

Child Protection Evidence Systematic review on Bruising

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Summary

Bruising is the most common injury in physical child abuse.¹ The main diagnostic dilemma is distinguishing abusive from non-abusive bruises and practitioners may still be asked to determine the age of bruises.

This systematic review evaluates the scientific literature on abusive and non-abusive bruising in children published up until **January 2019** and reflects the findings of eligible studies. The review aims to answer two clinical questions:

1. What characteristics of bruising suggest physical child abuse?
2. Can a bruise be accurately aged?

The 2019 update found two new published studies relating to the characteristics of bruises that met the inclusion criteria.^{2,3}

There are a number of possible clinical findings suggestive of abuse. These including bruising in pre-mobile children, bruises that are seen away from bony prominences and bruises that carry the imprint of an implement used or a ligature.

Child protection agencies are required to determine the likely timing of when an injury occurred. Clinicians may still be asked to estimate the age of bruises based on a naked eye assessment of colour which is not possible. There is currently no scientific basis for estimating the age of a bruise from its colour.

Key findings:

- Bruising was the most common injury in children who have been abused. It is also a common injury in non-abused children, the exception to this being pre-mobile infants where accidental bruising is rare (0-1.3%). The number of bruises a child sustains through normal activity increases as they get older and their level of independent mobility increases.
- Cases have been reported where bruising was a “sentinel injury” in children prior to the recognition of child abuse, highlighting the importance of recognising abnormal characteristics of bruising in children, enabling detection as early as possible and potentially preventing escalation of abuse with avoidance of serious abusive injury or death.
- In the most recent update, two new studies relating to the characteristics of bruises that met the inclusion criteria have been published.
- There is no change in the evidence that it is not possible to age a bruise based on a naked eye assessment. There is, however, an increasing body of literature addressing optimal imaging of bruises which is highlighted in the ‘other useful resources’ section.
- This review highlights the importance of recognising characteristics of bruising in children to enable the correct identification of abuse.

Background

This systematic review evaluates the scientific literature on abusive and non-abusive bruising in children published up until January 2019 and reflects the findings of eligible studies. The review aims to answer two clinical questions:

1. What characteristics of bruising suggest physical child abuse?
2. Can a bruise be accurately aged?

Methodology

A comprehensive literature search was performed using all OVID Medline databases for all original articles published since 1950. Supplementary search techniques were used to identify further relevant references. See [Appendix 1](#) for full methodology including search strategy and inclusion criteria.

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

Findings for clinical question 1 What characteristics of bruising suggest physical child abuse?

In total 44 included studies address this question.²⁻⁴⁵ Most applied to children aged less than ten years of age.

1.1 Comparative studies of non-abused and abused children

Three comparative studies were included assessing abusive and non-abusive bruising,^{9,23,35} two detail bruising characteristics in children aged less than three years admitted to the Paediatric Intensive Care Unit (PICU)^{23,35} and the other included children aged 1-14 years attending a paediatric outpatient centre.⁹

A study of 322 children aged 1-14 years attending as out-patients were compared for bruising characteristics.⁹ A scoring system for distinguishing abusive and non-abusive cases was derived based on bruise length and location. It was found that bruising to the ear, face, neck, torso and buttocks was significantly more common in abused children ($p < 0.001$) and that abused children

had significantly more bruises in all regions except the legs. The bruises in abused children were found to be larger than in non-abused children in all regions of the body.

A younger population of 105 children aged less than three years requiring intubation in PICU were examined for injuries to the ears, neck, and jaw and oral injuries.²³ Bruising was present in 10 of the 14 children that had been abused, the location of the bruising was on the ears, eyelids, jaw, buttocks, abdomen and forehead. Two of the bruised children also had petechiae. Oral, jaw and neck injuries were significantly associated with abusive trauma ($p < 0.001$).

A comparison of 95 children aged 0-4 years admitted with severe head injury was carried out.³⁵ The study found that abused children had significantly more bruising ($p < 0.0005$) and that bruising to the ear, neck, hand, right arm, chest and buttocks were predictive of abuse. Bruising on the torso, ear, or neck for a child equal to, or less than four years of age and any bruising in any region for an infant less than four months of age were predictive of abuse. Bruises found on the face, cheek, scalp, head and legs were non-discriminatory. A bruising clinical decision rule was derived, (TEN-4 BCDR) with a sensitivity of 97% and a specificity of 84% for predicting abuse.

