



University
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With what certainty can it be claimed that
rib fractures or classical metaphyseal lesions in infants
are attributed to physical abuse?

A systematic literature review

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II. Declaration

I declare that the content of this project report is my own work and has not previously been submitted for any other assessment. The report is written in my own words and conforms to the University of Dundee's Policy on plagiarism and academic dishonesty. Unless otherwise indicated, I have consulted all of the references cited in this report.

Dundee 16th of September 2019

Ankin Güvencel

III. List of abbreviations

AG	Ankin GÜvencel
AE	Anders Eriksson
AHT	Abusive Head Trauma
CML	Classic Metaphyseal Lesion
CPR	CardioPulmonary Resuscitation
CT	Computed Tomography
DSS	Department of Social Services
E-Code	External-cause-of-injury-or-poisoning Code
ED	Emergency Department
ICD-9-CM	International Classification System of Diseases, 9 th Revision, Clinical Modification
ICD-10	International Classification System of Diseases, 10 th Revision,
IT	Ingemar Thiblin
MOOSE	Meta-analysis Of Observational Studies in Epidemiology
MRI	Magnetic Resonance Imaging
NC	North Carolina, USA
NJA	Nytt Juridiskt Arkiv
OI	Osteogenesis Imperfecta
PPV	Positive Predictive Value
PIRO	Population, Index test, Reference test and Outcome
KID	Kids' Inpatients Database
QUADAS	Quality Assessment of Diagnostic Accuracy Studies
SBS	Shaken Baby Syndrome
SBU	The Swedish Agency for Health Technology Assessment and Assessments of Social Services (Statens beredning för medicinsk och social utvärdering).
SIDS	Sudden Infant Death Syndrome
SDH	Subdural Hematoma, Subdural Haemorrhage
SS	Skeletal Survey
TBBD	Temporary Brittle Bone Disease
WHO	World Health Organization
ZPC	Zone of Provisional Calcification

IV. Glossary of terms and definitions

Appendicular skeleton.....	The part of the skeleton within the limbs, as well as the pectoral and pelvic girdle.
Bucket-handle fractures.....	see Classic Metaphyseal Lesion
Callus.....	The bony healing tissue which forms around the ends of broken bone.
Classic Metaphyseal Lesion (CML).....	Lesions in the end of long bones claimed to be highly specific for abuse in infants.
Corner fractures.....	see Classic Metaphyseal Lesion
Incidence.....	The occurrence of newly diagnosed with a medical condition within a specified period of time.
Incorporation bias.....	When the index test is incorporated in (composite) reference standards.
Index test.....	The test whose performance is being evaluated with the reference test.
Infant.....	Refers to a baby below the age of 1 year
Pathognomonic	Characteristic for a particular medical condition. A pathognomonic sign is a particular sign whose presence means that a particular condition is present beyond any doubt.
Positive predictive value.....	The percentage of true positives amongst all positives.
Prevalence	The actual share of cases alive with the medical condition in the population at a given time.
Reference test.....	Ideally a “gold standard”, the standard against which the index test is evaluated.
Selection bias.....	May occur when study cases are not included consecutively or randomly.
Sensitivity.....	True positive rate. The proportion of actual positives correctly identified as such.
Specificity.....	The true negative rate. The proportion of actual negatives correctly identified as such.

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VII. Abstract

Rib fractures, especially posterior rib fractures, and so called classic metaphyseal lesions (CMLs) have been considered as highly specific for abuse in infants. This systematic literature review aims to answer the question “With what certainty can it be claimed that rib fractures or CMLs in infants are attributed to physical abuse?” The methodology advocated by the Swedish Agency for Health Technology Assessment and Assessments of Social Services (SBU) was applied. This systematic review differs from previous systematic reviews by the reference test of choice. This review used only admitted, witnessed or video recorded cases of abuse as reference test, in order to avoid incorporation bias and circularity. The search resulted in 4512 abstract and 35 manually searched articles, of which 426 articles deemed as relevant and scrutinised in full text. 424 of those did not meet the general inclusion criteria. The remaining 2 were scrutinised concerning quality, of which 0 was deemed high quality, 1 moderate quality and 1 low quality.

The narrative analysis of the only study with high enough quality to be included in the result, Adamsbaum et al., 2019, concerned classic metaphyseal lesions and gave the following graded result:

There is *limited scientific evidence* that CMLs can be caused by abuse.

There is *insufficient scientific evidence* on which to determine the diagnostic accuracy of CML to be caused by abuse.

Regarding rib fractures, based on the strict inclusion criteria for this systematic review:

There is *insufficient scientific evidence* that rib fractures can be caused by abuse and therefore also *insufficient scientific evidence* on which to determine the diagnostic accuracy of rib fractures to be caused by abuse.

1. Introduction

So-called classic metaphyseal lesions (CMLs) (Kleinman et al., 2016, Kleinman, 2008, Walker et al., 2016, Dwek, 2011, Flaherty et al., 2014) and rib fractures, especially posterior rib fractures (Kleinman et al., 2016, Walker et al., 2016, Dwek, 2011, Flaherty et al., 2014), are claimed to be highly specific for abuse in infants, and both CMLs (Kleinman et al., 1986) and rib fractures (Kleinman et al., 1986, Lonergan et al., 2003) are by some stated to be “virtually diagnostic” of abuse. This study aims to assess the available literature and conduct a meta-analysis on high-quality studies to answer the question: “With what certainty can it be claimed that rib fractures or classic metaphyseal lesions in infants are attributed to physical abuse?”

The consequence of a wrongful assessment of a case of suspected child abuse has far-reaching consequences for the child, the suspected perpetrator, and the family. Not recognizing child abuse can lead to continued physical abuse, and even have fatal consequences. A wrongful accusation and conviction is also catastrophic, with serious effects on psychological development and attachment on the child, and imprisonment of an innocent care-giver, who is doomed in the public's eye even after having served his/her sentence, despised, and separated from the family. Hence, both under-diagnosis and over-diagnosis may be disastrous. Returning to an abusive environment may be fatal for the baby, but destroying an innocent person's life is also detrimental.

Furthermore, in these cases, assessments and decisions often rest on medical evidence only. The infant is too young to communicate what happened, child abuse occurs in a secluded home environment without witnesses, and the potential scene might have been altered weeks ago. In the absence of other evidence, the medical assessment often needs to stand by itself "beyond reasonable doubt."

Lastly, the suspicion of child abuse raises very strong emotional reactions. The demand for strong integrity by the assessor is thus paramount. Being impartial and unbiased is an unchallenged statement within the forensic science

community, but there are few cases where it comes to its head as it does in a case where the evidence is limited to medical findings, and where the assessment has such far-reaching consequences. In summary, high quality scientific methodology is of utmost importance in several aspect concerning evaluation of suspected child abuse.

Several systematic literature reviews and meta-analyses of the diagnostic accuracy of rib fracture in infants and children have been published (Williams and Hardcastle, 2006, Kemp et al., 2008, Royal College of Paediatrics and Child Health, 2018, Paine et al., 2019), and one of metaphyseal fractures in general, including CML (Royal College of Paediatrics and Child Health, 2018). All these reviews include, however, reference tests with high risks of incorporation bias. What this systematic review adds to the scientific community, besides being the first systematic review focusing also on CMLs, is a critical approach to the choice of a reference test, lowering the risk of bias.

2. Background

This systematic literature review concerns physical child abuse and the diagnostic accuracy of rib fractures and CMLs. This chapter aims to paint the background and the reason for searching an answer to the stipulated research question.

Background will be given in a broad variety of fields such as anatomy, radiology, histology, biomechanics, historical, societal and from the point of medical investigations.

Child abuse and neglect – definitions and prevalence

Child abuse and neglect is a broad term used world-wide. But it is not always obvious what this term means. The accepted way of raising children differs around the world, influence by cultural and judicial differences. Sweden for instance, as the first country in the world, banned corporal punishment of minors already in 1979 (Hindberg, 2001), whereas other countries still allow corporal punishment to different degrees or in different settings. It is estimated that only 11 % of the worlds' children are protected from corporal punishment in all forms and settings, also in their home (The Global Initiative to End All Corporal Punishment of Children, 2019)

An attempt to define child abuse, also in an international context, was made by the World Health Organization (WHO):

“Child abuse or maltreatment constitutes all forms of physical and/or emotional ill-treatment, sexual abuse, neglect or negligent treatment or commercial or other exploitation, resulting in actual or potential harm to the child’s health, survival, development or dignity in the context of a relationship of responsibility, trust or power.”

Child abuse and neglect be divided into physical abuse, sexual abuse, psychological abuse and neglect (Runyan et al., 2002). The focus of this systematic review is *physical* abuse, which according to Runyan and co-authors (2002) can be defined “the acts of commission by a caregiver that cause actual physical harm or have the potential for harm”.

Since probably many cases of physical child abuse go uncovered, incidence and prevalence is uncertain, and the estimations reported varies depending on methodology, type of injuries and geographic location. One of the main themes in this systemic review is the issue of how to rightly assess if abuse has occurred or not, how to define the “gold standard test” for abuse, and to present figures on how common child abuse is worldwide problematic. As uncertain published figures are, some reported statistics can help putting the issue of physical abuse in a context.

Fatal abuse is relatively more straight forward to compare between countries, compared to non-fatal abuse. WHO has estimated that 57 000 deaths yearly are attributed to homicide among children under 15 years of age, and that infants and very young children are at greatest risk, with rates for the subgroup 0–4-year-olds being more than twice as high as for 5–14 year-olds. The homicide rates are associated with income levels, with the highest homicide rates for children under 5 years of age found in the WHO African Region (17.9 per 100 000 boys and 12.7 per 100 000 girls) and the lowest rates in high-income countries in the WHO European, Eastern Mediterranean and Western Pacific Regions (2.2 and 1.8, respectively) (Runyan et al., 2002).

Comparative data on non-fatal physical child abuse are much more difficult to obtain. Zolotor and Shanahan (2011) compiled the results from different reports from the USA in general and from the state of North Carolina in particular, and presented different figures depending on methodology, with death certificates at the top and surveillance of risk factors at the base considering the largest proportion of the population (Figure 1).

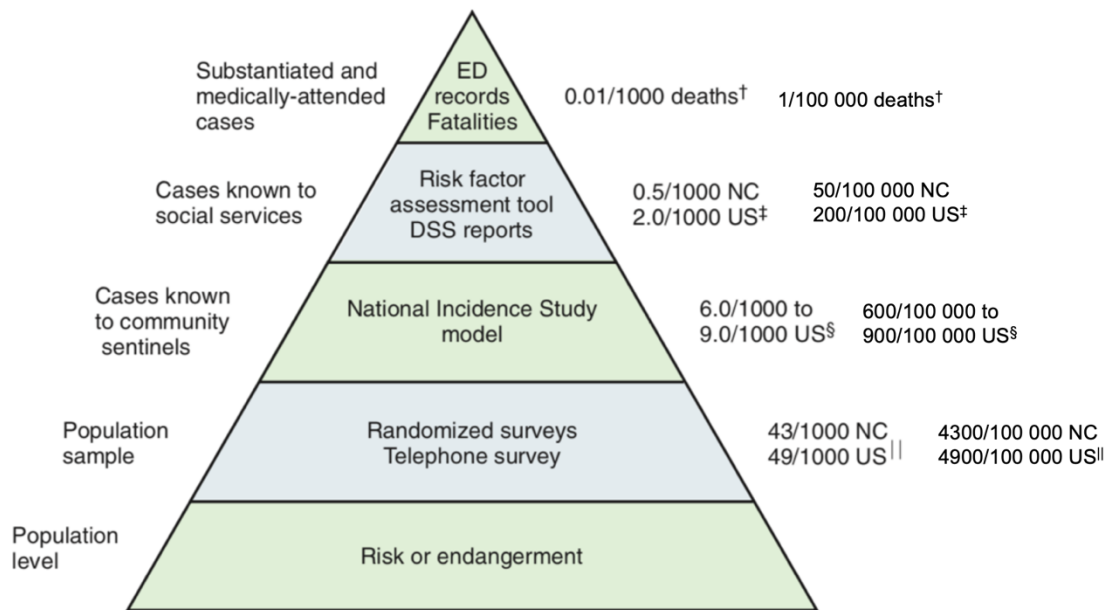


Figure 1. Physical child abuse in the USA (Zolotor and Shanahan, 2011).

ED = Emergency Department; **DSS** = Department of Social Services; **NC** = North Carolina, USA; **US** = United States of America

[†] Rate based on 30 child abuse homicides reported in 2003 by the NC Office of the Chief Medical Examiner and census estimate of midyear population <18

[‡] Substantiated reports to social services for physical abuse in 2006, NC and US estimates

[§] Physical abuse as reported by sentinels 1993, lower estimate for harm standard, upper estimate for endangerment or risk of harm standard

^{||} Estimates based on 2002 self-reported survey of parents reporting shaking a child <2, beating, burning, or kicking a child, or hitting a child with an object somewhere other than the buttocks and a 1995 survey of US parents.

As can be seen, the proportions of children identified as physically abused varies a lot depending on methodology, and this is before taking national and cultural differences into consideration.

An overview of how statistics of child abuse and neglect in general can be configured was presented by the U.S. Department of Health & Human Services (2019) regarding the year 2017. Child protection Service agencies noted referrals rates for children (0-18 year of age) to be 55.7 per 1000 children. Of those, 31.8 per 1,000 children received an investigation or alternative response from the agency, and a total of 17 % of the children were classified as victims of child abuse and neglect. That means a victim rate of 9.1 victims per 1000 children in the national US population as a whole. 18.1 % of the victims had suffered from physical abuse only or in combination with other types of abuse or neglect.

Children in their first year of life had the highest rate of victimisation at 25.3 per 1,000 children of the same age. Further, 2.32 deaths attributed to abuse and neglect occurred per 100 000 children. Of the children who died 41.6% suffered physical abuse either exclusively or in combination with another maltreatment type, which means 0.965 deaths due to physical abuse per 100 000 children.

A large study on the incidence of fractures attributed to physical abuse (Leventhal et al., 2008), gives an idea on what to expect (Table 1). The study was based on the Kids' Inpatients Database (KID) from 2003, including >85 % of the states in the USA. Fractures were defined by the ICD-9-CM code and abuse by an E-code for assault or the ICD-9-CM code for maltreatment syndrome. The results were compared to a Welch study from 1996-1998 (Sibert et al., 2002) which included infants and children where the abuse diagnosis was made by a multidisciplinary assessment (Table 1). The way of defining abuse based on codes in medical records and on multidisciplinary assessments has in the present systemic review been regarded as leading to a high risk of incorporation bias. The studies do, however, serve as a good example of how the general view on the prevalence of fractures in general and abusive fractures in particular, is presented in text books and consensus statements - where fractures are common in the first and the third year of life, but where the proportion of fractures attributed to abuse is much higher in the first year (Leventhal et al., 2008).

Table 1. Rates of abusive fractures according to age group in the KID data base from 2003 (national US estimations) compared to rates from a Welsh study from 1996-1998. (Leventhal et al., 2008, Sibert et al., 2002)

Age (months)	Incidence of fractures, estimates (cases per 100 000 children in the age group)	Incidence of abusive fractures, estimates (case per 100 000 children in the age group)		Proportion of abuse (%)
		KID, 2003	Welch	
0-11	145.0	36.1	48.3	24.9
12-23	67.1	4.8	15.6	7.2
24-35	163.8	4.8		2.9

According to the US guidelines of "The evaluation of suspected child physical abuse" physical child abuse affects boys to a slighter higher rates than girls, and infants have the highest risk of fatal and server physical abuse. Risk factors for infant abuse include maternal smoking, the presence of more than 2 siblings, low infant birth weight, there is also an association with poverty (Christian and Commiteee on Child Abuse and Neglect, 2015).

The skeleton with special focus on infants' long bones and ribs

This systematic literature review concerns skeletal manifestations claimed to have a high specificity of physical abuse, namely rib fractures and CMLs at the end of the long bones of the limbs. Before focusing on those specific manifestations, a short overview of the human skeleton with special focus on the infant's ribs and long bones is appropriate.

The adult human skeleton consists of approximately 206 different bones (Figure 2) (Bass, 1987)

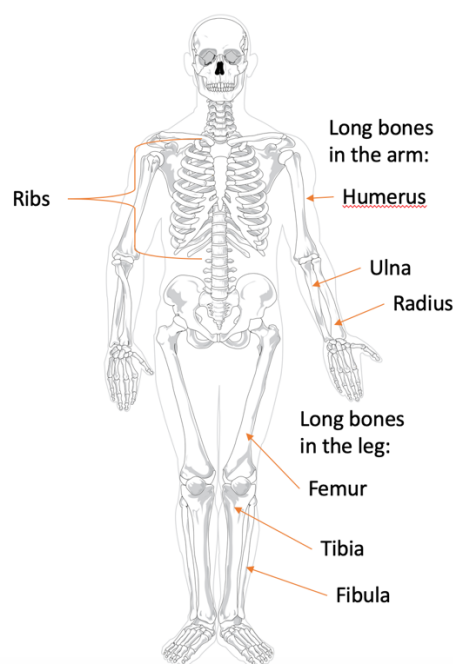


Figure 2. The adult human skeleton (Villarreal, 2007).

