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A systematic review of abusive visceral injuries in childhood—Their range and recognition☆

S.A. Maguire[a,*], M. Upadhyaya[b], A. Evans[c], M.K. Mann[d], M.M. Haroon[e], V. Tempest[a], R.C. Lumb[a], A.M. Kemp[a]

[a] Child Health Department, School of Medicine, Cardiff University, University Hospital of Wales, Heath Park, Cardiff CF14 4XN, UK
[b] Department of Paediatric Surgery, Bristol Children's Hospital, Bristol BS2 8BJ, UK
[c] Radiology Department, University Hospital of Wales, Heath Park, Cardiff CF14 4XN, UK
[d] Support Unit for Research Evidence, Cardiff University, University Hospital of Wales, Heath Park, Cardiff CF14 4XN, UK
[e] Leicestershire Partnership, Families, Young People and Children's Services, Bridgepark Plaza, Bridgepark Road, Thurmaston, Leicester LE4 8PQ, UK

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ABSTRACT

Objectives: To define what abusive visceral injuries occur, including their clinical features and the value of screening tests for abdominal injury among abused children.
Methods: We searched 12 databases, with snowballing techniques, for the period 1950–2011, with all identified studies undergoing two independent reviews by trained reviewers, drawn from pediatrics, radiology, pediatric surgery and pathology. Of 5802 studies identified, 188 were reviewed. We included studies of children aged 0–18, with confirmed abusive etiology, whose injury was defined by computed tomography, contrast studies or at surgery/post mortem. We excluded injuries due to sexual abuse, or those exclusively addressing management or outcome.
Results: Of 88 included studies (64 addressing abdominal injuries), only five were comparative. Every organ in the body has been injured, intra-thoracic injuries were commoner in those aged less than five years. Children with abusive abdominal injuries were younger (2.5–3.7 years vs. 7.6–10.3 years) than accidentally injured children. Duodenal injuries were commonly recorded in abused children, particularly involving the third or fourth part, and were not reported in accidentally injured children less than four years old. Liver and pancreatic injuries were frequently recorded, with potential pancreatic pseudocyst formation. Abdominal bruising was absent in up to 80% of those with abdominal injuries, and co-existent injuries included fractures, burns and head injury. Post mortem studies revealed that a number of the children had sustained previous, unrecognized, abdominal injuries. The mortality from abusive abdominal injuries was significantly higher than accidental injuries (53% vs. 21%). Only three studies addressed screening for abdominal injury among abused children, and were unsuitable for meta-analysis due to lack of standardized investigations, in particular those with 'negative' screening tests were not consistently investigated.
Conclusions: Visceral injuries may affect any organ of the body, predominantly abdominal viscera. A non-motor vehicle related duodenal trauma in a child aged < five years warrants consideration of abuse as an etiology. In the absence of clear evidence for a screening

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* Corresponding author.

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strategy, clinical vigilance is warranted in any young child with suspected abuse for the presence of abdominal injury, where the absence of abdominal bruising or specific symptoms does not preclude significant injury.

Introduction

Trauma is the leading cause of death in children aged over one in most developed nations, and causes significant morbidity, in addition to the financial burden on the health services (Gaines & Ford, 2002). Blunt trauma is more common than penetrating injuries in childhood, accounting for 90% of admissions in trauma series (Gaines & Ford, 2002; Touloukian, 1968). There are several unique anatomical reasons that make the intra abdominal organs in children more susceptible to blunt trauma. Children have a less muscular and a thinner abdominal wall; the diaphragm is more horizontal thus the liver and spleen are more anterior and less protected by ribs, which are themselves elastic and very compressible, potentially crushing solid organs below (Gaines & Ford, 2002).

Motor vehicle collisions (MVC) are the commonest cause of abdominal trauma followed by those sustained at play or at home (Holmes, Sokolove, Land, & Kuppermann, 1999). While abusive head trauma (AHT) is the commonest cause of death among abused children (Roaten et al., 2006; Sibert et al., 2002), it is estimated that abdominal trauma contributes to up to 50% of abusive fatalities (Ledbetter, Hatch, Feldman, Fligner, & Tapper, 1988). The true prevalence of abusive abdominal injuries is difficult to determine. While it is reported as occurring in 0.5–4% (Cooper et al., 1988; Holmes et al., 1999, 2002) of child abuse admissions, unless clinicians specifically consider abuse as a possible cause of trauma in children presenting to the ED, it is unlikely to be recognized (Louwers et al., 2011), with potentially devastating consequences (Byard & Heath, 2010). Likewise, significant visceral injury may present with little or no specific signs, where as few as 12% may have abdominal bruising (Ledbetter et al., 1988). As some children may present with non-specific symptoms, e.g. vomiting, irritability, it would be of value to define which clinical and hematological features could help to identify those children that require further radiological imaging such as contrast Computerized Tomography (CT) (Hilmes et al., 2011; Lindberg et al., 2009). The systematic review aims to define the spectrum of abusive visceral injuries, and define the value of screening tests.

Methods

An all-language literature search across 12 bibliographic databases (Appendix 1) was conducted to identify original articles published from 1950 to May 2011. The initial search strategy (Appendix 2) was developed across OVID Medline databases using keywords and Medical Subject Headings (MeSH headings) and was modified appropriately to search the remaining bibliographic databases.

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The search sensitivity was augmented by the use of a range of supplementary 'snowballing' techniques including consultation with subject experts and relevant organizations, and hand searching selected websites, non-indexed journals and the references of all full-text articles (Appendix 1). 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. Relevant studies with an English language version available were scanned for eligibility by the lead researcher; those that met our inclusion criteria (Table 1) were reviewed (Fig. 1).

A panel of pediatricians, radiologists, an information specialist, a forensic pathologist and a pediatric surgeon conducted two independent reviews of all relevant articles, using standardized critical appraisal forms (Appendix 3) 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 (Critical Appraisal Skills Programme (CASP); Polgar & Thomas, 1995; Rychetnik & Frommer, 2002; Weaver et al., 2002; Weightman, Mann, Sander, & Turley, 2004). All reviewers underwent critical appraisal training purposefully designed for this review. 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 (Table 1).

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Quality standards

Regarding evidence type, the optimal study design to address our primary question (what visceral injuries occur as a consequence of physical abuse, and what are their distinguishing characteristics) would be high quality comparative studies (case control/cross sectional) of abusive injury vs. accidental injury (AI). Given the difficulties of researching in this field, we accepted high quality case series/studies, where abuse had been confirmed. We wished to minimize 'circularity' in relation to confirmation of abuse, i.e. to ensure that those cases classified as 'abused' in our review did not have that diagnosis based

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Table 1
Inclusion and exclusion criteria.

