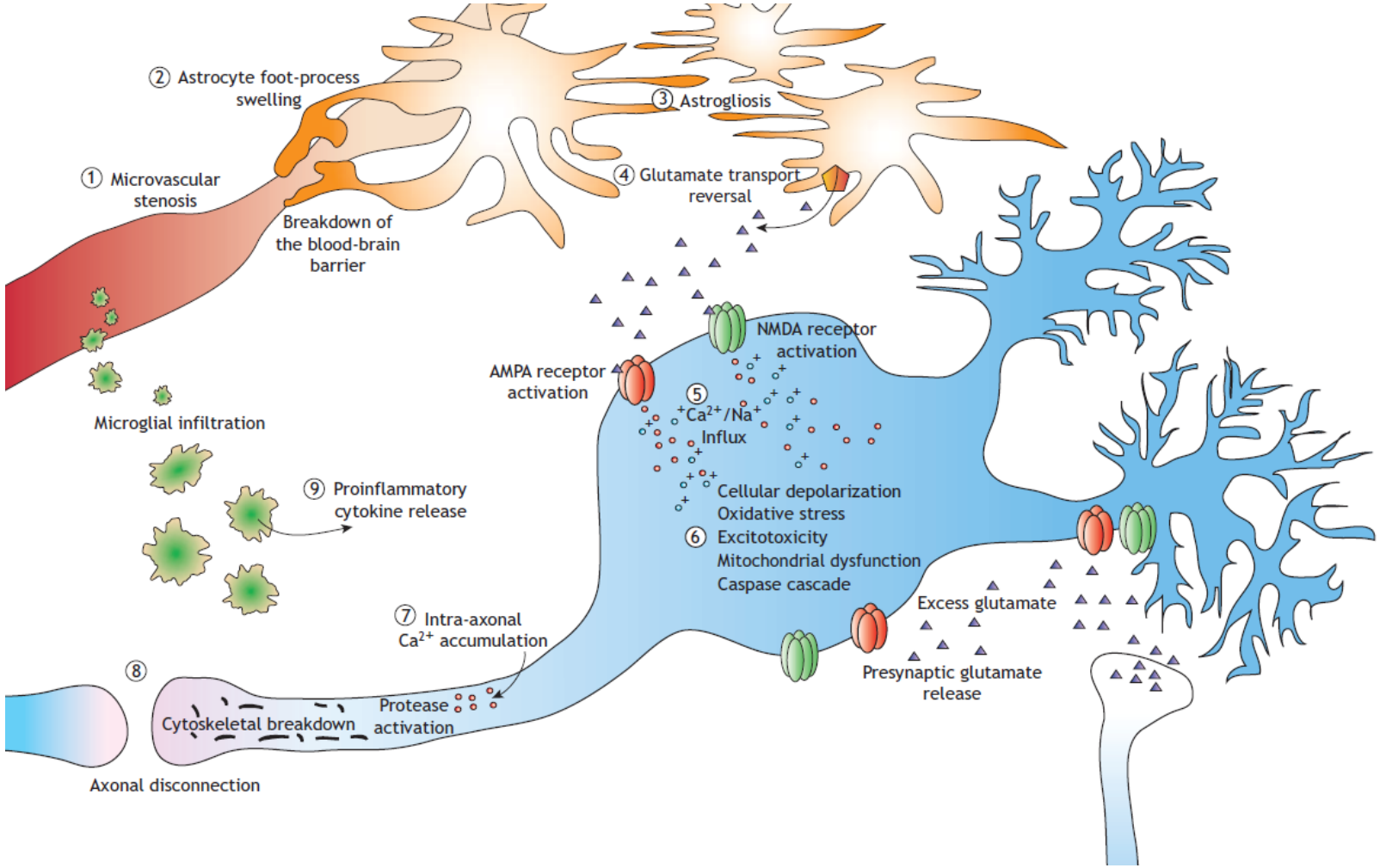
We can’t do anything about the primary injury.

- Primary Injury

- Secondary Injury
  - Raised Intracranial Pressure
  - Hypoxia
  - Hypotension
  - Hyperthermia
  - Inflammation
  - Seizures
  - Excitotoxicity

PREVENTABLE

We can’t do anything about the primary injury.



2. Infant TBI

Skull fractures are common after accidental falls

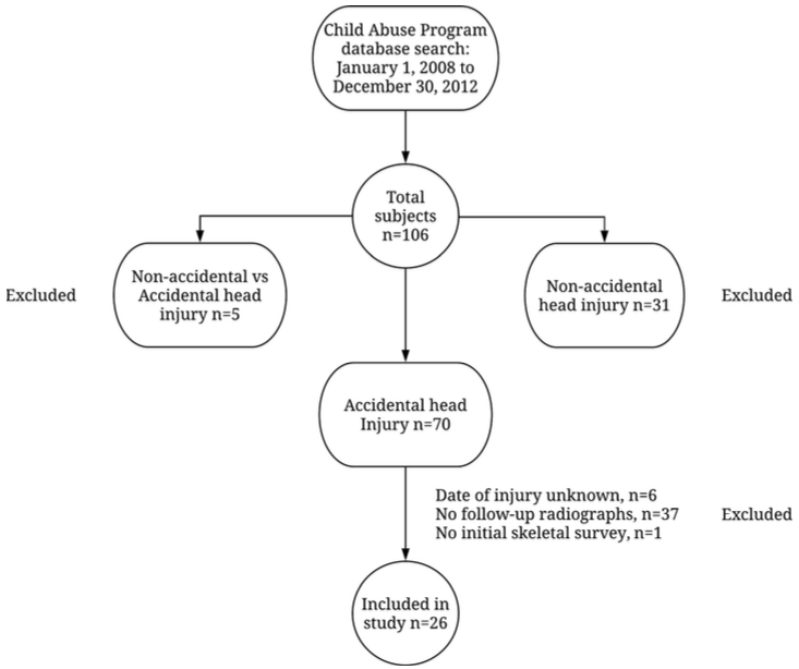


FIGURE 1. Flow chart of subject selection.

