

Child Protection Evidence

Systematic review on

Visceral 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

Abdominal injuries are a significant cause of morbidity and mortality amongst abused children.^{1,2} The challenge for clinicians is to recognise that such injuries have occurred, as many symptoms are non-specific and occur predominantly in pre-school children.³ Whilst almost every organ of the body has been reported as having been injured, the literature in this review predominantly addresses abdominal injuries.

This systematic review has been updated and now evaluates the scientific literature published until September 2021. It includes visceral injuries that are not included in the other systematic reviews, apart from ear, nose and throat injuries, which are the subject of a separate review (<https://www.rcpch.ac.uk/resources/child-protection-evidence-ear-nose-throat>).

There has been limited evidence identified since the 2018 update and so the key findings remain unchanged. A single case series has been included in the 2021 update which aimed to assess the use of screening urinalysis to detect abdominal injuries in suspected physical abuse.⁴

The review aims to answer two clinical questions:

- What are the features of visceral injuries occurring as a consequence of physical abuse?
- What is the value of non-radiological investigations in detecting abusive abdominal injury?

Key findings:

- Many abdominal injuries, in particular hepatic injury, may be clinically occult and thus active consideration of blunt abdominal injury in children with suspected abuse is necessary
- Abdominal injuries such as transection or laceration of the third/fourth part of the duodenum in children aged less than five years, particularly those less than two years old, who have not experienced a motor vehicle collision should prompt specific child protection investigations
- In the child sustaining head injury or who is unconscious as a consequence of their abusive injuries, abdominal injuries must be considered during their investigation
- Many children sustaining abusive abdominal injury have evidence that there has been repeated blunt abdominal injury, although they have not come to attention with previous injuries. Thus, non-specific symptoms in young children with suspected abuse should prompt abdominal investigations
- While a positive serology test may warrant further investigation, those with negative serology may also have significant intra-abdominal injury
- Infants less than 6 months of age with bruising but no other symptoms or signs of injury may still have occult abdominal injury

- Absence of bruising does not preclude the presence of significant abdominal injury as up to 80% of cases may have no bruising present

Background

This systematic review evaluates the scientific literature on abusive and non-abusive visceral injuries in children published up until September 2021 and reflects the findings of eligible studies. The review aims to answer two clinical questions:

- What are the features of visceral injuries occurring as a consequence of physical abuse?
- What is the value of non-radiological investigations in detecting abusive abdominal injury?

Methodology

The literature search for the visceral injuries systematic review update was performed in September 2021 using relevant databases for all original articles published since 1950. 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 for each study, ranking was used to indicate the level of confidence that abuse had taken place.

Findings of clinical question 1

What are the features of visceral injuries occurring as a consequence of physical abuse?

A total of 94 articles addressed this question.^{1,3,5-96} These studies included fatal and non-fatal abuse. Where the term “abdominal injury” is used this refers to blunt abdominal injury. The age of the samples ranged between 0 - 16 years.

Two studies analysed the results by gender and found no difference between the abused and non- abused children.^{26,81}

A number of papers report on the insertion of needles into the body, these have been described to cause external injuries to the in the chest⁸⁷, abdomen^{34,65,87}, neck and forearm⁶⁵ and internally in the heart⁷⁹, liver³⁴ and intestines.⁸⁷

Influence of ethnicity and socio-economic group

These aspects were not addressed by the included studies.

1.1 Abdominal injuries

Comparative Studies

Of the six comparative studies,^{1,3,10,50,81,93} four addressed blunt abdominal injuries.^{1,10,81,93} All of these studies identified abused children with abdominal injury as significantly younger than accidentally injured children, with the mean age across the three studies for abused children all being less than three years,^{1,10,81,93} compared to the mean age of the accidentally injured group which was greater than seven years.^{1,10,81,93} The commonest cause of accidental injury was motor vehicle collision.^{1,3,10,81,93}

Where age was given no child less than four years of age sustained an accidental duodenal injury from a fall^{3,10} and no child less than two sustained a duodenal injury from any accidental mechanism.⁸¹

Co-existent injuries were common amongst the abused cohort (including fractures, head injury, burns, bites and oral injury).^{1,10,93} Two studies exclusively addressed duodenal injuries,^{3,81} which are rare in childhood. They account for 0.3% of abdominal trauma,³ and for 1.5/1000 trauma admissions in children less than five years old.⁸¹ Abused children with duodenal injury were found to be significantly younger (mean age 2.25 +/- 0.7 years) than accidentally injured children (mean age 7.6 +/- 4.4 years),³ no child less than two years of age sustained an accidental duodenal injury.⁸¹