Inclusion criteria
- Studies of children aged 0 to <18 years
- Alive or deceased on presentation
- Injury confirmed by one or more of the following:
- Contrast studies
- Computed Tomography (CT) scanning, with or without contrast
- Surgery
- Post mortem examination

Exclusion criteria
- Studies with mixed child and adult subjects, where the children's data could not be extracted
- Inadequate clinical detail of included cases
- Studies including a mixture of abusive and accidental injuries, where the details of these two groups could not be extracted
- Studies exclusively addressing the outcome/management of visceral injuries
- Studies of sexual abuse, thus all ano-genital/rectal injuries

Ranking	Criteria used to define abuse
1	Abuse confirmed at case conference or civil, family or criminal court proceedings or admitted by perpetrator, reported by child, or independently witnessed
2	Abuse confirmed by stated criteria including multi-disciplinary 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

solely on the injury in question (e.g. small bowel injury). Thus we used our previously described 'Ranking of Abuse' (Maguire et al., 2009), including only those studies ranked 1–2 as below (Table 1). In order to address the second question (what non-radiological tests may indicate the presence of an abusive abdominal injury), the optimal design would be a diagnostic test study, where all children underwent the 'gold standard' test i.e. CT imaging ± contrast *or* contrast imaging studies in addition to the test under consideration. As the end point of these studies was to determine if occult injuries were present, rather than characterize those injuries, we accepted studies with a lower rank of abuse (4–5) for this question.

Results

Overall, 88 studies described the abusive visceral injuries in children, of which 64 addressed abdominal injuries (Anchala & Wright, 2001; Aoki, Nata, Hashiyada, & Sagisaka, 1997; Barnes et al., 2005; Beauchamp, Belanger, & Neitzschman, 1976; Beckmann & Nozicka, 2000; Benhaim et al., 1995; Beshay, Beshay, & Rosenberg, 2001; Boysen, 1975; Bratu, Dower, Siegel, & Hosney, 1970; Cameron, Lazoritz, & Calhoun, 1997; Caniano, Beaver, & Boles, 1986; Case & Nanduri, 1983; Chen et al., 1994; Coant, Kornberg, Brody, & Edwards-Holmes, 1992; Conradi & Brissie, 1986; Cordner et al., 2001; deRoux & Prendergast, 1998, 2000; Dillard & Stewart, 1985; Dworkind, McGowan, & Hyams, 1990; Eisenstein, Delta, & Clifford, 1965; Fain & McCormick, 1988; Gaines, Shultz, Morrison, & Ford, 2004; Glick & La Quaglia, 2000; Gornall, Ahmed, Jolleys, & Cohen, 1972; Grosfeld & Ballantine, 1976; Gunther, Symes, & Berryman, 2000; Gurland, Dolgin, Shlasko, & Kim, 1998; Halsted & Shapiro, 1979; Hamilton & Humphreys, 1985; Hicks & Gaughan, 1995; Hilmes et al., 2011; Jacombs et al., 2004; Kelley, 1982; Kleinman, Raptopoulos, & Brill, 1981; Lautz, Leonhardt, Rowell, & Reynolds, 2009; Ledbetter et al., 1988; Lindberg et al., 2009; McCort & Vaudagna, 1964; Neuer, Roberts, & McCarthy, 1977; Ng & Hall, 1998; Ng, Hall, & Shaw, 1997; Nijs, Vanclooster, de Gheldere, & Garmijn, 1997; Olazagasti, Fitzgerald, White, & Chong, 1994; Orel, Nussbaum, Sheth, Yale-Loehr, & Sanders, 1988; Pena & Medovy, 1973; Porzionato, Macchi, Aprile, & De Caro, 2008; Rosenberg, 1984; Salmon, 1971; Sawyer, Hartenberg, & Benator, 1987; Simpson, 1965; Sirotnak, 1994; Slovis, Berdon, Haller, Baker, & Rosen, 1975; Stewart, Byrd, & Schuster, 1970; Sujka, Jewett, & Karp, 1988; Swadia, Thakore, Patel, & Bhavani, 1981; Terreros & Zimmerman, 2009; Tracy, O'Connor, & Weber, 1993; Vollman, Keenan, & Eraklis, 1966; Wilson, Anderson, & Duncan, 1996; Wood, Rubin, Nance, & Christian, 2005; Wu, Chen, & Auringer, 2000; Yang, Kuppermann, & Rosas, 2002; Yavuz et al., 2008), and 27 intra-thoracic and pharyngeal (Ablin & Reinhart, 1990; Anderst, 2007; Bansal & Abramo, 1997; Cohle, Hawley, Berg, Kiesel, & Pless, 1995; Cumberland, Riddick, & McConnell, 1991; Dobi-Babic & Katalinic, 2008; Fain & McCormick, 1988; Geismar, Tilelli, Campbell, & Chiaro, 1997; Gipson & Tobias, 2006; Grace, Kalinkiewicz, & Drake-Lee, 1984; Green, 1980; Guleserian, Gilchrist, Luks, Wesselhoeft, & DeLuca, 1996; Karpas, Yen, Sell, & Frommelt, 2002; Kleinman, Spevak, & Hansen, 1992; Lieberman, Chiasson, & Podichetty, 2010; Marupaka & Unnithan, 2007; McDowell & Fielding, 1984; McEniery, Hanson, Grigor, & Horowitz, 1991; Ng et al., 1997; Reece, Arnold, & Splain 1996; Rees, Symons, Joseph, & Lincoln, 1975; Roche, Genieser, Berger, & Ambrosino, 1995; Salmon, 1971; Sola, Cateriano, Thompson, & Neville, 2008; Stone, Harawitz, San Filippo, & Gromisch, 1976; Tavill, Trimmer, & Austin, 1996; Tostevin, Hollis, & Bailey, 1995). Overall, there were 81 cases series/studies, six cross sectional studies, and one uncontrolled retrospective cohort. The commonest reasons for exclusion were low rank of abuse (51), irrelevance to the review questions (35) and inadequate confirmation and/or detail relating to the visceral injury (17) (a study could be excluded for more than one reason). There were only five high quality comparative studies of accidental vs. abusive abdominal injuries, three addressing hollow/solid organ abdominal injuries (Barnes et al., 2005; Ledbetter et al., 1988; Wood et al., 2005), one

