

# Child Protection Evidence

## Systematic review on

# Spinal Injuries

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While the format of each review has been revised to fit the style of the College and amalgamated into a comprehensive document, the content remains unchanged until reviewed and new evidence is identified and added to the evidence-base. Updated content will be indicated on individual review pages.

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## Summary

Spinal injuries in children are uncommon and most arise from motor vehicle crashes or sport-related incidents in older children<sup>1</sup>. Abusive spinal fractures are rarely recorded, and it's difficult to ascertain their true prevalence. The paediatric spine is particularly susceptible to cervical injuries due to its orientation and the relative weight of the head in comparison to low muscle tone<sup>2</sup>. This can predispose children to spinal cord injury without obvious injury to the musculoskeletal structures<sup>3</sup>.

This review aims to characterise abusive spinal injury and its associated radiological features. Since both musculoskeletal and spinal cord injuries are included, the studies were identified and reviewed during our fractures and neurological injury systematic reviews. Therefore, we originally used both the fractures and neurological injury methodology and tools.

In **October 2013** we combined terms from both the fractures and neurological injuries search strategies in order to create a separate search strategy specific to spinal injuries.

### Key messages:

- Exciting new data relating to ligamentous injury in the cervical spine of infants subjected to abusive head trauma is a worthwhile addition to the previous literature<sup>4</sup> Further new data has been published relating to the yield of spinal imaging on skeletal survey<sup>5,6</sup>

## Background

This systematic review evaluates the scientific literature on abusive and non-abusive spinal injuries in children published up until 2013 and reflects the findings of eligible studies. The review aims to answer the following clinical question:

- What are the clinical and radiological characteristics of physically abusive spinal injuries?

## Methodology

A literature search was performed using a number of databases for all original articles and conference abstracts published since 2010. Supplementary search techniques were used to identify further relevant references. See [Appendix 1](#) for full methodology including search strategy and inclusion criteria.

Potentially relevant studies underwent full text screening and critical appraisal. To ensure consistency, ranking was used to indicate the level of confidence that abuse had taken place and also for study types.

# Findings of clinical question 1: What are the clinical and radiological characteristics of physically abusive spinal injuries?

- Spinal Injuries<sup>4-33</sup>, 870 studies reviewed, 30 met inclusion criteria
- Age: range 1 – 10 years
- Gender: Data not analysed by gender
- Four studies evaluated the yield of skeletal surveys for spinal fractures<sup>5,6,8,23</sup>:
  - In children younger than two years old, Kleinman identified 25 fractures in 2.7% (10/365) children (mean age 10.9 months)<sup>5</sup>
  - Karmazyn identified four spinal fractures in 0.3% (3/930) of children younger than two years old<sup>23</sup>
  - Lindberg identified 21 fractures in 0.8% (14/1750) children less than 24 months of age<sup>6</sup>
  - Barber identified 22 spinal fractures in 1.9% (14/75) children less than four years old<sup>8</sup>

## 1.1 Cervical injuries

- 18 studies described cervical injuries<sup>4,5,7,8,12,16,17,19,20,22,24-28,30,32,33</sup>
- Age range: 1-48 months
- 1 comparative case series of children aged less than 2 years with spinal fracture noted 11 out of 29 were due to abuse. These injuries were predominantly cervical (8 out of 11) and 3 thoraco-lumbar<sup>25</sup>

### Presenting features

- Many of the children presented with respiratory distress<sup>7,8,17,19,20,24,26-28,30,32</sup>
- Altered consciousness and/or neurological deficit were the second most common symptoms<sup>7,8,16,17,19,20,24-28,30,32,33</sup>
- Pain on movement of the neck was noted in 2 cases<sup>21,27</sup>
- 1 child was asymptomatic with a C5-6 fracture dislocation and mild cord compression (diagnosed during investigation after twin was abused)<sup>30</sup>
- Koumellis identified three children with cervical subdural haematoma (SDH) associated with abusive head trauma; in two cases the SDH extended to the sacral region<sup>26</sup>
- In a series of 14 children with spinal fractures to the thoracic, lumbar or sacral spine identified on skeletal survey, Barber reports one child with respiratory arrest, abusive head trauma and rib fractures who had a fracture at C4 identified on CT scan<sup>8</sup>
- Kleinman identified a child with a hangman's fracture at C2<sup>24</sup>