Even though the bones in the human body vary greatly macro-anatomically, they are surprisingly similar in their make-up. Bone is a mineralised connective tissue that functions as a stiff framework giving support and protection to vital organs, anchoring muscles and connective tissue, and working as a lever in locomotion (White et al., 2012).

The ribs of the human thorax are usually arranged in 12 pairs, situated symmetrically on each side of the thoracic spine. They provide protection of the thoracic organs and are crucial in the respiratory movements by supporting anchor of important respiratory muscles. The 12 ribs have different size but are fairly

similar in appearance, except for the most upper and lower ribs (the “atypical” ribs, usually the 1st, 2nd, 10th, 11th and 12th rib differs from the “typical” 3rd-9th ribs). The ribs usually consist of a head, a neck, an angle and a shaft (Figure 3).

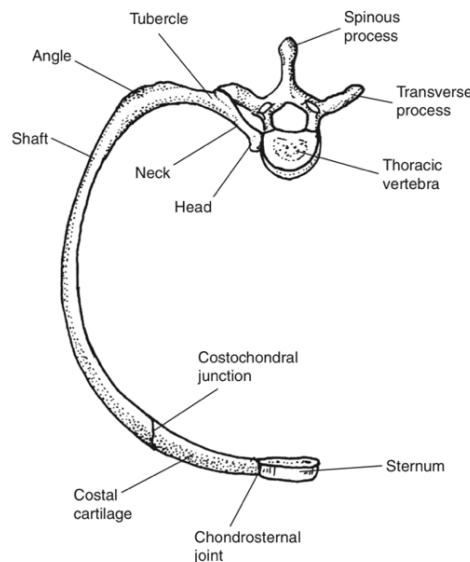


Figure 3. A right “typical” rib in anatomical position with its articulation to the thoracic vertebra and sternum (Cunningham et al., 2016b).

The head articulates to the body of a thoracic vertebrae, and the tubercle between the neck and angle (typically not apparent on the 11th and 12th rib) articulates with the transverse process of the same thoracic vertebrae. The 1st through 7th ribs usually articulate directly to the sternum via costal cartilage, the 8th to the 10th ribs are usually attached to sternum indirectly by a common costal cartilage, and the 11th and 12th ribs are usually not attached to the sternum (White et al., 2012).

The long bones of the arm consist of the humerus, the radius and the ulna, and the long bones of the leg comprise of the femur, the tibia and the fibula. These bones have the same principal configuration; a long tubular structure with articulation in both ends, but vary in size, shape, and type of articulation. Long bones all comprise of a hollow shaft, the diaphysis. In either end of the shaft there is a slight flare which makes up the metaphysis, and this is the area which is affected in classical metaphyseal lesions. The most extreme part of a long bone is called the epiphysis. The physis, between the metaphysis and the epiphysis, contains the growth plate in juvenile bones. This is a cartilaginous plate that runs perpendicular to the long bone’s long axis, and in this area where additional bone

tissue is added causing longitudinal growth during infancy and childhood. The cartilaginous growth plate is mineralised into bone when growing ceases and adulthood start to approach (White et al., 2012).

Besides acting as a stiff framework that supports, protects, and is crucial for locomotion, the skeleton also has physiological and metabolic functions. For example, the bones serve as a centre for production of blood cells and act as a reservoir of trace elements such as calcium and phosphate. The view on bone tissue has changed over the years and the tissue is no longer regarded as a passive framework, but instead as a highly dynamic and adaptive tissue responding to hormonal changes, mineral demands as well as mechanical load and activity (Grabowski, 2009).

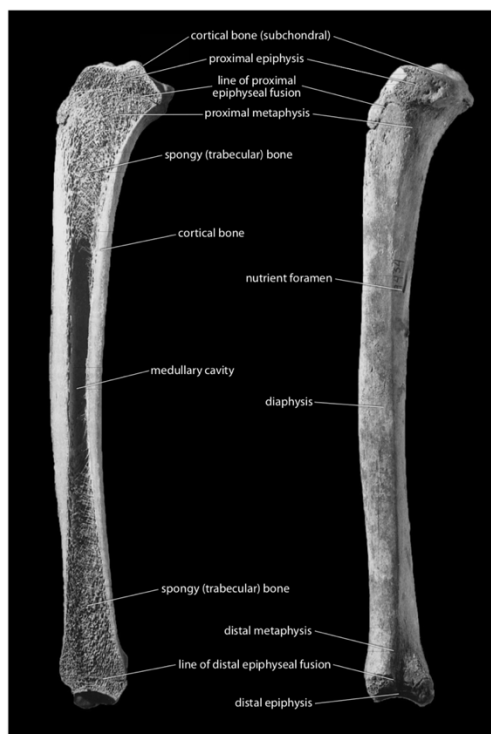


Figure 4. Anatomy of a long bone (tibia) and macroscopic structure (White et al., 2012).

Structurally, adult human bone tissue can be divided into two types; *Cortical* bone, also called compact bone, is dense and solid in appearance and is found mainly in the shaft (the diaphysis) of the long bones and on the bone surface. *Trabecular* bone, also called spongy bone or cancellous bone, has a trabecular, porotic honeycombing structure and can be found centrally in the ends of the long bones (the metaphysis and the epiphysis) (Figure 4) (White, 2012).

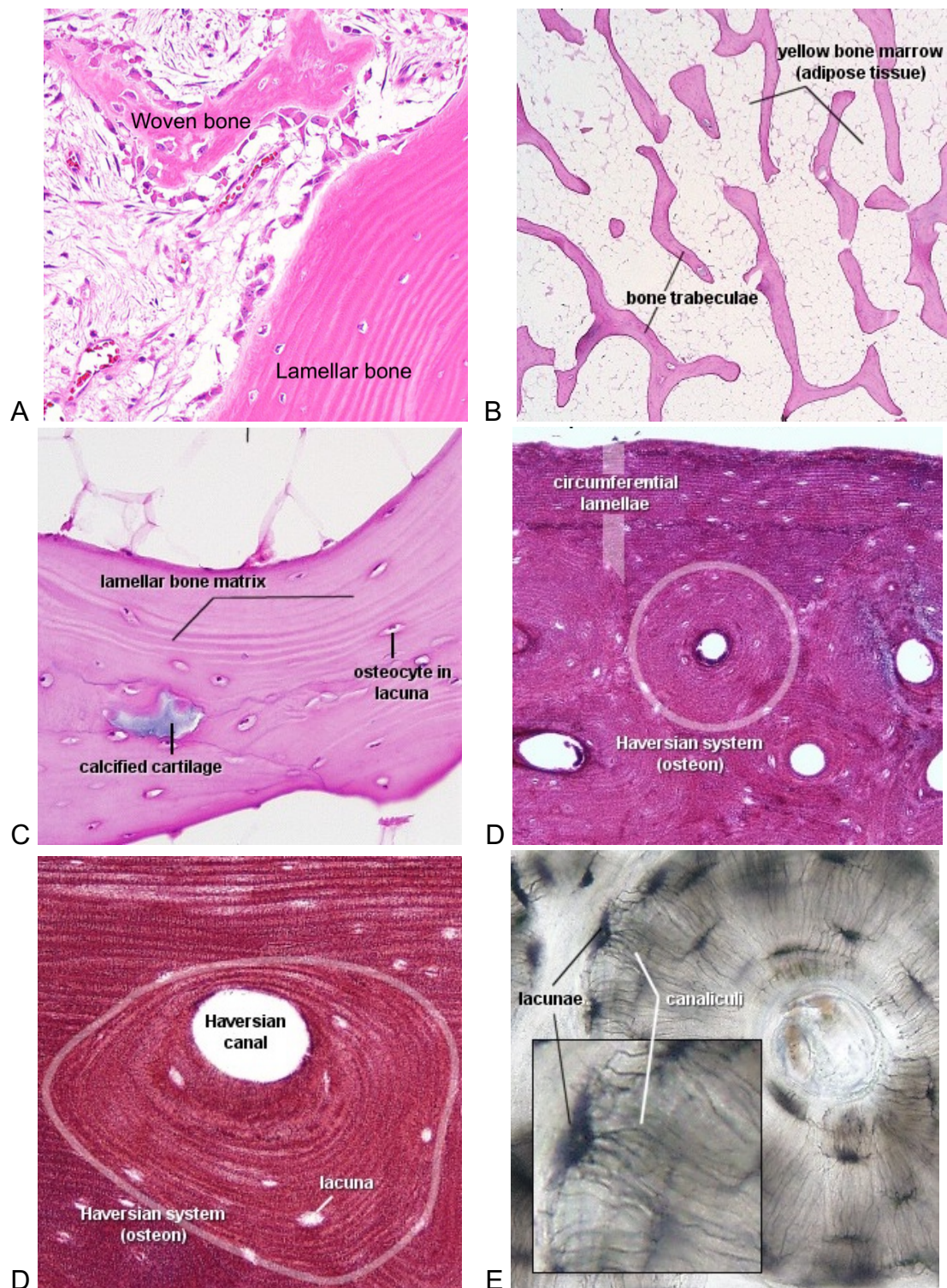


Figure 5. Histological features of bone tissue. A) Unmineralized woven bone and mature lamellar bone with a disorganized and organized appearance respectively. High-power field. B) Trabecular bone. Low-power field. C) Trabecular bone. High-power field. D) Cortical bone low power field. E) Cortical bone. Low power field. (Gardner, 2015) (Slomianka, 2009).

Despite the structural differences, compact and trabecular bone comprise of the same cellular and molecular components. The bony tissue contains approximately 50-70% inorganic material, 20-40% organic material and 5-10 % water. The bulk of the inorganic material is hydroxyapatite (calcium phosphate) which is a crystallised inorganic material in the matrix of bone, which is responsible for the bone tissues rigid and stiff properties. The organic material is to a large proportion composed of the protein collagen, mostly type I collagen, which forms long elastic fibres and is responsible for the flexible properties of bone. These components give the bone both elastic and rigid physical properties. In addition to hydroxyapatite and collagen, the bone tissue consists of non-collagenous proteins, polysaccharides, cells and blood vessels. The important cells in the bone tissue are osteoblasts which are the bone matrix producing cells, osteocytes that are osteoblasts that have been trapped in the bone matrix, and osteoclasts that are bone resorbing cells and important in remodelling (Clarke, 2008).

Histologically, bone can be divided into mature and immature bone. *Immature* bone, also called woven bone, usually forms rapidly and can be found embryonically and in fracture repair. It has a higher proportion of cells than mature bone, and the collagen fibres have a haphazard organisation. Cortical and trabecular bone are both types of *mature* bone, and the collagen is organised in layers, hence also called lamellar bone. In trabecular bone the layers are parallel arranged. In cortical bone the layers are mainly concentrically arranged in osteons or haversian systems, which is the fundamental functional unit of compact bone. The concentric layers surround a central canal (the haversian canal), which contains the nerve and blood supply to the bone. The osteocytes are osteoblast that are terminally differentiated and trapped in small gaps, lacunas in the bone matrix. The osteocytes communicate via an intricate cellular network through canaliculi to their neighbouring cells (Wei and Siegal, 2013) (Figure 5).

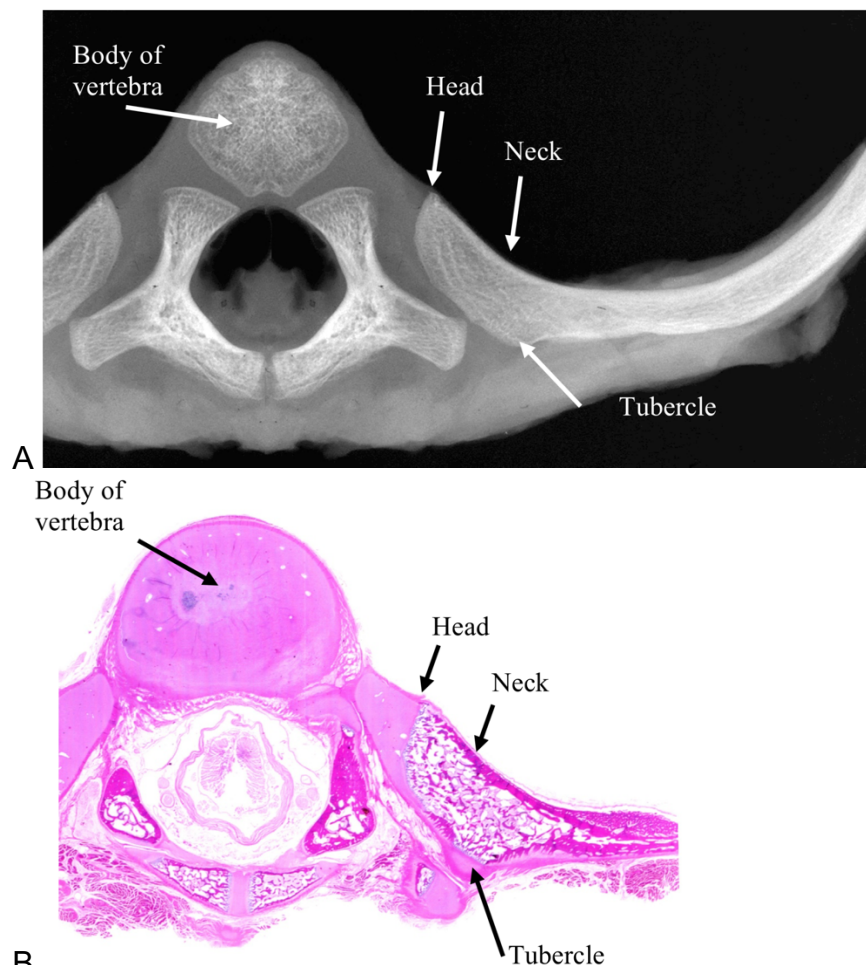


Figure 6. Normal anatomy of posterior rib-vertebral complex of an infant (Baker, 2012). A) Radiograph. B) Whole-mount histology. Note that the part of the head consists of cartilage cap which is seen as a homogenous pink area between the osseous head and body of vertebra. The arrow point on the head marks the junction between the cartilaginous and osseous part of the head. Also, the tubercle consists of cartilage.

Rib development

Ribs develop embryologically from a cartilage template having the same shape as the ossified rib, though endochondral ossification. The primary ossification commences in the 8th to 9th week of foetal life in the area of the rib angle, and spreads ventrally and dorsally until the 4th foetal month when the adult proportion of the rib bone and cartilage is reached. Until the appearance of secondary ossification centres at puberty, the only rib development concerns changes in size and shape. The foetal ribs are more horizontally situated than the adult ribs, where the frontal aspect of the chest has a more caudal position. During respiration, the newborn infant uses mainly the diaphragm and the abdominal wall muscles, and the thorax functions more or less just as a container for the lungs. This changes during life, and the ribs assume a more oblique position, which in combination with involvement of intercostal muscles and accessory respiratory muscles expands

the thoracic cage and compresses it during inhalation to facilitate breathing. The angular change of the ribs, and the descent of the frontal aspect of the chest results in different proportions of the infant chest compared to that of the adult, which has a relatively longer transverse diameter than that of the infant. This descent of the frontal aspect of the chest is associated with the onset of walking (Cunningham et al., 2016b), usually at ~12 months of age (Martorell et al., 2006). The secondary ossification centres of the ribs commence ossification at around puberty. Secondary ossification centres appear at the head and the articular region of the tubercle, but also on its non-articular region (Figure 6). These secondary ossification centres appear and fuse at approximately the same time (Cunningham et al., 2016b). Since the secondary ossification commences during puberty, the infant rib head and tubercle consist of cartilage.

Long bone development

The long bones of the arms and legs also develop from cartilage templates through endochondral ossification. The primary ossification centres appear in the shaft of the long bones between the 7th and 9th foetal week, first as a bony collar and later as a complete diaphysis. At birth the long bones of the arms and legs are represented mostly by the shafts only, whereas the ends are still represented by cartilage only. However, in the 36th to the 40th prenatal week, secondary ossification has usually commenced in the distal epiphysis of the femur and in the proximal epiphysis of the tibia. During the first year of life secondary ossification usually also commences in the epiphysis in the proximal and distal ends of the humerus, as well as in the head of the proximal end of the femur, and the distal ends of the tibia and the fibula. Further, secondary ossification centres at the end of the long bones continue to commence ossification during childhood. One of the last secondary ossification centres to ossify is the lateral epicondyle of the distal humerus, at the age of 10-12 years (Figure 7) (Cunningham et al., 2016a).

In long bones the growth takes place in the growth plate in the physis, next to the metaphysis. This zone remains unossified, within the growth plate, until growth ceases and the epiphysis fuses with the shaft. Different epiphyses fuse at different times, but the first starts to fuse at around 11 years of age, and the last fuses up to the age of 20 years. The female skeleton often develops earlier than that of males.