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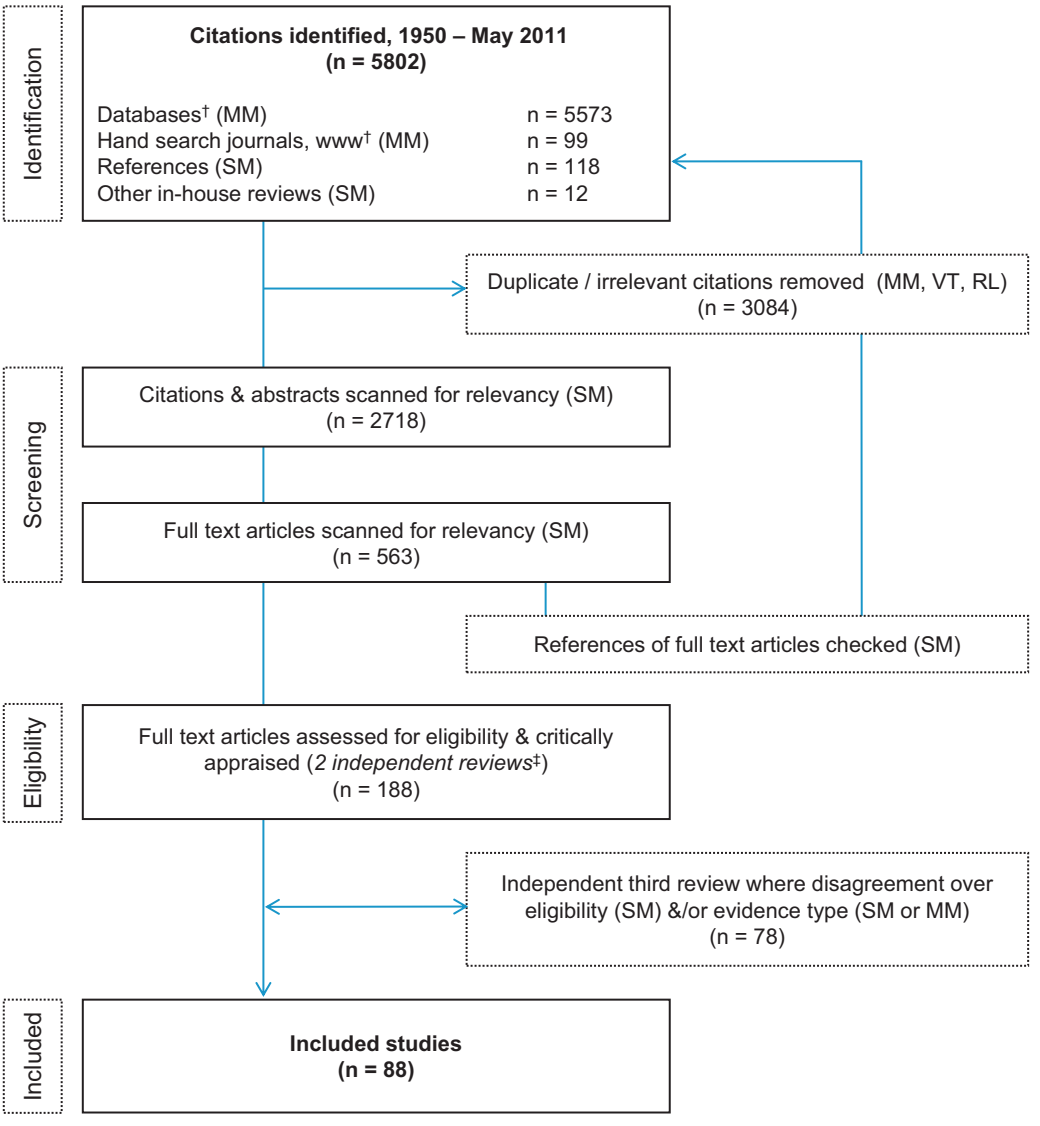

* flow diagram based on PRISMA guidance, http://www.prisma-statement.org/
† see Appendix 1. Databases, journals and website searched
‡ panel of trained reviewers – see acknowledgements

Fig. 1. Study Selection Process*.

exclusively duodenal injuries (Gaines et al., 2004) and one pancreatic injuries (Jacombs et al., 2004) (Table 2). As well as looking at abusive visceral injuries, three studies also addressed the value of serological tests to identify abdominal injuries in abused children (Coant et al., 1992; Hilmes et al., 2011; Lindberg et al., 2009).

Abdominal injuries: comparative studies

The only study to estimate population prevalence (Barnes et al., 2005), determined the incidence of abdominal injury due to abuse in the UK to be 0.9 cases/million children/year (95% CI 0.58–1.39) across all ages, and 2.33 (1.43–3.78) cases/million children/year in those aged less than five years. This is likely to be a minimum estimate, as only those children presenting *alive* to hospital were included, not those who died at the scene. In addition, it is not routine practise to investigate all children with suspected abuse for the presence of abdominal injury. From the limited comparative data available (Barnes et al., 2005; Gaines et al., 2004), it appears that small bowel injuries as a result of falls are not recorded in children < five years, the peak age for abusive injuries (Table 2).

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Table 2
Comparative studies of abdominal injuries in children.

Author	Abuse Cases/age	Accidental Cases/age		Age ascertainment	Visceral injuries	Key findings
Barnes et al. (2005)	20 cases Mean age 3.73 (SD 3.7) years	164 cases MVC Fall	 112 (68%) Mean age 9.7 (SD 3.82) years 52 (32%) Mean age 10.39 (SD 3.7) years	Age 0–14 years, between March 2001 and February 2003 All children admitted with internal abdominal injury Abused from British Paediatric Surveillance Unit (BPSU) and AI from Trauma Audit and Research Network (TARN)	44/52 (85%) of AI from falls had solid organ injuries, only 3 aged <5 years 12/20 (60%) of abused had solid organ injury, 10 aged <5 years 11/20 (55%) abused had hollow organ injuries, 9 aged <5 years 3/20 (15%) abused cases had hollow and solid organ injuries	**Age**: abused significantly younger than AI Incidence of abdominal injury due to abuse 0.9 cases/million children/year (95% CI 0.58–1.39). For all children, 2.33 (CI 1.43–3.78) cases/million children/year for those aged <5 years 17/20 (85%) abuse cases had co-existent injuries; fractures, HI, torn frenum, bites, burns 5/20 (25%) abused had no abdominal bruising [b]NB no child <5 years sustained hollow organ injury from a fall
Gaines et al. (2004)	8 cases Mean age 2.25 (±0.7) years	22 cases MVC Bicycle All terrain vehicle Assaul Other	 9 (41%) All aged >4 years 4 (18%) 2 (9%) 2 (9%) 5 (23%	Age 0–12 years, between January 1995 and December 2002 All children admitted to single trauma center with Duodenal injury	3/9 (33%) MVC had perforated duodenum 3/8 (38%) abused had perforated duodenum, 2 of whom had complicated post operative courses	All duodenal injuries <4 years due to abuse, only 1/8 (12.5%) had abdominal bruising 7/8 (87.5%) abuse cases had co-existent injuries; fractures, pancreatic injury, other intestinal injury, HI Abuse second commonest cause of duodenal injury

Table 2 (*Continued*)

