What are the clinical and radiological characteristics of spinal injuries from physical abuse: a systematic review

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ABSTRACT

Aim Systematic review of 'What are the clinical and radiological characteristics of inflicted spinal injury?'

Methods Literature search of 20 electronic databases, websites, references and bibliographies (1950–2009) using selected keywords. Critical appraisal: by two trained reviewers, (a third review, if discrepant). Inclusion criteria: primary studies of inflicted spinal injury in children <18 years, alive at presentation, with a high surety of diagnosis of abuse and sufficient detail to analyse.

Results 19 studies of 25 children were included. Twelve children (median age 5 months) had cervical injury. In seven cases, the clinical signs of spinal injury were masked by respiratory symptoms and impaired levels of consciousness; six of these children had coexistent inflicted head trauma. Twelve children had thoraco-lumbar injury (median age 13.5 months), 10/12 had lesions at T11–L2, and 9/12 had fracture dislocations. All children had focal signs: 10/12 had lumbar kyphosis or thoraco-lumbar swelling, and two had focal neurology. One child had cervical, thoracic and sacral injuries.

Conclusions Spinal injury is a potentially devastating inflicted injury in infants and young children. The published evidence base is limited. However, this case series leads us to recommend that any clinical or radiological indication of spinal injury warrants an MRI. In children undergoing brain MRI for abusive head trauma, consideration should be given to including an MRI of the spine. All skeletal surveys in children with suspected abuse should include lateral views of the cervical and thoraco-lumbar spine. Further prospective comparative studies would define the discriminating features of inflicted spinal injuries.

What is already known

- Spinal injuries are reported in child abuse, albeit infrequently.
- There is speculation regarding the significance of cervical spinal injury in inflicted head injury.

What this study adds

- Abusive spinal injuries can occur throughout the spine.
- Cervical spinal injuries tend are reported in young infants (median age 5 months).
- There is an association between cervical spinal injury and inflicted head trauma.

INTRODUCTION

'Baby P' sustained a fracture dislocation of the thoraco-lumbar spine as one of the many injuries that led to his tragic death at the age of 17 months from child maltreatment.[1] Questions have been raised as to how this serious injury might have been missed. Several post-mortem studies have also raised questions about the significance of injuries to the spinal cord in fatal cases of inflicted head injury.[2–4] However, spinal injury in physical child abuse is rarely described in the international scientific literature.

Overall, spinal injuries in children are uncommon, and most arise from motor vehicle crashes or sport-related incidents in older children.[5 6] Population studies estimate that 3–8% of spinal injuries are the result of child abuse[7]; however, it is difficult to quantify the true scale of the problem, as many studies do not appear to consider inflicted injury as a possible cause. Studies of children who have been physically abused estimate that 1% of children who suffer abusive head trauma have coexisting spinal trauma,[8] and between 1% and 3% of abusive fractures are to the vertebrae.[9 10]

There are structural and physiological features that influence the characteristics of paediatric spinal injury.[11] The infant spine is more elastic than the adult spine due to a largely ligamentous composition. It is relatively resilient to fractures but susceptible to ligament and spinal cord trauma. Injuries restricted to the structures within the spinal canal are thought to arise in hyperflexion or extension where the increased flexibility of the vertebral column relative to the spinal cord results in a functional shortening of the spinal cord. The paediatric cervical spine is particularly vulnerable to injury due to the additional features of the horizontal orientation of the facet joints, the underdevelopment of intervertebral joints, the relatively large size of the infant head together with the low tone of neck musculature. The fulcrum of cervical flexion is high at C2–3 in the infant moving to adult level of C5–6 by the age of 12 years.

We have conducted a systematic review of the published scientific literature in an attempt to

define the clinical and radiological features of inflicted spinal injuries in children, to inform clinical practice and future research.