Only 1/8 abused children had bruising to the upper abdomen³ and it was also found that abused children were more likely to experience duodenal transections than non-abused (35% vs 17%),⁸¹ although perforation was equally likely in another study.³

One study exclusively addressed pancreatic injury.⁵⁰ Abuse was discovered to be the third commonest cause of pancreatic injury, with motor vehicle collisions being the predominant cause. Mortality for pancreatic injury was low overall, however 4/10 abused children died. Co-existent injury was present in the fatal cases.

Solid organ injuries

Hepatic injury was predominantly described in 24 studies.^{1,6,8,10,11,16,17,20,22,33,41,43,46-48,51,54,58,60,64,65,75,84,93} Children were aged three weeks to eight years (where age was given).^{1,6,8,10,11,16,17,20,22,33,41,43,46-48,51,54,58,60,64,65,75,84,93}

The hepatic injuries included lacerations, contusions, subcapsular haematomas and complete transection of the liver.^{1,6,8,10,11,16,17,20,22,33,41,43,46-48,51,54,58,60,64,65,75,84,93}

Co-existent injury included bruising, rib fractures, head injuries, additional abdominal trauma, intra-thoracic trauma and bites.^{1,6,8,10,11,16,17,20,22,33,41,43,46-48,51,54,58,60,64,65,75,84,93} Bruising to the abdomen was recorded in 26/37 cases.^{8,11,17,21,23,33,41,43,46-48,51,54,60,64,65,75}

Splenic injury

Splenic injury is less frequently recorded.^{1,10,18,48,65,93} Amongst the comparative studies, one study did not report any abusive splenic injuries¹ whilst two studies noted them to be equally prevalent amongst abusively and accidentally injured children.^{10,93} Where described, the majority of children presented with haemodynamic shock, although the presence or absence of abdominal bruising was rarely noted (one case of multiple abdominal organ injury recorded abdominal bruising).⁹³ Details of co-existent injuries were not uniformly available. Where noted, they included other abdominal injuries.^{1,10,18,48,65,93}

Pancreatic injuries

Pancreatic injuries were predominantly addressed in 10 studies.^{20,41,48,50,54,63-65,69,78} A third of patients died and abuse was the second commonest aetiology amongst fatal cases.⁵⁰

The pancreatic trauma included transection of the head of the pancreas, acute necrotising pancreatitis, chronic pancreatitis and pseudocyst formation.^{20,41,48,50,54,63-65,69,78} An important late manifestation included osteolytic lesions (secondary to medullary fat necrosis associated with pancreatitis) causing pain and limitation of movement. These predominantly affect long bones, phalanges, tarsals and metatarsals, and may be accompanied by fever.^{63,78}

Many children with pancreatic injury had co-existent additional abdominal injuries and other injuries including burns, fractures, head injury and bruising.^{20,41,48,50,54,63-65,69,78}

Renal trauma

Renal trauma was addressed in three studies.^{48,74,92} It was the primary injury described in a four-month-old infant presenting with collapse due to sepsis. It was noted that the left kidney was infarcted in addition to splenic infarction and co-existent fractures.⁹²

Seven further cases of renal trauma were described in conjunction with other abdominal injuries.⁴⁸ One case of renal vascular injury to an ectopic kidney is also reported.⁷⁴

Other solid organ injuries

Three studies recorded additional solid organ injuries, including adrenal haematoma^{47,48} and adrenal laceration, including almost complete transection in one case.²⁸ Bruising to the abdomen/trunk was present in all cases, and multiple co-existent injuries were also present, including further abdominal injury, head injury, fractures and oral injury.^{28,47,48}

Hollow organ injuries

Overall, hollow organ injuries were recorded as frequently as solid organ injuries,^{1,3,6,10,12,16-18,24,27,31,32,37,38,44,46,53,60,65,66,68,70,82,87,90,93,94,96} however duodenal injuries occurred more commonly than expected.