Author	Abuse Cases/age	Accidental Cases/age		Age ascertainment	Visceral injuries	Key findings
Jacombs et al. (2004)	10 cases No data given on age	55 cases MVC Bicycle Fall Horse Sports Other	 35 (63%) 8 (15%) 3 (5.5%) 3 (5.5%) 3 (5.5%) 3 (5.5%)	Age 0–16 years, between January 1983 and September 2002 All children admitted to single trauma unit or undergoing post mortem with pancreatic injury	Injuries graded from 1 to 4 43 survived, 22 died; 4/10 (40%) abused and 18/55 (33%) AI	77% of fatal injuries due to MVC, 1% due to abuse 3/10 (30%) fatal abuse cases had co-existent injuries; HI, burns, fractures, mesenteric tear, liver injury Abuse was third commonest cause of pancreatic injury in children Further details provided from authors
Ledbetter et al. (1988)	17 cases Mean age 2.5 years	139 cases Mean age 7.66 years MVC Fall Other[a]	 98 (70%) 28 (20%) 13 (10%)	Age 0–13 years, between 1979 and 1986 All children admitted to one of two hospitals or undergoing post mortem with blunt abdominal injuries	Abuse was the cause of abdominal injury in 44% of those <4 years 61% of AI had injury to single solid organ, only 8% (11/139) had hollow organ injury (7 perforations, 4 intramural hematomas) vs. 65% (11/17) abused with hollow organ injury (7 perforations, 4 intramural hematomas) Abused predominantly jejunal (5), duodenal (1) gastric (1) vs. AI colon (3) jejunum (1), duodenum (1) gastric (1) Abused higher mortality (53%) vs. AI (21%) Delayed presentation: 91% of AI attended within 3 h vs. all the abused delayed	**Age**: abused significantly younger than AI **Gender**: more boys than girls, each group 2:1 Abused had more hollow organ injuries, predominantly small bowel AI cases due to MVC had co-existent injuries 13/17 (76%) abuse cases had co-existent injuries; rib fractures, HI, burns, pulmonary contusions 15/17 (88%) had no additional bruising NB only 2/17 (12%) abused had abdominal injury No splenic injury among the abused, whereas 65/139 (47%) of the AI had splenic injuries, with only 11/139 (8%) having bowel injury

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Table 2 (*Continued*)

Author	Abuse Cases/age	Accidental Cases/age		Age ascertainment	Visceral injuries	Key findings
Wood et al. (2005)	13 cases 54% < 36 months	108 cases HVA[b] LVA[c]	 77 (63%) 22% < 36 months 31 (26%) 3% < 36 months	Age < 6 years, between January 1991 and September 2001 All children admitted with abdominal injuries and AIS score ≥2 Excluded HI with GCS < 14, spinal or thoracic trauma Retrospective	Solid organ injuries similar between AI/abuse, hollow organ commoner in abuse, $p = 0.031$, hollow and solid organ injury only in abuse Abused more severe than AI, $p < 0.001$ (AIS > 3) Delayed presentation: 76/77 (99%) HVA, 13/31 (42%) LVA, 2/13 (15%) of abused presented within 2 h ($p < 0.001$). By 12 h, 65% of LVA vs. 46% of abused presented ($p < 0.001$)	**Age**: abused significantly younger (25% AI < 3 years, vs. 54% abuse, $p = 0.001$) Excluding HVA, 30% of abdominal injuries in those age <6 years due to abuse Excluding HVA (no clinical dilemma) delay to care and high severity (AIS score > −3) best predictor of abusive injury i.e. specificity 90% but predictive value only 67% 4/13 (31%) abuse cases had co-existent injuries; fractures, HI NB three accidental LVA with delayed presentation – 4 year old splenic laceration from fall from jungle gym, 5 year old splenic laceration blunt trauma with bicycle handlebars, 4 year old with jejunal perforation from falling onto a rock

AI: accidental injury, AIS: Abbreviated Injury Scale, HI: head injury, HVA: high velocity accidental trauma, LVA: low velocity accidental trauma, and MVC: motor vehicle collision.

[a] Sports, struck by falling object, kicked by farm animals.

[b] MVC, fall > 10 feet.

[c] Household, bike, fall < 10 feet.

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Gaines et al. (2004) estimated that 2.8% of their *child abuse* admissions over this seven year period had duodenal injury, even though such injuries only accounted for 0.3% of *trauma* admissions overall. Across the three studies detailing bowel injury, duodenal injuries were not recorded in children less than four years of age due to accidental causes (Barnes et al., 2005; Gaines et al., 2004; Wood et al., 2005). Combined bowel/solid organ injury was recorded more commonly in the abused children (Ledbetter et al., 1988; Wood et al., 2005). There were no clear gender differences, with two studies noting more abdominal injuries in boys than girls (Gaines et al., 2004; Ledbetter et al., 1988) (both abused and accidental 2:1), yet Barnes et al. (2005) found the ratio reversed. One clear difference emerging between abusive and accidental abdominal injuries was the age of the child, where abused children were younger (Wood et al., 2005), with a mean age ranging from 2.5 to 3.7 years vs. 7.6 to 10.3 years (Barnes et al., 2005; Ledbetter et al., 1988). The other striking difference between these two groups was in relation to mortality, where the abused children were significantly more likely to die of their injuries (53%) than those accidentally injured (21%) ($p = 0.014$, Fisher's Exact test), and only two accidentally injured died of their abdominal injury alone (Ledbetter et al., 1988). Delayed presentation was only analyzed in two comparative studies; Ledbetter et al. (1988) noted 100% of abuse cases presented more than 3 h after injury vs. 9% of accidental cases, although this included high velocity injuries; Wood et al. (2005) determined positive predictive value of delayed presentation (>12 h) combined with severity of injury (Abbreviated Injury Scale (AIS) ≥ 2) to distinguish between abuse cases and low velocity injuries (falls < 10 feet, bike, domestic) was only 67%, while noting that 100% of high velocity injuries presented within 12 h.

What abdominal injuries occur in child abuse?

While our case series/studies showed that every organ in the abdomen has been injured, study design and heterogeneity prevented us from conducting a formal meta-analysis. Overall, injuries to solid organs and hollow organs are equally common, although precise percentages vary between studies (Hilmes et al., 2011). This may be attributable to the varying study populations, where some are a mixture of "cohorts" examining either fatal injuries or mixed intake studies (both fatal and non-fatal injuries). Fatal injuries may have more injuries affecting intra-abdominal organs, and a greater proportion of the cohort are likely to have had a post mortem thus identifying all injuries.

Hollow organ injuries

Studies of predominantly hollow organ injuries (Anchala & Wright, 2001; Beckmann & Nozicka, 2000; Bratu et al., 1970; Cameron et al., 1997; Caniano et al., 1986; Cordner et al., 2001; deRoux & Prendergast, 1998; Dworkind et al., 1990; Eisenstein et al., 1965; Glick & La Quaglia, 2000; Gornall et al., 1972; Gurland et al., 1998; Hamilton & Humphreys, 1985; Hilmes et al., 2011; Kelley, 1982; McCort & Vaudagna, 1964; Ng et al., 1997; Nijs et al., 1997; Orel et al., 1988; Porzionato et al., 2008; Stewart et al., 1970; Terreros & Zimmerman, 2009; Tracy et al., 1993; Wu et al., 2000; Yavuz et al., 2008) highlight the predominance of small bowel injury, and in particular perforation or transection of the duodenum, predominantly involving the junction of the third and fourth part (Beckmann & Nozicka, 2000; Cordner et al., 2001; deRoux & Prendergast, 1998; Hamilton & Humphreys, 1985; McCort & Vaudagna, 1964; Ng et al., 1997; Nijs et al., 1997; Tracy et al., 1993; Yavuz et al., 2008). Many other cases involved hematoma of the duodenum, causing varying degrees of obstruction (Bratu et al., 1970; Kelley, 1982). It is notable that the diagnosis was frequently delayed in these cases, and that when further investigations were conducted, numerous co-existent injuries were identified (Appendix 4).

