Abusive head trauma – mechanisms, myths and mysteries

Jo Tully
VFPMS seminar 2019
HISTORY

1860
Ambroise Tardieu
French physician
Medical, psychiatric, social and demographic features of child abuse as a syndrome

1946 Dr Caffey
Paediatrician/Radiologist
SDH and long bone fractures inconsistent with accidental cause (also noted retinal haemorrhages)

1953 Silverman
Multiple fractures from intentional trauma not organic disease

1962 Dr Kempe
Paediatrician
‘Battered child syndrome’

1971
Dr Normal Guthkelch
Paed neurosurg
UK
‘Infant shaken whiplash syndrome’

1972-1974
Caffey
Parent infant traumatic stress
‘Infant shaken head trauma’

2009
American Academy of Paediatrics
‘Abusive head trauma’

On the Theory and Practice of Shaking Infants
Its Potential Residual Effects of Permanent Brain Damage and Mental Retardation
John Caffey, MD, Pittsburgh

In the first modern discussion in 1946 of the parent-infant stress syndrome (PIDS), or battered baby syndrome, I described six infants, 18 months or younger, who suffered from the coalescence of subdural hematomas and characteristic bone lesions. During the last 25 years, substantial evidence, both manifest and circumstantial, has gradually accumulated which suggests that the whiplash-shaking and jerking of abused infants is common cause of the subdural as well as the cerebrovascular lesion; the latter is the most serious acute complication and by far the most common cause of early death.

Today we invite your attention to a world leader in child and adolescent health.
The spectrum of abusive head trauma

A well-recognized constellation of brain injuries caused by the directed application of force to an infant or young child, resulting in physical injury to the head and/or its contents.

- **Impact alone** – throwing, slamming, punching – contact injuries
  - All children although younger predominate
  - Injury to brain, skull fractures, facial or scalp injury

- **Shaking (+/- impact)** – the “shaken baby syndrome”
  - Inertial forces +/- contact
  - Classically infants under 12 months
  - Recognisable pattern of SDH, RH and encephalopathy
  - May have other associated injuries – rib and metaphyseal fractures (30-70%), bruising (<50%), spinal injury

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What this talk is NOT.....

Short falls and direct impact trauma

• Single event
• Can kill (but very, very rarely!!!)
• Almost always result in minimal to no injury
• Very rarely cause intracranial injury
• Sometimes result in scalp injury, skull fracture
  • single linear parietal bone
• Focal SDH and brain contusion
• EDH and “lucid interval”
• Rarely retinal haemorrhages – occipital impact?
What happens when you shake a baby?
Important anatomy

Meninges – subdural space
Bridging veins
- travel up from surface of the cerebrum
- pass through subdural space to sagittal sinus
- Sagittal sinus fixed to inside surface of the skull
AHT – mechanisms

- Acceleration - deceleration / rotational forces
- Impact – direct forces
- Combination of impact and acceleration-deceleration

Forces act on...
- Scalp
- Skull
- Spaces / CSF
- Meninges
- Brain
- Ventricles
- Brainstem / tentorium
- Spine
• Scalp injury, face/neck bruising
• Skull #
• Increasing HC
• ICH – classically SDH
• DAI
• Cerebral oedema
• C-spine fracture – rare
• Cervical ligamentous injury
• Spinal cord injury/SDH
• Rib/long bone fractures
• Retinal haemorrhages
Clinical features – modes of presentation

• **Acute encephalopathy** - severe shake, catastrophic event, sudden collapse, apnoea, arrest = VERY close in time to collapse

• **Sub-acute encephalopathy** – increasing brain swelling, NOT 100% OK after the shake (symptoms might be subtle)

• **Sub-acute non-encephalopathy** – fractures, bruising

• **Chronic** – increasing HC & raised ICP

• Irritability
• Poor feeding
• Vomiting
• Lethargy
• Resp. compromise
• Seizures
• Apnoea
• Delayed development
How common is the problem?