Reference	Population (N, age)	Number of bruises	Site of bruising	Other findings
Dunstan 2002 ⁹	Single centre Out-patient setting Age 1-13 years old Abused case: identified from child protection database (n=133) Control: attending OP for other reasons (n=189)	133 abused children with 763 bruises. 189 controls with 282 bruises.	Statistical difference noted if bruise: left ear, face (left and right), anterior chest and abdomen, back, buttocks and other head and neck areas.	<2% of those classified as non-abused had a bruise with an identifiable shape. Abused children, 57% had at least one with an identifiable shape.
Pierce 2010 ³⁵	Single centre Retrospective case control study PICU Included patients admitted to ICU due to trauma 0-48 months PA n=42	71 patients had bruising. PA: median 6 bruises (IQR: 1-10 bruises; max 25). Accidental: median 1.5 bruises (interquartile range: 1-2 bruises). All patients with accidental trauma had ≤ 4 bruises.	All bruising to the ear, neck, hands, right arm, chest and buttocks were predictive of abuse (no patients with accident-related trauma demonstrating bruising in these areas). The back and abdominal regions of the torso were statistically significant or approached statistical significance,	All bruising to the genitourinary area and hip occurred only in patients with abusive trauma, but the number was too small for determination of statistical significance. Bruising to the face, cheek, scalp, head, and legs were present in patients with abusive and accidental trauma and was not discriminating for abusive trauma.

	Accidental trauma n=53		respectively, for discriminating abuse.	
Lopez 2014 ²³	Single centre PICU cohort Prospective observational study Age: 0-3 years Intubated in previous 24 hours Examined head and neck for injuries n=110	12 patients had head or neck bruising. 10 identified as abuse.	Only assessed head and neck.	Most common injuries were intracranial haemorrhage, bruising, oral injuries, and fractures (strongly associated with abusive trauma ($p \leq 0.002$)). 2/11 patients had bruising in other area. 1 was PA with bruising to trunk + extremities.

Table 1: Summary of comparative studies of bruising in abused and non-abused children

1.2 Characteristics and sites – Bruising in non-abused children

Gender

Studies found that there is no difference in bruising characteristics between boys and girls.^{6,19,29,35,41,43}

Trends in accidental bruising

Accidental bruising is most commonly sustained in children as they become older, with 37-79% of children who are walking having bruises (mean 1.5-2.8 per child, range 1-16).^{6,19,35,41,44} Bruising is strongly related to mobility and bruising in a baby who is not yet crawling with no independent mobility is very uncommon.^{6,19,35,41,44} Bruising is a common injury in non-abused children, the exception to this being pre-mobile infants where accidental bruising is rare (0.6-1.3%). Two studies found increased accidental bruising was noted with increased family size.^{6,19} Two studies assessed seasonal differences in bruising, one found increased accidental bruising in the summer months²¹ while this was not found in the other more recent study.¹⁹

The sites and characteristics of bruising in non-abused children

Bruising is uncommon in a number of sites including the buttocks, face, neck, ears, abdomen or upper arm, posterior leg, foot or hands.^{6,7,9,19,35,41,43,44} In mobile children the most common sites of bruising are the shins and the knees.^{19,41,43-45} Slips, trips and falls commonly cause bruising on the back of the head and the front of the face, including the T of the forehead, nose, upper

lip and chin,^{7,19} however less than 5% of accidental bruising was on the cheeks and less than 6% around the eyes.^{7,19}

Most accidental bruises occur over bony prominences and are commonly seen on the front of the body, corresponding to sites that are bumped in falls.^{6,7,19,41} Other accidental bruising may occur when children are pulling to stand and bump their head, this will usually occur on the forehead.^{6,7,41} Up to 10% of children who are walking may have bruising to the forearm.^{6,7,9,19,35,41,43,44}

The distribution of bruising from eight mechanisms of unintentional injury was investigated, excluding children with a known bleeding disorder, medication that might impair coagulation, pre-existing disability, any child protection concerns or any unwitnessed injuries in children less than 4 years of age.³ Out of 372 children there were 559 injury incidents resulting in 693 bruises. In this sample of accidental bruising the largest proportion of bruises were found below the knee on the front of the leg (27.4%), followed by the forehead (22.2%). Bruising was rarely observed on the buttocks, upper arm, back of legs or feet.

No bruises were observed on the ears, neck or genitalia. There was one case of abdominal bruising (running into the corner of a metal bench). It was rare to have four or more bruises (0.9%; falling downstairs, sports injury and RTC). No more than five bruises were identified from a single incident.³ Petechial bruising was uncommon and was noted in 1/293 (0.3%) this was from an unintentional incident (fall from horse onto elbow). Patterned bruising was found in 9/293 (3.1%) and all were school-aged.³

A study looked specifically at the characteristics of bruising in preschool children with bleeding disorders.² In this group of children there were 5613 bruises recorded from 1146 collections in 103 children with bleeding disorders, and 3523 bruises from 2570 collections in 328 children without a bleeding disorder. Children with severe bleeding disorders had larger bruises than non-bleeding disorder children at all developmental stages. The differences were greatest in pre-mobile children.² Children with bleeding disorders rarely had bruises on the ears, neck, cheeks, eyes or genitalia.