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Solid organ injuries

Liver injuries were noted to occur with equal frequency among the accidentally injured and the abused children in the three comparative studies addressing this (Barnes et al., 2005; Ledbetter et al., 1988; Wood et al., 2005). Ledbetter recorded splenic injuries only among the accidentally injured children, yet Barnes and Wood noted similar prevalence between abuse/accidental cases, and two further studies recorded abusive splenic injuries (Caniano et al., 1986; Ng et al., 1997). Likewise, Hilmes et al. (2011) in their study of abused children aged less than five years, noted 6/35 children with splenic injuries, all managed conservatively. Among the 13 studies with primarily liver injuries (Aoki et al., 1997; Beauchamp et al., 1976; Cameron et al., 1997; Coant et al., 1992; Conradi & Brissie, 1986; Fain & McCormick, 1988; Gunther et al., 2000; Hicks & Gaughan, 1995; Hilmes et al., 2011; Kleinman et al., 1981; Salmon, 1971; Simpson, 1965; Sujka et al., 1988), there were 34 children aged three weeks to eight years (15/19 < three years). Liver injuries included laceration, contusions, subcapsular hematomas, and involved each lobe of the liver, and on at least three occasions split the liver entirely (Appendix 5).

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Multiple abdominal injuries are described in 10 studies (39 children), aged eight weeks to seven years (38/39 < five years old) (Anchala & Wright, 2001; Caniano et al., 1986; Grosfeld & Ballantine, 1976; Gunther et al., 2000; Hamilton & Humphreys, 1985; Hilmes et al., 2011; Kleinman et al., 1981; McCort & Vaudagna, 1964; Ng & Hall, 1998; Ng et al., 1997). The most recent

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of these (Hilmes et al., 2011) recorded 15 children aged less than five years with liver injury, of whom 12 had associated extra-hepatic solid organ, bowel or mesenteric injury.

Pancreatic injuries

Only one comparative study addressed pancreatic injuries (Jacombs et al., 2004), where they noted that MVC were the commonest cause of fatal pancreatic injury in childhood, but abuse accounted for 1% of fatalities. Additional details were kindly provided by the authors, which showed that all four of the fatally abused children in this series had multiple additional injuries (Table 2). Other reports of pancreatic injuries (Chen et al., 1994; Grosfeld & Ballantine, 1976; Hilmes et al., 2011; Jacombs et al., 2004; Kleinman et al., 1981; Neuer et al., 1977; Ng & Hall, 1998; Ng et al., 1997; Pena & Medovy, 1973; Slovis et al., 1975) (Appendix 6) highlight that they may be found in association with hollow organ injuries, or present as chronic injuries characterized by pseudocyst formation (Chen et al., 1994; Grosfeld & Ballantine, 1976; Kleinman et al., 1981; Neuer et al., 1977; Ng & Hall, 1998; Pena & Medovy, 1973; Slovis et al., 1975). An important longer term complication, arising up to six weeks after the original injury, is the development of multiple osteolytic lesions predominantly in the long bones, phalanges, tarsals and metatarsals (Neuer et al., 1977; Slovis et al., 1975), thought to be due to fat necrosis. The child will usually manifest pain on walking if the feet are involved, and persistent fever is also well described, however the bony lesions usually resolve with no sequelae.

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Further intra-abdominal injuries

Urinary tract and renal vascular injuries. Six case studies/series record intraperitoneal rupture of the bladder (Halsted & Shapiro, 1979; Lautz et al., 2009; Ng et al., 1997; Sawyer et al., 1987; Sirotnak, 1994; Yang et al., 2002), and renal trauma (Hilmes et al., 2011; Wilson et al., 1996). Wilson et al. reported infarction of the left kidney in a four month old, who presented with severe pneumococcal sepsis, caused by an associated complete infarction of the spleen. Hilmes et al. noted seven children with renal trauma aged 0–5 years, three of whom had associated abdominal bruising. One died from an intracranial injury, the remainder recovered fully. The six children with bladder rupture, aged 10 months to six years, presented with varying degrees of renal failure and an acute abdomen, and all had tears in the dome of the bladder (Halsted & Shapiro, 1979; Lautz et al., 2009; Ng et al., 1997; Sawyer et al., 1987; Sirotnak, 1994; Yang et al., 2002). Where the mechanism of injury was determined, it was due to being punched in the abdomen (Sirotnak, 1994; Yang et al., 2002), and frequently the children did not present for some days after the injury. Four of the children had no additional injuries other than bruising recorded (Halsted & Shapiro, 1979; Lautz et al., 2009; Sirotnak, 1994; Yang et al., 2002), although the level of further investigations performed is unclear. One study records renal vascular injury (Rosenberg, 1984) and recorded trauma to the vascular pedicle of an ectopic kidney.

Gastric injuries. A two year old child was fatally abused when his stepfather forcefully slammed the boy onto his upraised knee soon after a feed; he then proceeded to slap him (Case & Nanduri, 1983). This caused a rupture of the stomach along the greater curvature, and subsequent peritonitis.

Adrenal injury. Adrenal injuries are rarely recorded, but are associated with a high fatality rate, and multiple co-existent injuries, both intra and extra abdominal (deRoux & Prendergast, 2000; Hicks & Gaughan, 1995; Hilmes et al., 2011). Adrenal hematoma is the commonest recorded injury (Hicks & Gaughan, 1995; Hilmes et al., 2011) while adrenal laceration was recorded once (deRoux & Prendergast, 2000).

Chylous ascites. Damage to the lymphatics, leading to chylous ascites, was the primary presenting injury in six cases (Benhaim et al., 1995; Beshay et al., 2001; Boysen, 1975; Dillard & Stewart, 1985; Olazagasti et al., 1994; Vollman et al., 1966). Those with chylous ascites (aged 10 weeks to 2.5 years) presented with abdominal distension, other than a 19 month old boy who presented with a left inguinal hernia, found to be filled with chyle (Olazagasti et al., 1994). Of note the same child had had a right herniorrhaphy one month earlier, noted to be filled with white intra-peritoneal fluid, and at three weeks of age he had a femoral fracture, but no investigations were performed on either occasion. All of the children with chylous ascites had multiple other injuries including fractures, with three children also having healed burns (Benhaim et al., 1995; Boysen, 1975; Vollman et al., 1966) or abusive head trauma (Dillard & Stewart, 1985; Olazagasti et al., 1994).