- Likely to be a significant **underestimate**
- USA data
  - About 1200 infants injured, up to 5 deaths per day due to IHT…?
- Australian data
  - Up to 29/100,000 infants under 2 years vs 22/100,000 for cancer
  - About 65 cases of IHT per year nationwide..?
  - 22 Australian children killed by carers vs 32 children dying from medical conditions (2016)
- **Unseen, unreported or unknown** - these are the ones we know about…………………
- Sentinel injuries/previous presentation
  - *Jenny et al 1999* < 1 in 5 cases recognised if;
    - Normal respiration
    - No seizures
    - No skin injuries
    - Caucasian family with 2 parents
    - 30% cases “missed”
- Recent systemic review Maguire et.al APNOEA important discriminator
How many are we missing and why are we missing them?

• How many might be below the water? ……Denver study
• 31% cases presenting to hospital were “missed”
• 1 in 3 of these go on to be re-injured
• 4 out of 5 deaths might have been prevented

Why are we missing them?
• Vague/non-specific symptoms
• No story from carers or child
• Other stories – parental shifting of blame
• Clinicians unwilling to believe

30 per 100,000 under 2 years

???? – American data suggests 150 for every 1 presenting…
Why shake a baby? -the who, when, what and why? – confessional data  
*Adamsbaum 2012 paediatrics*

- **Why?**
  - Quietens the baby
- **Who?**
  - 45% father/step-father, 27% mother, 21% child minder - predominantly men although greater strength = greater recognition
- **When?**
  - 62% because it stopped the crying
- **What?**
  - 100% reported extremely violent shaking
  - In 55% it was repeated 2-30 times (mean 10), some daily
  - Impact in 24%
- **Aware of plea bargaining and false confessions BUT for all to be systematic lies defies logic**

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“I shook her so she’d be quiet, it lasted maybe 5 minutes; I was exasperated; I shook her up and down, in front of me, without holding her against me; I was shaking her hard; I was crying just like she was”

“I shake him almost every day when I’m watching him; I can’t tell you how many times”

“He was crying, it drove me crazy, I shook him…maybe 10 times and threw him on the sofa”
The challenges facing clinicians

- Majority of cases are young and non verbal
- Family/clinicians unwilling to consider abuse
- Are the findings a result of trauma or a medical condition?
  - Medical conditions can be confused with abuse
  - Always consider alternative possibilities
  - With AHT this is a VERY important aspect of care
- If trauma, abuse, neglect or accidental
- If trauma, What type, size, direction of mechanical force?
- Legal controversies over cause/entity
The approach........

• Detailed history surrounding
  • Presenting complaint
  • Trauma history
  • Psychosocial history

• Physical examination

• Other causes for presentation can usually be eliminated through detailed Hx, exam, sub-speciality consults, lab investigations and radiological imaging
INTRACRANIAL HAEMORRHAGE
Subdural haemorrhages – medical causes

- Bleeding diathesis eg Fx 13 deficiency
- Medical conditions
  - Glutaric Aciduria Type 1
  - Scurvy
  - Menkes kinky hair
- Congenital malformations
- Infectious eg meningitis
- Role of genetic disease eg Ehlers Danlos

MUST consider

- Location/distribution
- Story provided
- Appropriate lab tests/consults
- Radiology
- What else could have produced these findings?
Subdural haemorrhages – traumatic causes

Birth related
- Common
- All modes > vaginal - ?oxytocin
- Resolve by 4 weeks
- Located posteriorly
- Asymptomatic

Inflicted
- Thin films, multiple, mixed density (OR 6)
- Interhemispheric, parafalcine (OR 9.5)
- Over convexities (OR 4.9)
- Along tentorium
- In posterior fossa (OR 2.5)

Accidental
- Localised, unilateral
- May cause mass effect
- Less likely to cause loss of consciousness, focal parenchymal injury
- Extradural > accidental

Neuroimaging; what neuroradiological features distinguish abusive from non-abusive head trauma? Kemp 2011
RETINAL HAEMORRHAGES

Cardinal feature of AHT, found in 85% of infants
Retinal anatomy

- Retina has 10 layers
- RH’s appear different depending on location within layers – preretinal, intraretinal or subretinal
Pathophysiology

- Evidence supports acceleration-deceleration/rotational forces – shearing stress and asynchronous movements at vitreo-retinal interface “vitreous traction” and of globe within orbit
General characteristics

- In AHT characterized by acceleration-deceleration +/- blunt impact, incidence about 85%
- More common in fatal AHT compared to non-fatal
- Much less common in impact head trauma
- More common in abusive HT than accidental HT (0-3% unless very severe eg MVA when may approach 20%)

Evaluation

• By ophthalmologist – preferably within 24hrs and no later than 72hrs
• Detailed descriptive note/photos of pattern, number, extent and type
• Pre-retinal – obscure vessels
• Superficial RH’s in nerve fibre layer – flame or splinter shaped
• Deeper RH’s – dot or blot
• Vitreous haemorrhages, retinoschisis, retinal folds
AHT or not? - Pattern, type, extent and distribution......