## Injuries present

- Musculoskeletal injury occurred at any point throughout the cervical spine<sup>7,17,19,20,24,26-28,30,32,33</sup>), with upper cervical spine predominantly injured in a case-series (seven out of eight)<sup>25</sup>
- One case involved central cord syndrome of C1-7<sup>17</sup>
- Two cases involved spinal cord injury without musculoskeletal injury<sup>17,27</sup>
- One case report of a fatally injured of a 13 month old infant showed a complete tear of the anterior ligament and diastases of the vertebral bodies at C5/C6, in conjunction with the lumbar spinal injury and transection of the aorta<sup>16</sup>
- Two case-control studies addressed abnormalities on MRI. One included STIR sequence<sup>4</sup> while one examined T1, T2, DWI and sagittal fast-spin echo inversion recovery<sup>22</sup>
- One study identified cervical injury in 36% of children. There was no significant association between these injuries and suspected or confirmed abuse<sup>22</sup>. Two infants sustained cervical spinal cord injury, who also had extensive brain injuries and ligamentous injury<sup>22</sup>
- The second study identified nuchal, interspinous, posterior atlanto-axial, posterior atlanto-occipital and capsule ligamentous injury. While these were not exclusively present among children with abusive head trauma, they were more common in this group. They were not present in non-traumatic cases<sup>4</sup> Only 6% of abusive head trauma cases and 2% of non-abusive head trauma cases had bony injury
- A comparative case series showed that abusive cervical injuries involved ligamentous injury in eight out of eight, seven of these had normal plain films, and 1 child had co-existent thoracic injury. There were no fractures or spinal cord injuries<sup>25</sup>
- Additional injuries included rib and extremity fractures in 3 out of 8 infants<sup>25</sup>

### Co-existent abusive head trauma

- Seven cases included a variety of intracranial injuries co-existent with cervical injury<sup>7,17,19,26,27</sup>
- The cervical injuries ranged throughout C1-7<sup>7,17,19,26,27</sup>
- In a large case-control study, amongst those children with abusive head trauma aged 0-2 years with cervical spinal imaging, 7/29 (24%) had cervical subdural haemorrhage versus 0/47 for accidental trauma<sup>12</sup>
- Two case-control studies of children with abusive versus non-abusive head trauma addressed the correlation between intra-cranial and spinal injury<sup>4,22</sup>
- One found no significant association between cervical spine injuries and abusive head trauma (confirmed or suspected)<sup>22</sup>
- The other identified a strong association between cervical ligamentous injury and cerebral ischaemia<sup>4</sup>
- All eight children with cervical injury had a co-existent intracranial injury<sup>25</sup>

## 1.2 Thoraco-lumbar injuries

- 16 studies described thoraco-lumbar injuries<sup>5,8-16,18,21,25,26,29,31</sup>
- Age range: 0-4 years

### Presenting features

- Commonest presenting features were visible swelling / deformity<sup>10,11,13-15,18,21,26,29</sup>
- Kyphosis / kyphoscoliosis was a complication in almost half the cases<sup>10,11,13-15,18,21,26,29</sup>
- Neurological deficit below the level of injury was a common feature<sup>10,11,13-15,18,21,26,29</sup>
- One out of three with thoracic-lumbar had intracranial haemorrhage<sup>25</sup>
- One child (with co-existent abusive head trauma) had respiratory distress<sup>21</sup>
- 2/24 children with AHT and spinal abnormalities were symptomatic, one with priapism and one with back pain<sup>12</sup>