Intrathoracic and vascular injury

Cardiac and vascular injuries. Six studies addressed cardiac injuries (Cohle et al., 1995; Cumberland et al., 1991; deRoux & Prendergast, 2000; Karpas et al., 2002; Rees et al., 1975; Sola et al., 2008), while two recorded injury to the aorta (Lieberman et al., 2010; Roche et al., 1995). Cardiac injuries are described in 12 children, (aged nine weeks to five years), including two (aged five months (Karpas et al., 2002) and five years (Rees et al., 1975) respectively) with traumatic ventriculoseptal defects. The infant presented immediately after being punched repeatedly in the chest, whereas the older child did not

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present until two weeks after being kicked in the chest. Both had significant cardiac failure, and neither had other abusive injuries recorded, but neither study reported conducting a skeletal survey. Further injuries included a needle penetrating the pericardial sac (Sola et al., 2008), the remaining eight cases (all fatal) had tears to the right ventricle and one had a large laceration of the left ventricle, and small lacerations to the interventricular septum and apex of right ventricle (Cohle et al., 1995; Cumberland et al., 1991). The latter child also had hepatic lacerations, splenic, jejunal and bilateral adrenal hematomas (Cohle et al., 1995). A further case had a right atrial tear with multiple other injuries (deRoux & Prendergast, 2000). In relation to the right atrial tears, it is postulated that either the tethering of the heart by its great vessels leads to tears in the atria at their venous attachments secondary to sudden acceleration/deceleration. Likewise the sudden rise in venous pressure in the inferior vena cava secondary to a blow to the abdomen, could lead to an intimal tear in the atria. Five of the eight children had co-existent blunt hepatic injuries, and 6/8 had associated rib fractures in addition to multiple other injuries. The aortic injuries included a toddler who died as a result of a ruptured aorta in combination with a fracture dislocation of the lumbar spine at L2/L3, where mechanism of injury was consistent with a forced hyperextension of the spine (Lieberman et al., 2010) and a pseudoaneurysm to the descending aorta following trauma (Roche et al., 1995).

Chylothorax. Four children with traumatic chylothorax, aged six to 18 months, presented with increasing respiratory distress, all of whom had co-existent multiple fractures (Anderst, 2007; Geismar et al., 1997; Green, 1980; Guleserian et al., 1996).

Pulmonary trauma. Three infants, aged 21 days to five months, sustained blunt trauma to the lungs, including contusions and perforation (Dobi-Babic & Katalinic, 2008; Gipson & Tobias, 2006; McEniery et al., 1991), the youngest of whom presented with a flail chest (Gipson & Tobias, 2006). All presented with respiratory distress, and had co-existent rib fractures. Further cases of hepatic injury were also noted to have pulmonary injuries; traumatic bullae of lungs (Salmon, 1971) and subpleural contusions and hemothorax (Fain & McCormick, 1988).

Pharyngeal/esophageal trauma. Ten infants (18 days to 10 months old) are recorded as having abusive injuries to the posterior pharynx (Bansal & Abramo, 1997; Grace et al., 1984; Kleinman et al., 1992; McDowell & Fielding, 1984; Ng et al., 1997; Reece et al., 1996; Tostevin et al., 1995) and three are reported with primarily esophageal injuries (Ablin & Reinhart, 1990; Marupaka & Unnithan, 2007; Tavill et al., 1996). Among these injuries, all children had some degree of respiratory distress, while other clinical presentations included subcutaneous emphysema (Ablin & Reinhart, 1990; Bansal & Abramo, 1997; McDowell & Fielding, 1984) oral bleeding (Bansal & Abramo, 1997; Grace et al., 1984; McDowell & Fielding, 1984; Reece et al., 1996; Tostevin et al., 1995), or upper airway obstruction (Kleinman et al., 1992; Ng et al., 1997). Two of the youngest infants (newborn (Marupaka & Unnithan, 2007) and eight weeks old (Tavill et al., 1996) respectively) both had subcutaneous emphysema, but neither had co-existent injuries recorded, although further investigations were not detailed.

Needle injury. Four studies (Ng et al., 1997; Sola et al., 2008; Stone et al., 1976; Swadia et al., 1981) describe five children, aged eight weeks to 11 years old, with the insertion of needles into the chest, abdomen, neck and arm. In one case (Ng et al., 1997) a sibling had died aged 26 days with needles in the body and brain.

What clinical features indicate that an abusive abdominal injury is present? Only two studies (Hilmes et al., 2011; Lindberg et al., 2009) examined the association between clinical symptoms and the presence of an injury. Lindberg et al. looked at the utility of clinical signs and laboratory tests in diagnosing an abusive abdominal injury (including liver, bowel, spleen, pancreas, adrenals and kidney). They noted that abdominal tenderness, distension, abdominal bruising and abnormal bowel sounds had a likelihood ratio of ≥ 5 for abusive abdominal injury. There were however important limitations with this study, in particular the lack of a uniform application of a gold standard diagnostic test to every patient (only 255/1676 children underwent definitive testing, i.e. CT/Magnetic Resonance Imaging (MRI)/surgery/post mortem). Hilmes et al. was a retrospective review of abused children less than five years old undergoing abdominal CT, where 35/84 had abnormalities. They examined the association between symptoms and 'positive findings' on CT, and noted that only abdominal distension ($p = 0.03$) and abdominal bruising ($p = 0.003$) were significantly associated with abdominal injury.

What is the value of serological screening tests? Two diagnostic test studies set out to address this question (Coant et al., 1992; Lindberg et al., 2009), but unfortunately, not all children who had serology underwent a gold standard test. One further study encompassed an analysis of the utility of hepatic enzymes, amylase and/or lipase in a group of 84 abused children who all underwent CT, 35 of which were abnormal (Hilmes et al., 2011). Overall, these studies indicate that while a negative test (hepatic or pancreatic serology) is of no value, a positive test warrants consideration of abdominal CT, as all those with hepatic/pancreatic injury who underwent enzyme assays were positive (Table 3).

Discussion

The spectrum of abusive injury is vast, from pancreatic trauma to traumatic pseudo-aneurysm of visceral arteries (Allorto, Royston, & Hadley, 2009), however, abdominal injuries predominate. Blunt injury to the liver and small bowel being most frequent (Hilmes et al., 2011). Multiviscera involvement is not uncommon. Abdominal injuries are seen predominantly in toddlers, age range from 2.5 to 3.7 years, in contrast to accidental abdominal injury, which is commoner in older children

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Table 3
Value of serological tests.

Study	Subjects	Serology vs. confirmatory test	Test/*n* (%)	Result
Coant et al. (1992)	Abuse without overt abdominal injury 0–12 years *N* = 49	ALT/AST/LDH/alkaline phosphatase vs. CT	4/49 (8%)	4/49 patients had raised transaminases/LDH 3/4 had liver injuries on CT and severe other injuries
Lindberg et al. (2009)	Physically abused children 0–5 years *N* = 1272	AST/ALT vs. CT/MRI/post mortem/surgery	Positive test 138/259 (53%) Negative test 117/1013 (11.5%)	(Applying a cut off of 80 IU/L) Sensitivity77%, specificity 82% PPV 16%, NPV 99%, positive/negative likelihood ratio 4.3/0.3
Hilmes et al. (2011)	Abused children 0–5 years Variable indications for CT	ALT/AST in those with abnormal CT vs. normal CT Amylase ± lipase in those with abnormal CT vs. normal CT	21/27 (78%) with abnormal CT had elevated AST/ALT vs. 19/29 (66%) of those with normal CT 14/28 elevated Amylase/lipase abnormal CT vs. 2/14 normal CT	No details on 'cut-off' applied Hepatic – sensitivity 78%, specificity 34% PPV 52% Pancreatic – sensitivity 50%, specificity 86% PPV 87%

Test/*n* equates to the proportion of patients who had a gold standard test carried out.
ALT: alanine transaminase, AST: aspartate transaminase, CT: Computerized Tomography, IU/L: international units/liter, LDH: lactate dehydrogenase, MRI: Magnetic Resonance Imaging, NPV: negative predictive value, and PPV: positive predictive value.

from 7.6 to 10.3 years (Barnes et al., 2005). *Abusive* abdominal injury carries a significantly higher morbidity and mortality (53%) than accidental blunt abdominal injury (Ledbetter et al., 1988). It has been noted that after head injuries, abdominal trauma is the second commonest cause of mortality in children who are abused (Phillips & van der Heyde, 2006). This is not the exclusive preserve of the very young as children up to eleven years old have also been described.