MATERIALS AND METHODS

We systematically searched the international scientific literature to address the question 'What are the clinical and radiological features of spinal injury in physical abuse?' This question was one of a series of key questions that spanned two systematic review themes, namely inflicted fractures and inflicted injury of the central nervous system.[12]

We conducted an all-language literature search for the period 1950 to February 2009, across a range of databases and websites (figure 1) using an extensive list of keywords (figure 2), supplemented by references, conference abstracts and bibliographies. We scanned 8992 studies and abstracts, and 780 relevant studies were reviewed independently by two trained reviewers, using standardised critical appraisal criteria. A third review was conducted if there was disagreement. Our reviewers were drawn from paediatrics, neuro-radiology, paediatric neurology, orthopaedics, paediatric radiology and pathology. The methodology was based on standardised systematic review methodology.[13]

Quality standards

We defined 'spinal injury' to include musculoskeletal injury to the vertebral column and/or injury within the spinal canal. In the context of a low prevalence condition and after an initial scope of the literature, we considered that we were unlikely to find high-quality comparative studies. Our inclusion criteria therefore were as follows:

- Primary observational studies of children less than 18 years of age with inflicted spinal injuries confirmed by radiology (x-ray, MRI or CT).
- Studies with a high surety of confirmation of an abusive aetiology, not relying solely on the injury in question. We used our previously published ranking of abuse (table 1) and included studies with rank of abuse 1–2.
- For comparative studies, confirmation of accidental aetiology by independently witnessed cause or full reconstruction of the scene of injury.
- Studies where the child was alive on arrival at hospital and clinical details of the child's condition and radiological investigations were clearly documented.

The exclusion criteria were as follows:

- Review articles and expert opinion.
- Mixed adult and child data where the children's data could not be extracted.
- Studies where the children were dead at the time of presentation or those that relied purely upon post-mortem data.

Where studies fulfilled most criteria, we contacted authors for missing data or points of clarification.

RESULTS

We included 19 small case series or case studies, published between 1975 and February 2009, representing 25 children who had sustained inflicted spinal injury.[8 11 14–30] All studies ranked 1–2 for abuse, confirmed by communication with authors in two studies.[28 30] Each child described was assigned a case number (table 2).

The cases ranged from 1 to 48 months of age; 23 cases were under 2 years old. There was an equal male:female ratio. We grouped the cases according to cervical (12 cases) or thoracolumbar lesions (12 cases). One child had cervical, thoracic and sacral lesions (case 13).

Presenting features

Nine children presented with variable degrees of respiratory distress and impaired levels of consciousness (cases 1, 2, 4, 6, 7, 8, 12, 13, 14). Fourteen children had focal spinal

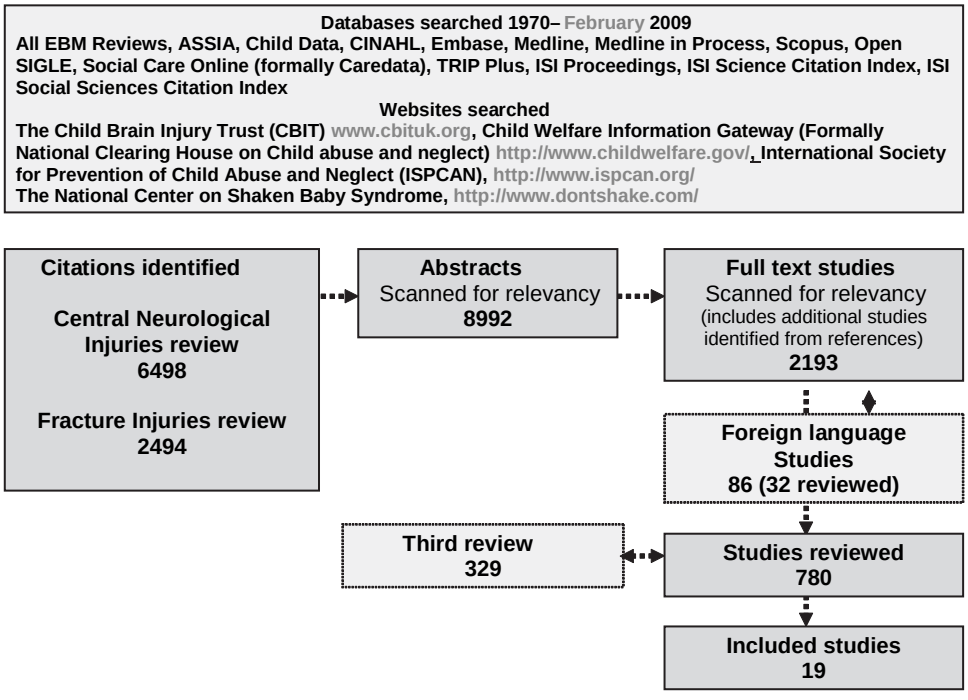

Figure 1 Systematic review process.