- Typical response
  - Cry/look stunned
  - Comfort easy
  - Mild ‘concussion’
  - Scalp lump

Fracture complexity does not necessarily corelate with abuse

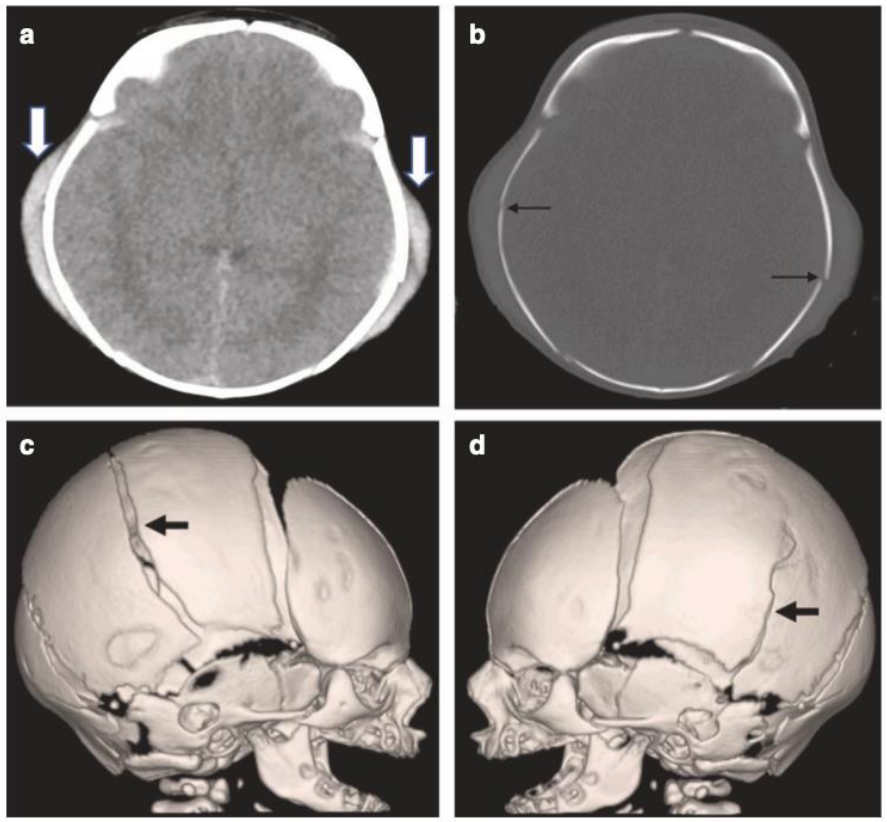
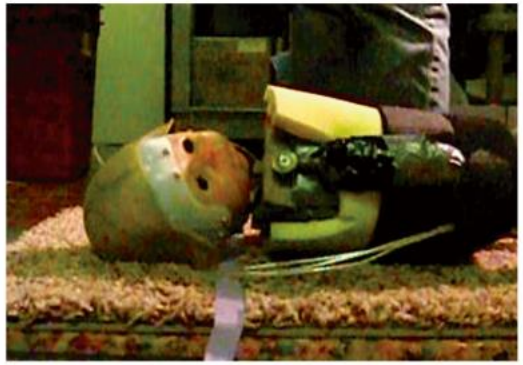


Fig. 3 **Infant who fell from caregiver's arms onto tile floor; third-degree witness.** No prior concern for head injury. STS developed bilaterally

Structural characteristics of younger infant skulls ~ more complex fractures

Threshold height to fracture skull



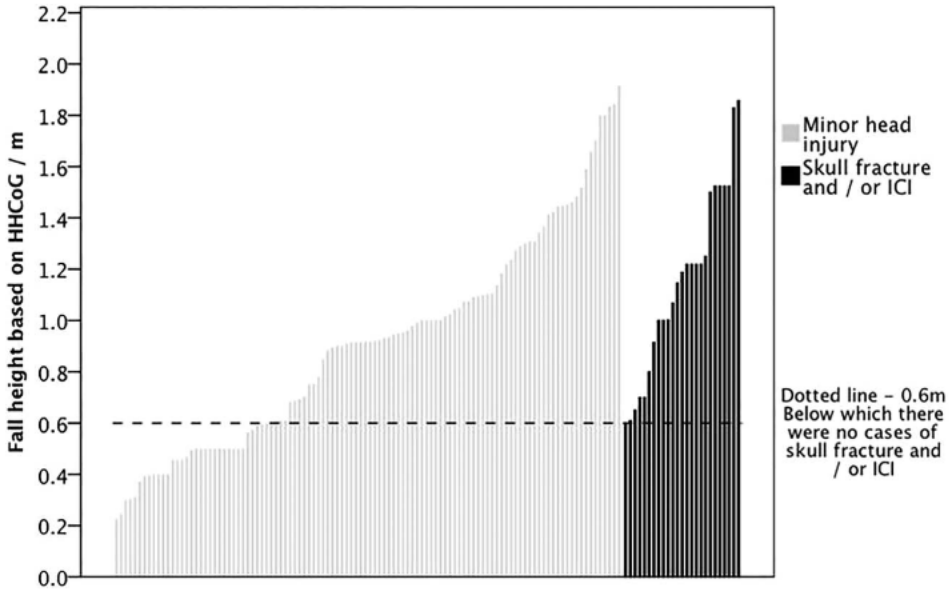




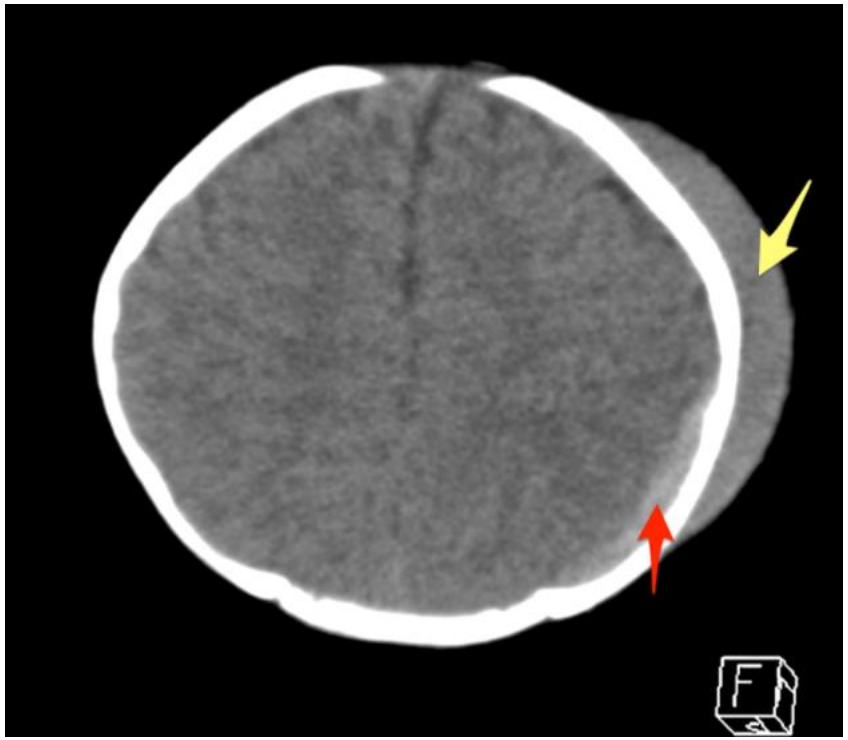


Threshold height to fracture skull

Figure 1 Height of head centre of gravity (H_{HCoG}) for minor head injury, skull fracture or ICI (intracranial injury) resulting from falls in children ≤48 months of age.