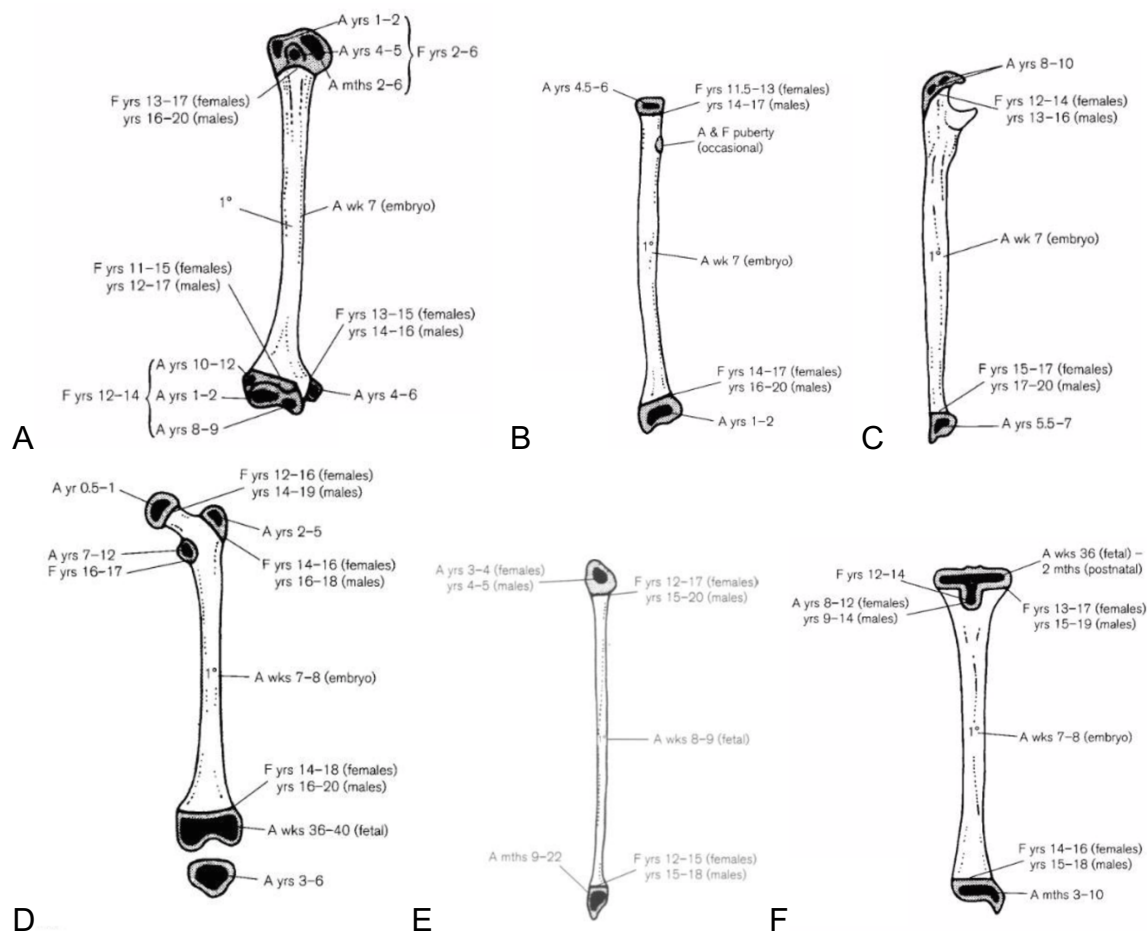


Figure 7. The long bones in the arm and leg with primary ossification centres, appearance of secondary ossification centres, and fusion of epiphyses ((Scheuer and Black, 2000) I°= Primary ossification centre; A=Appearance; F=Fusion A) Right humerus; B) Left radius; C) Left ulna; D) Left femur; E) Right fibula; F) Right tibia.

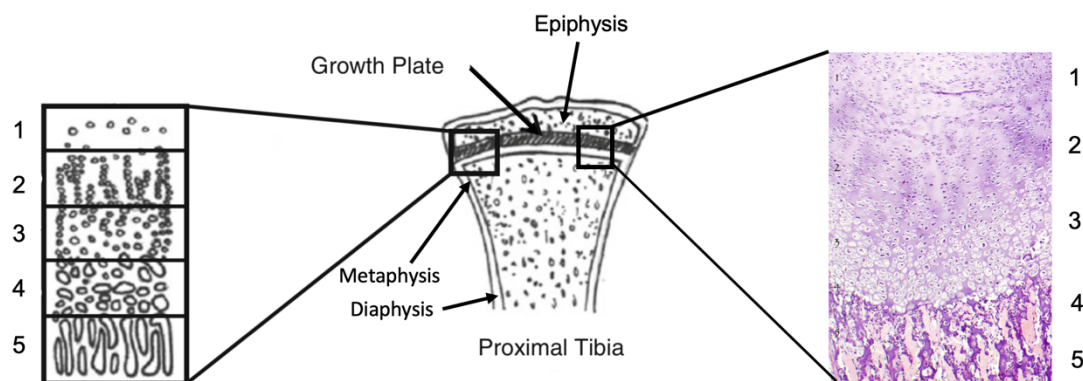


Figure 8. Growth plate in long bone with active ossification (Humphries, 2011, Wei and Siegal, 2013, Tsai et al., 2014). The growth plate, located between the epiphysis and the metaphysis, can be divided into five zones in the direction of the diaphysis as follows: 1) Resting (reserve) zone of cartilage with small inactive cartilage cells. 2) Proliferative zone of cartilage where the cartilage cells, the chondroblasts divide. 3) Hypertrophic zone where the chondrocytes are maturing and increase in size. 4) Calcified zone or the zone of provisional calcification (ZPC). The zone of mineralisation where the chondrocytes die and bone deposition on calcified cartilage starts. The ZPC is histologically and radiologically visible at different levels, radiologically visible closer to the epiphysis, than histologically. 5) Primary spongiosa (ossification zone). The bone spicules are made up of cellular calcified cartilage cores, and the immature bone is deposited at the periphery of the calcified cartilage. (Humphries, 2011, Wei and Siegal, 2013)

The site of CMLs is at the metaphysis, at the growth plate between the diaphysis and the epiphysis where cartilage matures to bone under growth (Figure 8).

A term frequently used in this context is subperiosteal bone collar (SPBC), which is a peripheral bony collar that extends from the metaphysis around the physis (Figure 9). The diaphysis and metaphysis are covered by periosteum and the cartilage at the epiphysis is covered with perichondrium. At the level of the physis, where the SPBC is situated, these fibrous septa are stronger, and the fibrous tissue forms a ring around the physis, “the ring of LaCroix” (Rosenberg, 2015).

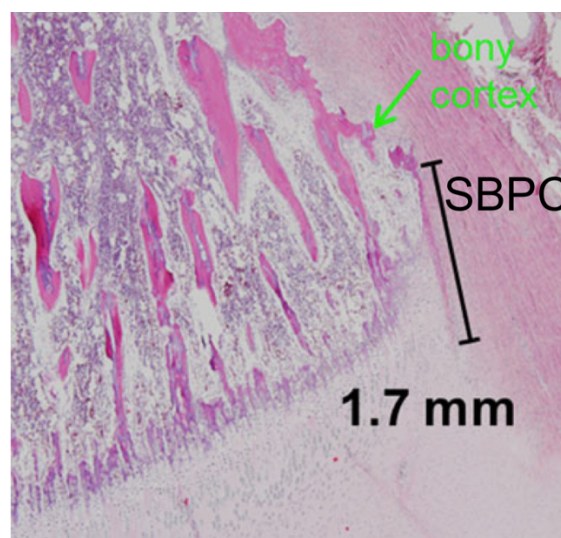


Figure 9. Left tibia in an infant with subperiosteal bone collar (SPBC) marked with black (Tsai et al., 2014).

Fractures

A fracture is defined as “a disruption in the continuity of a bone” and the disruption depends on the “direction, energy, loading rate and duration of load”. Also other factors play important roles in bone dynamics, most importantly the health and maturity of bone. Growing bone has a higher proportion of organic components and a lower proportion mineral content which makes the growing bone less stiff and more malleable. Also diseases such as osteogenesis imperfecta and rickets affect the properties of the bone, making it more prone to fractures (Zephro and Galloway, 2014b).

The modulus of elasticity, or Young’s modulus, graphically describes the relationship between stress and strain for a solid material, such as bone, that

undergoes compression or tension (Figure 10). The curve describes the load the material can bear before failure, i.e. fracture, as well as the deformation prior to fracture. Elastic deformation occurs first, when the bone can return to its original form after the stress ceased. Plastic deformation occurs next, when the bone cannot return to its original shape after the stress ceased, and starts at the yield point. The failure point is reached when the bone breaks.

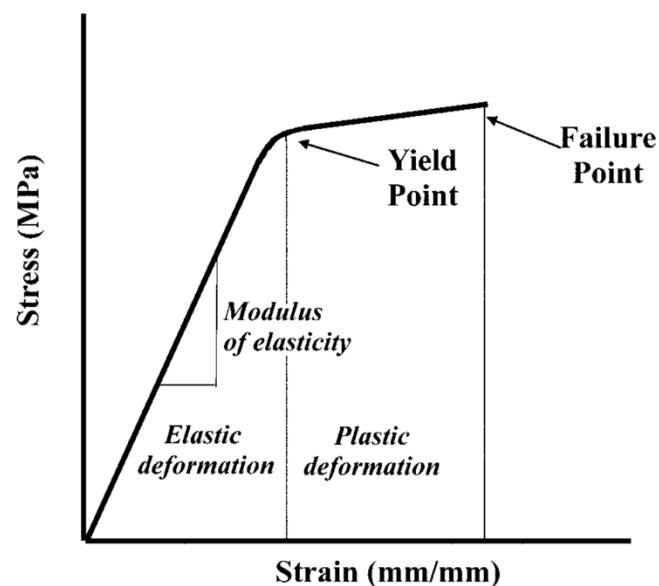


Figure 10. Young's modulus, graphically describing the relationship between stress and strain (Zephro and Galloway, 2014b). Strain: Reference to the bone itself. The deformity of an object in response to an external force. Stress: Reference to the force. The applied force divided by the cross-sectional area.

In summary, bone can absorb large amounts of energy under elastic deformation and a small amount of energy under plastic deformation before fracture occurs. Stiffer material, for instance adult bone, has a steeper initial part of the curve, resisting deformation prior to failure better (Zephro and Galloway, 2014b). Biomechanical studies have shown that infant bone is less strong, less stiff and more ductile than adult bone. In experiments with ribs from infant donors, 1/3 of the samples were so flexible that the failure criterion "fracture", had to be changed to 30% strain after yield instead, since fracture never resulted. Moreover, the studies demonstrated that stiffness and strength increased during the first year of life, while ductility did not change significantly (Ambrose et al., 2018).

Fractures can be caused by different types of forces such as tension, compression and shear, and different combinations of these forces, for instance bending and torsion. Bone as material is anisotropic which means it can withstand stress better

in certain directions; compressive stress better than tensile or shear stress (Zephro and Galloway, 2014b).

As a result of the different properties of growing bone compared to adult bone, the growing bone being more ductile and less stiff than the more brittle adult bone, common fracture types differ between juveniles and adults. Usually *incomplete fractures*, i.e. fractures still partly keeping the continuity between the involved bone segments, are more often seen among juveniles than among adults. There is a variety of incomplete fracture types, for instance a *bow fracture* which actually not *per se* is a fracture, but a changed curvature or angulation of the involved bone segments. Bow fractures can be caused by both longitudinal compression and bending, and are histologically visible as a series of microfractures. Another type of incomplete fracture is the *greenstick fracture*, which is caused by a bending force that results in incomplete transverse fractures emerging on the tensile side and a bowing or angulation on the compression side, where the bone still has not lost its continuity. This type of fracture is typically seen in the ribs (Zephro and Galloway, 2014a).

Complete fractures are, as the name suggests, fractures that result in complete discontinuity between the involved bone segments. These fractures can for instance be transverse, oblique, spiral shaped or comminute, and can be seen both in juveniles and adults. In juveniles, often higher energy has been involved than in incomplete fractures. Simplified, the mechanism of transverse fractures can be described as bending, and oblique fractures can be described as a combination of compression and bending (Zephro and Galloway, 2014a).

History of child abuse and key articles

The earliest description of child abuse in the scientific literature was made by Tardieu, a French forensic pathologist who already in the 1860's described ill-treated and battered children (cited in Roche et al., 2005). This publication did not, however, reach international awareness, but in 1946 Caffey, a paediatric radiologist from New York, published his classical paper (Caffey, 2011), which is said to have initiated a general awareness of child abuse (Grover and Crawford,

2016). Caffey described six infants with subdural hematoma and multiple long bone fractures in different stages of healing, situated especially around the metaphysis. He was “puzzled” by the findings since there was no history of trauma in any of the cases and the infants showed no clinical or roentgenological evidence of skeletal disease weakening the bones. He did not supply any explanation of the findings, but concluded that the fractures appeared to be of traumatic origin and that “the traumatic episodes and the causal mechanism” remained “obscure”. He postulated long bone fractures or subdural hematoma warranted additional investigation for subdural hematoma and long bone fractures, respectively. In 1953 Silverman, another paediatric radiologist from New York, continued to explore the roentgenological findings of children with “unrecognized skeletal trauma” and described three infants with multiple fractures including a posteromedial rib fracture and metaphyseal “rarefaction” and “lesions” (Silverman, 1953). After careful investigations, several episodes of trauma were revealed, potentially explaining the findings, and he frankly suggested that the infants had been deliberately injured by their caregiver.

However, the child abuse phenomenon did not reach general awareness in the medical community until 1962, when Kempe and colleagues (Kempe et al., 1962) coined the term “the battered-child syndrome”. They abandoned the former term “unrecognized trauma” and used it to “characterize a clinical condition in young children who have received serious physical abuse”. After the conduction of a nation-wide survey in the US they reported that from the 71 replying hospitals 302 such cases were reported, and 77 districts attorneys reported that they knew another 447 cases and concluded that this was a particularly common problem in the hospitals. Kempe and colleagues presented two cases and summarised their clinical experience and reported what was typical for this syndrome. Furthermore, they presented radiological features of the battered-child syndrome and concluded “To the informed physician, the bones tell a story the child is too young or too frightened to tell”. The “classical” radiological picture was typically seen in a “very young child” and included subdural hematoma with or without skull fractures, multiple fractures at different stages of healing, mostly in the appendicular skeleton and in the metaphyseal-epiphyseal area, and new bone formation around the shaft. The epiphyseal-metaphyseal changes were described more detailed as

“irregularities of mineralization in the metaphyses of some of the major tubular bones with slight malalignment of the adjacent epiphyseal ossification centre”. “The radiological features are so distinct that other diseases generally are considered only because of the reluctance to accept the implications of the bony lesions”. They concluded “the radiologic manifestations of trauma are specific, and the metaphyseal lesions in particular occur in no other disease of which we are aware. The findings permit a radiologic diagnosis even when the clinical history seems to refute the possibility of trauma. Under such circumstances, the history must be reviewed, and the child's environment, carefully investigated.” They recommended the physician diagnosing the battered child syndrome to report “the possible willful trauma” to the police or a children's protective service (Kempe et al., 1962).

This publication had a major impact on the medical community, attracted attention to child abuse and evoked general awareness in society. A consequence of this was that within a few years, all US states mandated reporting of suspected abuse by medical personnel (Kocher and Kasser, 2000).

In 1971 the British neurosurgeon Guthkelch published an article where he presented 23 children with subdural hematoma (SDH, collection of blood between the brain [pia mater] and the dense connective tissue surrounding the brain [dura mater], of which 22 of were younger than 18 months. The causes of SDH in these cases were “proved or strongly suspected parental assault.” Guthkelch hypothesised that the finding of SDH, often in the absence of other marks of trauma to the head, could be explained shaking (Guthkelch, 1971). One year later, in 1972 Caffey associated traumatic shaking with the findings of subdural hematoma and retinal haemorrhages (bleeding in the thin layer, the retina, that lines the back of the eyes) and fractures in long bones especially metaphyseal lesion of corner fracture type and bucket-handle type. He attributed the findings to acceleration-deceleration trauma and rotation while shaking the infants (Caffey, 1972). In 1974 he introduced the term Whiplash shaken infant syndrome (Caffey, 1974) and suggested that the children previously were described as “battered infants”, and exemplified it with the six infants he himself described in the article from 1946, actually were “shaken infants”, and that the term battered infants was a

misnomer. He concluded that “current evidence, though manifestly incomplete and largely circumstantial warrants a nationwide educational campaign on the potential of pathogenicity of habitual, manual casual whiplash shaking of infants”.