Bruising in disabled children

Bruising to the hands, arms and abdomen was significantly more common in disabled than able bodied children and characteristics showed the feet, knees and thighs as frequent sites of accidental bruising.^{14,30} Areas that were rarely bruised accidentally in disabled children were lower legs, ears, neck, chin, anterior chest and genitalia.^{14,30}

Bruising is significantly increased with increasing independent mobility when stratified into categories of unrestricted walker, restricted walker and wheelchair dependent ($p=0.001$).³⁰

The causes of injury varied by mobility with falls predominating in the walkers in comparison to equipment usage and as a consequence of wheelchair use ($p < 0.001$).³⁰

Influence of ethnicity and socio-economic group

Non-abusive bruising within different ethnic groups is not well described in the literature, however one study noted that black African American children were observed to have bruises much less frequently than white children ($p < 0.007$).⁴¹

A number of studies suggest that characteristics of bruising in non-abused children do not differ by socio-economic group.^{6,9,18,21,27,41,43,44}

1.3 Characteristics and sites – Bruising in abused children

Gender

Three studies found that there is no difference in bruising characteristics between boys and girls.^{18,19,29}

The sites and characteristics of bruising in abused children

Any part of the body is vulnerable to bruising from abuse,^{5,31,42} however the head is the most common site of bruising in child abuse.^{4,8,9,15,16,19,31,40,45} Other commonly bruised sites in abuse include the ear, neck, trunk, buttocks, thighs, and arms.^{4,8,9,16,19,31,40,45} Among a study of 519 children referred under child protection procedures, 350 children with substantiated abuse showed significantly more bruising than those with abuse excluded. The abused children had significant numbers of bruises on the cheeks, neck, head, trunk, front of thighs, upper arms, buttocks or genitalia.²⁰

Bruising to the face was assessed in one study.³⁴ Three infants aged less than five months each presented with bruising to the face which was not investigated further. All three re-presented with abusive head trauma, reiterating that bruising to the face in a non-mobile infant may be a sentinel injury.³⁴

There are a number of bruising characteristics that have been identified in abused children. Bruises on soft parts of the body such as the cheeks, ears, neck, genitalia and, buttocks are rarely seen in non-abused children, in contrast to abused children.^{12,19,28,35} Abusive bruises can carry the imprint of the implement used. These include single or multiple linear bruising due to being struck with a rod-like instrument, banding where the hand has been tied or an imprint of the implement such as an electrical cord, studded belt or dog collar.^{5,10,11,15-18,20,29,31,32,37,42} Specific characteristics of abusive bruising are described and include; vertical gluteal cleft bruising and

bruising to the pinna of the ear where the shape of the bruise assumes the line of anatomical stress rather than the shape of the injuring object.^{11,15,22,31} Patterned bruising may be accompanied by petechiae in abused children.^{5,16,20,29} The presence of petechiae with bruising occurs more commonly in abuse than accidental injuries, with a positive predictive value of 80.0 (95% CI 64.1, 90.0). The absence of petechiae is not helpful in excluding abuse.²⁹ One study found 54/350 (15.4%) of the abused children had petechiae.²⁰

Although bruising is the most common injury in physical abuse, fatal non-accidental head injury and non-accidental fractures can occur without bruising.^{4,8,9,16,31,40,45} Abusive bruises can occur amongst other types of soft tissue injuries. These may be recent and older injuries e.g. scars and healed abrasions.^{5,31,42} The presence of areas of bruising interspersed with small abrasions is consistent with being hit with a rope.^{5,31,42} Clusters of bruises are a common feature in abused children. These are often defensive injuries as the child tries to protect their head: on the upper arm, side of chest, outside of the thigh, or bruises on the trunk and adjacent limbs.^{5,19,20,31,37,42} A combination of digital photography and a plastic overlay outlining alleged perpetrator's handprints may help to identify who caused the injury.³²

Bruising associated with fractures

Abusive fractures were rarely accompanied by overlying bruises. 58% of fractures had no bruises near the fracture site, 21% had bruising near the site of at least one fracture, of these bruising or subgaleal hematoma near the site of a skull fracture was seen most often, bruising in association with long bone and rib fractures was uncommon.³³

Further investigation can sometimes show up fractures, 23.3% of 137 infants aged less than six months that were investigated for an isolated bruise were found to have occult fractures. Another study of children with abusive fractures found 5% of children had subgaleal haematomas (9/10 with associated skull fracture).³³

Scalping

A boggy swelling to the forehead and periorbital oedema with no skull fracture, due to 'scalping', violently pulling the child's hair, leading to subgaleal haematoma^{38,39} has been described.

