Spinal Injury in Abusive Head Trauma

Objectives
Simplified anatomy of infant spine
Evidence base: spinal injury in physical abuse and AHT
– Type and prevalence of injuries

To inform
– Understanding of mechanism of injury in AHT
– Potential links to cranial neuropathology
– Radiological investigation strategy

Abusive head trauma AHT, spinal cord Injury SCI

Conflict of interest

• I have no relevant financial relationships with the manufacturer(s) of any commercial product(s) and/or provider(s) of commercial services discussed in this CME activity.
• I do not intend to discuss an unapproved/investigative use of a commercial product/device in my presentation.
Post Mortem studies

• Cervical extra axial haemorrhages in AHT (Hadley et al 1988, Feldman 1997)

• PM studies have proposed a link between
  – Cervical SCI and AHT
  – Cervical SCI and hypoxic ischaemia brain injury (Geddes/Shannon)
  – Cervical SCI and cerebral oedema (Brennan)
  – Small Edh deemed artifactual (Rutty et al)

Anatomy 1: Cervical Spine Vertebrae in infants

• Horizontal facet joints,
• Incompletely formed vertebral joints, and vertebrae
• Wedge shape vertebrae:
• Short spinous and transverse processes

Anatomy 2: Cervical Spinal Ligaments

Complex ligament structures

• Posterior (atlanto-occipital, atlanto-axial and nuchal ligament)

• Posterolaterally capsular ligaments of the occipital condyles and atlanto-axial joints

• Myodural bridges – fibrous bridges that connect the cervical musculature and the nuchal ligament with the cervical dura
Anatomy 3: Cervical spinal dura

- Continuous with cerebral dura
- Similar structure less vascular and little innervation.
- No bridging veins
- ‘Arteries and veins travel from the extradural space to the intradural space via the nerve root sheaths’

The evidence base

Systematic Review


Published in 2010: What is the pattern of spinal injury in physical abuse?
Totality of literature (1950-2009)
- 19 case reports of 25 children with spinal injury

2010-2013
- 7 large case series/ cross sectional studies
Spinal injury in physical abuse
25 Cases: M:F 1:1
23/25 cases under two years

Cervical injury: n=12
Mean age 6 months
- 6 high cervical injuries at C2/3
- 10 musculoskeletal (6 sc involved)
- 2 SCI alone
- 50% associated AHT
Symptoms
- Presented impaired: respiration and conscious level

Thoraco-lumbar: n=12
Mean age 13.5 months
- At thoracolumbar junction T11-L2
- Fracture listhesis / compression of vertebral body
- 50% musculoskeletal and spinal cord involvement
- 1 AHT and thoracolumbar SDH with cord compression
Symptoms
- 10/12 thoraco-lumbar deformity
- One had associated head injury
Systematic review updated 2009-2014


Vertebral fractures
Karmazyn 2011, Kleinman 2013, Lindberg 2013, Barber 2013

Estimated prevalence

- in suspected PA 0.3-2.7%
- when SS positive 0.8-9.7%
- in AHT 5.7%
- 71% of children with spinal fracture on SS have AHT (Barber et al)

Characteristics of fractures

- Often multiple
- Thoracic and lumbar
- Often associate multiple other fractures
- Mostly vertebral body compression fractures
- Lateral and AP films optimised visualisation

www.core-info.cf.ac.uk
Spinal SDH in AHT
Koumelliis et al 2009,

- 18 infants with spinal MRI scan (T1 and T2-weighted sagittal+/axial)
- 8/18 (44%) had occult spinal SDH
- 6 large spinal SDHs
- All 8 had intra cranial supratentorial and infratentorial SDH
- Spinal and posterior fossa SDH: same signal intensity
- Supratentorial SDH mixed intensity.
- Two cervical spinal SDH were continuous with the posterior fossa SDH.

Spinal SDH in AHT
Choudhary et al 2012

Comparative study (<2 yrs): neuroimaging of the spine (mean 23hrs)

Accidental cases (concern abdominal or spinal injury) (n=70)
- 1/70 spinal SDH
- 21/70 had small intracranial SDH, one of whom had the spinal SDH.

AHT cases (n=67)
- Spinal SDH 24% (17/70) cervical imaging
- Spinal SDH 63% (24/38) thoracolumbar imaging
- All 31 had intracranial supratentorial and posterior fossa SDH
- Spinal SDHs same attenuation as intracranial SDH,
- Most spinal SDH posterior dura.

Spinal ligament injuries
Choudhary et al. 2014

Comparative study (<4 yrs):
MRI (STIR sequence)

- AHT: 78% of 67 children cervical ligament injury (p<0.05)
- Acc. Hi: 43% of 46 had cervical ligament injury
- Non-traumatic cases: 1% of 70.