Since the introduction of the Whiplash shaken infant syndrome the phenomenon has gained worldwide attention, mostly under the term Shaken Baby Syndrome (SBS) introduced in 1984 (Ludwig and Warman, 1984). This syndrome included three symptoms, “the triad”: subdural hematoma, retinal haemorrhages and encephalopathy (symptoms of brain dysfunction), and the triad became synonymous with abusive shaking. In 2009 the American Academy of Pediatrics recommended to instead use the term Abusive Head Trauma (AHT), so that also direct impact on the head was included (Christian and Block, 2009). Sometimes other symptoms and signs have been included in the syndrome, such soft tissue injuries and/or fractures, and in particular CML and rib fractures have been mentioned. Rib fractures have been explained by grabbing around the chest during shaking (Kleinman, 2015, Kleinman and Schlesinger, 1997a, Kleinman et al., 1996a), and the CMLs by violent shaking of the infant while held in the trunk or limbs causing shearing forces in the metaphyses (Kleinman et al., 1986).

However, the Shaken baby paradigm has been challenged by several authors, especially during the last years. The controversies have concerned findings such as the triad, and fractures. This will be discussed further in the section “Controversies in theories”.

Rib fractures

Rib fractures have not been associated with abuse as long as classic metaphyseal lesions, and were for instance not mentioned as an important finding in the classic article by Caffey from 1946 (Caffey, 2011). Not until in the 1950's the association between rib fractures and physical abuse started to play a more significant role (Silverman, 1953). More researchers have studied rib fractures than CML, but just as for CMLs Kleinman and colleagues are key authors, especially in correlating radiological and histopathological findings (Tsai et al., 2012, Kleinman et al., 2002, Kleinman and Schlesinger, 1997b, Kleinman et al., 1996b, Kleinman et al., 1992, Kleinman et al., 1988).

Different locations of rib fractures

Rib fractures can occur at different sites along the ribs from the costovertebral articulation to the costochondral junction. Different studies divide the rib into different anatomical regions when describing the fracture site, which is problematic when comparing studies. Even the same authors sometimes change the vocabulary during the years (Kleinman, 2015, Kleinman et al., 1996a). A suggestion of a classification system has been proposed (Pinto et al., 2015, Love et al., 2013), but since this classification system was proposed only recently, and few studies have adopted the system. In this review the following names will be used to define the anatomical regions: posterior including head and neck (neck also includes the tubercle), posterolateral, anterolateral, anterior and costochondral junction (Figure 11) However, in some studies posterior rib fractures include also posterolateral fractures (Barsness et al., 2003, Cadzow and Armstrong, 2000)

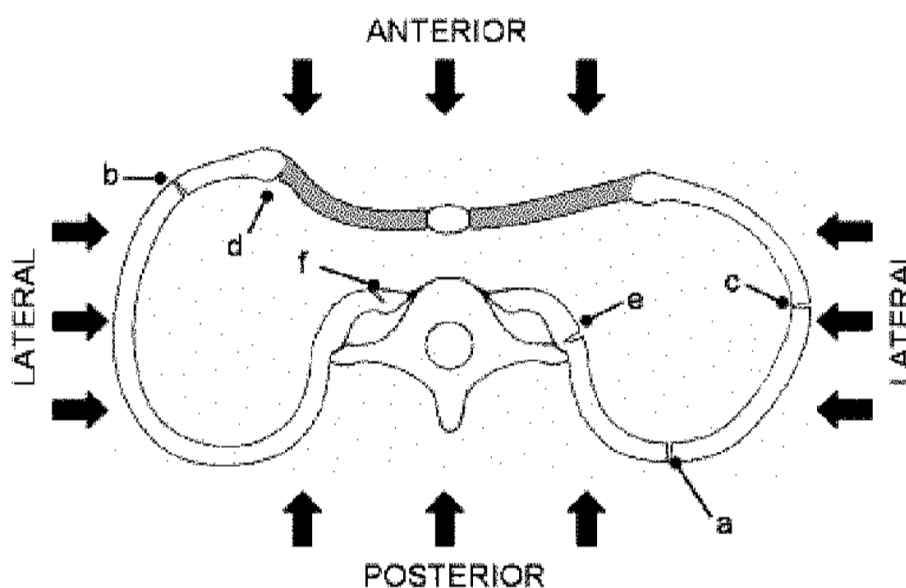


Figure 11. Anatomical regions of fractures in the ribs as defined in this review. Ribs under anterior posterior compression. (Worn and Jones, 2007, Kleinman et al., 1996a) a=posterolateral; b=anterior; c=anterolateral; d=costochondral junction; e and f=posterior; e=costotransverse articulation; f=head

The fractures have been suggested to be described as complete or incomplete and can further be more precisely be described as buckle (incomplete), transverse (complete) or oblique (incomplete or incomplete) (Pinto et al., 2015, Love et al., 2013).

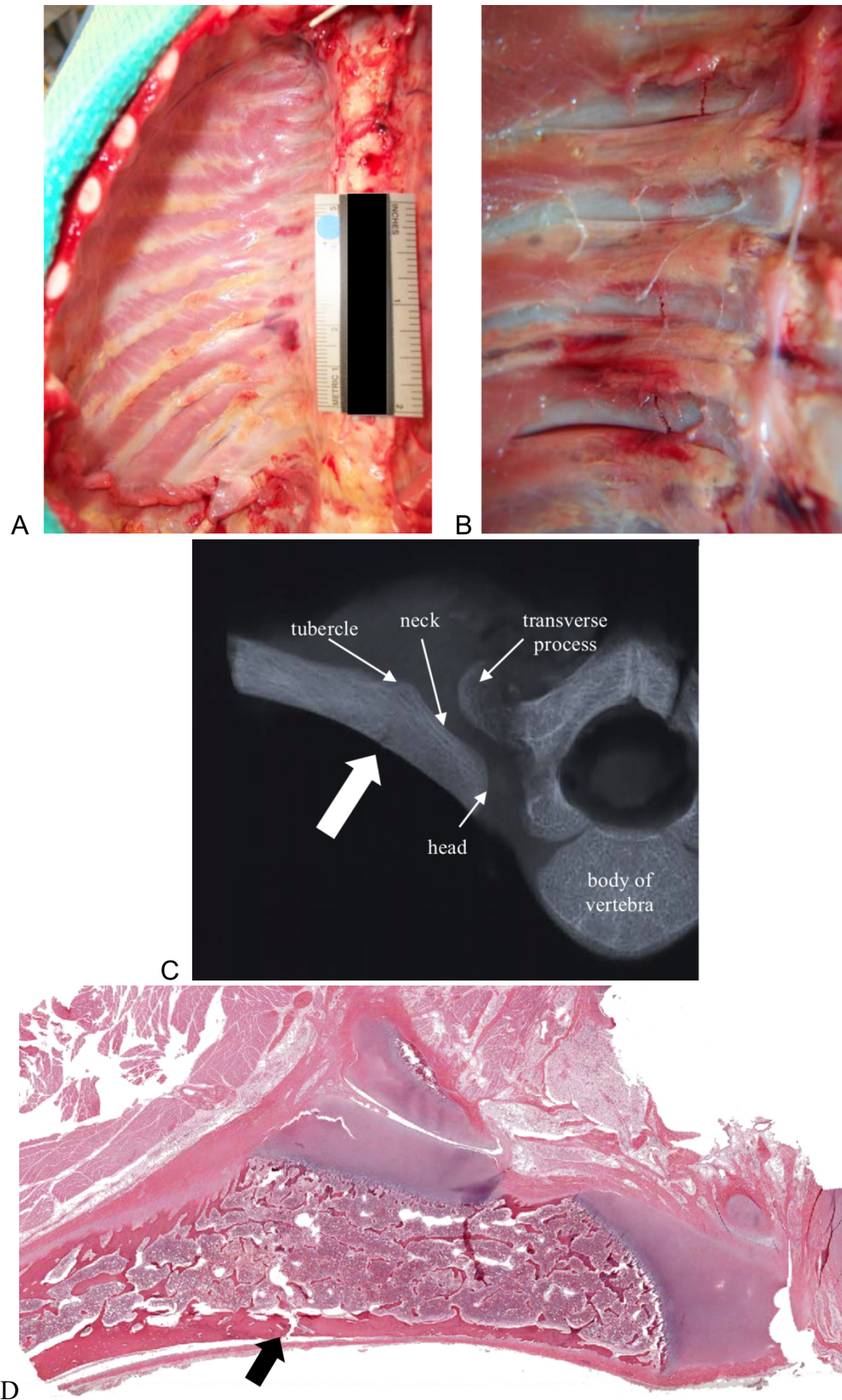


Figure 12.

Figure 12. Acute posterior rib fractures in an infant (Baker, 2012). A) Hemorrhage is seen over the posterior right 6th-9th ribs. B) The pleura has been stripped away to confirm fractures. C) Specimen radiograph. Large white arrow shows the fracture. The fracture was not visible on standard chest X-ray. D) Low power photomicrograph showing the location of the fracture on the ventral cortex of the rib (arrow).

Histopathological and radiological correlation

As mentioned before a fracture is a disruption in the continuity of a bone, and can histologically be seen as a gap in the bony tissue and a translucent gap, line or step-off on radiographs in the acute phase (Figure 12) (Raynor et al., 2018, Love and Sanchez, 2009).

The process of repair starts immediately, gradually building up and remodelling the bone by a callus, the bony healing tissue which forms around the ends of broken bone. The process can be described as follows: The first step in the healing process is bleeding from the disrupted vessels in the bone, forming a hematoma that coagulates. Inflammation starts and granulation tissue with inflammatory cells, vessels and fibrosis develops. Subperiosteal new bone formation occurs at the same time, in the form of immature woven bone, which is usually the first radiological sign of healing. Gradually a callus, consisting of fibrotic and cartilaginous tissue as well as primitive immature woven bone, builds up in the granulation tissue around the fracture site, gradually turning into a hard or bony callus organised in trabeculae. The bony callus successively gets more structured, and gradually coalesces with the subperiosteal new bone formation. In this way, the fracture gap is bridged by bony tissue and finally remodelled so that the fracture site consists of normal lamellar bone, hardly distinguishable from non-injured bone. The last remodelling can continue for years. (Wei and Siegal, 2013, Ubelaker and Montaperto, 2011, Sanchez et al., 2013, Raynor et al., 2018, Kleinman and Walters, 2015). For histological and radiological timing of the different events, see Table 2).

Table 2. Histological and radiologic stages of fracture healing (Raynor et al., 2018, Sanchez et al., 2013).

Histologically fracture (including ribs) dating guidelines for infants/toddlers (<18 months) (Raynor et al., 2018)		Radiological rib fracture dating guidelines for infants (<12 months) (Sanchez et al., 2013)	
Fresh	Fractures recognised as deficiencies in bone with a distinct fracture gap and some associated reaction.	0-1 week	Barely visible fracture line or step-off, no periosteal reaction.
<2 days	Haemorrhage in and around the fracture site with osteocyte necrosis in bone abutting the fracture line and, in some, more polymorphs in areas of haemorrhage than one would expect to have resulted from haemorrhage alone.		
<1 week	Formation of granulation tissue, evidence of chronic inflammation and formation of early fracture callus with condensation of connective tissue into primitive bone and cartilage like structures.		
<2 weeks	Obvious trabeculae of woven bone and nodules of cartilage in the medulla and on periosteum typical of "primary callus"	1-3 weeks	Periosteal reaction <2 mm in thickness, some resorption along fractures lines.
About 2 weeks	Almost all cases show widespread more intense haematoxyphilia of the matrix indicative of mineralisation. Callus bridges the fracture site.		
>2 weeks	Onset of remodelling of primary callus.	3-5 weeks	Early callous formation <4 mm in thickness, fracture lines still clearly visible.
>4 weeks	Formation of lamellar bone on the surface of existing woven bone and cartilage nodules.	5-7 weeks	Callous formation thickest at this stage and measure at least 4 mm.
		7-9 weeks	Callous formation starts to remodel, <4 mm with near complete bridging of the fracture line.
>2 months	Progressive matrix reorganisation	9-11 weeks	Consistent feature is focal sclerosis and cortical thickening with little change over several weeks to months.

Trauma mechanisms

A literature review on the injury mechanism of rib fracture in infants (Worn and Jones, 2007) concluded that the likely mechanism of rib fractures was relatively well-documented, but that "the magnitude of the forces and deflections, required to inflict any of the six types of rib fractures do not appear to have been addressed to date. However, with rib fractures commonly being used as indicators of abuse, a greater understanding of the forces and deflections required to cause such rib fractures is an important factor in improving diagnostic confidences in these cases". More than 10 years have passed since this review, but it appears that the mechanisms for the different types of rib fractures have yet not been established.

The most commonly described and supported theory is that rib fractures at the head and neck area are caused by anterior-posterior manual compression/squeezing of the thoracic cage (during for instance shaking) (Kleinman, 2015, Kleinman and Schlesinger, 1997a, Kleinman et al., 1996a). The squeezing presses the posterior part of the ribs posteriorly compared to the

vertebral column, causing leverage of the posterior part of the rib, over the vertebral transverse processes. This, in turn, cause tensile stress over the inner aspect of the rib's head and costotransverse articulation, and assuming that the ligaments are stronger than the ribs, fractures at the head and costotransverse articulation will result (Figure 11). Sternal pressure under cardiopulmonary resuscitation (CPR) is claimed not to produce the same leverage over the transverse processes, since the back is supported by a firm surface, and hence the posterior part of the ribs not moved posteriorly relative to the vertebral column. Experimental studies on three rabbits were used to support the hypothesis, as were two cases of posterior rib fractures after traffic crashes. The fractures were attributed to the same mechanism, where the child underwent marked forward deceleration by hitting a solid object with its ventral aspect thus causing the posterior part of the ribs moving posteriorly against the transverse processes (Kleinman and Schlesinger, 1997a). Kleinman suggested that the same mechanism, i.e. a perpetrator manually compressing the infant's chest, is consistent with the fractures seen posterolaterally, anterolaterally, anteriorly and at the costochondral junction (Kleinman, 2015) (Figure 11). Lateral compression as cause of fractures in the head, posterolateral, costochondral junction and has been suggested by a few authors, but anteroposterior compression seems to be favoured by most (Worn and Jones, 2007, Walker et al., 2016), and also to be favoured over direct impact (Worn and Jones, 2007), although opposing conclusions were reached in an experimental study on piglets (Blackburne et al., 2016).

Described specificity for abuse

Rib fractures have been described as highly specific for abuse both in individual studies and in non-systemic and systematic reviews. All identified systematic reviews have indeed concluded that rib fractures are specific for abuse. Williams and Connolly (2004) did not perform a metanalysis, but a narrative analysis of 10 included studies concluded that in children under 3 years of age, rib fractures were "highly predictive" of abuse. Kemp and co-authors (2008) concluded in their meta-analysis including 7 studies and in total 233 children, after exclusion of children involved in motor vehicle accidents, documented trauma and surgery, the

pooled estimate of probability of abuse given a rib fracture was 71 % (95% confidence interval 42%-91%). The Royal College of Paediatrics and Child Health (2018) conducted a metanalysis including 4 studies concerning children less than 4 years, and estimated that a PPV for rib fractures in relation to suspected or confirmed abuse was 66 % (95 % confidence interval 43-90%). The most recent systematic review by Paine and co-authors (2019) reported after analysis of 3 studies a probability of abuse amongst 0-11 month-olds with a rib fracture as 67-82% (95 % confidence interval 50-92.5 %).

Posterior rib fractures are often described as having the highest specificity of abuse and the statement can often be tracked back to a text book (Kleinman et al., 2015). However, studies have shown different results, some suggesting they are specific (Barsness et al., 2003), others not (Bulloch et al., 2000, Cadzow and Armstrong, 2000).

Classic metaphyseal lesion (CML)

The term “classic metaphyseal lesion” was coined by Kleiman and colleagues in 1986 (Kleinman et al., 1986). They attributed the lesion to Caffey who described the appearance in 1946 (Caffey, 2011) and detailed the lesion of metaphyseal irregularities and fragmentations of “the very young” in the publication from 1957 (Caffey, 1957), in which he also stated they were “pathognomonic signs of trauma”. Kempe and colleagues (Kempe et al., 1962) emphasised the importance of metaphyseal lesions in child abuse and claimed the lesions to be more or less pathognomonic for abuse. Since then, metaphyseal lesions have been regarded as an important finding in the evaluation of physical abuse. CMLs are frequently stated to be highly specific for abuse, and even claimed to be the manifestation more than “any other skeletal, central nervous system, or visceral abnormality occurring in cases of child abuse” (Kleinman et al., 2015).