Comparative studies highlighted the rarity of duodenal injury in accidental trauma and its relative frequency in abused children.^{1,3,10,93} It was evident that duodenal injury did not occur as a consequence of falls in any child less than four years of age.^{10,93,97}

Features of duodenal injury recorded in both comparative and non-comparative studies include intra-mural haematoma (with or without bowel obstruction), complete transection, subserosal haematoma, perforation or inflammation.^{1,3,6,10,12,16-18,24,27,31,32,37,38,44,46,53,60,65,66,68,70,82,87,90,93,94,96}

The commonest duodenal injury involved a transection or perforation between the third and fourth part of the duodenum.^{10,24,27,46,60,65,66,90,96} Where age was detailed, the children ranged from one week of age to five years of age,^{1,3,6,10,12,16,17,19,24,27,31,32,37,38,44,46,48,53,60,65,66,70,82,87,90,93,94,96,97} and there was a single case of a severely disabled thirteen year old child with an intra-mural haematoma of the second part of the duodenum.⁶⁸

Many children presented with an acute abdomen, although some cases did not come to attention for some days after the onset of symptoms.^{12,17,32,37,38,82,87} Solaiman describes a child presenting with a liver laceration due to blunt abdominal trauma.⁸⁰ Despite initial CT imaging, jejunal injury was not recognised until he re-presented over two months later with features of small bowel obstruction and was found to have a jejunal stricture and jejuno-jejunal fistula.

Co-existent injuries were frequently present, predominantly other abdominal injuries, but also fractures, head injury, and burns.^{1,3,6,10,12,16-18,24,27,31,32,37,38,44,46,53,60,65,66,68,70,82,87,90,93,94,96}

An eight week old infant is described with multiple needle insertions in the abdomen, including penetration of the rectum.⁶⁵ In addition, an 11 year old child is described with multiple needle insertions in the abdomen and one in the lower chest, including perforation of the caecum and liver.⁸⁷ Gaur and Gupta describe an 14 month old weighing five kilograms who presented with abdominal pain and persistent crying.³⁴ There was a puncture mark in the epigastrium but no other external injuries. Three sewing needles were found within the abdomen, one entangled in the omentum and two within the liver parenchyma.

Gastric rupture

A single case of gastric rupture was recorded in a two year old child, occurring due to a forceful blow to the abdomen, straight after a feed.¹⁹ Gastric rupture due to non-accidental trauma has been identified post mortem in a further case of a two year old presenting with respiratory distress due to a tension pneumoperitoneum.⁸⁸

Bladder injuries

Bladder rupture was the primary injury in six studies, in children aged four months to six years.^{45,56,65,76,77,95}

Rupture to the dome of the bladder occurred in all instances and the children presented variably with collapsed abdominal symptoms, haematuria, reduced urinary output and vomiting.^{45,56,65,76,77,95}

These highlight the potential mechanism of a direct blow to a full bladder leading to an acute rise in intravesical pressure.⁹⁵

Four out of the six children had no additional co-existent injuries other than bruising.^{45,56,77,95}

Colonic injuries

Colonic injuries are described in four studies, representing 100 abused children of whom four sustained large bowel injuries, all of which were in conjunction with other injuries.^{43,44,48,93}

The injuries recorded included colonic contusions,⁹³ rectal perforation,⁴⁸ serosal tears of the colon,⁴⁴ pneumatosis intestinalis⁴⁴ and meso-colonic tear.⁴³

Further abdominal injuries

Trauma to the abdominal lymphatics presenting as chylous ascites was recorded in a group of children ranging in age from 10 weeks – two and a half years.^{13-15,29,67,91}

Increasing abdominal distension was the commonest presentation although one child presented with a chyle filled hernia.⁶⁷

Co-existent injuries included fractures, burns, bruising, faltering growth, additional abdominal injuries and head injury.^{13-15,29,67,91}

1.2 Intra-thoracic injuries

One comparative study²⁶ of intra-thoracic injuries in children with rib fractures aged less than three years highlighted that abused children were more likely to be aged less than six months, whereas the majority of the accidentally injured children were aged one to three. It was also found that there was a correlation between the number of rib fractures and the extent of intra-thoracic injuries in the accidentally injured children but not the abused children.