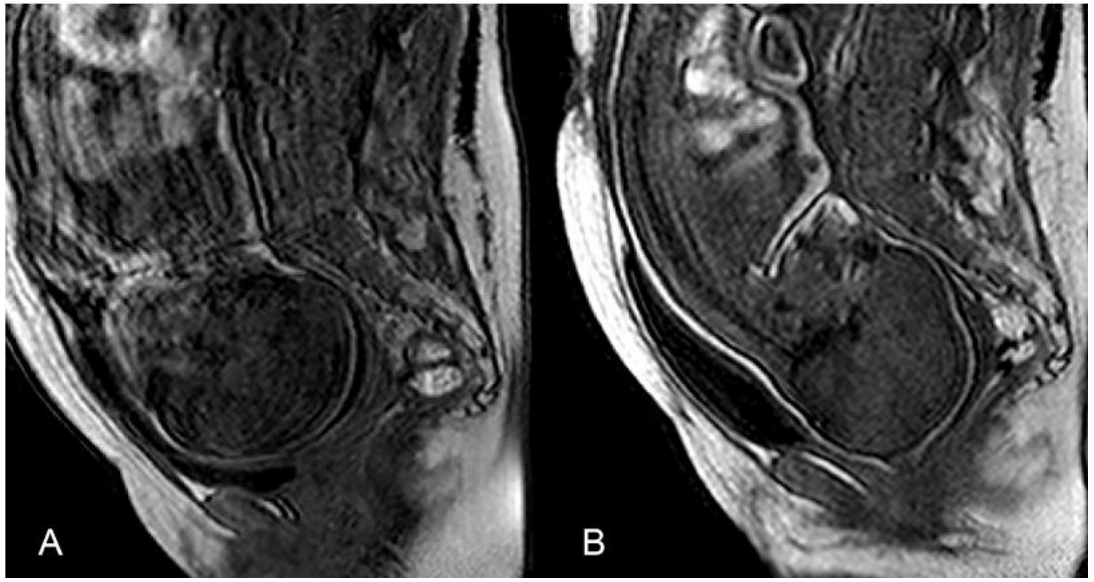
Fracture ageing

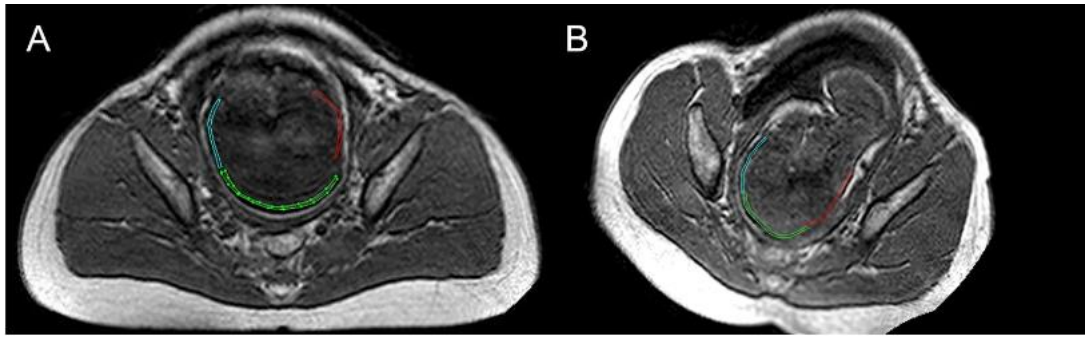


- Scalp swelling
  - Onset hrs to days
  - Lasts 2 wks
- Associated intracranial haemorrhage
  - Acute (white) blood on CT < 11d

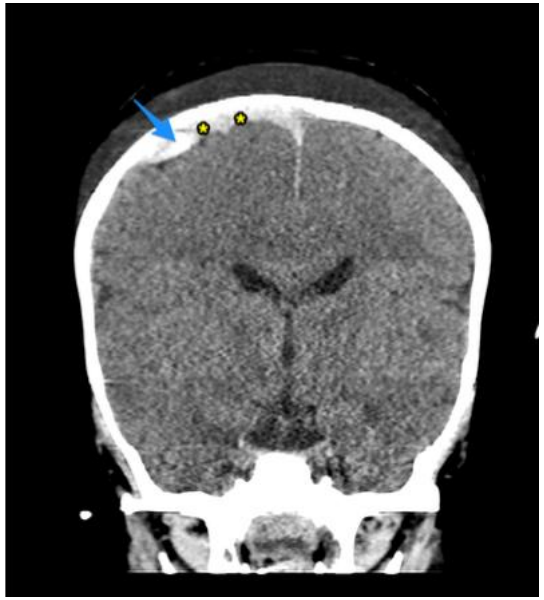
Fractures due to birth trauma

- 0.02 - 0.06 per 1000 births
- Spontaneous VD +/- forceps/vacuum
- Clinical signs at birth
  - scalp swelling, cephalohaematoma
  - Brain injury