Since 1986 Kleinman and colleagues have published at least 24 articles with (in most cases) either direct focus on CMLs, or an important association to this finding (Kleinman et al., 1986, Kleinman et al., 1991a, Kleinman et al., 1991c, Osier et al., 1993, Kleinman and Marks, 1995, Kleinman et al., 1995, Kleinman

and Marks, 1996c, Kleinman and Marks, 1996b, Kleinman and Marks, 1996a, Kleinman et al., 1996c, Kleinman and Marks, 1998, Kleinman, 2008, Drubach et al., 2008, Kleinman et al., 2008, Kleinman et al., 2009, Perez-Rossello et al., 2010, Drubach et al., 2010, Kleinman et al., 2011, Tsai et al., 2013, Tsai et al., 2014, Kleinman, 2014, Perez-Rossello et al., 2015, Tsai et al., 2017, Tsai et al., 2018, Tsai et al., 2019). The lesions were earlier studied systematically only on radiographs, but Kleinman and colleagues correlated the radiological findings with histopathological findings (Kleinman et al., 1986), and it is fair to state that Kleinman and colleagues have dominated the research field of CMLs, and their association to child abuse. Almost all research on radiological and histological features of CMLs derives from this group.

Radiological and histological appearance

The CMLs are on radiographs seen as being either of *corner type* or of *bucket-handle type* depending on their appearance. On radiographs, a “corner fracture” looks like a small bone piece, often triangular in shape, that has been broken off just adjacent to the physeal cartilage, in one or both metaphyseal corners of a long bone. A “bucket-handle fracture” looks like a thin translucent stripe running across the metaphysis, parallel and adjacent the growth plate and physeal cartilage (Figure 13) (Kleinman, 2008).

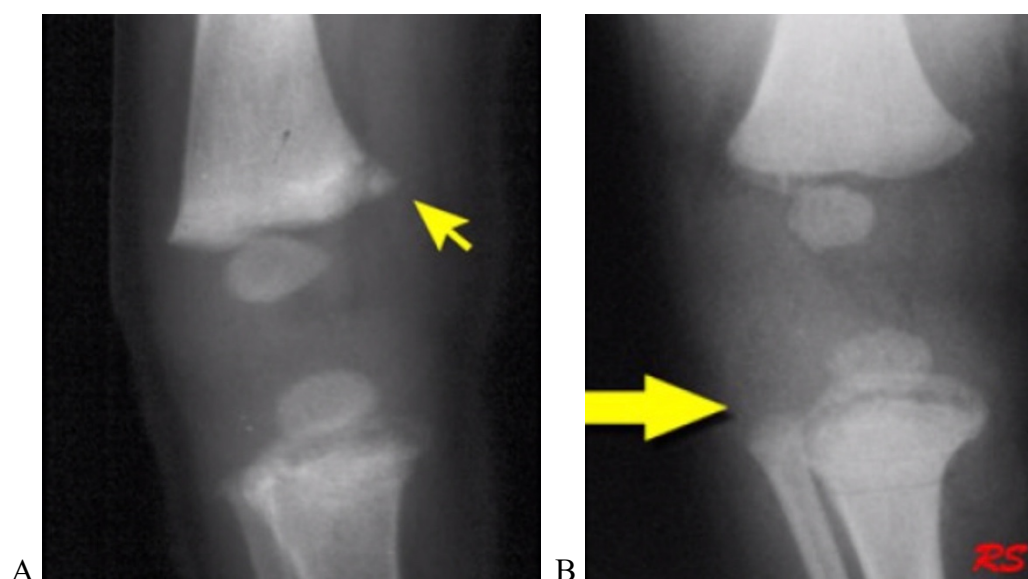


Figure 13. Classic metaphyseal lesions in proximal tibia. A) Corner pattern B) Bucket-handle pattern (Robben, 2006)

Caffey meant that CMLs represented a periosteal avulsion fracture of the metaphysis at the place the periosteum inserted to the epiphyseal cartilage, and depending on the size of the avulsion it was projected as either a “corner fracture” or an arched “bucket-handle fracture” (Caffey, 1957). This view was widely accepted until Kleinman and colleagues started their explorations. These authors instead suggested that the CMLs were more extensive than visible on the radiographs, running across the metaphysis in a planar fashion in the mineralised bone just adjacent the physeal cartilage. Centrally, the CML almost reaches the chondro-osseous junction, and peripherally the CML turns away from the physis undercutting a larger fragment of the subperiosteal bone collar of the metaphysis. Depending on the radiological projection, the appearance will differ (Figure 14).

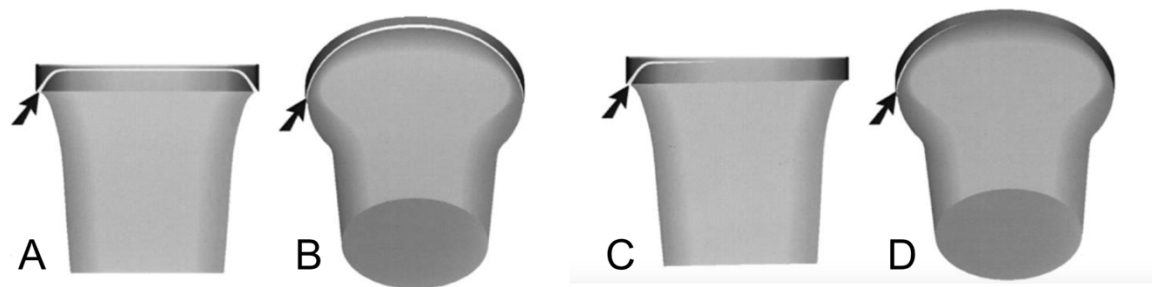


Figure 14. Classic metaphyseal lesion: Corner pattern and bucket-handle pattern. Fractures (arrows) extend adjacent to the osteochondral junction and then veer toward the diaphysis to undercut the larger peripheral segment that encompasses the subperiosteal bone collar. When the physis is viewed tangentially the CML appears as a corner fracture pattern (A, C). A view obtained with beam angulation results in a bucket-handle pattern (B, D). Extended injury (A, B) Localised injury C, D) (Kleinman, 2008).

At a projection perpendicular to the long axis of the metaphysis the peripheral thicker margin, at the bone collar, will have a triangular appearance, or a “corner fracture” pattern. At a cranially or caudally angulated projection, the margin of the fragment separated from the metaphysis will be visualised and the lesion will have an arched appearance, or a “bucket-handle” pattern (Kleinman, 2008).

Healing and histological appearance

CMLs are said to often heal without radiological signs of healing. Subperiosteal new bone formation is often missing and the fracture lines may just fade away (Figure 15), without any other signs. Sometimes however, subperiosteal bone formation may develop, sclerosis may occur at the fracture margin and focal extensions of the physeal translucency into the metaphysis might be visible. No precise data for the healing time of CMLs has been published, but Kleinman and

colleagues suggested that most CMLs become radiologically inconspicuous “at 4 weeks”. Histological haemorrhages are usually inconspicuous or absent and the only histological signs of the lesion are initially a disruption in the bone tissue in the metaphysis. Histologically early signs of healing, occurring within days, are decrease in cellularity in the “subphyseal metaphyseal region” together with osteoclastic absorption and development of granulation tissue and fibrosis. “Gradually the overall trabecular density along the plane of injury is diminished”. The histological correlate to the extensions of the physeal translucency into the metaphysis with abnormal presence of hypertrophic chondrocytes in the primary spongiosa. (Kleinman, 2008).

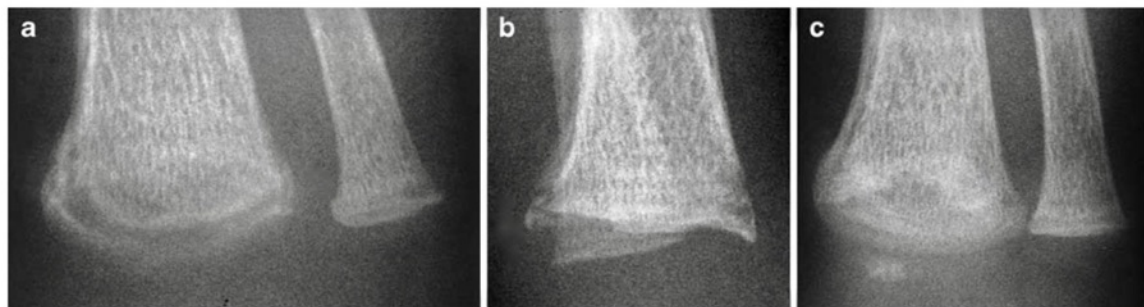


Figure 15. Classic metaphyseal lesion: Corner pattern and bucket-handle pattern. (Kleinman, 2008) A) Anterior-posterior projection of a distal tibia and fibula of a 5-months old infant. Arrows points toward classic metaphyseal lesion with bucket-handle pattern. B) Lateral projection of distal tibia and fibula in the same 5-months old infant. Arrow points toward classic metaphyseal lesion with corner fracture pattern. C) Anterior-posterior projection 3 weeks later with “indistinctness between the fracture fragment and the adjacent metaphysis, indicating early osseous union”.

Incidence

The CMLs are most frequently reported among very young infants. From a large dataset of infants (≤ 1 year) who had been evaluated for physical abuse, it was reported that CMLs were most often seen in infants up to 2 months, and that 84% of the infants were less than 6 months old (Thackeray et al., 2016). Further, in a large cohort of infants (≤ 1 year) evaluated for physical abuse, CMLs occurred from 1 weeks to 10 months, with a mean age of 4 months (Barber et al., 2015). Also, in a large cohort of children < 5 years who underwent subspecialty evaluation for suspected physical abuse, 70 % of all CMLs were found in 0-6 month-olds, and 20 % in infants 6-12 months. In summary, CMLs are usually seen in the first couple of months of life (Lindberg et al., 2014).

CMLs have been reported to most often occur in the lower extremity, most commonly in the distal femur, proximal tibia and distal tibia followed by the

proximal humerus (Kleinman et al., 1995, Barber et al., 2015). Other studies have shown similar results (Adamsbaum et al., 2019).

A majority (58 %) of infants with CML/s had >2 CMLs (mean 2.5, range 1-11), and it has also frequently been reported that infants with a CML have other injuries, e.g. that 87% of the infants with CML/s had additional skeletal injuries including rib, skull and /or long bone fractures (Barber et al., 2015).

Differential diagnoses

The bucket-handle fracture should not be confused with buckle fractures (torus fractures), buckling in the cortex of the bone caused by axial loading/compression. This is seen as an outwardly displaced buckling on the side of the bone, or as an angulation usually in the long bones in the junction between the diaphysis and metaphysis (Zephro and Galloway, 2014a, Swischuk, 2013).

Epiphyseal-metaphyseal fractures or epiphyseal separations (Salter-Harris fractures), should not be confused with CMLs. These fractures principally run thorough the cartilage of the growth plate, and not in the mineralised part of the metaphysis just adjacent to the cartilage as in CML (Kleinman et al., 2015). The fracture line can turn away from the cartilaginous growth plate into the mineralised bone either into the epiphysis or into the metaphysis, the latter called Salter-Harris type II fracture, resembling a “corner fracture”(Zephro and Galloway, 2014a). There are 5 types of Salter-Harris fractures, based on the propagation of the fracture line. One of the most common types is type II, most often encountered in the long bone of the ankle or wrist (Swischuk, 2013). In contrast to CMLs, Salter-Harris fractures are not considered to have a high specificity for abuse, but are often seen after accidental trauma (Kleinman et al., 2015).

Trauma mechanism

CMLs are considered to be specific for abuse in infants less than 1 year (Offiah et al., 2009, Kleinman, 2008, Dwek, 2011). The most common mechanism behind CMLs is believed to be violent shaking of the infant while held in the trunk or limbs causing shearing forces in the metaphysis (Kleinman et al., 1986). Shaking

provides an explanation to why CMLs are seldomly seen in toddlers who are more difficult to shake like a doll. Other proposed mechanisms are forceful pulling or twisting of the limbs (Kleinman, 1990).

A finite element analysis on a 3-months-old infant's distal tibia and fibula mimicking forceful manipulations of the ankle by eight load modalities, showed that the likelihood of cortical bone failure of the CML is higher along the subperiosteal bone collar when the ankle is under tension, compression, valgus and varus bending, dorsoflexion and plantar flexion, but not under internal and external rotation. The medial margin of the subperiosteal bone collar showed focal strains during varus and valgus bending, which may explain the known tendency for focal distal tibial CMLs to occur medially (Tsai et al., 2017).

Detection of rib fractures and CML

Rib and CMLs fracture can be detected through different techniques; by imaging modalities such as radiographs, macroscopically under autopsy (at least rib fractures) and histologically. Rib fractures and CMLs can also be examined macroscopically after maceration to enable study of the bare bone or in cases of complete skeletonization.

A so called skeletal survey (SS) is routine in the investigation of suspected child abuse of children less than 2 years old. SS is a systematically performed series of high-quality radiographs of the entire skeleton aiming to identify occult fractures, excluding underlying differential diagnosis such as skeletal dysplasia or metabolic conditions, and aid in fracture dating. The procedure ensures that subtle fractures are detected, whilst keeping the radiation dose as the low as reasonably achievable. Both US guidelines and UK guidelines recommend at least 20 standard images (Table 3). Follow-up skeletal survey is recommended 10-21 days after the initial SS (Nguyen and Hart, 2018).

Table 3. International imaging guidelines (radiographs) for skeletal surveys (Nguyen and Hart, 2018).

US guidelines American College of Radiology-Society for Pediatric Radiology	UK guidelines Royal College of Radiologists-Royal College of paediatrics and Child Health
- Thorax (AP and lateral), to include ribs,¹ thoracic and upper lumbar spine - Pelvis (AP), to include the mid lumbar spine - Lumbosacral spine (lateral) - Cervical spine (AP and lateral) Skull (frontal and lateral), additional views if needed – oblique or Towne view - Humeri (AP) - Forearms (AP) - Hands (PA) - Femora (AP) - Lower legs (AP) - Feet (AP or PA)	- Thorax (AP), right and left oblique views of the ribs - Pelvis (AP) - Lumbosacral spine (lateral) - Cervical spine (lateral) - Skull (frontal and lateral), Towne view if occipital injury suspected - Humeri (AP)² - Forearms (AP) - Hands (PA) - Femora (AP) - Lower legs (AP) - Feet (AP)

¹=Oblique views recommended, but not routine.

²=Lateral coned views of the elbows, wrists, knees and ankles may demonstrate metaphyseal injuries in greater detail. The consulting radiologist should decide this at the time of checking the films with radiographers.

AP=anteroposterior; PA=posteroanterior

Oblique views of the chest are recommended since posterior rib fractures are difficult to visualise on anteroposterior projections, and an oblique view increases the accuracy (Hansen et al., 2008, Ingram et al., 2000) Further, acute rib fractures, in particular posterior rib fractures, are difficult to detect, whereas healing fractures with a callus is easier to detect, and therefore a follow-up SS can aid the diagnostic procedure. But, since CMLs often heal without radiological signs of healing, follow-up SS does seldomly add any information regarding CMLs (Kleinman, 2008, Nguyen and Hart, 2018).

Bone scintigraphy can be used to complement the SS, and is particularly valuable in detecting rib fractures. However, a positive finding on bone scintigraphy is not specific for fractures and need to be confirmed by radiographs (Nguyen and Hart, 2018).

Computed tomography (CT) offers the advantaged of 3D imaging, and chest-CT has a high sensitivity for rib fractures in all stages of healing, but exposes the patient to a high radiation dose and is not recommended as standard examination in living patients if there is no other indication for chest-CT (Nguyen and Hart, 2018).