The prevalence of abusive abdominal trauma is estimated by Barnes et al. to be 0.9 cases/million children/year (95% CI 0.58–1.39) for all children, and 2.33 (CI 1.43–3.78) cases/million children/year for those aged <5 years (Barnes et al., 2005), although this study did not include fatally abused children and thus may be an underestimate. In addition, as visceral injury is often not suspected, and therefore not screened for, true prevalence remains unknown. While Cooper et al. (1988) found blunt abdominal trauma in only 0.5% of total child abuse admissions to two hospitals over 15 years, it is suggested that occult abdominal trauma (OAT) may be as high as 6–8% among abused children, who do not have overt signs of such injury (Coant et al., 1992).

This has led to recommendations that all children with injuries suspicious of abuse should be 'screened' for OAT (Coant et al. (1992) suggested performing liver enzymes in all suspected abuse cases with a CT abnormal results), however the validity of these screening tests remains undetermined. Coant et al. (1992) screened 49 children presenting with suspected physical abuse but no signs or symptoms of abdominal injury, four of whom had elevated transaminases and Lactate Dehydrogenase, three of whom had liver lacerations on abdominal CT. However, as only those children with *positive* serology underwent CT imaging, the true sensitivity or specificity of this screening cannot be determined. More recently, Hilmes et al. reviewed 84 abused children aged 0–5 years undergoing abdominal CT (for clinical indications), 56 of whom had liver enzymes checked, and 42 amylase/lipase, showing no significant differences in positive results between those with and without injury (Hilmes et al., 2011). In addition, many visceral injuries, such as splenic or adrenal trauma, will not have any specific 'screening' test and as such, clinical vigilance for possible internal injury in abused toddlers is key (Lane et al., 2009). In some children, the presence of an abdominal injury may not be apparent until the child is resuscitated for shock, after which abdominal distension becomes apparent (Keating, Shackelford, Shackelford, & Ternberg, 1972).

When an abdominal injury is suspected in any child, the radiological assessment is the same as for children with accidental abdominal injuries (Di Pietro et al., 2009). While a plain abdominal film may indicate perforation, the gold standard investigation is CT scan of the abdomen. As well as determining the extent of the injury, which plays a major role in guiding both conservative and surgical management (Lynn et al., 2009), it also improves the accuracy of clinical assessment in pediatric patients, particularly where there is decreased level of consciousness (Holmes et al., 2002).

While pediatricians favor the use of Ultrasound (U/S) as a non-invasive investigation, its role in pediatric abdominal trauma is controversial (Di Pietro et al., 2009). The variety of studies in the literature using different U/S techniques (ranging from FAST (focused abdominal sonography for trauma) to full abdominal assessment), make it difficult to accurately compare and assess its utility. U/S is reliable at identifying free fluid (Holmes, Gladman, & Chang, 2007; Poletti et al., 2003), however it has low sensitivity for both solid organ and hollow viscous injury (sensitivity ranges from 33 to 98%) (Holmes et al., 2007; Lynn et al., 2009; Retzlaff, Hirsch, Till, & Rolle, 2010; Richards, Knopf, Wang, & McGahan, 2002; Sola et al., 2009), and as many patients sustain significant injury without associated free fluid (Coley et al., 2000; Gaines, 2009; Poletti et al., 2003; Retzlaff et al., 2010; Richards et al., 2002; Shanmuganathan, Mirvis, Sherbourne, Chiu, & Rodriguez, 1999) the majority of these cases may be missed at U/S. A recent Cochrane review of U/S in acute abdominal trauma (Stengel et al., 2008) concluded that there is no evidence in favor of using U/S over CT in blunt abdominal injury as its sensitivity is too low for definite exclusion.

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Consequently, although U/S has obvious advantages in an emergency in the unstable patient who may proceed immediately to laparotomy (Richards et al., 2002) it cannot be recommended as the imaging investigation of choice.

Contrast enhanced CT is now considered the definitive imaging modality for pediatric patients with blunt abdominal trauma at most centers (Awasthi et al., 2008; Coley et al., 2000; Di Pietro et al., 2009; Gaines, 2009; Gaines & Ford, 2002; Retzlaff et al., 2010). It is highly sensitive and specific for solid organ injuries (Sola et al., 2009) and is accurate at identifying extent, type and grade of injury. It is less accurate for intestinal and pancreatic injury (Gaines, 2009; Retzlaff et al., 2010; Sola et al., 2009), however the use of newer generation helical scanners have significantly improved sensitivity in this area (Awasthi et al., 2008). Furthermore, CT can also identify active bleeding and other associated bone injury (Sivit, 2009). The major drawback is the associated radiation dose, and efforts should be made to minimize the dose through optimal technical settings and use of ALARA ('as low a dose as is reasonably achievable') principles (Di Pietro et al., 2009; Donnelly, 2009), thus dictating that it is reserved for those children where there is high level of clinical concern (Gaines, 2009).

If a renal injury is suspected, a contrast CT with delayed scanning is helpful in identifying collecting system injury and leak (Di Pietro et al., 2009; Sivit, 2009). It can also improve accuracy where there is high suspicion of duodenal or pancreatic injury, which is of relevance in abused children, who may have injuries to multiple viscera (Di Pietro et al., 2009; Donnelly, 2009; Gaines, 2009; Nastanski, Cohen, Lush, DiStante, & Theuer, 2001; Sivit, 2009). The benefits in its use, however, need to be balanced against risk of a delay in imaging and the possible risks of aspiration (Nastanski et al., 2001; Sivit, 2009). Upper GI studies have a limited use in the acute setting but may be used adjunctively in the context of bowel trauma and in particular to evaluate and follow up duodenal hematomas (Di Pietro et al., 2009).