- Specificity of RH for AHT depends on number, extent and pattern
  - Too numerous to count
  - Multilayered
  - Extending to oro serrata
  - Retinal folds, retinoschisis
- Unilateral (3%) and asymmetric (20%)
- Absence of RH’s and RH’s around posterior pole does not exclude AHT
- Correlation between RH severity and presence of HI brain injury
  - RH’s do not occur in other conditions causing hypoxia
  - RH’s occur in AHT without HI injury
Are retinal haemorrhages only caused by abuse? Are they “pathognomic”? NO!

<table>
<thead>
<tr>
<th>Injury/condition</th>
<th>Discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidental trauma</td>
<td>PP, intra and pre, very rare after short falls except occipital impact</td>
</tr>
<tr>
<td>MVA, crush</td>
<td>Hx</td>
</tr>
<tr>
<td>CPR</td>
<td>Extremely rare, few, PP</td>
</tr>
<tr>
<td>ECMO</td>
<td>13% of pts, Hx</td>
</tr>
<tr>
<td>Prematurity</td>
<td>At demarcation of vascularised and avascular retina</td>
</tr>
<tr>
<td>Raised ICP</td>
<td>Small number on or around optic disc</td>
</tr>
<tr>
<td>Medical</td>
<td>Leukaemia - + white infiltrates Coagulopathy/anemia – rare, few, PP Vasculitis Meningitis, sepsis, endocarditis – rare, few, PP CMV – necrotic retinitis Menkes, Glutaric aciduria, galactosaemia – rare, PP CO poisoning</td>
</tr>
<tr>
<td>Ruptured aneurysm/AV malformation</td>
<td>severe, extensive</td>
</tr>
</tbody>
</table>
Multilayered...
Retinoschisis and retinal folds

- Retinal folds
  - Pleats in retina as result of vitreo-retinal traction
  - Circular haemorrhagic or hypopigmented ridges
  - Usually around macula
  - 3% of AHT, approx 40% in severe AHT

- Retinoschisis
  - Splitting of retina layers, usually ILM
  - Blood-filled cavity

- Specific for AHT unless crush HI, fatal MVA, fall greater than 10m
Birth-related RH’s can be tricky…..

- Birth
  - 25% by SVD, 42% vacuum, 52% forceps and vacuum, 6% in LSCS
  - Head compression/PG surge
  - usually bilateral, mostly intraretinal, posterior pole
  - may be severe & extensive
  - majority resolve within 10 days, may persist up to 58 days
  - persist if deeper intraretinal
  - No folds or retinoschisis
  - Multiple/numerous IRH’s in infant older than 4 weeks are not birth-related (Binenbaum 2016)
  - Babies with IRH within 1st month may be difficult to distinguish from AHT

Watts 2013
Other causes

- Almost all can be distinguished by Hx, clinical, laboratory and radiology
- Characteristic pattern only described in
  - MVA/crush/fall from great height
  - Severe coagulopathy
  - Leukaemia
  - Sepsis
Timing - *Binenbaum 2016*

- Children < 2 yrs of age
- Intra-retinal cleared faster than pre-retinal
- TNTC were only present at initial exam and not at F/U
- At 1 week all eyes had 0 or few IRH’s
- Latest an isolated IRH persisted was 32 days
- Latest an isolated PRH persisted was 111 days.
- No RH’s progressed or increased in number.
- If TNTC IRH’s – within few days and less than a week
Forming an opinion on RH’s

Ophthalmic concerns in abusive head trauma Levin 2016

• Multilayered, numerous (AHT, severe MVA/crush injury, falls > 10m)
• Uncommon in accidents – unilateral, posterior pole, few in number
• Do not occur with coughing, vomiting, seizures
• Common after birth (esp instrumentation) – majority resolve by 10 days (up to 2 months). If early IRH may be tricky.
• Usually easily exclude other causes (cannot be confused)
• Other causes (raised ICP, hypertension, resuscitation)
  • Scattered around posterior pole, intraretinal
  • Not same distribution as AHT
SPINAL INJURY IN ABUSIVE HEAD TRAUMA
What about spinal injuries?