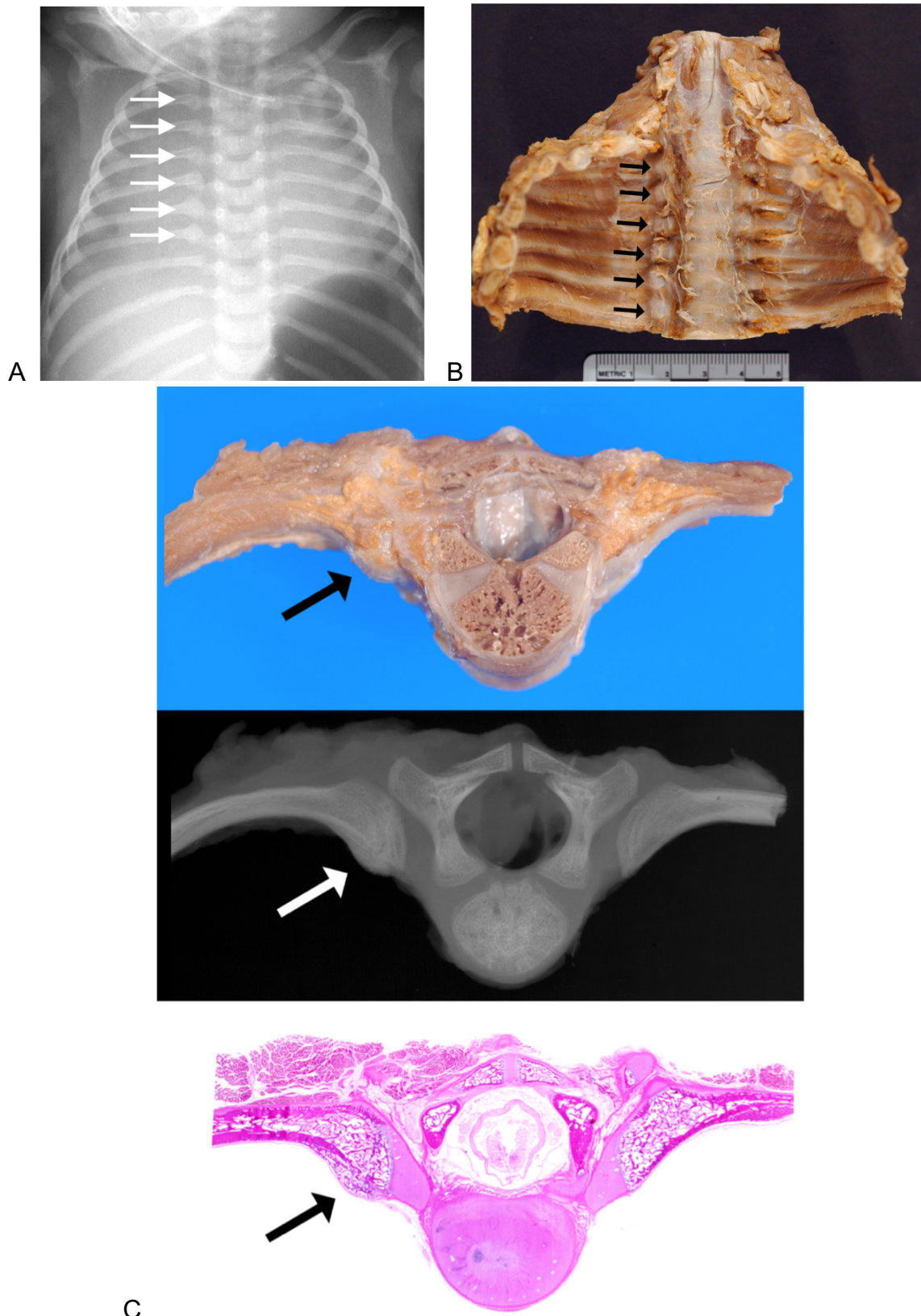


Figure 16. Healing posterior rib fractures in an infant (Baker, 2012). A) Multiple healing posterior, right rib fractures (arrows). The radiograph was taken at the time of autopsy. B) Multiple healing posterior right rib fractures (arrows). Gross photography. C) Gross, radiographic, and whole mount histological features of a posterior fracture (arrows).

High resolution CT have been used in experimental settings to visualise CMLs with promising results (Tsai et al., 2014). Further, radiographs have been shown

to be superior to MRI in identifying CML and rib fractures in infants (Perez-Rossello et al., 2010).

Autopsy, naturally, offers additional opportunities for examination. An approach is to start with post-mortem CT and/or SS. During autopsy the ribs are easily reachable and examined, especially after the pleura is stripped away.

Haemorrhages should be noted, and any suspicious areas on prior SS or post-mortem CT should be dissected. The free dissected specimen should be photographed, radiographed and subsequently prepared for histological examination, preferably in the same position for easier comparison (Figure 16). The metaphyses are not as easily examined as the ribs due to their anatomical positions. The end of the long bones can be treated in the same way. i.e. be free dissected and prepared for histological examination (Baker, 2012).

Histological evaluation is particularly valuable in age estimation of fractures, especially concerning CML which seldom heals with radiological signs (Kleinman, 2008, Raynor et al., 2018).

Investigation of abuse

US guidelines of suspected child physical abuse (Christian and Committee on Child Abuse and Neglect, 2015) stresses the importance of early recognition of child abuse and neglect, especially in infants and toddlers who have the highest risk of fatal or life-threatening outcome. The infant may reach the attention of physician in a variety of ways and under different circumstances, but the approach is in essence similar, firstly stabilise the infant if the condition is critical and then carefully obtain a history, preferable by giving the caregiver the opportunity to describe in detail the events that brought the infant to the physician. Histories that should raise concern for abusive trauma and additional information valuable for the physician to obtain are detailed in Table 4.

Table 4. Additional information valuable for the physician to obtain and histories that should raise concern for abusive trauma (Christian and Commiteee on Child Abuse and Neglect, 2015).

Histories that should raise concern for abusive trauma	Additional information valuable for the physician to obtain
1. There is either no explanation or a vague explanation given for a significant injury. 2. There is an explicit denial of trauma in a child with obvious injury. 3. An important detail of the explanation changes in a substantive way. 4. An explanation is provided that is inconsistent with the pattern, age, or severity of the injury or injuries. 5. An explanation is given that is inconsistent with the child's physical and/or developmental capabilities. 6. There is an unexplained or unexpected notable delay in seeking medical care. 7. Different witnesses provide markedly different explanations for the injury or injuries.	1. Standard history including medical, developmental, and social history. 2. Family history: especially of bleeding, bone disorders, and metabolic or genetic disorders. 3. Pregnancy history: wanted/ unwanted, planned/unplanned, prenatal care, postnatal complications, postpartum depression, delivery in nonhospital settings. 4. Familial patterns of discipline. 5. Child temperament: whether the child is easy or difficult to care for; whether there is excessive crying in an infant; parents' expectations of the child's behaviors and development. 6. History of abuse to child, siblings, or parents and previous and/or present CPS involvement with the family. 7. Substance abuse by any caregivers or people living in the home; mental health problems of parents; past arrests, incarcerations, or interactions with law enforcement; and domestic violence (which may be necessary to ask of each parent or caregiver individually). 8. Social and financial stressors and resources

The responsibility of the physician beside to initiate correct treatment, is to recognise potential abuse, obtain a thorough medical and event history and initiate appropriate work-up and if necessary, refer the infant to the right specialist. In the US as in many other countries a mandatory report to child protective authorities is demanded when suspicion of abuse is raised. Injury pattern are rarely pathognomonic for abuse or accidental injury, and besides careful consideration of the explanation provided, a thorough physical examination should be carried out and supplemented by radiographic and laboratory analyses (Christian and Commiteee on Child Abuse and Neglect, 2015). The importance of extensive and thorough documentations of the findings, as well as of absence of injuries, also with photographs, cannot be stressed enough and is invaluable if judicial procedures follow.

Since this review concerns fractures, other type of injuries, such as skin or abdominal injuries will not be given an account for. Fractures in infants can be discovered because of local symptoms such as swelling or unwillingness to use a

limb. Neither CMLs nor rib fractures give much symptoms but can be found on SS as occult fractures.

As mentioned, rib fractures and CMLs have often been claimed to be highly specific for abuse, also stated in recent guidelines. A frequently referenced source for this opinion is a list (Table 5) which originates from a text book (Kleinman et al., 2016), first published in 1987. This text book does not state the source of these conclusions, but in spite of this, the opinion is mentioned in almost every review on the topic, not least in the most recent guidelines concerning evaluation of children with fractures by the American Academy of Pediatrics and the Society for Pediatric Radiology in the US.

Table 5. Specificity for radiological findings (modified from Kleinman et al., 2016).

High specificity (Highest specificity applies in infants)	Moderate specificity	Common but low specificity
CMLs	Multiple fractures, especially bilateral	Subperiosteal new bone formation
Rib fractures, especially posterior rib fractures	Fractures of different ages	Clavicular fractures
Scapular fractures	Epiphyseal separations	Long bone shaft fractures
Spinous process fractures	Vertebral body fractures and subluxations	Linear skull fractures
Sternal fractures	Digital fractures	
	Complex skull fractures	
	Pelvic fractures	

In the US guidelines “Evaluating Children With Fractures for Child Abuse” (Flaherty et al., 2014), pre-existing medical conditions and bone diseases making bone more vulnerable to fractures or conditions that may result in skeletal changes - such as metaphyseal irregularities mimicking corner fractures and bucket handle fractures - should be considered as differential diagnoses. These include a variety of disorders such as osteogenesis imperfecta, rickets, scurvy, preterm birth, osteomyelitis, copper deficiency, Menkes disease, amongst other conditions. Differential diagnoses to consider are detailed in Table 6, which by no means represents a complete compilation of differential diagnoses, only those mentioned in guidelines or encountered during this review.

Table 6. Differential diagnosis. This compilation is not a complete list of differential diagnoses, but contains diagnoses that should be considered during the evaluation of a case of suspected abuse, in particular diagnosis mentioned in guidelines and consensus statements.

Differential diagnosis
Osteogenesis imperfecta (OI) OI is a heterogenous genetic disorder primarily affecting the skeleton with bone fragility and low bone mass, resulting in susceptibility to fractures and bone deformity. Besides fractures, a wide variety of accompanying symptoms and signs can be present, such as blue sclera, hearing loss, underdeveloped teeth (dentinogenesis imperfecta), (Marini et al., 2017), wormian bones in the skull (Rauch and Glorieux, 2004), and hypermobile joints (Palomo et al., 2017). The severity of OI varies widely from intrauterine fractures and death to mild forms without fractures. The disorder has traditionally been classified in seven different subgroups based on the clinical manifestations. The symptoms are attributed to mutations in the genes encoding for collagen type I, and those mutations cover 85-90 % of the OI cases. However, during the last 10 years a number of other mutations encoding for a range of other proteins has been discovered, and it is estimated that 10-15 % of the OI cases are caused by these mutations. The diagnosis is often based on the clinical symptoms, and is confirmed by genetic testing (Palomo et al., 2017).
Rickets or “the English disease” Rickets is pathological characterised by failure to mineralise newly-formed bone, due to lack of phosphate, which means that the bone matrix is unmineralised and endochondral calcification at the growth plate is absent or reduced, with associated growth-plate deformity. Rickets is characterised by bony deformity such as bow-legs or knock-knees and stunted growth, soft skull bones (craniotables) and widening of the costochondral junction (rickety rosary) (Elder and Bishop, 2014). Further, metaphyseal irregularities, cupping and physeal widening are other hallmarks of rickets, and occasionally discrete osseous fragments resembling corner fractures may be identified in the absence of more dramatic signs of rickets (Kleinman, 2008). Rickets is in most cases caused by vitamin D deficiency, mainly due to lack of sun exposure (the major source of vitamin D comes from synthesis in the skin during sun exposure) and by low dietary intake. In the clinical history dark skin colour, reduced skin exposure, no vitamin D supplementation during pregnancy, prolonged exclusive breast feeding and no vitamin D supplementation in infancy are typical. It is yet not know whether an “absolute threshold for vitamin D exists, below which rickets is inevitable”. Rickets can for instance also occur if vitamin D is within range but calcium intake is low and in rare cases abnormalities that mainly affect phosphate and low levels does not obligate show signs of rickets (Elder and Bishop, 2014). The US guidelines (Flaherty et al., 2014) states that the “claim that vitamin D deficiency or insufficiency cause skeletal lesions that lead to incorrect diagnosis of child abuse in infants is not supported by the literature and that a systematic clinical, laboratory and radiologic assessment should exclude that possibility”. However, a thorough review from the Lancet, the same year as the guidelines were published claims that “No association has been reported between low vitamin D in the absence of rickets and increased fracture risk during infancy. Childhood data for the frequency of clinical rickets in infants who present with vitamin D deficiency - induced hypocalcaemia are scare, and data for their subsequent fracture risk are absent. These important issues should be clarified. Such data are needed both to advise parents about the handling of infants potentially at increased risk of fracture, and to better clarify the extent to which biochemical measures such as isolated low 25OHD concentration need to be taken account of in cases of suspected child abuse”(Elder and Bishop, 2014). Vitamin D insufficiency/deficiency has been reported to have increased in Europe during the last decades (Cashman et al., 2016).
Preterm birth Preterm birth infants have a decreased bone mineralization at birth which normalises after the first year of life. Osteopenia of the prematurity has been is well known and is a complication of low birth weight, and the earlier and lower birth weight, the more vulnerable. Osteopenia in the premature is considered to be multifactorial and the risk increase during prolonged parenteral nutrition, bronchopulmonary dysplasia and/or prolonged treatment with diuretic or steroids. Asymptomatic rib fractures are a common finding as well as long one fractures. Sometimes osteopenia in the premature can be associated with vitamin D deficiency and then metaphyseal irregularities also can be present (Flaherty et al., 2014, Lucas-Herald et al., 2012).
Scurvy Scurvy is caused by insufficient intake of vitamin C, which is important for the synthesis of collagen. It is a rare condition nowadays but can result in metaphyseal lesion similar to CMLs as well as osteopenia with a higher risk of contracting fracture. Other characteristic skeletal bone changes and concurrent systemic symptoms aid in the diagnosing the condition (Flaherty et al., 2014).
Osteomyelitis Osteomyelitis is an infection in the bones that may cause multiple metaphyseal irregularities resembling CMLs (Flaherty et al., 2014).

Copper deficiency

Since copper plays an important role in cartilage formation copper deficiency can affect the bone formation in infants and children, and can cause bone fractures as well as radiological changes in the metaphyseal areas in form of cupping and fraying, sickle shape metaphyseal spurs and significant demineralization. It is a rare condition but can be seen in preterm infants who have a lower store of copper, but can also be seen in children with severe nutritional disorders such as liver failure or short gut syndrome. The condition is accompanied by other symptoms such as psychomotoric retardation, hypopigmentation and anaemia (Flaherty et al., 2014).

Menkes disease or “kinky hair syndrome”

Menkes disease is a rare congenital defect in copper metabolism causing severe copper deficiency due to disturbed intestinal uptake (Akinseye et al., 2019). The disease only occurs in boys. It shares many features with dietary copper deficiency, such as metaphyseal fragmentation and fractures, it has its own characteristic profile including kinky hair, wormian bones, anterior rib flaring and tortuous cerebral vessels. Menkes disease is associated with intracranial haemorrhages such as subdural hematoma which can be mistaken for abusive head trauma. The prognosis is poor, and most children pass away in an early age (Akinseye et al., 2019, Flaherty et al., 2014).

Systematic diseases

Chronic renal diseases may affect the bone metabolism by causing metabolic acidosis interfering with the metabolism of Vitamin D, resulting in the same radiographic picture as nutritional rickets. Also, chronic liver diseases, such as biliary atresia, may interfere with vitamin D metabolism, increasing the risk of fractures in children. Other systemic disease such as hyperparathyroidism, hypophosphatasia, hypophosphatemic (vitamin D resistant) rickets, and renal tubular acidosis can also cause variants of rickets (Flaherty et al., 2014).

Another systemic condition that can cause metaphyseal abnormalities mimicking CMLs are congenital syphilis (Swischuk, 1998).

Demineralisation due to disuse

When severe disability that limits or prevents normal movements there is a risk of fractures secondary to disuse demineralisation “even with normal handling”, for instance physiotherapy. The fractures are however more often diaphyseal than CMLs (Flaherty et al., 2014).

Physiotherapy

CMLs have been reported after **physiotherapy**, including massage and passive range of motions in the proximal tibia of an infant with myelomeningocele and concomitant hypertonic lower extremities, contractures and club foot (Della Grotta et al., 2019). One case of CMLs in a new-born, attributed to physical therapy. The infant was born preterm with increased muscle tone and contractures of both upper and lower limbs (Pickett et al., 1982). 5 cases with rib fractures, including one case with posterior rib fractures attributed to chest physical therapy has been reported (Chalumeau et al., 2002).

One case of CMLs in an infant, one case with rib fractures and one case with CMLs and rib fractures were attributed to passive exercise by the caretaker. Two were born premature and the exercise prescribed by the neonatal intensive care unit (Helfer et al., 1984).

Lateral rib fractures or periosteal reactions mimicking healing rib fractures attributed to chest physical therapy have been reported in 6 cases (Gorincour et al., 2004). Further, a case with posterior rib fractures attributed to chiropractic care have been reported. The infant was born preterm (Wilson et al., 2012).

Medical care

CMLs have also been reported after **serial casting treatment for clubfoot**. Eight infants who underwent treatment showed evidence of metaphyseal lesions, of which four infants had fractures of CML-like appearance (Grayev et al., 2001).

A case of CML was reported to be caused by witnessed manipulation of a foot prior to **placement of an intravenous catheter** in an infant with congenital vertical talus. The manipulation was described as a “torque over the left distal tibia and simultaneous tension/distraction of the ankle”. A “pop” was allegedly heard during manipulation and the baby started to cry. Subsequently, the ankle showed “a small amount of focal swelling”. The foot was radiographed before and after the manipulation and a bucket handle fracture was visible in the distal tibia after, but not before, the manipulation. The baby had a low vitamin D level, but the total lab results were normal and the total picture, including radiographs, showed no evidence of rickets. Molecular testing for OI was negative (Burrell et al., 2015).

Birth trauma

Rib fractures, including posterior rib fractures, attributed to birth trauma have been reported in the medical literature in seven cases (one had osteogenesis imperfecta). Large foetal body (foetal macrosomia), shoulder obstruction during labour (dystocia) and delivery by mid-forceps or vacuum extraction were associated risk factors (Mangurten et al., 1999).