Bruising in pre-mobile children

Research shows that it is very unusual for pre-mobile babies to sustain bruises accidentally and bruising in this age group raises significant concerns about physical abuse.

Young babies and infants are extremely vulnerable and at greatest risk of death or severe injury with significant associated mortality in physical abuse. Bruising is also a widely reported

“sentinel” injury in babies and younger and its recognition is vital in prevention of more severe abuse.

A more detailed examination of studies in premobile children was carried out to understand the evidence in this area. Analysis was difficult due to differing methodologies and definitions of developmental stage.

Six studies discussed bruising in pre-mobile children.^{6,19,20,41,44,46} One study focussed on children referred for a child protection medical.²⁰ Five of the six studies specifically excluded cases of suspected abuse. In one study the researcher made a subjective assessment of whether or not abuse was likely to have occurred.⁶

Case reports

Two papers described a small number of case reports.^{12,36} One study emphasised the need to investigate all pre-mobile children with unexplained bruising (one haemophiliac and two abused infants).¹² Another small case series mentioned three infants noted to have bruising but were not investigated for child protection concerns. All three re-presented with severe abuse (rank 1 – see [ranking of abuse](#)), two fatally.³⁶

Reference	Population (N, age)	Terminology (Developmental stage/mobility)	Prevalence of bruising	Mean number of bruises/sites	Findings	Author conclusions
Pierce 2016 ⁴⁶	Attending PED N=2488 Median age: 5 months Suspected abuse excluded	Pre-mobile. Inability to crawl, cruise or walk.	1.3% (18/1395)	NA	13/18 had a history of trauma. Those with medical presentation (5) -0.2% (3/1294) had a bruise.	Bruising on a pre-mobile infant should be considered an exception, especially in the absence of an adequate injury mechanism.
Kemp 2015 ¹⁹	Attending well baby clinics, hospital OP, mother and baby groups N=328 Mean age: 19 months Suspected abuse excluded	Pre-mobile Sub-classified as: not rolling and rolling.	Not rolling over: 1.3% Rolling over: 10.9%.	0.09 (mean per-collection).	Most common below knees, facial T, head, thighs, rear trunk. No cases involved eyes, ears, buttocks, genitalia.	Multiple bruising in the pre-mobile babies would be an unusual finding.
Kemp 2014 ²⁰	Children referred for a CP medical N =506 Mean age =20.8 months Suspected abuse included	Baby Pre-mobile, rolling or sitting.	NA	2.5 (0-22). Mean number of regions 1.6 (0 -6).	PA confirmed: Mean number 2.8 (0, 22) Mean number of regions:1.6 (0, 6). PA excluded: mean number 1.3 (0, 7) Mean number of regions: 0.8 (0, 3).	No specific conclusions regarding baby.
Sugar 1999 ⁴¹	Children attending well-child care clinics N=973 No median/mean age provided Suspected abuse excluded	Pre-cruisers No upright ambulation.	By age 0.6% (2) <6mths 4% (4) of 6-8mths 10.5% (4) 9-11mths. By development Pre-cruisers 2.2% Cruisers 17.8% Walkers 51.9%.	Pre-cruisers: mean 1.3 per child (range 1-2) 0.6% (3) ant tibia or knee 0.6% (3) forehead 0.6% (3) scalp 0.2%(1) upper leg 0 back/ chest/ forearm 0.2%(1) face.	Bruising extremely rare in infants <6 month.	Bruises in infants younger than 9 months and are not yet beginning to ambulate should lead to consideration of abuse or illness as causative.
Carpenter 1999 ⁶	HV hearing test clinics, child health surveillance clinics N = 177 babies	Baby Sits, crawls, walks.	12.4% (22/177) with bruising. 32 bruises in 22 babies:	25 on face/head, 7 on shins. All bruises on front of body and	Significant increase in bruising seen in infants with increase in mobility.	An important part of the history is whether the explanation is compatible with the injury seen. Accidental bruises tend to be on the front of the body in this age group.