Patient/population set	contusion	non-accidental head injury
child	contusional tear	parafalcine
baby	cranial injury	parenchymal contusion
babies	craniocerebral trauma	parenchymal laceration
infant	craniocervical	retinal heamorrhage
neonates	diagnostic triad	retinal hemorrhage
Child abuse set	diffuse axonal injury	rib fracture
battered baby	encephalomalacia	SCIWORA
battered child	encephalopathy	shaking baby syndrome
battered infant	extracranial CNS injury	shaking impact syndrome
child abuse	fracture	shearing injury
child maltreatment	growing skull fracture	skull fracture
child protection	haematoma	spinal cord injury without radiologic abnormality
intentional abuse	head injuries	spiral fracture
non-accidental injury	head trauma	subarachnoid hematoma subdural hematoma
non-accidental trauma	hematoma	subdural haematoma
non-accidental and injury	hydrocephalus	subdural hygroma
physical abuse	hygroma	thoracic lumbar sacral
shaken baby	hypoxic-ischaemic injury	traumatic effusions
shaken infant	hypoxic-ischemic injury	ventricular haemorrhage
soft tissue injury	impact injury	ventricular hemorrhage
Central Neurological injuries and Fractures set	infarction	whiplash impact syndrome
abusive head trauma	inflicted brain injury	whiplash injury
bleeding into brain	inflicted cerebral injury	whiplash shaken infant
blow to the head	inflicted traumatic head injury	**Radiological examination set**
brain	inflicted traumatic brain injury	bone scan
brain damage	interhemispheric	computed tomography
brain dissection	intracerebral bleeding	CT or CAT
brain distruption	intracerebral haemorrhage	diagnostic imaging
brain haemorrhage	intracerebral hemorrhage	diffusion weighted imaging
brain swelling (cerebral edema)	intracranial haemorrhage	isotope bone scan
brainstem	intracranial hemorrhage	magnetic resonance imaging (MRI)
central nervous system	intracranial injuries	neuro radiology
cerebral	intraparenchymal	neuroimaging
cerebral atrophy	intraparenchymal tear	neurologic examination
cerebral injury	intraventricular hematoma	plain films
cervical lumbar	laceration	radiological imaging
cervical spine injury	laminar necrosis	radionuclide
cervical spine neuropathology	leptomeningeal cyst	scintigraphy
classic metaphyseal lesion	metaphyseal chip fracture	skeletal survey
clavicle fracture	metaphyseal fracture	X-rays
CNS	multiple skull fracture	
	eggshell fracture	
	neurologic injury in child abuse	
	neuropathology	

Figure 2 Keywords and phrases used for finding articles for abusive spinal injuries.

deformities (cases 15, 17–21, 23–25) and/or focal neurological signs directly attributable to the spinal cord injury (cases 3, 10, 11, 16–19, 21, 22). One child (case 5) was symptom-free but was identified following a diagnosis of abuse in her twin sister. See online table.

In 11/25 cases, there was no explanation, and in 9/25 (1, 2, 9, 10, 13, 15–18), there were explanations of minor domestic trauma that included falls from the couch or bed. In five cases (cases 12, 14, 18–20), there was a history of inflicted trauma at presentation which was admitted in seven further cases by the end of the assessment process (case 1, 6, 7, 9, 11, 12, 22).

There was a delay in the recognition of spinal injury in 14/25 cases. Four children were initially treated for a respiratory illness (cases 2, 8, 12, 25). Two cases were misdiagnosed as a pathological fracture (case 17) or osteomyelitis (case 1). Three cases were missed on previous hospital admissions (cases 21, 23, 24), and there was a reported delay in the clinical recognition of spinal cord injury in four further case (cases 6, 13, 18, 22). In one case, there was a delay in presentation by the parents (case 20).

Collateral information that triggered or supported the recognition of physical abuse emerged at different points of the assessment process. Overall, 20 children had other associated abusive injuries (table 2). Nine children had cutaneous lesions (bruises, bites or burns) that would be consistent with physical abuse, three children had intraoral lesions, 16/25 cases had coexistent multiple fractures, two had intra-abdominal trauma, and seven sustained inflicted head trauma. The clinical outcome was reported in 19/25 cases, six of whom had a severe neurological deficit (quadriplegia/paraplegia), six sustained some degree of neurological impairment, and seven were reported to make a full recovery.