While the majority of abdominal injuries presented with an acute abdomen, it is apparent that for a number of children this is the culmination of repeated assaults to the abdomen, as indicated by mesenteric scarring found on post mortem (Byard & Heath, 2010; Dye, Peretti, & Kokes, 2008) and hemosiderin laden macrophages in the granulation tissue with mucosal regeneration and signs of acute trauma (Ng et al., 1997). Likewise, cases have been reported where previous abdominal injuries have been treated (ruptured duodeno-jejunal flexure) but where abuse was not originally suspected (Gornall et al., 1972). The fact that the abusive abdominal injury follows previous abuse or neglect, is reinforced by the fact that many of the children were found to have other healing injuries including fractures, malnutrition (Touloukian, 1968) head injuries, or burns (Gaines et al., 2004; Morzaria, Walton, & MacMillan, 1998) including cigarette burns (Bowkett & Kolbe, 1998; Ng & Hall, 1998). As the abused children may have a high degree (20–90%) of associated injuries (Herr & Fallat, 2006) a diligent search should be made for these.

Other children have been found to have visceral complications (e.g. myoglobinuria (DiGiacomo, Frankel, Haskell, Rotondo, & Schwab, 2000)) or visceral insult (e.g. commotio cordis (Baker, Craig, & Lonergan, 2003)) without overt visceral trauma. Also, non abdominal complications may be the presenting feature e.g. junctional ectopic tachycardia secondary to abdominal injury (Cloutier, Mehr, Lin, & Tanel, 2002). Likewise, there is some overlap between abusive abdominal injuries and Fabricated and Induced Illness, e.g. parents forcing coins into the esophagus of a four month old (Nolte, 1993); a lye enema to a seven year old resulting in a subtotal colectomy (Grosfeld & Ballantine, 1976).

The cases recorded often gave details of the mechanism of injury e.g. striking them in the stomach resulting in injury to the proximal jejunum (Chen et al., 1994). It is recognized that direct blows to the abdomen can injure solid organs or mesentery especially from a rigid surface. In addition, deceleration produces shearing forces between fixed and relatively mobile parts of gastro-intestinal tract, especially to bowel and mesentery particularly the duodeno-jejunal junction and ileo-caecal junction, presumably explaining why this is one of the commonest injuries recorded (Gregersen & Vesterby, 1984; Herr & Fallat, 2006). Some authors found that hollow organ injuries were more frequently recorded among the abused children (Roaten et al., 2006; Trokel, DiScala, Terrin, & Robert, 2003), although hepatic injuries may go unrecognized clinically as they can be relatively asymptomatic, and thus may easily be missed, as highlighted by Coant et al. (1992), where three children with significant hepatic injury had no abdominal signs or symptoms, only being identified when imaging was undertaken for elevated liver enzymes. The mechanisms of injury in accidents are better known i.e. seatbelt injuries or handle bar injuries which have a more predictable pattern. In the absence of a history in abused children, the mechanism is likely to involve a focal intrusion with direct compression against vertebra, or a sudden increase in intra-luminal pressure or shearing forces with blows on a tense tummy, all of which make the likelihood of small bowel injury greater than solid visceral injury.

It is notable that there is a lack of literature from less developed countries (Murty, Ming, Ezani, Yan, & Yong, 2006; Phillips & van der Heyde, 2006), and it is unclear whether this is due to a truly lower rate epidemiologically, or due to lack of recognition or research in these countries.

Abuse is reported as being the second (Miller et al., 1998) or third (Landau, van As, Numanoglu, Millar, & Rode, 2006) commonest cause of hepatic injury in children, with the commonest cause being motor vehicle collisions. Certain abdominal injuries, specifically duodenal perforation, are extremely rare accidental injuries in children younger than five years old (Gaines et al., 2004), where abuse is the leading cause of such injury (Clendenon, Meyers, Nance, & Scaife, 2004), thus child abuse should be actively excluded when pre-school children present with such injuries. In accidental injuries the history is quite consistent and clear and they usually present immediately after the event, although isolated cases have presented up to three days after accidental injury (Pokorny, Brandt, & Harberg, 1986). In abusive injury, delayed presentation was far commoner (Ledbetter et al., 1988; Wood et al., 2005), with a mean delay of 3.5 days (Miller et al., 1998) which often has an adverse affect on the reliability of clinical findings (Herr & Fallat, 2006). Delayed presentation has two main problems: quite often the patients are critically ill and therefore have a worse outcome (Herr & Fallat, 2006), and their symptoms could be masked due to the passage of time.

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Most abused children presented with no definitive history (Coant et al., 1992; Fossum & Descheneaux, 1991; Herr & Fallat, 2006) or with a history of a fall (Ledbetter et al., 1988). Typically the reported fall is from a low height, i.e. bed, crib, arms, stairs. In order to estimate the likelihood of sustaining significant abdominal injury from a fall, Huntimer et al. reviewed 312 confirmed cases of bowel perforation in children, and none were due to a fall down stairs; furthermore, none of the 677 patients with an *accidental fall* had a bowel perforation (Huntimer, Muret-Wagstaff, & Leland, 2000). Likewise, no child less than four years of age sustained a duodenal injury as a consequence of accidental injury due to a fall (Barnes et al., 2005; Gaines et al., 2004; Wood et al., 2005).

It is notable that abdominal bruising was absent in up to 80% of cases, emphasizing that the absence of bruising does not preclude serious intra-abdominal injury (Bowkett & Kolbe, 1998; Gaines et al., 2004; Herr & Fallat, 2006; Ledbetter et al., 1988).

Current surgical management of childhood trauma victims means that only a small proportion of patients will undergo laparotomy; the vast majority of those with solid organ injuries are now managed conservatively (Donnelly, 2009; Lynn et al., 2009; Retzlaff et al., 2010; Ruess, Sivit, Eichelberger, Taylor, & Bond, 1995; Sivit, 2009). It has been reported that for solid visceral injuries, less than 15% need laparotomy and less than 25% need blood transfusion (Holmes et al., 2002). Yet, even where the rate of intra-abdominal injury in accidental and abusive injury is almost the same (7.5 vs. 8.6%), the incidence of laparotomy is significantly more (3.5% vs. 1.6%) among the abused (Ledbetter et al., 1988; Roaten et al., 2006).

It was disappointing that many studies addressing prevalence had to be excluded due to the risk of circularity in the confirmation of abuse (Caniano et al., 1986; Fossum & Descheneaux, 1991; O'Neill, Meacham, Griffin, & Sawyers, 1973), some suggesting abdominal injuries may occur in 0.9–8% of abused children rising to 14–20% of fatally abused children (Kasim, Cheah, & Shafie, 1995; Pollanen, Smith, Chiasson, Cairns, & Young, 2002).

Conclusion

Abusive abdominal injury is a significant cause of morbidity and mortality in children, with hepatic and bowel injuries being equally common. Studies would suggest that it may be under recognized, and a high level of vigilance is required, particularly in younger children, and those who present with a small bowel injury without a history of major trauma. When abused children less than five years old are being assessed, abdominal injury must be considered. Current evidence suggests that one cannot rely on serological screening tests, although if conducted and positive, further investigations including CT with contrast are warranted. There is a clear need for large scale high quality comparative studies to further define precise differences between abusive and accidental injuries, particularly where the accidental injuries exclude MVC, and focus on falls and domestic injuries, which are the most common history offered in abuse cases.

Disclosure statement

None of the authors have any conflict of interest in relation to this work.

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