	Mean age= 36.1 weeks (SD, 4.9). Abuse not suspected in any case by researcher.		Sits 3.9% (4/101). Crawls 17.3% (9/52) Walks 37.5% (9/24). No explanation for 9 bruises but researcher did not suspect abuse.	over bony prominences.		
Wedgwood 1990 ⁴⁴	Children attending admissions unit of hospital. N=56 Under 4 years. Mean/median age: provided per group only. Suspected abuse excluded.	Group A: Children who had motor development no better than crawling. Group B: Children who could "cruise".	Group A Age 0.5-9.5 months (n=11; median; 3 months). No bruises present in this group. Group B Age 8-12.5 months (n=8; median: 10 months). 25% of children in this group had bruise.	No bruises present in group who had motor development no better than crawling.	Increase in bruising as motor developmental ability increases. By age group 28-46 months (n=13) walking and doing stairs with one foot per stair – all children had at least one bruise.	Bruising should be assessed in relation to developmental ability. No bruises seen in infants with motor development no better than crawling The study found a wide age range (overlapping) within each motor development group. Age alone is probably not a good indicator and bruising should be assessed relative to motor developmental ability. Common sites of bruising were knees and shins from cruising children onwards. Bruising to hands and feet not seen in any age group.

Table 2: Summary of studies describing bruising in pre-mobile children

Abbreviations: PED – Paediatric emergency department, PA – physical abuse, HV – health visitor, SD – standard deviation

1.4 Key Evidence Statements

A bruise must never be interpreted in isolation and must always be assessed in the context of medical and social history, developmental stage, explanation given, full clinical examination and relevant investigations.

Characteristics of bruising that are suggestive of physical child abuse:

- Bruising in children who are not independently mobile
- Bruises that are seen away from bony prominences
- Bruises to the face, abdomen, arms, buttocks, ears, neck, and hands
- Multiple bruises in clusters
- Multiple bruises of uniform shape

- Bruises that carry the imprint of implement used or a ligature
- Bruises that are accompanied by petechiae, in the absence of underlying bleeding disorders.

1.5 Research implications

Further research is needed in the following areas:

- Large comparative studies encompassing developmental stage in populations representative of ethnic and cultural diversity
- Large comparative studies of children with disabilities
- Studies exploring the relationship of explanations of injury to the characteristic of bruising sustained
- Large studies specific to bruising in pre-mobile infants. We recommend that future studies in pre-mobile infants adhere to the definition proposed by Kemp (pre-rolling and rolling).

1.6 Limitations of review findings

- There is a lack of comparative studies between abusive and non-abusive bruising
- There is a lack of data on bruising characteristics in children with disability

Findings for clinical question 2

Can a bruise be accurately aged?

Three studies have addressed this issue.^{6,47,48} Based on current evidence, the answer to this question is “no”. Although some publications “timetable” colour change in bruises and clinicians “confident” in ageing bruises may be welcomed by investigating agencies, it is not possible to age bruises based on their appearance seen with the naked eye.

Influence of ethnicity and socio-economic group

This is not addressed by the included studies.

Assessment of colour

Clinicians may be asked to estimate the age of a bruise based on a naked eye assessment of the colour of the bruise. These estimates of timescale are requested by child protection agencies to determine the likely timing of when the injury occurred and legal agencies to investigate potential perpetrators.

There is considerable variation in the way different observers interpret and describe colour.⁴⁷ Three included studies assess the colour of bruising,^{6,47,48} two show that different colours appear in the same bruise at the same time, however not all colours appear in every bruise.^{47,48}

In general, red/blue and purple colours were more commonly seen in bruises less than 48 hours old, whilst brown and green bruises were most often seen in bruises over seven days old. This is not always the case however, red/blue and purple were identified in up to 30% of observations in bruises older than seven days and yellow/brown or green were seen in up to 23% of bruises less than 48 hours old.⁶ One child had a blue bruise on the arm and a green/yellow bruise on the leg that were sustained at the same time.⁴⁸

Different estimates for when yellow is seen in a bruise are given. One study stated that yellow bruising was not seen before 24 hours⁴⁷ and a second study stated that yellow only appeared in bruises over 48 hours old.⁶ Bruises cannot be definitively aged by a naked eye assessment.

2.1. Key evidence statements

- The scientific evidence concludes that we cannot accurately age a bruise from clinical assessment or from a photograph
- Any clinician who offers a definitive estimate of the age of a bruise in a child by assessment with the naked eye is doing so without adequate published evidence.

2.2. Research implications

Further research is needed in the following areas:

- Evaluation of novel imaging techniques in children with bruises of known age
- Whether it possible to develop an accurate calibration of the colour of a bruise and overcome the huge variation in human colour discrimination
- Assessment of bruises in children of different skin colour, across all age ranges.

2.1 Limitations of review findings

- There is a lack of data relating specifically to the use of new techniques in children
- No large-scale studies of ageing of bruises in our population of interest have been conducted

Other useful resources

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

Clinical question 1: What characteristics of bruising suggest physical child abuse?