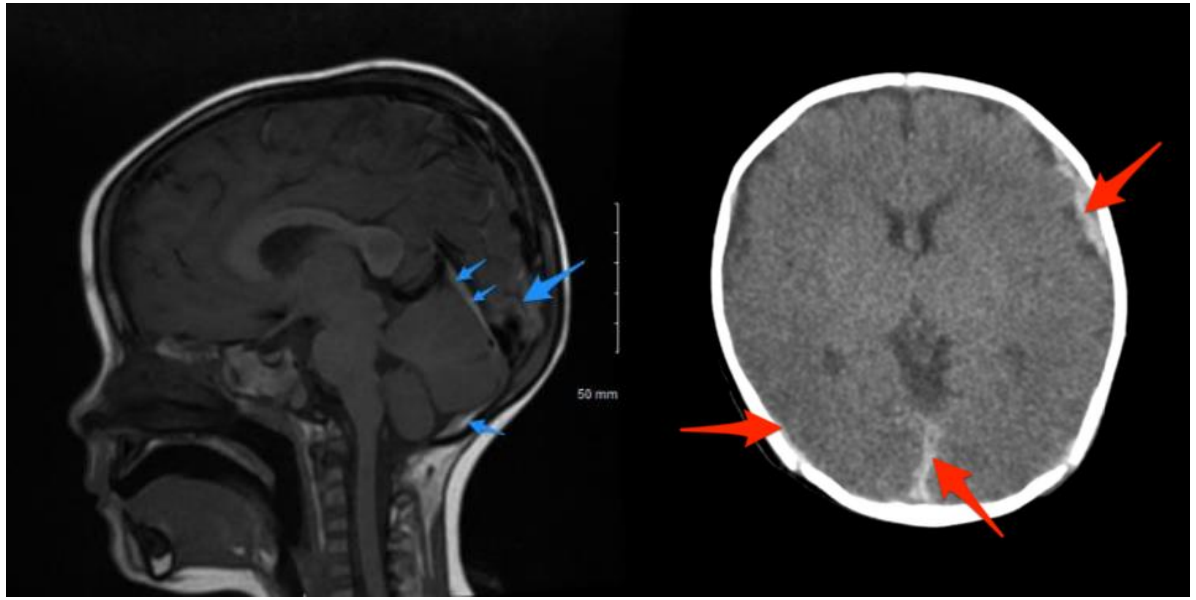




Focal versus multi-focal subdural collections

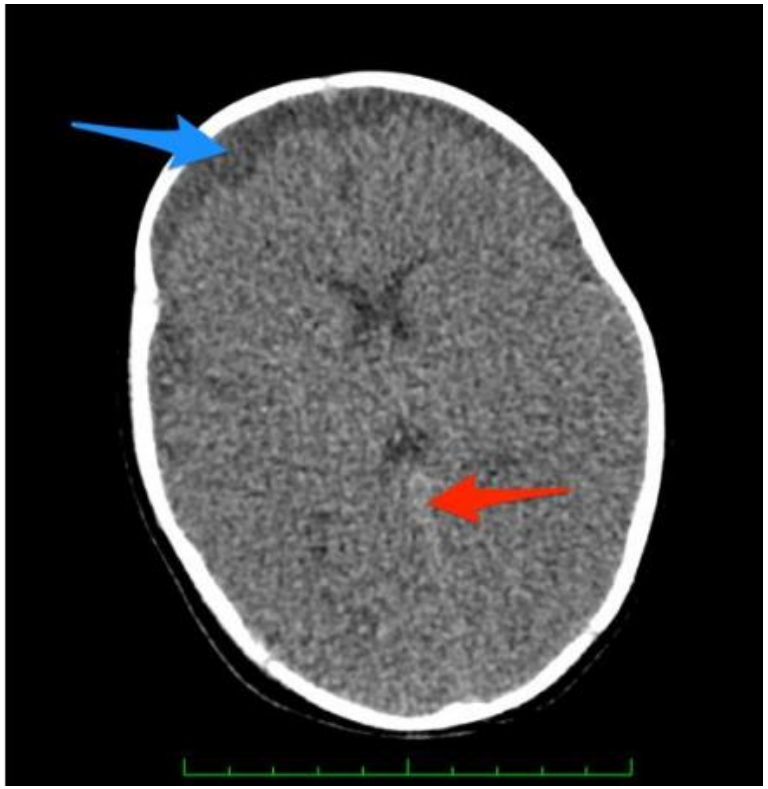


Focal
Impact



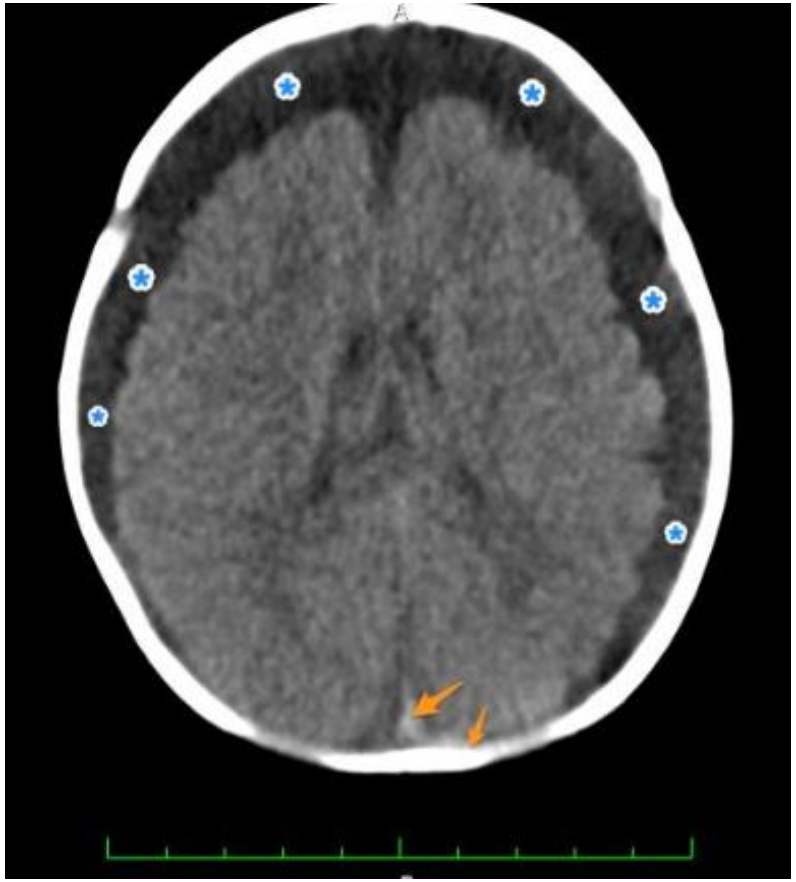
Multi-focal
Diffuse injury
Acceleration-deceleration
Shaking, car accidents

NAI subdural collections often low volume



- Interhemispheric
- Multi-focal
- Associated with hypoxic-ischaemic changes (brain swelling)