CMLs have been reported in 3 cases after uncomplicated elective caesarean sections. They were all situated in the distal femur metaphysis (O'Connell and Donoghue, 2007). Another case reports CML attributed to external cephalic version for frank breech and subsequent urgent caesarean section (Lysack and Soboleski, 2003).

Cardiopulmonary resuscitation (CPR)

A systematic review from 2006 concluded that rib fractures due to cardiopulmonary resuscitation were a rare complication to CPR in children, and when they do occur, they were likely to be anterior and may be multiple. No posterior rib fractures were recorded (Maguire et al., 2006). A later study made after the CPR technique changed. However, later studies have shown a higher incidence of rib fractures after CPR, for instance Reyes and co-authors (Reyes et al., 2011) who reported that 3.3 % infants of the studied population had rib fractures caused by CPR, possibly due to a change in CPR technique from a "two finger technique" to a "two thumbs encircling hands technique". An even later study however showed no rib fractures after CPR with the new "two thumbs encircling hands technique" (Franke et al., 2014). Rib fractures caused by CPR tend to be situated anteriorly or anterolaterally, and not in the posterior part of the chest (Kleinman, 2015).

Normal variants mimicking CMLs radiologically

Normal radiologically visible variants that can mimic CMLs in infants are: step-offs on the distal femur, proximal tibia, proximal fibula and distal radius and distal ulna; beaks on the proximal humerus and proximal tibia; irregularities in the proximal tibia, spurs on the distal femur, distal radius and distal ulna (Kleinman et al., 1991b)

The physical examinations – physical, radiological and laboratory (Table 7) – aim as much to identify injuries as to exclude differential diagnoses.

Table 7. Laboratory testing recommended by US guidelines in case of fractures in infants and toddlers suspected to be caused by physical abuse (Flaherty et al., 2014).

Indication	Laboratory testing
Standard bone health laboratory testing including:	Serum calcium Phosphorus Alkaline Phosphatase (ALP)
Also consider (especially if radiographic evidence of metabolic bone disease or osteopenia)	Parathyroid hormone 25-hydroxyvitamin D Urinary calcium/creatinine ration
If risk for scurvy or copper deficiency, consider:	Serum copper Vitamin C Serum ceruloplasmin
If risk for osteogenesis imperfecta, consider:	Skin biopsy for fibroblast culture or venous blood for DNA analysis

Controversies in theories

The last years the controversies in the field of physical child abuse have been intense and polemic. An example is the term temporary brittle bone disease (TBBD) which was introduced in 1993 (Paterson et al., 1993) as an alternative condition with transient bone weakness in the first year of life resulting in unexplained fractures in infants, and several mechanism such as decreased foetal

movements and collagen diseases (Miller, 1999, Miller and Hangartner, 1999). The hypothesis was met with scepticism and a consensus statement from the Society for Pediatric Radiology and the European Society of Paediatric Radiology concluded that the diagnosis TBBD could not meet the “basic legal evidentiary standard because it lacks appropriate rounding in scientific methods and procedures” and that it was “an unsupported speculation and subjective beliefs of a very small number of medical professionals” (Mendelson, 2005). Several articles on the topic were published later with a subsequent intense and polemic discussion in scientific journals (Miller, 2009, Paterson, 2009, Jenny, 2010). The same intense discussion followed an article by Ayoub and co-authors (2014).

They reviewed Kleinman’s and colleagues multiple articles on CMLs and concluded that the hypothesis that CMLs was caused by child abuse was poorly supported. Systematically they pointed out flaws in the evidence, such as no adequate control group, lack of replication and confirmation studies, as well as histological inconsistencies with trauma, for instance lack of haemorrhages in the lesions which are situated in a well vascularised area and the lack of callus formation during healing. Instead they found radiological and histological similarities with healing rickets. They conclude that until CMLs had been “experimental replicated and independently validated, their traumatic origin remains unsubstantiated”.

Controversies have also been seen in the diagnostic accuracy of AHT/SBS. Because of these controversies, an infant with triad findings only, i.e., without external signs of trauma, was taken to the Swedish Supreme Court (The Swedish Supreme Court, case no NJA 2014 s. 699), which concluded that the scientific evidence was not solid enough to beyond reasonable doubt conclude that the triad (without external signs of trauma) is caused by abuse. Because of this uncertainty regarding the scientific evidence, the Swedish Agency for Health Technology Assessment and Assessments of Social Services (SBU) conducted a systematic literature review on the topic. The report “Traumatic shaking - The role of the triad in medical investigation of suspected traumatic shaking - A systematic review” (hereafter called the Swedish traumatic shaking report) was published in Swedish in October 2016 (SBU, 2016) and in English in early 2017 (Elinder et al., 2018). The report concluded that there was *limited scientific evidence* that the triad and

therefore its components can be associated with traumatic shaking, and that there was *insufficient scientific evidence* on which to assess the diagnostic accuracy of the triad in identifying traumatic shaking. The report also revealed that most previous studies suffered from a high risk of bias, with methodological flaws, providing high risk of incorporation bias and circular reasoning. The debate in scientific journals has been intense after the publication of the report, mostly claiming the standards for defining abuse were too high and practically impossible to reach (Bilo, 2018, Debelle et al., 2018). Basically, however, almost all criticism has been refuted (Lynoe et al., 2018, Lynoe and Eriksson, 2019).

The debate around physical child abuse has been polemic and the term “denialist” has been used by some to describe a growing number of people denying child abuse and the sound evidence behind the diagnosis child abused based on signs and symptoms such as rib fracture and CMLs. Instead the denialists “manufacture doubt”, “creating impossible expectations of research”, and “selectively cite literature” to mislead the courts (Strouse, 2016). The “denialist”, on the other hand, describing the other side as believers, emotionally involved in child protections, not impartial, using the same methods to put innocent caregivers in prison.

Aim

The background with the history and controversies of the diagnostic accuracy of symptoms and signs attributed the physical abuse raises questions regarding the scientific certainty of the findings said to be attributed to physical abuse.

A systematic literature review of all types of such findings is warranted, but beyond the scope for a master dissertation. Hence, my choice was to limit the scope to a few skeletal manifestations. Since rib fractures and CMLs are the manifestations that most widely are accepted as specific of physical abuse in infants, and often used as an additional evidence to support the diagnosis abusive head trauma, those manifestations constituted a natural choice for this dissertation.

Hence, the aim of this systematic review is to answer the question:

“With what certainty can it be claimed that rib fracture or classical metaphyseal lesions in infants are attributed to physical abuse?”

3. Materials and Methods

Background

Reviews

A review of the existing literature is a way to assess what evidence there is for a specific claim and can either be systematic or non-systematic. A non-systematic review gathers information in a non-structured way reflecting the author's preferences, and does not enable the reader to assess the full basis of the author's conclusions. A non-systematic review also does not allow the reader to assess if the author has included the key literature or if the author included only articles he or she was familiar with or only articles that supported a conscious or non-conscious preconceived conclusion.

A systematic review, on the other hand, meets high demands on reliability and follows principles that minimize the risk of an arbitrary or biased effect upon the conclusions. A systematic review also enables the reader to evaluate the trustworthiness of the conclusions (SBU, 2018). By following a specific methodology for systematic literature reviews, the risk of making mistakes that can undermine the conclusions can be minimised. A methodology is a framework for the process of working, and does not replace the author's own critical thinking, but might help address critical process related issues before it is too late.

In conclusion, a systematic review helps identifying what is truly evidence-based, but the purpose is not just to identify studies with low or moderate risk of bias. According to Clarke and Chalmers (2018) another important aim of a systematic literature review is to disclose "rubbish" research and demonstrate "the enormous amount of research waste caused by poor quality studies."

This systematic review has, as far as possible, been conducted following the methodology described in the manual of the Swedish Agency for Health Technology Assessment and Assessment of Social Services (SBU, 2018, SBU, 2017).

Methodology of SBU

SBU, the Swedish Agency for Health Technology Assessment and Assessment of Social Services, is a Swedish authority with the mission "to assess health care and social service interventions from a broad perspective, covering medical, economic, ethical and social aspects." This is conducted by systematic literature reviews of published research, and the SBU has developed a review methodology described in the SBU's manual (SBU, 2018, SBU, 2017). The SBU was founded in 1987 and is one of the oldest health technology assessment organisations in the world (SBU, 2019).

The reason for choosing the SBU methodology was three-fold. Firstly, as mentioned above, an established methodology is needed to minimize the risk of mistakes and bias. Since SBU has more than 30 years of experience within the field of systematic literature reviews, the methodology has been scrutinised for many years and has been under constant development and refining. SBU and its work are also highly regarded in terms of trustworthiness and accountability within the Swedish health care system, as a survey made by the national governmental agency for statistics has shown (Statistics Sweden, 2010). Secondly, this masters dissertation project is a continuation of the SBU assessment "Traumatic shaking - The role of the triad in medical investigation of suspected traumatic shaking - A systematic review" (hereafter called the Swedish report on traumatic shaking). This project was carried out by the SBU and therefore conducted in accordance with the methodology described in the SBU's manual. Since this master project partly will be based on their literature search, it was natural to continue the work according to the same methodology. The third reason was that the author and the other involved experts all have previous knowledge of SBU's methodology, and have several personal contacts at SBU to discuss methodological issues with.

The methodology of the SBU's manual has been followed as close as possible.

According to the SBU, an excellent systematic review follows principles including (SBU, 2018):

- A specific question/problem.
- Reproducibility: reporting selection criteria (inclusion and exclusion criteria) in order to sort out relevant literature and also strategies for searching and assessing quality.
- A systematic search for all relevant literature addressing the question/problem.
- Extracting data and tabulation of quality-assessed studies.
- Composite appraisal of results in, for example, a meta-analysis.
- Judgement on how well-founded the results are (evidence grading).

Principals for reporting

To streamline the reporting of this systematic literature review to international standards, and to make the report cover all essential aspects, the principles of reporting meta-analyses of observational studies in epidemiology proposed by the Meta-analysis Of Observational Studies in Epidemiology (MOOSE) Group, were followed as close as possible (Stroup et al., 2000).

Methods

Question to be addressed

This systematic review aimed to answer the following question:

“With what certainty can it be claimed that rib fracture or classical metaphyseal lesions in infants are attributed to physical abuse?”

PIRO

This question narrows the area into the following PIRO:

P - Population: Infants ≤ 12 months of age

I - Index test: rib fracture or classical metaphyseal lesion

R - Reference test/gold standard: Admitted, witnessed or video recorded physical abuse

O - Outcome measure: Diagnostic accuracy

Criteria for inclusion and exclusion

Population

Included: Articles regarding infants ≤ 12 months of age were included. Also, articles where the mean age or median age of the study cases was ≤ 12 months, were included. If there was a well-defined subgroup with study cases ≤ 12 months of age, or mean age or median age ≤ 12 months, those articles were also included.

There is a necessity of a cut off age for the inclusion since adults and infants differ in numerous ways - such as anatomically, physiologically, developmentally and size-wise. The age cut off at ≤ 12 months was decided after careful consideration. Things taken into consideration were, e.g., communication skills, anatomical and physiological phases, motoric skills, accidental injury panoramas, bodily size in combination with motoric skills, and the type of abuse physically possible for the alleged perpetrator.

Firstly, at about 12 months of age, the infant starts to walk and becomes more mobile. The age for walking is, of course, not identical for all individuals, but a reasonable mean age for the onset of walking is 12 months (Martorell et al., 2006). Walking affects the type of injuries that can occur. An upright position and walking movements increase the risk of falls and therefore change the mechanism and panorama of accidental injuries. At the same time as the infant starts to walk, physiological and anatomical changes occur in the body. As noted earlier, the ribs have a more horizontal position at birth, but this changes as the frontal aspect of the chest descends at the onset of walking (Cunningham et al., 2016b). Hence, the cut off age ≤ 12 months is appropriate from an anatomical point of view when it comes to rib fractures. Rib fractures are also considered to be more specific for abuse in infants (Kleinman et al., 2016). For the long bones, no known physiological or anatomical changes that occur systematically in the metaphyseal areas during infancy and childhood has been identified. The epiphyses of the long bones go through principally the same kind of maturation process, but the anatomy is different with different kind of joints linking them together, different numbers of secondary ossification centres (1–3 different centres), and very

different ages of ossification commencement, from the 36th-40th week prenatally to about to 10 years of age. Also, the commencement of fusion varies widely and starts at approximately 11 years and ends at about 20 years of age. Because of those large difference in ages for the developmental stages of the metaphysis, there is no natural cut off age for CMLs based on anatomical development and growth. However, CMLs are only rarely seen in children above 12 months of age, and are considered as less specific when encountered in children above that age (Offiah et al., 2009, Kleinman, 2008, Dwek, 2011); the specificity is associated with the infant not yet being ambulatory (Dwek, 2011).

Further, not only the types of accidental trauma can be assumed to be associated with age in infants, but also the type of physical abuse can be assumed to be different in an infant, a toddler and a child. For instance, the weight and size of a child is crucial for what type of physical abuse it can be exposed to. Shaking, for instance, is not easy to conduct on an older and bigger child, as compared to a newborn who can be shaken like a doll. A newborn usually has a weight of just over 3 kg and a height of approximately 50 cm; a 1-year-old usually a weight just over 9 kg and an approximate length of 75 cm (World Health Organization, 2006). It is reasonable to assume that shaking a child over 10 kg starts to become difficult.

Moreover, rib fractures and CMLs are often used to strengthen the assumption of the so-called shaken baby syndrome (Choudhary et al., 2018). Some studies have even used rib fractures as a reference test for abuse in studies on subdural hematomas in infants (Rubin et al., 2003, Gilliland and Folberg, 1996). Therefore, the specificity of these fractures in the age group mostly prone to the so called triad findings (subdural hematoma, retinal bleedings and encephalopathy), claimed to be caused by shaking with or without impact, is the most relevant age group to study. Abusive head trauma is considered to most often occur at the age of 0-1 year with a peak age around 2 months of age. This was the reason in the Swedish report on traumatic shaking to choose the cut of age at ≤ 12 months (Elinder et al., 2018). A cut off age in harmony with this former project is beneficial also from the point of comparison and supplementing knowledge to the previously carried out systematic review.

Index test

Included: Since the term “classic metaphyseal lesion” first was introduced 1986 (Kleinman et al., 1986), a descriptive diagnosis of CML was also accepted.

Excluded: Vague descriptions or ambiguous descriptions were excluded, so that for instance Salter-Harris or buckle fractures should not be included.

Observations

Excluded: To reduce the risk of arbitrary results and to reduce the risk of selection bias, studies with < 10 cases of rib fractures or CMLs attributed to physical abuse were excluded.

Language

Included: Articles in English, German, French, Swedish, Norwegian and Danish were included.

Study type

Included: Case-control, cohort and registry studies, and studies of qualitative methods of analysis.

Excluded: Systematic and non-systematic reviews, conference proceedings, consensus statements, editorials, letters, and debate articles were excluded. Also, biomechanical studies and animal studies were excluded.

Systematic and non-systematic reviews were excluded from the review since they only reproduce previously published research. Instead, each original article was scrutinised in detail. The results of the reviews will be considered in the Discussion section, however. Conference proceedings are not peer-reviewed and therefore did not meet the criteria for quality. Consensus statements were excluded even if they were peer-reviewed because they represent a manifest of opinions among an often undefined group of authors, rather than evidence-based conclusions. Editorials, letters and debate articles were excluded for the same reason.

Methodology for selection of studies

Search criteria

In the Swedish report on traumatic shaking, a systematic literature search was conducted in collaboration with the selected medical experts and an experienced information specialist and other employees and experts at the SBU, in all around 40 individuals (Elinder et al., 2018, Eriksson, 2019, personal communication, 17th April). The aim of their systematic literature review was to determine how reliably the triad - subdural haematoma, retinal haemorrhages and various forms of brain symptoms (encephalopathy) - or its components - can be explained by traumatic shaking of infants up to 1 year of age (Elinder et al., 2018). Initially however, it was planned to include also rib fractures and CMLs in the systematic literature review, but the scope was too comprehensive, and it was later decided not to include evaluation of fractures (Eriksson, 2019, personal communication, 17th April). Because fractures were included in the literature search, this search was highly suitable for the present systematic literature review of CMLs and rib fractures. The search for the Swedish report on traumatic shaking was conducted through PubMed, Embase and Cochrane library on 15th October 2015 (Appendix 1).

To also cover publications during the last 3.5 years, a complementary search was performed in PubMed in June 2019 (Appendix 2). This supplementary search used the index test CML only, and rib fractures in combination with infants only, and more synonyms than the earlier search used. In this way, the search was broadened because more synonyms were used, but also narrowed down since the scope was limited and abusive head trauma, for instance, was not covered in the search.

Studies were also manually searched through the reference lists of individual articles and reviews.