Cardiac and vascular injuries

Direct cardiac trauma was described in children aged nine weeks to five years.^{22,25,28,52,72} It was found that half of the children died as a consequence of their injury.^{22,25,28}

Injuries included traumatic ventriculoseptal defects,^{22,52,72} laceration and intimal tears of the right atrium,^{25,28} transmural laceration of the apex of the left ventricle and traumatic right ventricular aneurysm.⁷² A single case described intra-cardiac needle insertion by the parent.⁷⁹

Vascular injuries included two injuries to the abdominal aorta.^{57,73} One occurred as a consequence of a kick to the abdomen of a three year old boy, resulting in a large pseudo-aneurysm presenting

four months after the assault.⁷³ The second case was a fatal acute traumatic transection of the abdominal aorta in association with complete fracture-dislocation of the lumbar spine. This case in a three-and-a-half-year-old, was thought to be due to a hyperextension injury to the spine.⁵⁷

Pulmonary trauma

Children aged three weeks to 18 months have been described with pulmonary contusions or subpleural contusions.^{30,33,36,62,75}

Co-existent injuries included multiple rib fractures, head injury, bruising and abdominal injuries.^{30,33,36,62,75} The children presented with respiratory difficulty or collapse and pneumothorax in one case.³⁰

In a comparative study of abused and non-abused children less than three years old with rib fractures and intra-thoracic injuries it was found that pneumothoraces, pulmonary contusion and pulmonary laceration were more common in abused than non-abused children.²⁶ Pleural effusion occurred equally in both groups. There was no difference between the groups in relation to co-existent intra-cranial or intra-abdominal injury.

One case recorded needle insertion into the neck, mediastinum, and left forearm. The mediastinal needle lay close to the great vessels.⁶⁵

Pharyngeal and oesophageal trauma

Pharyngeal and oesophageal trauma were predominantly addressed in 10 studies.^{5,9,39,55,59,61,65,71,86,89}

Injuries to the posterior pharynx included tears, occasionally complicated by retropharyngeal pouch or abscess formation.^{9,39,61,65,71,89} The children presented with subcutaneous emphysema, oral bleeding or drooling, respiratory distress or difficulty swallowing.^{9,39,61,65,71,89}

Injuries to the oesophagus included laceration and perforation.^{5,59,86} The children were aged from newborn (age not specified)⁵⁹ to nine months⁶ and all presented with irritability, poor feeding, respiratory distress or increasing swelling of the neck and chest with subcutaneous emphysema.^{5,59,86}

Chylothorax

Trauma to the thoracic duct leading to chylothorax is recorded in children aged six to 18 months.^{7,35,40,42,49} Children presented with increasing respiratory distress,^{7,35,40,42,49} all children had co-existent rib fractures and most had other fractures.^{7,35,40,42,49} In addition, bruising, subdural haematoma and corneal abrasions were noted in one case.⁷

1.3 Key evidence statements

- Many abdominal injuries, in particular hepatic injury, may be clinically occult and thus active consideration of blunt abdominal injury in children with suspected abuse is necessary
- Abdominal injuries such as transection or laceration of the third/fourth part of the duodenum in children aged less than five years, particularly those less than two years old, who have not experienced a motor vehicle collision should prompt specific child protection investigations
- In the child sustaining head injury or who is unconscious as a consequence of their abusive injuries, abdominal injuries must be considered during their investigation
- Many children sustaining abusive abdominal injury have evidence that there has been repeated blunt abdominal injury, although they have not come to attention with previous injuries. Thus, non-specific symptoms in young children with suspected abuse should prompt abdominal investigations
- Absence of bruising does not preclude the presence of significant abdominal injury as up to 80% of cases may have no bruising present

1.4 Research implications

- Only one study to date has determined the incidence of abdominal injury due to child abuse (UK data)¹⁰ and this study excluded children who died as a consequence of abuse or accidental trauma. There is a need for large scale epidemiological data to determine the prevalence and incidence of abusive abdominal injury
- It remains disappointing that only a small number of comparative studies are included in this review. There is an urgent need for large scale case control studies of abdominal injuries to delineate the distinguishing characteristics of abusive and accidental injury

1.5 Limitations of review findings

- Only 7/90 included studies were comparative and none were case control, thus limiting definition of distinguishing features between abusive and accidental injury
- Due to the large number of highly selected case studies/series, meta-analysis was not possible
- Many large-scale studies of blunt abdominal injury had to be excluded as it was not clear whether or not abuse had been considered as a possible aetiology, or where this was mentioned whether there was inadequate confirmation of abuse

- Case studies/series afford considerable clinical detail of the included cases, however the generalisability of these findings is limited
- Only 24/94 included studies were published in the last 10 years

Findings of clinical question 2

What is the value of non-radiological investigations in detecting abusive abdominal injury?