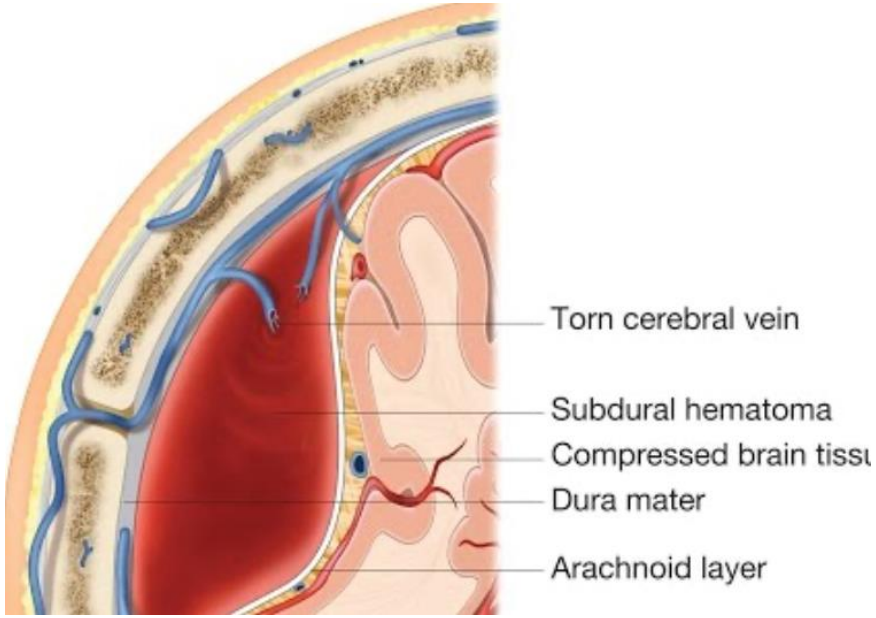
Subdural collections contain blood and CSF

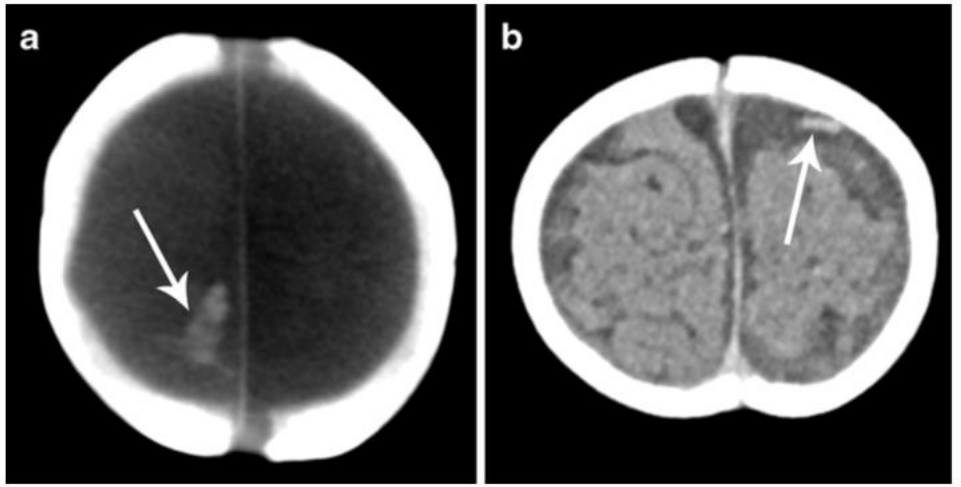


- *Subdural haematoma*
- *Subdural effusion*
- *Subdural haematohygroma*
- Subdural collection

- CSF leaks via tears in arachnoid membrane

Subdural bleeds caused by torn bridging veins





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REVIEW ARTICLE

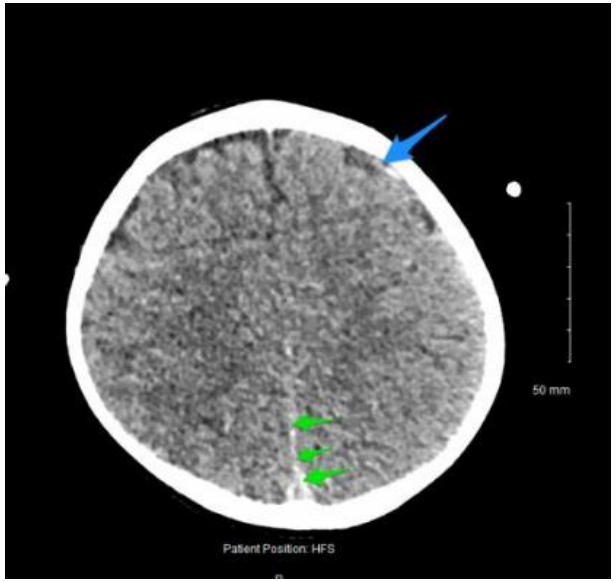
ACTA PÆDIATRICA NURTURING THE CHILD | WILEY

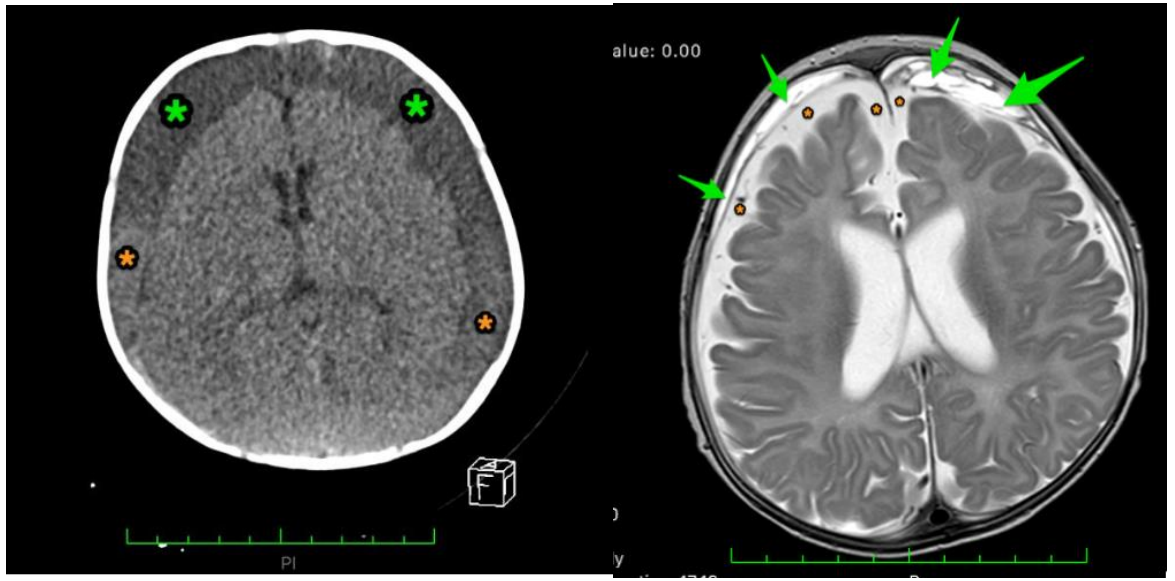
Thrombosis is not a marker of bridging vein rupture in infants with alleged abusive head trauma