### Injuries present

- Musculoskeletal injuries including vertebral compression fractures (often multiple<sup>5,8,9,25</sup>) / dislocations / subluxations affecting T3-S3<sup>5,8-11,13-15,18,21,25,26,29</sup>, ligamentous injury<sup>16,25</sup>
- Spinal cord contusion or compression co-existed<sup>10,11,13-15,18,21,26,29</sup>
- There were no cases of neurological injury without musculoskeletal injury among this group<sup>10,11,13-15,18,21,26,29</sup>
- Barber described 14 children who had thoracic spinal (25 injuries), lumbar spinal (6 injuries) and sacral<sup>8</sup> fractures on skeletal survey<sup>8</sup>
- 10/14 children had associated intracranial injuries (seven of whom had retinal haemorrhages)
- 9/14 children had additional skeletal injuries
- Seven children had spinal injury at multiple levels
- Thoraco-lumbar injuries were vertebral body compression fractures, one child had a dislocation injury. Multiple injuries were contiguous in six cases and non contiguous in two
- MR was performed in four cases. No child had a spinal cord lesion, two children had spinal subdural haemorrhage
- In a case-control study, 24/38 AHT cases had thoraco-lumbar subdural haemorrhage versus 1/70 accidental head trauma cases<sup>12</sup>
- A case study of a 13 month old infant had complete transection of the abdominal aorta and IVC in conjunction with injury to L1/L2 anterior longitudinal ligament<sup>16</sup>
- In three infants with thoraco-lumbar injury, one child had T12-L1 ligamentous injury with co-existent spinal extradural haemorrhage<sup>25</sup>

### Co-existent abusive head trauma

- 20 children had co-existent head trauma<sup>8,21,26</sup>

## 1.3 Spinal imaging of children presenting with abusive head trauma

Three studies have addressed the value of spinal imaging amongst those with abusive head trauma (AHT)<sup>12,22,26</sup>

- Koumellis et al. conducted a case series<sup>26</sup>:
  - 8/18 infants with AHT had spinal subdural collections
  - All had supratentorial and infra tentorial subdural haematoma
  - 6 / 8 were large and extended from the sacral region to cervical(2), thoracic(3) and lumbar(1) regions
  - Two were small in cervical or thoraco-lumbar respectively
  - 2 / 18 cases had fracture of thoracic spine seen on plain x ray, one of which had a small epidural haematoma
- Choudhary and colleagues conducted a case-control study of 67 AHT cases versus 70 non-AHT cases<sup>12</sup>:
  - 31 / 67 AHT had spinal subdural haemorrhage (SDH)
  - All had intracranial supratentorial and posterior fossa, subdural haematoma including 15 small intracranial SDH and 16 moderate SDH
  - The majority of the spinal SDH was along the posterior dura although some were circumferential and some exclusively anterior
  - Only 1 / 70 non-AHT had spinal subdural – this child had substantial posterior fossa injuries including displaced comminuted occipital bone fracture and cerebellar contusions
- Kadom et al. conducted a case control study of 74 children less than three years of age; 38 with AHT<sup>22</sup>:
  - One child had a spinal subdural haemorrhage

## 1.4 Implications for practice

- All young children with suspected abuse should be fully examined for possible spinal injury<sup>34</sup>
- Where skeletal survey is being performed (in children aged less than two years), this must include AP and lateral spinal images<sup>34</sup>, although spinal ligamentous injury may be missed on plain film, thus MRI should be considered if spinal injury is suspected
- Where an infant is being investigated for abusive head trauma, consideration should be given to magnetic resonance imaging of the spine<sup>34</sup>, as ligamentous injuries may be missed on plain film. The addition of STIR sequences maybe of value in identifying cervical ligament injuries associated with abusive head trauma<sup>12</sup>