- Petechiae in the absence of bruising may occur as a consequence of suffocation. Petechiae was located on the skin of the face and throat, the upper thorax, the shoulders and the mucous membranes of the mouth⁴⁹
- Soft tissue injury, evidenced by elevated CPK⁵⁰ or renal failure as a consequence of haemoglobinuria has been sustained when children were severely physically abused⁵¹
- Absence of abdominal bruising does not preclude a significant abdominal injury⁵² just as the absence of bruising does not preclude abusive head trauma (AHT)⁵³
- Amongst a group of infants aged less than one year with confirmed abuse, the most frequent “sentinel injury” identified prior to this was a bruise¹
- Tourniquet syndrome has been described in infants as both an abusive and non-abusive injury⁵⁴⁻⁵⁷
- In a study of 77 infants with abusive fractures, 32% had missed opportunities for the diagnosis of child abuse. The most common sign on examination during medical visits prior to the diagnosis of abuse was bruising or swelling⁵⁸
- An analysis of 146 infants less than six months with suspected abuse and an apparently isolated bruise underwent investigation, 23.3% of whom had positive skeletal survey, and 27.4% positive neuroimaging¹⁵
- An American study suggests an algorithm to identify the necessity to undertake skeletal survey after applying the Rand/UCLA appropriateness method. This study identified four combinations of bruises in children younger than two years of age where skeletal survey (SS) is necessary to undertake (please see figure 2 in original article)⁵⁹

Potential mimics

- Acute haemorrhagic oedema of infancy may present with multiple purpuric lesions which may mimic bruising⁶⁰
- Subgaleal haematoma has been described in a toddler following hair braiding⁶¹
- Mongolian blue spots are recorded on feet, scalp, knee and back as well as lumbosacral and gluteal area⁶²

Clinical question 2: Can a bruise be accurately aged?

Perception of colour

- There is considerable variation in the way the same observer describes colour in a bruise and then in a photograph of the same bruise⁶³
- Individual perception of the colour yellow varies and our ability to perceive it declines with age^{64,65}

- A non-invasive method, reflectance spectrophotometry, of measuring haemoglobin and its degradation products may prove a useful tool in the estimation of the age of bruises^{64,65}

Histological dating

- Histological dating of bruises relies on a predictable characteristic of cellular responses; however data in bruises from three children did not confirm these classical findings³⁷

Accuracy of age estimation

- Standardised bruises generated in adults had age estimation performed on clinical photographs by forensic examiners⁶⁶
- Only 48% of bruises were estimated accurately to within 24 hours of the true age, thus age estimation from photographs is unreliable⁶⁶

Ultraviolet photography

- Ultraviolet photography may reveal bruises that are no longer visible to the naked eye, i.e. two to ten-month-old injuries. This photography has been used in fatal and non-fatal cases, but longitudinal studies are lacking in a paediatric context⁶⁷

Infra-red photography

- Infra-red imaging was assessed to determine if it could detect bruises no longer visible with the naked eye or on conventional imaging. It did not reveal any significant evidence of bruising that was not otherwise visible⁶⁸
- A study of post-mortem cases noted that IR identified contusions that were not visible clinically although one false negative also occurred. The precise characteristic was not evident by IR⁶⁹

Reflection spectra

- Reflectance spectroscopy may assist in ageing bruises but, to date, there is only experimental data available^{70,71}
- Use of reflection spectra to determine age of bruising explored in adults and children – not yet used in clinical practice⁷²
- A stochastic photon transport model in multilayer skin tissue combined with reflectance spectroscopy measurements is used to study normal and bruised skins; this is proposed as a potential model for ageing bruises⁷³

Chromophore concentrations

- Adult studies evaluating chromophore concentrations as an aid to ageing bruises show a high amount of variance to date. Not yet suitable for clinical use⁷⁴

Ultrasound of bruising

- Ultrasound was used to determine the depth and extent of a bruise⁷⁵

Colorimetric scale

- Single case study proposing a colorimetric scale for the evaluation of bruises/bites⁷⁶
- The accuracy with which observers estimate the age of a bruise from a photograph is little more than 50%(24/44)^{47,77}
- The accuracy of estimating the age of a bruise to within 24 hours in vivo was only 40%⁴⁷
- Neither colour, tenderness, nor swelling was significantly correlated with accuracy of the age of a bruise⁴⁷

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Appendix 1 - Methodology

We performed an all-language literature search of original articles, their references and conference abstracts published since 1950. 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 the 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 2016 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 2019 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.⁷⁸ In addition, we used a selection of systematic review advisory articles to develop our critical appraisal forms.^{6,9,79-81} 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.

Our panel of reviewers included paediatricians, designated and named doctors and specialist nurses in child protection. All reviewers underwent standardised critical appraisal training, based on the CRD critical appraisal standards,⁶ and this was supported by a dedicated electronic critical appraisal module.