Sverre Morten Zahl[1] | Julie A. Mack[2] | Cyrille Rossant[3] | Waney Squier[4] | Knut Wester[5]

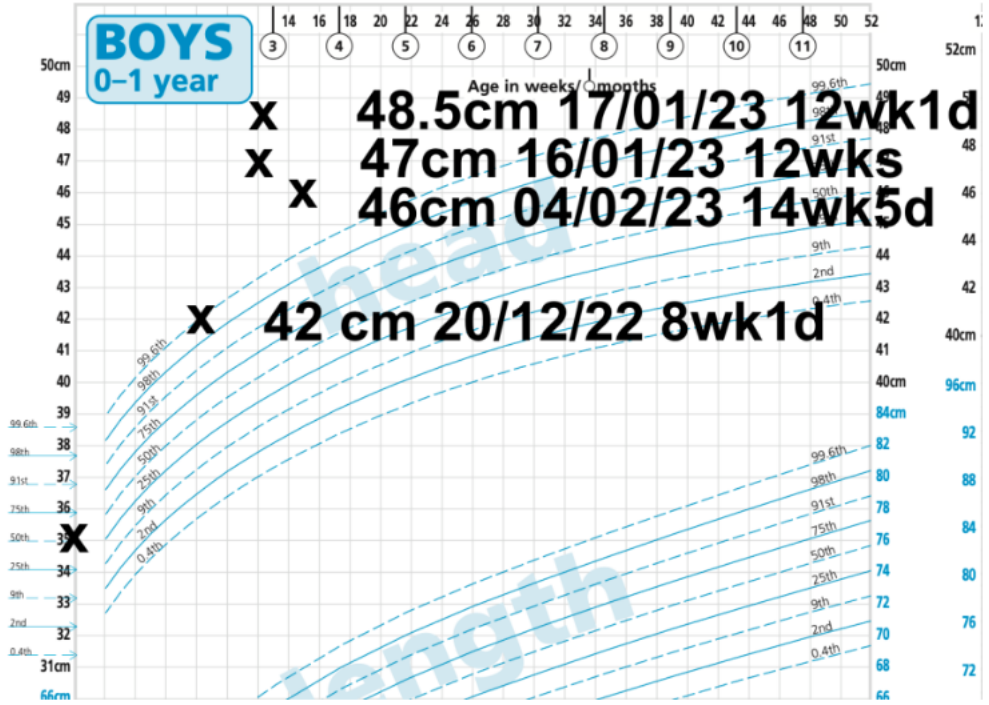
Acute versus chronic subdural collections

- Acute blood white on CT < 11d
- Chronic collections
  - Membranes > 2 weeks
  - Large volume





Head circumference sometimes the only clue







Birth-related subdural bleeds are common

Frequency and natural history of subdural haemorrhages in babies and relation to obstetric factors

E H Whitby, P D Griffiths, S Rutter, M F Smith, A Sprigg, P Ohadike, N P Davies, A S Rigby, M N Paley

ORIGINAL RESEARCH

Prevalence and Evolution of Intracranial Hemorrhage in Asymptomatic Term Infants

V.J. Rooks
J.P. Eaton
L. Ruess
G.W. Petermann
J. Keck-Wherley
R.C. Pedersen

BACKGROUND AND PURPOSE: Subdural hemorrhage (SDH) is often associated with infants experiencing nonaccidental injury (NAI). A study of the appearance and natural evolution of these birth-related hemorrhages, particularly SDH, is important in the forensic evaluation of NAI. The purpose of this study was to determine the normal incidence, size, distribution, and natural history of SDH in asymptomatic term neonates as detected by sonography (US) and MR imaging within 72 hours of birth.

MATERIALS AND METHODS: Birth history, delivery method, duration of each stage of labor, pharmaceutic augmentation, and complications during delivery as well as postnatal physical examination were recorded. Brain MR imaging and US were performed on 101 asymptomatic term infants at 3–7 days, 2 weeks, 1 month, and 3 months. Clinical follow-up at 24 months was recorded.

Radiology

Intracranial Hemorrhage in Asymptomatic Neonates: Prevalence on MR Images and Relationship to Obstetric and Neonatal Risk Factors[1]

Christopher B. Looney, BS
J. Keith Smith, MD, PhD
Lisa H. Merck, MD, MPH
Honor M. Wolfe, MD
Nancy C. Chescheir, MD
Robert M. Hamer, PhD
John H. Gilmore, MD

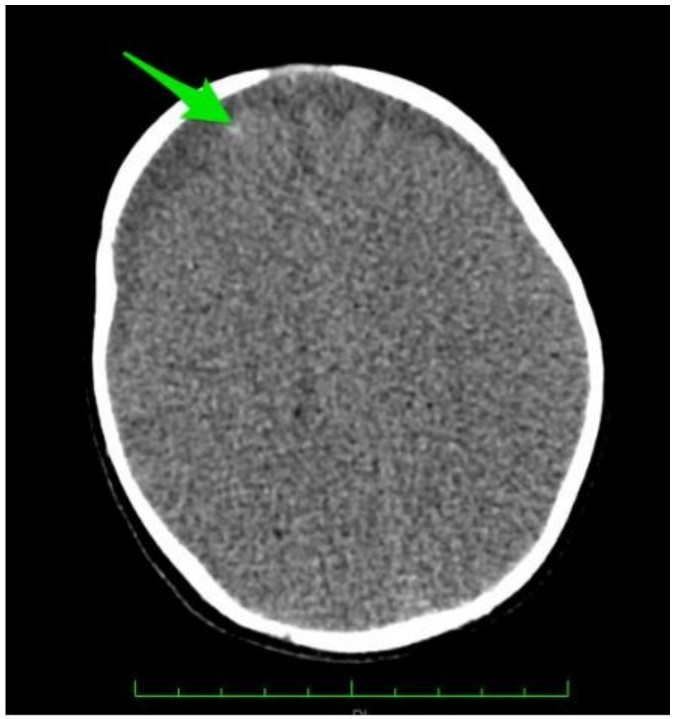
Purpose: To retrospectively evaluate the prevalence of neonatal intracranial hemorrhage (ICH) and its relationship to obstetric and neonatal risk factors.