There are six articles that addressed this question.^{4,21,48,58,98,99} The age ranged between newborn to 12 years. The results were not analysed by gender.

Influence of ethnicity and socio-economic group

These aspects were not addressed by the included studies.

2.1 Serological tests

Four diagnostic test studies addressed the value of serological markers in identifying occult abdominal injury.^{4,21,58,98,99} The optimal study design would include all children undergoing a “gold standard” investigation such as an abdominal computerised tomography (CT) scan. Two studies did not do this, thus limiting the value of their findings.^{5,8} One did but only 19.4% underwent definitive testing.⁹⁹

A prospective study of 49 children less than 12 years of age presenting with suspected physical abuse underwent testing with liver transaminases, lactate dehydrogenase (LDH), alkaline phosphatase and amylase. 4/49 had elevated transaminases/LDH, three of whom had liver laceration. No child with negative serology underwent imaging.⁵

A prospective multi-centre study of 1,676 children with suspected abuse aged less than five years screened with transaminases found 259 children had elevated transaminases of whom 138 underwent “gold standard” testing. There were 41/138 that had identifiable abdominal injury. A cut off of 80 IU/L was deemed “positive” and based on this the sensitivity of testing was 77% with a specificity of 82%. Not all children presenting underwent serology, and it is not clear how the children were selected for testing.⁵⁸

A retrospective review investigated 2,890 children aged less than 10 years whose siblings were evaluated for abuse, 53.2% underwent serological testing, although the criteria for performing the screening was not specified. There were 310 children that had elevated transaminases of whom two thirds underwent definitive testing and 29.3% of whom had an intra-abdominal injury.

It is of note that 13.7% of those with negative transaminases who underwent definitive testing also had an intra-abdominal injury.⁹⁹

A secondary analysis of this data explored the level of positive serology in infants less than six months of age presenting with an isolated bruise. There were 92/146 (63%) that underwent serology, of whom 14 had elevated enzymes and 12 underwent CT. Overall 4/15 children that underwent CT had a liver laceration or contusion, it is not clear whether these children had elevated enzymes or not.⁹⁸

A study of the value of CT imaging of 84 abused children aged less than five years of age compared positive CT imaging to positive serology.⁴⁸ There were 56 children that underwent serology and it was found that 21/27 children with abdominal injury had elevated transaminases and 19/29 with normal abdominal CT also had elevated serology.⁴⁸ Elevated amylase or lipase was found in 14/28 children with abdominal injury and in 2/14 with a normal CT.⁴⁸

2.2 Urinalysis

A recent case series assessed the utility of screening urinalysis to detect abdominal injuries in suspected victims of child physical abuse.⁴ This study tested 237 children aged seven years and under and found no features of intraabdominal injury in 186. There were 24 children with blood in urine on dipstick testing; 10 of these had no features of abdominal injury, 19 underwent abdominal imaging by CT scan, ultrasound or direct visualisation, with 8 having positive findings. Only one child had a negative urine dipstick but positive findings on imaging.

2.3 Key evidence statements

- While a positive serology test may warrant further investigation, those with negative serology may also have significant intra-abdominal injury
- Infants less than six months of age with isolated bruising but no other symptoms or signs of injury may still have occult abdominal injury
- Urinalysis is of limited value in identifying children requiring further investigation for possible abdominal injury

2.4 Research implications

- Future studies should be prospective studies of children presenting with suspected abuse, all of whom undergo serological testing with precisely defined cut-offs. Abdominal CT would currently be the imaging of choice to delineate abdominal injuries
- It would be optimal for children with negative investigations to undergo imaging to truly define specificity and sensitivity. However it is recognised that the radiation involved may pose ethical dilemmas and alternative imaging modalities (such as contrast enhanced

ultrasound) require further evaluation in the context of assessment of suspected physical abuse

2.5 Limitations of review findings

- Only five diagnostic test studies have been conducted, not all children with positive serology or urinalysis underwent diagnostic imaging, and in no study did all children with negative investigations undergo “gold standard” testing
- The reasons were not given for all cases to explain why clinicians elected to test or not test serological markers

Other useful findings

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

Clinical question 1

Visceral consequences of injury

Rhabdomyolysis has been described as a consequence of severe physical abuse with multiple extensive bruises, and has resulted in renal failure.^{100,101}