## 1.5 Limitations of review findings

- Radiological investigations varied over the course of this review but, when MRI was performed, it yielded additional information to CT / plain film
- There is a lack of large scale comparative literature to delineate the difference in spinal injuries from abusive and non-abusive mechanisms
- With increasing use of MRI, more injuries are being detected, however the imaging sequences selected by authors vary from one study to another

## Other useful resources

The review identified a number of interesting findings that were outside of the inclusion criteria. These are as follows:

### Clinical question 1

- Study of accidental spinal injury confirming that upper cervical injury is commoner in younger children with thoraco-lumbar injuries becoming more common with increasing age<sup>2</sup>
- One post-mortem study demonstrated that 70% of children with abusive head trauma had pathological cervical cord injuries<sup>35</sup>
- In another, a 3.5 year old child was found dead with complete fracture dislocation through L2-L3 intervertebral disc with completely disrupted anterior longitudinal ligament, haematomas in para-spinal muscles, and extradural haematoma around caudal spinal cord. This was associated with traumatic transection of the abdominal aorta<sup>36</sup>
- Study describing the correlation between radiology and histopathology of vertebral fractures in fatal cases of child abuse<sup>37</sup>
- Infants who may present with features suggestive of physical abuse including spinal injury should have differential diagnoses (e.g. Menkes disease) considered<sup>38</sup>
- Optimal radiological techniques are essential for the identification of spinal injury in children; currently MRI would appear to be the imaging technique of choice to identify relevant soft tissue injuries<sup>22,39-41</sup>
- Physiological anomaly a coronal cleft may be present in the vertebral body in infants in the first year of life. They are predominantly in the lumbar-spine but may be mistaken for a compression fracture<sup>42</sup>
- Biomechanical studies have explored the failure properties of cervical spine ligaments<sup>43</sup> and the pattern of histological injury following shaking in animal studies<sup>44</sup>

## Related publications

### **Publications arising from spinal injuries review**

Kemp A, Joshi A, Mann M, Tempest V, Liu A, Holden S, Maguire S. What are the clinical and radiological characteristics of spinal injuries from physical abuse: a systematic review. Archives of Disease in Childhood . 2010;95(5):355 -360 [Pubmed]

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## Appendix 1 – Methodology

This review aims to characterise abusive spinal injury and its associated radiological features. Since both musculoskeletal and spinal cord injuries are included, studies before 2013 were identified and reviewed during our fractures and neurological injury systematic reviews. Therefore, prior to 2013 we have used both the fractures and neurological injury methodology and tools.

In October 2013 we combined terms from both the fractures and neurological injuries search strategies in order to create a separate search strategy specific to spinal injuries.

### Inclusion criteria

#### Fractures

Inclusion	Exclusion
Papers with all evidence types	Personal practice
English and non-English papers	Review papers
Papers from conferences – paediatric, radiology, orthopaedic	Management of fractures papers
Patients between 0-17 years of age	Papers where the population included adults and children
	Studies of non-abusive data only
	Methodologically flawed papers

#### Neurological injuries

Inclusion	Exclusion
Children aged 0 years up to 18th birthday	Studies about complications, management or prognosis of AHT / nAHT
Observational comparative study (cross-sectional / case-control / case series / longitudinal cohort)	Non-comparative studies
Children with AHT	Consensus statements or personal practice studies
Ranking of abuse 1 or 2 for AHT	Studies addressing exclusively post-mortem neuro-pathological findings
nAHT: non-abusive aetiology confirmed	Studies with mixed adult and child data, where the children's data cannot be extracted
Children who were alive at presentation	Methodologically flawed studies (e.g significant bias, where AHT was not adequately confirmed or where inadequate clinical details were given)
All language studies	Studies that only addressed head injury where there was no intracranial abnormality

Relevant clinical details given for each group	Studies with low surety of diagnosis of abusive injury (rank 3-5 abuse)
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## Ranking of abuse

Distinguishing abuse from non-abuse is central to our review questions. As our reviews span more than 40 years, standards for defining abuse have changed markedly. We have devised the following ranking score where “1” indicates the highest level of confidence that abuse has taken place. These rankings are used throughout our systematic reviews (where appropriate).