Materials and Methods: Pregnant women were recruited for a prospective study of neonatal brain development; the study was approved by the institutional review board and complied with HIPAA regulations. After informed consent was obtained from a

Resolve by 4-6 weeks
Back of head

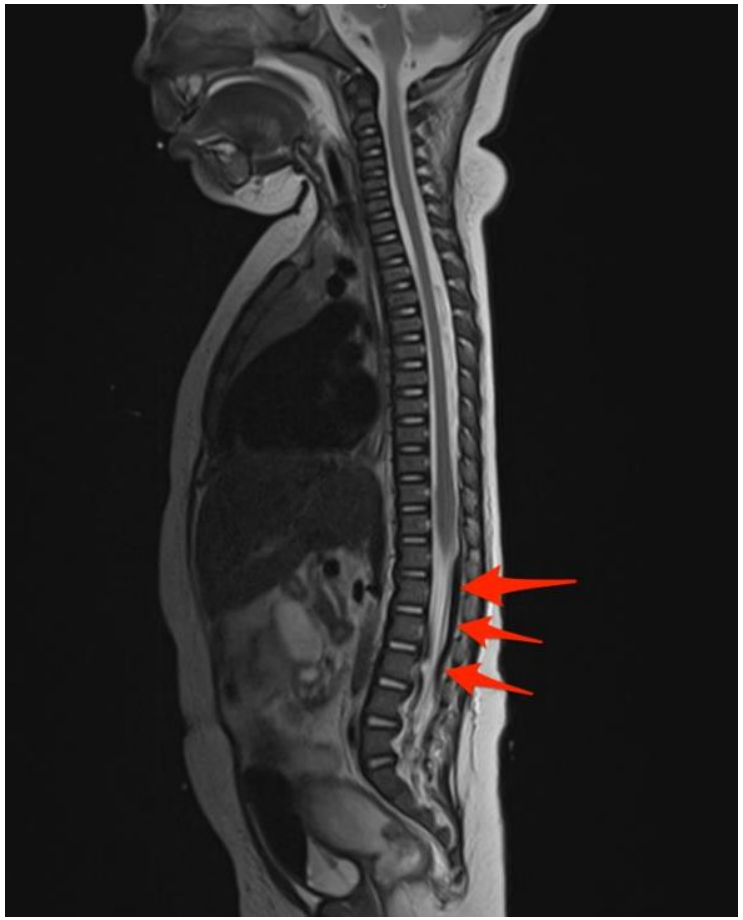
Hypoxic-ischaemic injury

- Radiology



- Clinically – encephalopathy
  - Not right
  - Irritability
  - Abnormal movements
  - Seizures
  - Limp/floppy
  - Apnoea
  - Pallor, mottled
  - Deep coma
  - Death

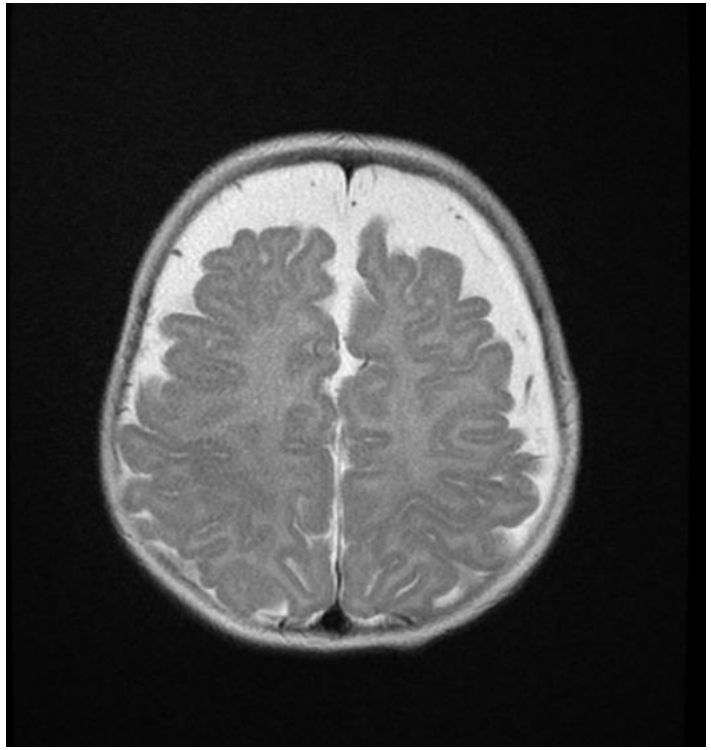
Unclear origin of spinal subdural blood



- 40-60% of infants with NAI
- More common in NAI (as far as we know)
- ?redistribution from head

BESSI is likely a risk factor for subdural collections

- BESSI
  - Enlarged extra-axial cerebrospinal fluid (CSF) spaces
  - Prematurity
  - More common in boys
  - Neuro-developmental disorders such as glutaric aciduria type 1
  - Benign course when idiopathic
  - Increased risk of SDH



3. Clinical vs legal

Infant TBI causality



Differential diagnosis

- determine the nature of a patient's illness for purposes of diagnosis and treatment



Differential aetiology

- takes the diagnosis of the patient's condition and then determine the cause

Both methods require process of elimination reasoning.

We rarely pursue the question of cause when treating patients.