Commotio cordis has been described where the assault on the child involves a direct blow to the chest resulting in ventricular dysrhythmia and subsequent death. Significantly, no pathological abnormality was found in the heart on autopsy and in only one case were co-existent rib fractures present (in this child the perpetrator also admitted to severe squeezing of the chest).¹⁰²⁻¹⁰⁴

Single case study with detailed post-mortem findings. The objectives of the study were to compare other children who had died due to non-accidental abdominal injuries, but the 26 cases also include children who had survived. Multiple different injuries/mechanisms described.¹⁰⁵

Vulnerability of infants to abdominal injury

Young children are susceptible to injury due to a less muscular, thin abdominal wall, the diaphragm being more horizontal and the liver and spleen more anterior, thus less protected by the ribs. As the ribs themselves are elastic and more compressible, direct trauma to the chest may crush solid organs below.⁹⁷

Epidemiology

While the following referenced studies did not meet our inclusion criteria for rank of abuse they provide a population estimate of the prevalence of abusive abdominal trauma in children in the USA,¹⁰⁶⁻¹⁰⁸ and the proportion of children with fatal abuse with abdominal injury in the UK.²

Trauma service involvement

Given the prevalence of poly-trauma amongst abused infants and children, prompt trauma service evaluation would be of value to optimise management and reduce mortality.¹⁰⁹

Association with other injuries

There was no significant difference in the likelihood of having an abdominal injury between the burns and comparison group.¹¹⁰ There was also no significant difference in the likelihood of abdominal injury when the burn presents as a primary or secondary finding.

Clinical question 2

Optimal radiological investigation of suspected abdominal injury is a CT scan of the abdomen¹¹¹ with or without contrast.¹¹²

A plain abdominal film may indicate perforation, and ultrasound (U/S) is non-invasive and easily accessible. However, either of these investigations may miss significant injury.^{109,112-116}

A Cochrane review concluded there is no evidence in using U/S in preference to CT scan for blunt abdominal injury as its sensitivity is too low for definitive identification of injury.¹¹⁷ However, two recent review explore the use of contrast-enhanced ultrasound to detect intra-abdominal trauma. Its use has not been evaluated in children with suspected physical abuse who have no history or clinical findings to suggest intra-abdominal injury.^{118,119}

A study demonstrated that urinalysis has a low sensitivity, but high specificity for abdominal injury from any cause when compared with CT scan.¹²⁰ This means that if positive, urinalysis is a good indicator of abdominal injury, but if negative it cannot exclude injury.

Related publications

Publications arising from visceral injuries review

Maguire SA, Upadhyaya M, Evans A, Mann MK, Haroon MM, Tempest V, Lumb RC, Kemp AM. A systematic review of abusive visceral injuries in childhood - Their range and recognition. *Child Abuse and Neglect*. 2013;37(7):430-445

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Appendix 1 – Methodology

In the original visceral injuries systematic review an all-language literature search of original articles, their references and conference abstracts published since 1950 was performed. The initial search strategy was developed across OVID Medline databases using keywords and Medical Subject Headings (MeSH headings) and was modified appropriately to search the remaining bibliographic databases. The search sensitivity was augmented by use of a range of supplementary 'snowballing' techniques including consultation with subject experts and relevant organisations, and hand searching selected websites, non-indexed journals and the references of all full-text articles.

Prior to the 2018 update, identified articles, once scanned for duplicates and relevancy, were transferred to a purpose-built Microsoft Access database to coordinate the review and collate critical appraisal data. Where applicable, authors were contacted for primary data and additional information. Translations were obtained when necessary. Relevant studies were scanned for eligibility by the lead researcher and those that met our inclusion criteria were reviewed. For the 2018 update studies were managed using Endnote and only data included in English language papers or with an English language abstract were accessed for relevancy. No contact was made with authors in this update.

Standardised data extraction and critical appraisal forms were based on criteria defined by the National Health Service's Centre for Reviews and Dissemination (Centre for Reviews and Dissemination 2009). We also used a selection of systematic review advisory articles to develop our critical appraisal forms.¹²¹⁻¹²⁴ Articles were independently reviewed by two reviewers. A third review was undertaken to resolve disagreement between the initial reviewers when determining either the evidence type of the article or whether the study met the inclusion criteria. Decisions related to inclusion and exclusion criteria were guided by Cardiff Child Protection Systematic Reviews, who laid out the basic parameters for selecting the studies.