Ranking	Criteria used to define abuse
1	Abuse confirmed at case conference or civil or criminal court proceedings or admitted by perpetrator
2	Abuse confirmed by stated criteria including multidisciplinary assessment
3	Abuse defined by stated criteria
4	Abuse stated but no supporting detail given
5	Suspected abuse

## Search strategy

The below table presents the search terms used in the 2014 Medline database search for spinal injuries, truncation and wildcard characters were adapted to the different databases where necessary.

1. CHILD/	55. spinal subdural.tw.
2. (paediatric or pediatric or neonate*).af.	56. cervical.af.
3. (child: or infant: or toddler: or babies or baby).af.	57. exp Spinal Cord Injuries/
4. or/1-3	58. Spinal Injuries/
5. ((non-accidental or nonaccidental) adj3 (trauma or injur:)).af.	59. spinal cord trauma.af.
6. ((non-abusive or nonabusive) adj3 (injur: or trauma)).af.	60. Spinal Cord Compression/
7. (non-accidental: and injur:).af.	61. Cervical Vertebrae/
8. soft tissue injur:.af.	62. hyperflexion injur*.af.
9. physical abuse.af.	63. hyperextension injur*.af.
10. ((inflicted or noninflicted or non-inflicted) adj3 (brain injur: or cerebral injur: or head injur:)).af.	64. or/23-6365. Fractur*.af.
	66. exp Fractures, Comminuted/
	67. exp Fractures, Bone/

11. (inflicted traumatic head injur: or inflicted traumatic brain injur:).af.	68. exp Fractures, Compression/
12. (maltreat* or shaking).af.	69. hangmans fractur*.af.
13. (AHT or Abusive Head Trauma).af.	70. Cervicomedullary injur*.af.
14. (or/5-13) and 4	71. (Atlanto-Axial Joint adj3 injur*).af.
15. (child abuse or child maltreatment or child protection).af.	72. (fracture dislocation or crush fractur*).af.
16. (battered child or shaken baby or battered baby).af.	73. (or/65-72) and 64
17. (battered infant or shaken infant).af.	74. (Spinal adj5 fract*).af.
18. (Shak: Baby Syndrome or shak: impact syndrome).af.	75. (Cervical adj5 fract*).af.
19. Caffey-Kempe syndrome.af.	76. (thoracic adj5 fract*).af.
20. **Child Abuse"/di [Diagnosis]	77. (lumbosacral adj5 fract*).af.
21. or/15-20	78. (thoraco-lumbar adj5 fract*).af.
22. 14 or 21	79. (sacral adj5 fract*).af.
23. extracranial CNS injur*.af.	80. (lumbar adj5 fract*).af.
24. Craniocerebral Trauma/	81. or/74-80
25. cervical spine injur:.af.	82. 73 or 81
26. cervical spine neuropathology.af.	83. skeletal survey.mp.
27. diffuse axonal injur:.af.	84. ((paediatric or pediatric) adj3 radiolog:).mp.
28. extracranial CNS injur:.af.	85. ((paediatric or pediatric) adj3 nuclear medicine).mp.
29. (extradural haematoma or hematoma).af.	86. Scintigraphy.mp.
30. extradural haemorrhage.af.	87. (bone scan or X rays).mp.
31. exp Neck Injuries/	88. isotope bone scan:.mp.
32. neck injur*.af.	89. (MRI or magnetic resonance imaging).af.
33. (parenchymal contusion or laceration).af.	90. exp Tomography, X-Ray Computed/
34. spinal cord injur:.af.	91. (CT or CAT scan*).af.
35. (subdural haematoma or hemotoma).af.	92. diagnostic imaging.af.
36. (subarachnoid hematoma or subarachnoid haematoma).af.	93. (neuroradiology or neuroimaging or neuro-imaging).af.
37. (subdural haemorrhage or subdural hemorrhage).af.	94. (radiological imag* or neurologic* imag*).af.
38. whiplash impact syndrome.af.	95. diffusion weighted imaging.af.
	96. **Diffusion Magnetic Resonance Imaging"/
	97. (plain films or ultrasound scan* or 3D