Inclusion criteria

The inclusion criteria used in this update of the review are listed in the table below.

General criteria

Inclusion	Exclusion
Studies which defined characteristics of bruising in non-abused or abused children	Personal practice
Studies assessing age of bruises	Review papers
Children up to their 18 th Birthday	Post-mortem studies
English articles (non-English up to 2016 update)	Studies where the population included adults and children but where we could not extract data that applied solely to children
	Single case reports
	Methodologically flawed papers

Ranking of abuse

Distinguishing abuse from non-abuse is central to our review questions. The systematic reviews span more than 40 years and include international publications. Standards for defining abuse have changed markedly over time and across continents. To optimise the ability to apply a consistent quality standard across all publications, we have devised the following ranking score based upon legal and social care child protection decision processes where “1” indicates the highest level of confidence that abuse has taken place. These rankings are used throughout our systematic reviews (where appropriate).

Since its introduction, rank 1 in this classification has been expanded to include ‘independently witnessed, and reported by the child’.

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

5	Suspected abuse
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Studies are also ranked according to their study type. The published literature in this field is based primarily upon observational studies. The higher ranking of comparative studies, providing the highest quality evidence.

Ranking of evidence by study type

Ranking of evidence by study type	
T ₁	Randomised controlled trial (RCT)
T ₂	Controlled trial (CT)
T ₃	Controlled before-and-after intervention study (CBA)
O ₁	Cohort study/longitudinal study
O ₂	Case-control study
O ₃	Cross-sectional
O ₄	Study using qualitative methods only
O ₅	Case series
O ₆	Case study
X	Formal consensus or other professional (expert) opinion (automatic exclusion)

Search strategy

Seventeen databases were searched. In previous iterations of this review four journals which were hand searched and two websites as well. For this update and going forward hand searching will no longer be carried out. A complete list of the resources searched can be found below.

Databases	Time period searched
ASSIA (Applied Social Sciences Index and Abstracts)	1987 – 2016
Child Data	1996 – 2009 [†]
CINAHL (<i>Cumulative Index to Nursing and Allied Health Literature</i>)	1982 – 2019
Cochrane Central Register of Controlled Trials (CENTRAL)	1960 – 2016
EMBASE	1980 – 2019

HMIC (Health Management Information Consortium)	1979 – 2016
MEDLINE	1951 – 2019
MEDLINE In-Process and Other Non-Indexed Citations	1951 – 2019
Open SIGLE (System for Information on Grey Literature in Europe)	1980 – 2005*
PsycINFO	1987 – 2004†
Pubmed E publications (Epub ahead of print)	2019
Scopus	2009 – 2019
Social Care online (previously Caredata)	1970 – 2016
Trip Plus	1997 – 2012‡
Web of Knowledge – ISI Proceedings	1990 – 2016
Web of Knowledge – ISI Science Citation Index	1981 – 2016
Web of Knowledge – ISI Social Science Citation Index	1981 – 2016
* ceased indexing † institutional access terminated ‡ no yield so ceased searching	
Journals ‘hand searched’	Time period searched
Child Abuse and Neglect	1977 – 2016
Child Abuse Review	1992 – 2016
Websites searched	Date accessed
Child Welfare Information Gateway (formerly National Clearinghouse on Child Abuse and Neglect)	April 2016
National Center on Shaken Baby Syndrome (NCSBS)	April 2016

The search terms used in Medline database search are presented below, truncation and wildcard characters were adapted to the different databases where necessary. Changes to the search strategy were adopted only after consultation with the clinical expert sub-committee.

1. child*.mp.	41. (bruis: adj3 child:).mp.
2. baby.mp.	42. (petechiae adj3 child abuse).mp.
3. (infant\$ or baby or babies or toddler\$).mp.	43. (ecchymoses adj3 child abuse:).mp.
4. exp child/	