- Recent studies have suggested that spinal injuries may be more common than previously thought.
- Ligamentous injury, spinal extra-axial haem, vertebral body subluxations or #, spinal cord injury.
- All types of injury more common in AHT than accidental.

Spinal injury should be looked for

- Under-reported and under appreciated
- *Choudhary 2014* – Cervical ligamentous injury
  - 78% of AHT group
  - 46% accidental group
  - Spinal SDH/ligamentous injury to neck highly associated with AHT
- Imaging of the spine should be part of AHT evaluation – can be highly informative…..
The controversies – what the defense make of AHT

Does SBS exist?
Can only shaking injure an infant’s brain?
Are the SDH’s and RH’s caused by trauma if there is no other objective evidence?
Why is the neck not damaged?

“The battlelines drawn as shaken baby syndrome controversy set to run”

“Dangerous Vaccines Found to Cause Symptoms of Shaken Baby Syndrome”

“Battlelines drawn as shaken baby syndrome controversy set to run”

“The Boston Globe”
The controversy continues…..

• 2003 - Geddes: “unified hypothesis” pathogenesis of SDH +RH was hypoxic ischaemic damage not trauma
  • “only ever meant to be a theory”
• Dr Waney Squier – need impact
  • Struck off the medical register for misleading the courts
• Biomechanical studies
• The Swedish study
• Confession statements – are they all systematically lying
• Consensus statement

Squier W, Adams L.B. The triad of retinal haemorrhage, subdural haemorrhage and encephalopathy in an infant associated with evidence of physical injury is not the result of shaking, but is most likely to have been caused by a natural disease J. Prim Health Care 2011:3(2)159-163
Neutral Citation Number: [2016] EWHC 2739 (Admin)

IN THE HIGH COURT OF JUSTICE
QUEEN'S BENCH DIVISION
ADMINISTRATIVE COURT

Case No: CO/2061/2016

Royal Courts of Justice
Strand, London, WC2A 2LL

Date: 03/11/2016

Before:

MR JUSTICE MITTING

Between:

DR WANEY MARIAN VALERIE SQUIER
and
GENERAL MEDICAL COUNCIL

Appellant

Respondent

SIR ROBERT FRANCIS QC AND MISS CLODAGH BRADLEY QC
(instructed by RadcliffesLeBrasseur) for the Appellant
MR TOM KARK QC AND MISS ALEXANDRA FELIX
(instructed by The General Medical Council) for the Respondent

Hearing dates: 17, 18, 19, 20 & 21 October 2016

Approved Judgment
Alternative theories – the defense

• Healthy infants die because a birth related SDH re-bleeds spontaneously or with minimal trauma?
• SDH are caused by episodes of hypoxia?
• SDH can be the result of venous sinus thrombosis?
• SDH are caused by immunisations?
• The signs/Sx of AHT can be caused by benign extra-axial fluid of infancy?
• Short falls can cause signs/Sx of AHT? *(Plunkett)*
• Biomechanical studies have proven that shaking cannot cause serious head injury?

RESPONDING TO THE ALTERNATIVE THEORIES
Healthy infants die because a birth-related SDH re-bleeds spontaneously or with minimal trauma?

• Birth-related SDH happen - resolve by 4 weeks (1 case - 3 months)
• Re-bleeds happen – seen after neurosurgery BUT
  • Incidental finding
  • Small in size
  • Usually asymptomatic and not clinically catastrophic
  • From area of previous haemorrhage (not new area)
  • May result in slowly increasing HC..?
SDH are caused by episodes of hypoxia?

• Geddes et al. PM examination of dura of 53 babies
  • 50 natural deaths, 3 AHT deaths
  • Retina not examined in 50 non-trauma deaths
• Barnes 2007 – case report on 1 infant, sudden collapse/died, choked on formula
  • hired gun
  • Didn’t care for child, report Hx, report other injuries present
  • successful conviction
• Byard - Confirmed hypoxia – imaged – SDH not seen
The signs/Sx of AHT can be caused by benign extra-axial fluid of infancy?