Differential aetiology – working backwards

Simple skull fracture

Complex skull fracture

Focal subdural bleed

Hypoxic-ischaemic injury

Subdural collection + BESSI

Multi-focal subdural collections + interhemispheric blood + hypoxic-ischaemic injury + spine subdural

Multi-focal subdural collections + interhemispheric blood

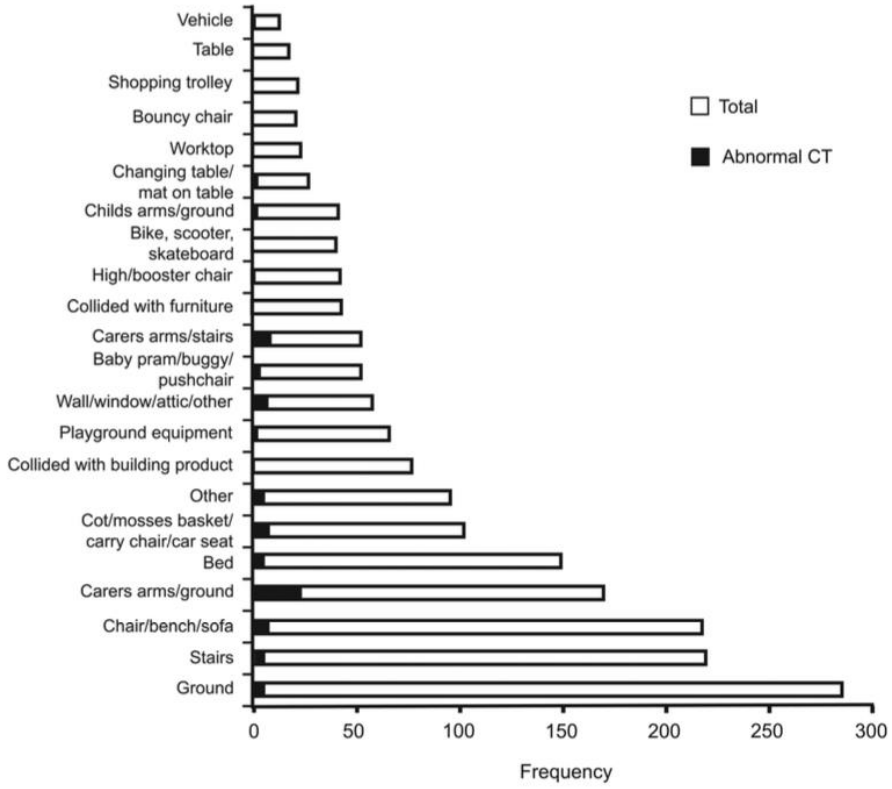


NAI

Differential diagnosis – working forwards

- Falls
  - Skull fracture
  - Focal ICH
  - (multi-focal ICH)
  - (hypoxic-ischaemic injury)
  - (death)

Figure 2 Object fallen from for 1775 children admitted to hospital with a head injury from a fall.



Burrows P, *et al*. *Arch Dis Child* 2015;**100**:1032–1037. doi:10.1136/archdischild-2014-307119

Differential diagnosis – working forwards



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DOI: 10.1002/ccr3.9105

Clinical Case Reports Open Access WILEY

CASE REPORT

26 cm fall caught on video causing subdural hemorrhages and extensive retinal hemorrhages in an 8-month-old infant

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[1]Universidad de La Laguna, Avda. Astrofísico Fco. Sánchez, La Laguna, Spain

[2]Previously Department of Neuropathology, John Radcliffe Hospital, Oxford, UK

[3]Radiology, Penn State Hershey Medical Center, Hershey, Pennsylvania, USA

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Key Clinical Message

Severe, too many to count retinal hemorrhages (RH) in infants have been associated with abusive head trauma, but can occur in short falls. An 8-month-old male fell backward from a height of 26 cm, landing on his buttocks then hitting the back of his head on a vinyl floor. The fall was videotaped. Acute subdural hemorrhages were found along with extensive, too many to count intra-RH in both eyes. Falls from small heights on to the occiput can lead to extensive RH of the type often associated with abusive head trauma.

KEYWORDS

abusive head trauma, retinal hemorrhages, shaken baby syndrome, short falls

Differential diagnosis – working forwards

- Clinically – encephalopathy
  - Not right
  - Irritability
  - Abnormal movements
  - Seizures
  - Limp/floppy
  - Apnoea
  - Pallor, mottled
  - Deep coma
  - Death



Differential diagnosis – working forwards

- BRUE
  - apparent life-threatening event (ALTE)
  - Brief resolved unexplained event (BRUE)

- a brief (< 1 min) episode characterized by one or more of the following:
  - cyanosis or pallor,
  - change in muscle tone (increased or decreased),
  - change in responsiveness,
  - absent, irregular, or decreased breathing

Differential diagnosis – working forwards

- BRUE
  - apparent life-threatening event (ALTE)
  - Brief resolved unexplained event (BRUE)
- HIE e.g. choking does not cause significant SDH
- ?resuscitative shakes

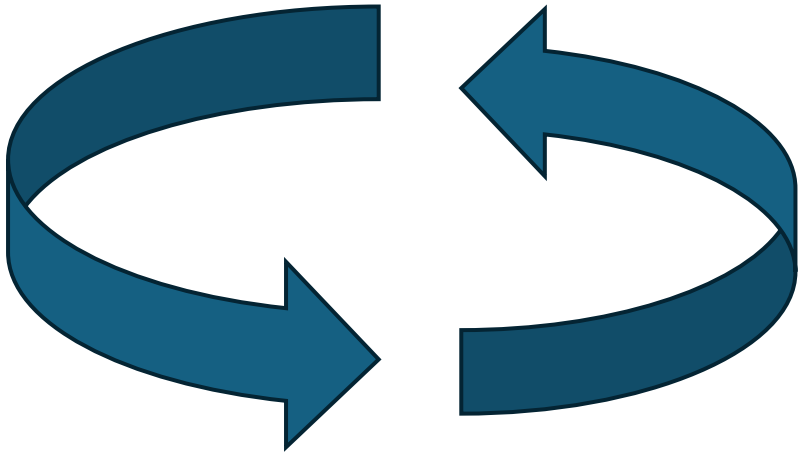
Challenges in determining cause from the medical evidence alone

NAI ⟷ ACCIDENT

Multifocal SDH

Population level statistics – shaking much more likely

History of plausible household fall but rare outcome of such a fall



Challenges in determining cause from the medical evidence alone

- Rare versus improbable

- Childhood brain tumours
- Annual incidence 40 per million
- 1 in 25,000

Summary

- Infants have large heads and weak necks – vulnerable to brain injury.
- Skull fractures common after accidental falls at home.
- Multifocal SDH surrogate marker of diffuse brain injury.
- Encephalopathy reflects multitude of mechanisms occurring at the microscopic level.
- Degree of hypoxic-ischaemic injury important determinant of outcome

Summary

- Limits of medical evidence. Never say never.
- Medically unknown remains in the differential.