<p>5. 1 or 3 or 4</p> <p>6. child abuse.mp.</p> <p>7. child protection.mp.</p> <p>8. child maltreatment.mp.</p> <p>9. (battered child or shaken baby or battered baby).mp.</p> <p>10. or/6-9</p> <p>11. Soft Tissue Injuries/</p> <p>12. physical abuse.mp.</p> <p>13. physical punishment.mp.</p> <p>14. serial abuse.mp.</p> <p>15. non-accidental injur\$.mp.</p> <p>16. nonaccidental injur\$.mp.</p> <p>17. non-accidental trauma.mp.</p> <p>18. nonaccidental trauma.mp.</p> <p>19. (nonaccidental: and injur:).mp.</p> <p>20. wound:.mp.</p> <p>21. "Wounds and Injuries"/</p> <p>22. *Skin/in [Injuries]</p> <p>23. "Soft Tissue Injuries"/di [Diagnosis]</p> <p>24. (or/11-23) and 5</p> <p>25. 10 or 24</p> <p>26. exp Contusions/</p> <p>27. exp Purpura/</p> <p>28. Bruis*.mp.</p> <p>29. (hematoma or haematoma).mp.</p> <p>30. Hematoma/</p> <p>31. exp Scalp/</p> <p>32. (contusion or scalping).mp.</p> <p>33. H?emophilia.mp.</p> <p>34. platelet disorder*.mp.</p>	<p>44. ((petechiae or ecchymoses) and child abuse:).mp.</p> <p>45. ((petechiae or ecchymoses) and child maltreatment).mp.</p> <p>46. ((petechiae or ecchymoses) and child protection).mp.</p> <p>47. ((petechiae or ecchymoses) and injur\$).mp.</p> <p>48. ((petechiae or ecchymoses) adj3 injur\$).mp.</p> <p>49. (hemosid: adj3 bruis:).mp.</p> <p>50. or/41-47</p> <p>51. 40 or 50</p> <p>52. (dat: adj3 bruis:).mp.</p> <p>53. (characteristic: adj3 bruis:).mp.</p> <p>54. (age: adj3 bruis:).mp.</p> <p>55. or/52-54</p> <p>56. (imaging or images or photograph*).tw.</p> <p>57. cross polarized imag*.tw.</p> <p>58. ((Infrared or ultraviolet) adj2 (imag* or photograph*)).mp.</p> <p>59. Infra-red imag*.tw.</p> <p>60. exp Time Factors/</p> <p>61. exp Color/</p> <p>62. exp Spectrophotometry/</p> <p>63. Image Processing, Computer-Assisted/</p> <p>64. Photography/</p> <p>65. Imaging, Three-Dimensional/</p> <p>66. or/56-65</p> <p>67. 25 and 55</p> <p>68. 25 and 51 and 66</p> <p>69. 67 or 68</p> <p>70. limit 69 to yr="2016 - Current"</p>
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35. blood disorder*.mp.	
36. von Willebrand Factor/	
37. Blood Coagulation Disorders/	
38. von Willebrand Diseases/	
39. Hemophilia A/	
40. or/26-39	

Pre-review screening and critical appraisal

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

Appendix 2 - Related publications

Publications arising from this review

Maguire S, Mann MK, Sibert J, Kemp A. Can you age bruises accurately in children? Archives of Disease in Childhood. 2005;90(2):187-189

- Added to DARE Database: The Database of Abstracts of Reviews of Effects (DARE) is a collection of quality assessed systematic reviews of health care research identified in the biomedical literature from 1994 onwards. For those reviews which meet the Centre for Reviews and Dissemination (CRD) quality criteria, structured abstracts are written summarising the content and methods used to conduct the review and offering a commentary on the rigour with which the review was conducted.

Maguire S, Mann MK, Sibert J, Kemp A. Are there characteristics of bruising in childhood which are diagnostic or suggestive of abuse? Archives of Disease in Childhood. 2005;90(2):182-186

Maguire S. Bruising as an indicator of child abuse: when should I be concerned? Paediatrics and Child Health. 2008;18(12):545-549

Maguire S, Mann M. Systematic reviews of bruising in relation to child abuse—what have we learnt: an overview of review updates. Evidence Based Child Health: A Cochrane Review Journal. 2013;8:255-263.

Primary studies arising from this review

Maguire S, Ellaway B, Bowyer VL, Graham EAM, Ruddy GN. Retrieval of DNA from the faces of children aged 0-5 years: a technical note. Journal of Forensic Nursing. 2008;4(1):40-44.

Lawson Z, Nuttall D, Young S, Evans S, Maguire S, Dunstan F, Kemp AM. Which is the preferred image modality for paediatricians when assessing photographs of bruises in children? International Journal of Legal Medicine. 2011;125(6):825-830.

Lawson Z, Dunstan F, Nuttall D, Maguire S, Kemp A, Young S, Barker M, David L. How consistently do we measure bruises? A comparison of manual and electronic methods. Child Abuse Review. 2013.

Graham EAM, Watkins WJ, Dunstan F, Maguire S, Nuttall D, Swinfield CE, Ruddy GN, Kemp AM. Defining background DNA levels found on the skin of children aged 0-5 years. International Journal of Legal Medicine. 2014;128(2):251-258.

Kemp AM, Maguire SA, Nuttall D, Collins P, Dunstan F. Bruising in children who are assessed for suspected physical abuse. *Archives of Disease in Childhood*. 2014;99(2):108-113.