Our panel of reviewers included paediatricians, paediatric surgeons, radiologists, pathologists, information specialists and designated and named doctors in child protection. All reviewers underwent standardised critical appraisal training, based on the CRD critical appraisal standards,¹²¹ and this was supported by dedicated electronic critical appraisal resources.

Inclusion criteria

We included high quality case series/studies, where abuse had been confirmed. To minimise circularity in relation to confirmation of abuse, we included only those studies where the rank of abuse was 1 or 2. In order to address the role of non-radiological investigations in detecting abusive abdominal injury, we accepted studies with a lower rank of abuse (4-5) for this question, in order to determine if occult injuries were present.

Inclusion	Exclusion
Children aged 0 to < 18 years	Studies with mixed child and adult subjects, where the children's data could not be extracted
Alive or deceased on presentation	Inadequate clinical detail of included cases
Injury confirmed by one or more of the following:	studies including a mixture of abusive and accidental injuries, where the details of these two groups could not be extracted
Contrast studies	studies exclusively addressing the outcome / management of visceral injuries
Computed tomography (CT) scanning, with or without contrast	studies of sexual abuse, thus all ano-genital / rectal injuries
Surgery	
Post mortem examination	

Ranking of abuse

Ranking	Criteria used to define abuse
1	Abuse confirmed at case conference or civil, family or criminal court proceedings or admitted by perpetrator or independently witnessed
2	Abuse confirmed by stated criteria including multidisciplinary assessment
3	Diagnosis of abuse defined by stated criteria
4	Abuse stated as occurring, but no supporting detail given as to how it was determined
5	Abuse stated simply as 'suspected', no details on whether it was confirmed or not

Search strategy

The below table presents the search terms used in the 2021 Medline database search for visceral injuries, truncation and wildcard characters were adapted to the different databases where necessary.

1. exp Child Abuse/	76. renal fracture.af.
2. child abuse.af.	77. *"Kidney"/in [Injuries]
3. (child protection or child maltreatment).af.	78. *"Aortic Rupture"/
4. (battered child or shaken baby or battered baby).af.	79. renal contusion:.af.
5. exp Shaken Baby Syndrome/	80. "Renal Artery"/in [Injuries]
6. exp Battered child Syndrome/	81. subcapsular h?ematoma.af.
7. or/1-6	82. hepatic laceration:.af.
8. (child: or infant: or baby or toddler:).ti,ab.	83. Lacerations/
9. child/ or Infant/ or Child, Preschool/	84. contusion.af. or Contusions/
	85. rectal injur:.af.

10. 8 or 9	86. **Rectum"/in [Injuries]
11. inflicted injur:.af.	87. Peritonitis/
12. non-accidental injur*.af.	88. peritoneal fluid.af.
13. non-accidental trauma*.af.	89. perinephric collection.af.
14. (non-accidental: and injur*).ti,ab.	90. Transaminases/
15. soft tissue injur*.af.	91. Foreign Bodies/
16. (physical abuse or physical punishment).af.	92. gamma-Glutamyltransferase/ or GGT.af.
17. assault.mp.	93. Intestine, Small/
18. (or/11-17) and 10	94. Amyloid/
19. 7 or 18	95. liver enzymes.af.
20. Contrast study.af.	96. "Spleen"/in [Injuries]
21. Tomography, X-Ray Computed/	97. Thoracic Injuries/
22. (MRI or Magnetic resonance imaging).af.	98. thoracic trauma.af.
23. plain film.af.	99. mesenteric.af.
24. ultrasound scan.af.	100. duodenal h?ematoma.af.
25. CT scan.af.	101. Wounds, Nonpenetrating/
26. CTA scan.af.	102. *Intestines/in [Injuries]
27. Radiography, Abdominal/	103. hepatic fracture:.af.
28. Abdominal ultrasound.af.	104. hepatic hematoma.af.
29. Contrast-enhanced ultrasound.af.	105. Amylases/
30. barium meal.af.	106. Alanine Transaminase/ or ALT.af.
31. Barium enema.af.	107. Aspartate transaminase/ or AST.af.
32. angiogram.af.	108. Aortic trauma.af.
33. Tomography, Spiral Computed/	109. Cardiac laceration:.af.
34. intravenous pyelogram.af.	110. Cardiac perforation.af.
35. upper GI series.af.	111. "Heart Injuries"/
36. lower GI series.af.	112. gastric perforation.af.
37. (esophagram or oesophagram).af.	113. gastric laceration:.af.
38. 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or	114. gluteal.mp.
28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36	115. (Haemorrhage: or hemorrhage:).af.
or 37	116. ileal injur:.af.
39. Intestinal Perforation/	117. lung laceration:.af.
40. duodenal perforation.af.	118. Mediastinal trauma:.af.
41. Splenic Rupture/	119. Pulmonary contusion:.af.
42. Rupture, Spontaneous/	120. Pulmonary laceration:.af.
43. oesophageal tear*.af.	121. Ascites/
44. oesophageal laceration*.af.	122. Chylous Ascites/
45. Cardiac Tamponade/	123. Hematuria/
46. pericardial tamponade.af.	124. H?ematuria.af.
47. bladder rupture:.af.	125. Lipase/