- Common, infants unusually large heads
- Immature balance between CSF prod and absorp → expansion CSF within subarachnoid space
- Resolves 1-2 years – no obvious consequences
- Can this mimic AHT?
  - Rarely get small localised SDH
  - No collapse
  - No RH’s
- May predispose to SDH after minor trauma but does not explain the signs and Sx of SHT
Short falls can cause signs and Sx of AHT?

• **Plunkett 2001**
  • 18 children died after falling from playground equipment
  • None < 1 year
  • Limited data presented
  • Several > 1.4m (short fall)
  • “several had RH’s” but no exam done by ophthalmologist

• **Chadwick 2008**
  • Risk of death from short fall < 1 in 1 million
  • No deaths reported in multiply witnessed short falls

• **Atkinson 2018**
  • 8 children – mean age 12 months
  • SDH (6 unilateral) + RH’s
  • 1 died
Biomechanical studies have proven that shaking cannot cause serious head injury?

- **Durhaime** – infants cannot be harmed by shaking alone, need impact
  - Primitive models
- Injury thresholds for the infant head and brain not been determined
  - Infant brains different from adult – higher water content and more vulnerable unmyelinated axons, more deformable, different biochemical response to trauma
- **Bandak**
  - Neck cannot withstand the forces needed to cause AHT
  - More injuries expected (2004 – neck not routinely Ix)
- More recent data supportive
SDH can be the result of venous sinus thrombosis or are caused by immunisations?

- Newborns more susceptible to VST and co-existing SDH often found
- After postnatal period SDH from VST in the absence of trauma not been reported
- Die from severely raised ICP - VST may be present – causation cannot be assumed
- Vasovagal falls after immunisation BUT no evidence that immunisation can cause the features seen with AHT
Timing of injury – who was with the baby at the time?

How do we tell?
Opinion on timing may inform who the Police charge with a serious crime?

*Estimate* of window of time within which injury might have occurred (“injury time window”)
Can we be more sure than this?
Forming an opinion on timing

Is it

- Based on the story provided?
- Based on clinical picture (what happens to infant)?
- Based on radiological findings?
- All of the above?

How strong is the evidence base?

- Dating is imprecise
- Many factors that can affect the appearance acute SDH (No validated model)
- Mixed attenuation do not always suggest repeat episodes
- Acute mixed density SDH more common in AHT (hyperacute/acute, blood and CSF – arachnoid tear, acute/chronic haem)
PUTTING IT ALL TOGETHER - DISTINGUISHING AHT FROM ACCIDENTAL HEAD TRAUMA
“Heathcote man Joby Rowe guilty of shaking baby daughter Alanah, causing her death”
Assessment approach

• Story provided
  • What forces are required to injure or kill a baby?
    “I sat down hard on the couch with him in my arms”
    “I put him down on the bed and he bounced a bit”
    “he fell off the change table and stopped breathing”
  • Reliable? Truthful? Alibi? Incomplete? Mixture?

• Examination
  • Concordance with exam findings and evidence base
    • RH, other injury

• Investigation to exclude alternative causes and find supporting ‘evidence’
  • Pathology – coagulation, rare causes, genetics
  • Radiology – spinal injury, occult #, specific patterns of SDH
Maguire S et al Which clinical features distinguish inflicted from non-inflicted brain injury? A systematic review *Arch Dis Child* June 2009

- History - Low height fall, no history of trauma
- May present with a variety of symptoms
- Several factors eg young age more commonly associated with AHT
- In children with an intracranial injury apnoea and retinal haemorrhages most predictive feature of AHT
- Mixed density SDH
Summary

- AHT poses many challenges to the clinician
- Careful consideration of alternative causes
- High quality evidence exists but the area is also plagued by “non believers!”
- Recent consensus statement 2018
- Importance of specifics of findings plus supporting ‘evidence’ especially neck/spine
  - Eye exam EARLY
  - Spinal imaging important
“When all other possible causes for each component of the triad have been excluded, the only remaining known cause is injury (whether shaking, impact or a combination of both) and the minimal force required to produce injury is substantial”

GROUP OF EMINENT PEDIATRICIANS AND NEUROPATHOLOGISTS
UK AND USA
ARCH DIS CHILD 2006