Table 1 Rank of abuse[31]

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

Cervical injuries

The 12 children where the spinal injury was located solely in the cervical region had a median age of 5 months (age range 1–48 months). The child who was 48 months of age had developmental delay and hypotonia prior to the injury. Ten children sustained musculoskeletal injury; six of these had associated spinal cord injury. Two children had spinal cord injury alone. Six of the children had high cervical lesions, and six had coexistent abusive head trauma (cases 1, 2, 6, 7, 10, 11). The pattern of musculoskeletal injury varied and included hangman's fractures at C2/C3, anterolisthesis, compression fractures of the vertebral body and bilateral pedicle fractures. Spinal cord injuries included central cord injury, spinal cord compression and transection. One child had vertebral arterial obstruction and a stroke (case 11).

Thoraco-lumbar injuries

The 12 children with thoraco-lumbar spinal injury were older, with a median age of 13.5 months (6–16 months). Eleven had musculoskeletal lesions at the thoraco-lumbar junction T11–L2. The majority (9/12) were fracture dislocations, and three were compression fractures of the vertebral body. Six of the 11 had associated spinal cord involvement, five had cord compression or contusion, and one had tethering. One case had no evident musculoskeletal injury but widespread thoraco-lumbar SDH with cord compression.

All children had focal signs of the spinal lesion; despite this, the clinical diagnosis was initially missed in eight cases: 10/12 had marked thoraco-lumbar deformity, and five presented with a lumbar kyphosis, three of whom presented some time after the abusive incident. Five children had a thoraco-lumbar swelling. Six children had associated spinal cord involvement and paraplegia, and one had associated inflicted head trauma.

Radiological features

As the included studies span 33 years, the imaging strategies varied between cases. Plain radiography was performed in all cases bar one (case 14). In four cases, this was the sole radiological investigation (cases 19, 21, 23, 24), and in six cases the plain films were reported as normal. Cases 7 and 10 had no apparent musculoskeletal injury, while one case (case 6) had a ligamentous injury associated with spinal cord injury. This case preceded MRI availability; the subtle features of disc widening became evident on serial plain film imaging and CT scan, and were confirmed after 2 weeks when there was evidence of linear densities at the margins of C5/6 vertebrae on lateral plain film, suggesting healing anterior ligamentous injury. In three cases, fractures or dislocations were not evident on initial films (cases 2, 3, 22) but were confirmed on further plain film or MRI. Radionuclide scans showed increased isotope uptake at the sites of musculoskeletal injury in the three cases where it was performed (case 4, 5, 9).

MRI scans were performed in 16 cases, and all provided additional important clinical information. In 12 cases (case 1–5, 7, 10, 14, 15, 17, 18, 22), damage to the spinal cord was identified; in two cases (case 8, 13), fracture dislocations were confirmed, but cord injury was excluded. In four cases (cases 2, 5, 17, 20), musculoskeletal injuries were localised to the ligamentous or intravertebral discs, one of whom had a normal plain film (case 2). In four cases (cases 12, 13, 17, 22), the MRI identified associated soft-tissue swelling.

CT was performed in seven cases; in three cases, it confirmed the plain film findings (cases 13, 15, 16), while in four instances, the axial CT scan further delineated the nature of the musculoskeletal injury prior to surgical intervention (cases 1, 8, 11, 20).

Proposed mechanism of injury

Statements of witnesses and confessions of the perpetrators confirmed the mechanism of injury in eight cases. Four cases of confirmed shaking had associated intracranial injury, three of whom sustained cervical injury (cases 1, 7, 11) and one thoraco-lumbar injury, (case 14). Two children were thrown (cases 12, 20), one of whom landed in a jack-knife position with thoraco-lumbar hyperflexion (case 20). One child was forcibly spanked (case 13), and a 1-year-old was involved in rough play (case 12). The child with cervical, thoracic and sacral injury (case 13) presented with a history that the father had fallen while holding the child some weeks previously. MRI, however, identified acute oedema in the sacral lesion that implied that the child had been slammed on a hard surface in a seated position, eliciting swelling in the sacral area, setting up an axial load on the spinal column, together with a hyperflexion in the thoraco-lumbar region.