Predominantly to posterior ligamentous complex (the nuchal, atlanto-occipital and atlanto-axial ligaments)
Spinal ligament injuries
Choudhary et al. 2014

- Suggesting hyper flexion injury.

- A significant association between
  - Occipitocervical ligamentous injury and brain ischemia in the AHT and Acc HI group.
  - Cervical ligament injury and spinal SDH in AHT
    (nuchal/interspinous/AA ligament 60% predictive of Spinal SDH)

Spinal ligament injuries
Kadom et al. 2014

Cervical spinal MRI: 74 (< 3yrs) investigated for suspected AHT
(38 AHT, 26 Acc HI, 10 unsubstantiated)

- Cervical spinal soft tissue injury in 36% of 74
- Most: ligamentous injuries.
- No difference between outcomes
- Significant associations between
  - Posterior fossa hemorrhage and AHT
  - Diffuse brain hypoxia with AHT.
- 83% (10/12) of cases with both cervical injuries and diffuse hypoxic brain injury were AHT.
Summary findings: in AHT

- Bony injury: low prevalence (0.8-5.7%)
- Spinal SDH: common (44-63%)
- Cervical spinal ligament injury (36-78%)

Significant association between posterior cervical spinal ligament injury and
a. hypoxic brain injury
b. Spinal SDH

Implications

In shaking: cervical injury is plausible

Infant neck unstable and flexible
- low muscle tone, poor head control
- laxity of spinous ligaments,
- shape of the infant vertebrae
- a large head relative to body
- a more cranial fulcrum of movement for the infant neck (C2/3) vs. (C5/6) older child
Why fewer bony than soft tissue injuries?
- flexibility of the infant spinal column > than spinal cord
- increasing the vulnerability of the spinal cord and extra axial structures in hyperflexion.
- the vertebrae can sublux and impact the spinal cord and return to their position.

Supportive evidence
- injury to the cervical spinal cord, ligaments and extra axial structures with minimal spinal skeletal injury in AHT.

Causal mechanism of spinal SDH?
- Two proposed mechanisms
  - tracking of intracranial SDH
  - injury to the vessels around the spinal cord

However
- Lack of bridging veins
- Lack of co-existing localised thoraco-lumbar injury cast doubt on second theory.

Tracking theory
- Spinal dura contiguous with cranial dura
- Posterior fossa SDH continuous cervical SDH
- Posterior fossa SDH present in all thoraco-lumbar SDH, same attenuation.
- Blood pools at most dependent point in infant
- No coexisting thoraco-lumbar ligament or bony injury.

Choudhary theory (spinal SDH> AHT than Acc Hi and cervical ligament injury associated with spinal SDH)

Shaking: myodural bridges transmit forces from the cervical muscle and ligaments to the dura and pull it away from the arachnoid opening up the posterior subdural space and allow migration of blood from a posterior cranial SDH into the spinal subdural space, and...
Hypothesis: cervical spinal injury impairs respiratory centres contributing to cerebral hypoxia

- Choudhary: posterior cervical ligament injury strongly predictive of brain ischaemia (PPV 84-88%)
- Kadom's findings would also support this hypothesis

However

- Hypoxic brain injury is present both with and without cervical SCI (Geddes, Brennan, Choudhary, Kadom)

Alternative proposals

- Transient cervical SCI that cannot be visualized on MRI or at PM may contribute to apnea and hypoxic ischemia during shaking, it is unlikely to be the only pathogenesis.

- Brain hypoxic ischemia from secondary brain damage with compromised cerebral perfusion as part of the cascade reaction

Imaging Recommendations

In suspected physical abuse children < 24 months

- Skeletal survey should include lateral spinal X-Rays.
- MRI if spinal abnormality suspected on SS or
- If spinal injury suspected clinically lateral X-ray and MRI
- Should spinal X rays be included in follow up SS?
In suspected AHT

• All children with suspected AHT should have a complete spinal MRI early in the course of their clinical assessment.

• To identify occult spinal soft tissue ligament injury.

Conclusions 1

• There is clear evidence of spinal involvement in AHT.
• The greater involvement of the cervical spine in AHT supports flexion hyperextension injury during shaking as a mechanism for AHT.
• Coexisting hypoxic ischaemia
• Cervical spinal injury is more common in AHT
• However cervical cord trauma is unlikely to be the only biomechanical trigger for the intracranial pathology seen.

Conclusions 2

• Occult thoracolumbar SDH are more common in AHT
• SS to include AP and lateral X Ray
• MRI of the entire spinal column is recommended investigation in suspected AHT.
• to optimise CP management and medico-legal proceedings.
• Future research: high quality comparative studies full spinal imaging.