48. kidney rupture:.af.	126. mesentary.af.
49. pancreas rupture:.af.	127. viscus.af.
50. Rupture/	128. Viscera/
51. Abdominal Injuries/	129. osteolytic lesions.af.
52. liver injur:.af.	130. chylothorax.af.
53. Kidney Injur:.af.	131. Heart Septal Defects, Ventricular/
54. intestinal injur:.af.	132. chylothorax/
55. colonic injur:.af.	133. cervical soft tissue lesion*.af.
56. Visceral injur:.af.	134. ((cardiac or ileal or liver or kidney or colonic or spleen or duoden* or oesophagus or esophageal or abdominal or lung or pancrea* or viscera or bowel or intestine) adj3 (rupture or trauma or tear)).mp.
57. Esophageal Perforation/	135. ((spleen or pelvic or duodenal) adj3 (lacerat* or injur*)).af.
58. thorax injur:.af.	136. Gastrointestinal injur*.mp.
59. bladder perforation.af.	137. Gastrointestinal Tract.mp.
60. bowel perforation.af.	138. occult abdominal injur*.mp.
61. esophageal laceration:.af.	139. Subcapsular h?ematoma.af.
62. Heart Rupture/	140. lymphatic chylous ascites.mp.
63. Pancreatic Pseudocyst/	141. Chylous Ascites/
64. Hematoma/	142. Alkaline Phosphatase/
65. Hematemesis/	143. ALK Phos.mp.
66. H?ematemesis.af.	144. or/39-143
67. vascular injur:.af.	145. 19 and 38 and 144
68. pharyngeal.af.	146. 19 and 144
69. Hematoma/	147. 145 or 146
70. h?ematoma.af.	148. limit 147 to (humans and yr="2018 - Current")
71. oesophageal injur:.af.	
72. bowel injur:.af.	
73. jejunal injur:.af.	
74. Jejunum/	
75. renal laceration:.af.	

Thirteen 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)	1987 - 2014
Child Data	1958- 2009 [†]
CINAHL (<i>Cumulative Index to Nursing and Allied Health Literature</i>)	1982 - 2014
Cochrane Library (formerly All EBM Reviews - Cochrane DSR, ACP Journal Club, DARE, and CCTR)	1996-2014
EMBASE	1980 - 2021
MEDLINE	1950 - 2021
MEDLINE In-Process and Other Non-Indexed Citations	1951-2021
Open SIGLE (System for Information on Grey Literature in Europe)	1980 - 2005 [*]
Pubmed e publications	2014
Scopus	1960-2021
Web of Knowledge – ISI Proceedings	1990 - 2014
Web of Knowledge – ISI Science Citation Index	1981 - 2014
Web of Knowledge – ISI Social Science Citation Index	1981 - 2014
* ceased indexing † institutional access terminated	
Journals 'hand searched'	Time period searched
Child Abuse and Neglect	1977 - 2014
Child Abuse Review	1992 - 2014
Websites searched	Date accessed
British Association for the Study and Prevention of Child Abuse and Neglect (BASPCAN)	May 2014
British Society of paediatric Radiology	May 2014
Child Abuse Professional Network (CAPnet)	May 2014
Child Welfare Information Gateway (formerly National Clearinghouse on Child Abuse and Neglect)	May 2014

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. These first two stages were carried out by a systematic reviewer at the RCPCH and a clinical expert. Finally, a full text screen with a critical appraisal was carried out by expert reviewer 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 (evidence@rcpch.ac.uk).