DISCUSSION

Inflicted spinal injuries are rarely reported in the scientific literature; however, the condition clearly occurs and represents a serious form of child abuse with a high risk of sustained neurological impairment. This systematic review was limited by the lack of large-scale comparative studies to identify features that distinguish inflicted from non-inflicted injury. Several oft quoted studies were excluded, due to a lower ranking of abuse, or a lack of clinical detail.[32–37] However, the included case reports provide a high level of detail and inform a case series of 25 children with confirmed inflicted spinal injury. Although this is a highly selected population, the findings are important, illustrating the current extent of the published literature on this subject with implications for clinical practice.

The condition was primarily reported in children under the age of 2 years old where spinal injury was associated with other injuries known to be associated with physical abuse, in particular multiple skeletal fractures that were reported in 77% of the cases and inflicted head trauma in 50% of the children with cervical spinal injury.

There appeared to be two distinct patterns of injury according to the age of the child. Cervical spinal injuries were recorded in the younger infants (median age 5 months) who presented with signs of impaired consciousness and respiratory distress. In contrast, thoraco-lumbar injury presented in older infants (median age 13.5 months) with visible spinal deformity or focal neurological signs.

In more than half of the cases, the spinal injury was not recognised by the clinicians at the initial presentation. This appeared to be because the signs of cervical spinal injury were masked by the coexistent impaired levels of consciousness, and respiratory symptoms or thoraco-lumbar injuries were not recognised at initial clinical presentation.

This review addresses children who present to clinical services with inflicted spinal injury. An additional collection of post-mortem studies have raised clinical dilemmas. Two such studies [2 38] demonstrated cranio-cervical epidural haemorrhage and neuropathological changes in a significant number of infants who died from inflicted head trauma. They hypothesise that these findings are suggestive of stretch injury from hyper-extension flexion injury to the neural axis and propose a mechanism of brain stem damage with resultant apnoea causing hypoxic ischaemic brain damage. In contrast, Rutty *et al*[3] suggest that cervical epidural haemorrhage is a post-mortem artefact possibly caused by handling of the child in the post-mortem period and should not be overinterpreted as a sign of non-accidental injury in the absence of appropriate clinical history and other pathological findings. A further post-mortem study[39] reported extra-axial cervical spinal haematomas in 5/6 children with inflicted abusive head trauma and spinal contusions in four cases.

These clinical uncertainties raise the question for clinicians as to whether they should routinely exclude spinal injury in infants where inflicted head injury is suspected. It remains unclear how many children with inflicted head trauma have coexistent radiological evidence of spinal injury. Feldman published a study of 12 confirmed abusive head-trauma cases undergoing MRI of the spine, none of whom had spinal injuries.[40] However, four had thin subdural or subarachnoid cervical bleeds at autopsy. In a similar study of 18 children with confirmed inflicted head trauma, eight were found to have spinal subdural haemorrhage; all of these were clinically occult, and none had associated cord injury.[41] The authors propose that the spinal subdural haemorrhage may be an extension of the intracranial haemorrhages; in two cases, the spinal subdural haemorrhages were shown to be continuous with posterior fossa subdural haemorrhages, while in the other cases it was proposed that the haemorrhage had pooled in the sacro-lumbar region. Two of the 18 children had thoracic spinal fractures that were diagnosed on plain film, and one had a small underlying extradural bleed.

In light of these findings, we would recommend that all children less than 2 years of age with suspected physical abuse undergo a full examination, to exclude clinical signs of spinal injury and have a skeletal survey, which should include lateral imaging of the cervical spine as well as the standard lateral and AP thoraco-lumbar spine x-ray, as per recent guidance.[42] If a spinal musculoskeletal abnormality is evident on x-ray, or spinal cord injury is suspected clinically, an MRI of the spine is indicated to exclude or delineate any spinal cord injury or to explore other differential diagnoses. In addition, we suggest that an MRI of the spine should be considered in children with inflicted head injury if spinal injury cannot be firmly excluded on clinical assessment. MRI of the spine adds little extra to overall scan time compared with the multiple head sequences and would confirm or exclude associated spinal injury. Axial CT may be a useful adjunct to define the characteristics of any bony injury. There was little data regarding the value of radionuclide scan or follow-up spinal x-rays in detecting musculoskeletal injury. Where these were performed, additional or supportive information was helpful.

We believe that the data from this case series can inform clinicians about some of the clinical indicators of inflicted spinal injury to underpin an investigation pathway. A prospective comparative study of spinal injury, from all causes, in preschool children, with standardised imaging strategies would greatly improve the evidence base behind this subject and could be undertaken utilising national surveillance systems.

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