39. whiplash injur:..af.	reconstruction).af.
40. whiplash shaken infant.af.	98. exp Ultrasonography/
41. infarction.af.	99. (Susceptibility Weighted Imaging or SWI).tw.
42. (hypoxic-ischemic injur: or hypoxic-ischaeamic injur:).af.	100. neuro* radiology.af.
43. (contusion: or contusional tear).af.	101. neuro* examination*.af.
44. (hematoma or haematoma).af.	102. or/83-101
45. laceration:..af.	103. healing.mp.
46. shearing injur:..af.	104. (timing adj3 healing).mp.
47. traumatic effusion:..af.	105. ((dating or date or pattern*) adj3 fractur*).mp.
48. sciwora.mp.	106. (ag: adj3 fractur*).mp.
49. spinal cord injury without radiologic abnormality.af.	107. (ag* adj3 fractur*).mp.
50. thoracic lumbar sacral.af.	108. ((dating or date or pattern* or age or aging) adj3 fractur*).mp.
51. leptomeningeal cyst.af.	109. (aging adj3 fracture).mp.
52. (Extradural haemorrhag: or extradural hemorrhag: or extradural spinal haemorrhag: or extradural spinal hemorrhag:).af.	110. exp Aging/
53. (intraparenchymal hemorrhag: or intraparenchymal haemorrhag:).af.	111. exp Time Factors/
54. diffuse axonal injur*.tw.	112. or/103-111
	113. 102 or 112
	114. 22 and 82 and 113
	115. limit 114 to yr="20

Fifteen databases were searched together with hand searching of particular journals and websites. A complete list of the resources searched can be found below.

Databases	Time period searched
ASSIA (Applied Social Sciences Index and Abstracts)	2010-2014
Child Data	N/A
CINAHL ( <i>Cumulative Index to Nursing and Allied Health Literature</i> )	2010-2014
Cochrane Central Register of Controlled Trials	2010-2014
EMBASE	2010-2014
MEDLINE	2010-2014

MEDLINE In-Process and Other Non-Indexed Citations	2010-2014
Open SIGLE (System for Information on Grey Literature in Europe)	N/A
Pubmed e-publications	Nov 2014
Scopus	2010-2014
Social Care online (previously Caredata)	2010-2014
Trip Plus	N/A
Web of Knowledge – ISI Proceedings	2010-2014
Web of Knowledge – ISI Science Citation Index	2010-2014
Web of Knowledge – ISI Social Science Citation Index	2010-2014
<b>Journals 'hand searched'</b>	<b>Time period searched</b>
Child Abuse and Neglect	2010-2014
Child Abuse Review	2010-2014
<b>Websites searched</b>	<b>Date accessed</b>
The Alberta Research Centre for Health Evidence (ARCHE)	12 Nov 2014
Child Welfare Information Gateway (formerly National Clearinghouse on Child Abuse and Neglect)	12 Nov 2014
Google Scholar	Nov

## Pre-review screening and critical appraisal

Papers found in the database and hand searches underwent three rounds of screening before they were included in this update. The first round was a title screen where papers that obviously did not meet the inclusion criteria were excluded. The second was an abstract screen where papers that did not meet the inclusion criteria based on the information provided in the abstract were excluded. In this round the pre-review screening form was completed for each paper. These first two stages were carried out by clinical experts. Finally a full text screen with a critical appraisal was carried out by members of the clinical expert sub-committee. Critical appraisal forms were completed for each of the papers reviewed at this stage. Examples of the pre-review screening and critical appraisal forms used in previous reviews are available on request ([clinical.standards@rcpch.ac.uk](mailto:clinical.standards@rcpch.ac.uk)).