Assessment of relevance

Abstracts found through the literature searches were retrieved and duplicates removed. The abstracts from the Swedish report on traumatic shaking was scrutinised independently by the author (Ankin GÜvencel/AG: MD, board-certified

specialist in forensic pathology and clinical forensic medicine and master student in forensic anthropology) and two experts in forensic medicine (Anders Eriksson/AE: MD, PhD, board-certified specialist in forensic pathology and clinical forensic medicine and senior professor at the Unit of Forensic Medicine at Umeå University; Ingemar Thiblin/IT: MD, PhD, board-certified specialist in forensic pathology and clinical forensic medicine and professor at the Unit of Forensic Medicine at Uppsala University). All abstracts regarded as relevant for the addressed question were retrieved in full text. Only one of the three assessors had to regard the article as relevant in order to qualify for full text assessment. The abstracts retrieved from the search made in June 2019 were (for practical reasons) scrutinised by the author (AG) only.

The full text articles, including relevant manually searched articles, were scrutinised by the author (AG) and a second expert (AE). Articles were excluded if they did not meet the inclusion criteria. The main reasons for exclusion were noted (Appendix 5). If the assessors arrived at different conclusions regarding inclusion or exclusion, the disagreement was solved by discussion, based on a relevance checklist developed from the SBU's manual (SBU, 2017), but adopted for the addressed question (Appendix 3). If disagreement persisted after discussion, a third expert (IT) was engaged.

Assessment of quality of individual articles

The included articles were scrutinised regarding quality by the author (AG) and a second expert (AE). The assessment was based on the checklist of quality (QUADAS), developed from the SBU's manual (SBU, 2017), and the prior Swedish report on traumatic shaking (Elinder et al., 2018), and adopted to the addressed question (Appendix 4). If disagreement persisted after discussion, a third expert (IT) was engaged. According to the SBU manual (SBU, 2017) an individual study can be assessed as either high quality, moderate quality or low quality. The main interest for the quality assessment is the study design and the risk for biases, but also the quality of reporting the result.

Methodology for summarising and synthesizing the result

According to SBU's manual (SBU, 2017) only studies deemed as having high or moderate quality are eligible to be considered in the Results section. Meta-analysis is a way to statistically synthesize the results of several studies. If no meta-analysis is possible to conduct, if for instance the studies are too heterogeneous to be compared statistically, a narrative analysis can be carried out (SBU, 2017).

Methodology for grading evidence

The final step in the assessment is to make an overall evaluation of the strength of the scientific evidence. The system advocated by the SBU's guidelines is the system partly based on the international GRADE system, which classifies the strength of the scientific evidence. In the GRADE system, the quality of the scientific evidence is based on a four-point scale: high, moderate, low, and very low evidence. The terminology used by SBU is slightly different, with the following grades: strong evidence, moderate strong evidence, limited evidence, and insufficient evidence (SBU, 2017).

4. Results

Search and assessments

3774 articles were identified through the search in the Swedish report on traumatic shaking. 348 abstracts were identified through the supplementary rib fracture search, and 580 were identified through the supplementary CML search, summing up to 4512 abstracts after removal of duplicates. Of these 4512 abstracts, 4113 were excluded as not relevant for the addressed question. 399 articles were searched for in full text. Another 35 articles were identified through manual search in reference lists, summing up to 434 articles searched for in full text (Figure 17)

Despite considerable effort trying to access all articles, 8 could not be found. However, none of these articles was regarded as a key article based on the abstract and/or how they were referenced to in other articles. The reason for including them as relevant was to be able to definitely rule out any possibility that those articles could contribute to the answer of the addressed question, and not a firm belief that those articles would contribute to the final result.

Hence, 426 articles were scrutinised in full text. Of those 424 did not meet the overall inclusion criteria and were excluded (Appendix 5). In no case, disagreement could not be solved through discussion and consensus. Of the remaining 2 articles none was deemed to be of high quality, 1 to be of moderate quality (Table 6) and 1 to be of low quality. A meta-analysis was consequently not possible to conduct.

The main reason for articles to excluded or regarded as having low quality was the absence of studies using the stipulated reference test (admitted, witnessed, or video recorded study cases).

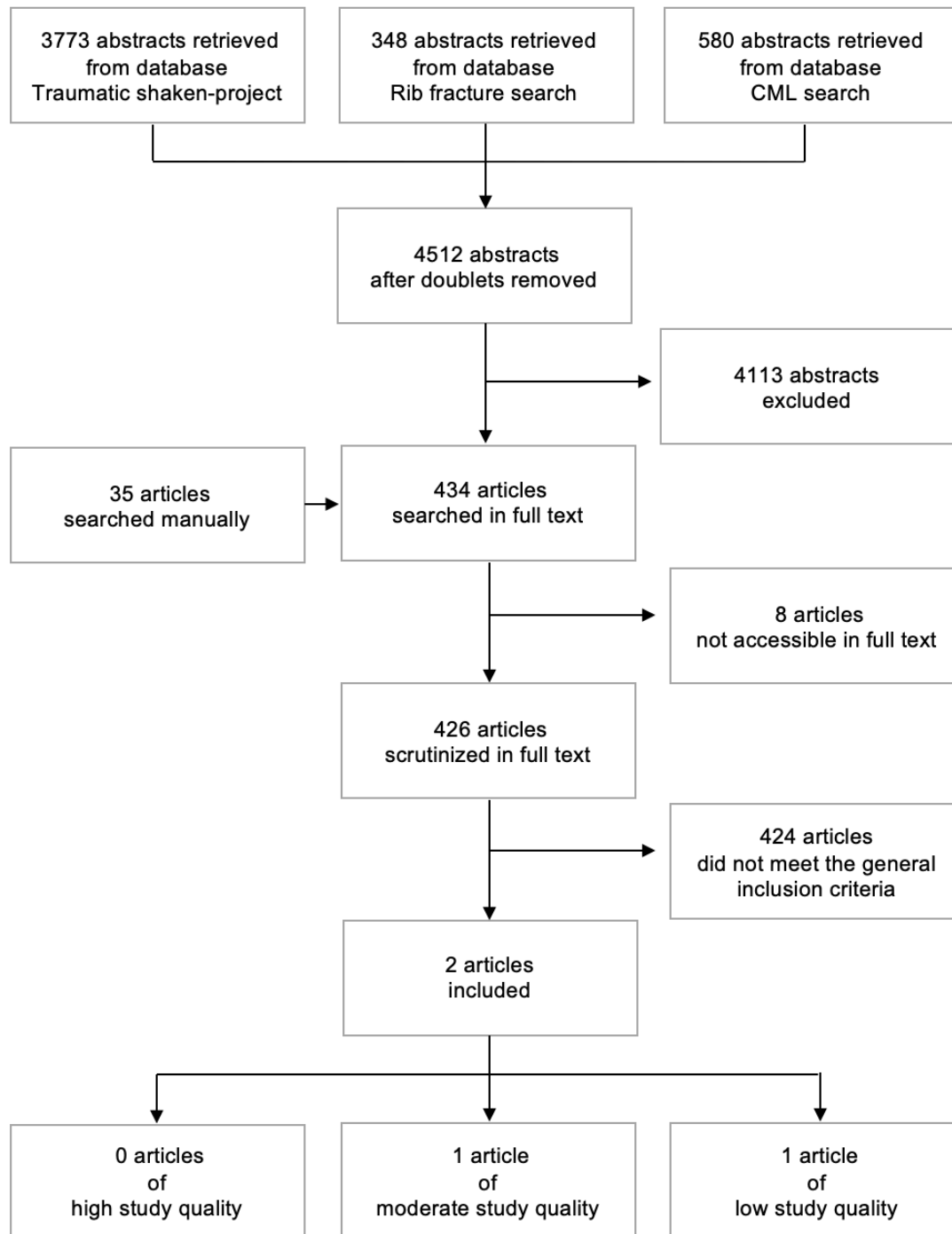


Figure 17. Flow chart of literature search and assessment.

Quality of evidence

When using the stated criteria (population, index test, reference test, outcome, observation) for this systematic literature review, only two studies were included for quality assessment (Adamsbaum et al., 2019, Carty and Pierce, 2002). Only one of these (Adamsbaum et al., 2019) was regarded as having moderate quality

and none as having high quality. Since only one study was deemed to have high enough quality to be included in a meta-analysis, the purpose of a meta-study was redundant. A narrative analysis of this study is instead presented.

Included study - moderate quality: Adamsbaum et al., 2019

The focus of the study by Adamsbaum et al (2019) was CMLs, but they also mention rib fractures in the reported data. In the study, more than 10 cases of rib fractures were reported, fulfilling the criterion for minimal number of study cases. However, the focus of the review was CMLs, and the admissions were not correlated to rib fractures. Thus, there is no review of the admission to assess acts that can explain the rib fractures. Further, the article did not report data for both the confession and the no confession group, and only stated that there "was no significant difference in the demographics or the injuries (localisation and number of CMLs, different age of fractures, concomitant or previous traumatic injuries, retinal haemorrhage, and SDH) between the 2 groups with or without confessions." The focus on CMLs, the lack of precise data reported for the two groups with ambiguous indications that rib fractures really were as common in both groups, made us deem this article to have low quality concerning rib fractures.

The study was an observational study of a cohort of legally prosecuted child abuse cases from January 2002 through December 2017 in France, in which study cases were referred to from the courts around the country (Table 8). It was not stated if the courts were criminal courts or all types of courts. The objective was to use legal statements by perpetrators to gain new insights into the causative mechanism of CMLs. The cases were initially identified by the hospitals, who later engaged the legal system, and a referral was made to one of the authors. Cases with at least one CML were included, and demographic data (sex, age, number and location of CMLs and other injuries) was extracted from the available background material.

The confessions came from legal proceedings or investigations, none of the suspected perpetrators confessed in the early stages during the victim's

hospitalization. Both cases with a confession (N=27) and cases without a confession (N=40), were analysed as a confession group and a no confession group. No confession was defined as “no confession or the explanations of the injuries changed over time (injuries blamed on falls, accidental impact, games, actions of another child under 5 years of age, or handling by the radiographers).” The data for the two groups, confession and no confession, was not reported separately but as one group. No differences between the groups were reported, but not all parameters were unambiguously reported as identical, which makes it difficult to scrutinise the reported data.

The results showed (Table 8) that there was no sexual predominance among the victims and that the median age of all infants (N=67) was 3.4 months (range 0.4-16.1 months with only one study case >12 months). The median number of CMLs in each case was 2 (range 1-9), with 34 % having a single CML, 33 % having two CMLs, and 33 % having more than two lesions. Lower extremity CMLs were far more common than lesions located in the upper extremity. The most common locations were the long bones at the knee (61 %), the ankle (54 %), the shoulder (22 %), the elbow (21 %) and the wrist (21%). Additional injuries were frequently noted, and only 27 % of the cases had no other concomitant injuries or previous injury. Additional injuries were: skull fractures (15 %), SDH (36 %), rib fractures (46 %), diaphyseal fractures (12 %), and 73 % of the cases had fractures of different ages. Further, 57 % of the cases had soft tissue injuries, and 36 % of the cases had previous injuries according to the available medical records.

Table 8. Characterisation of the study with moderate scientific quality

Author Year Country Reference	Objective Outcome Index test Reference test	Study design Setting Inclusion criteria Exclusion criteria	Number of cases Age Medical examinations	Results	Methodological considerations	Study quality
Adamsbaum et al., 2019 France	Objective To use legal statements by perpetrators to gain new insights into the causative mechanism of CML. Outcome: Characterisation of patients with CML caused by abuse and analysis of abuse confessions. Index test CML Reference test Admitted abuse. Confession group Confessions from legal proceedings or investigation, no one confessed during the hospitalization of the victims.	Study design Retrospective observational study of a cohort of legally prosecuted child abuse cases between Jan 2002 and Dec 2017. Setting Referred from courts around France to the authors of the articles. The initial abuse diagnosis at the hospitals was based on the pattern of the CMLs and the presence of other signs of abuse (a previous history of traumatic injury, concurrently identified injury, subdural hematoma etc) and was then confirmed in 100 % of cases by the authors who had access to all of the medical and legal records. Inclusion criteria ≥ 1 CML Exclusion criteria None stated.	Number of cases 67 cases 34 females, 33 males 57 alive 10 deceased Premature born: 8 cases Age Median age 3.4 months (range 0.4-16.1) ² (only one child <12 months) Medical examinations Physical examination by the paediatrician authors of the living children. Full skeletal survey Head CT-scan or MRI reviewed by a forensic paediatrician and a paediatric radiologist. Laboratory assessment ³ : 11 cases (16 %)	Entire group <i>Number of CML</i> Median (range): 2 (1-9) Single CML: 23 cases (34 %) Multiple CML: 44 cases (66 %) 20 cases (33 %) with 2 CML <i>Most common location</i> ³ Knee: 41 cases (61 %) Ankle: 36 cases (54 %) Shoulder: 15 cases (22 %) Elbow: 14 cases (21 %) Wrist: 14 cases (21 %) <i>Other injuries (selection)</i> Rib fractures: 31 cases (46 %) ⁵ Skull fractures: 10 cases (15 %) Diaphyseal fractures: 8 cases (12 %) Subdural hematoma: 24 cases (36 %) Concurrently identified injuries: 38 cases (57 %), included bruises in unusual/concerning locations (30), burns (4), a bite (1), an intraoral injury (1), a hymeneal injury (1), an epigloottal ulcer (1), a liver laceration (1), and a lung contusion with pneumothorax (1). Different age fractures: 49 cases (73 %) Previous traumatic injuries: 24 cases (36 %) No previous or concomitant traumatic injury: 18 cases (27 %) Confession group : 27 cases ¹ No confession group : 40 cases “There was no significant difference in the demographics or the injuries (localization and number of CMLs, different age fractures, concomitant or previous traumatic injuries, retinal haemorrhage, and SDH) between the 2 groups with or without confessions.”	Retrospective design with abuse cases only, and no appropriate control group. The result for the two groups, confession and no confession, is not reported separately, only result from the entire group, supplemented with a statement there were no significant differences between the two groups. (Not all aspects commented for instance sex and age, and uncertainties about type of fractures.) No spontaneous confessions and no description on current law practice, such as plea bargain, or technique for interrogation (for instance practice of Reid technique). The definition of “no confession” is not clearly defined. It is not stated whether no confession means that the perpetrator did not know how the CML occurred, or if the authors did not accept the explanation, for instance “injuries blamed on falls, accidental impact, games, actions of another child under 5 years of age, or handling by the radiographers”.	Moderate

					Details around the acts of abuse are difficult to interpret, especially forces in abuse compared to normal handling of a baby/accidents similar to acts described in the no confession group. No information on the circumstances of the deceased population (for instance autopsy technique, time since death).	
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1 Different numbers are given in the article (27 and 28)

2 The age was calculated from the time of birth, or if premature, corrected age, to the age when the CML was diagnosed.

3 "blood calcium and phosphate, urine calcium and phosphate, alkaline phosphatase, 25-hydroxy vitamin D, parathyroid hormone, and blood and urine creatinine, all of which were normal"

4 CML occurred only in long bones

5 Calculated from Table III

Table 9. Features of the group with detailed confessions.

Features of the group with detailed confessions (Adamsbaum et al., 2019)	
	Detailed confession for CML n = 27 (N, %)
Sex of perpetrator	
Female	8 (29.6%)
Male	19 (70.4%)
Circumstances¹	
Diapering	12 (44.4%)
Dressing/undressing	8 (29.6%)
Crying	6 (22.2%)
Feeding or refusal to eat	4 (14.8%)
Mechanism¹	
Torsion	9 (33.3%)
Traction	9 (33.3%)
Compression	5 (18.5%)
Forced movement	9 (33.3%)
Excerptions	
Mechanisms	
"When she cried while I was changing her, I would yank her around and pull her thighs out to the side in an inappropriate way to put on her diaper. It was a violent movement." "I deliberately hurt him repeatedly. It would always happen the same way. I would start changing his diaper, if the baby stayed calm and didn't cry, things would go well; if the baby started crying, things would go badly. Typically, I would push the diaper changing movements too far. To be clear, I didn't make yank him around. I would grab one leg in each hand and lift them up. His legs would be straight and I'd push them as far as they would go toward his head. This put a lot of stress on his knee joints. Let's just say that most of my actions involved the joints. Naturally, the baby would get even more worked up because it hurt and I knew it hurt. The baby's crying would make me lose control even more. Sometimes I twisted his ankles in and out. I would take his heel and turn his foot side to side; it started the night he came home from the maternity hospital. I'd say that in the end it was happening almost daily." "For the past month and a half it has gotten worse. It's true that I mistreated them. I twisted their ankles while I was undressing them or when they didn't want me to dress them. I did it to their wrists, too. Once, I was feeding her. She was trying to put her hand into the food container. I grabbed her wrist and pulled it upward." "I admit using violence while dressing my daughter or caring for her. I would grab her by the shins hard and pull on her legs to stretch them out so I could put on her clothes. I would hold her legs straight out by putting one hand on her foot and the other on her thigh in order to put on her pants or onesie. The movements were not appropriate. I've used force to hold her leg. I've also yanked on her legs to pull her toward me when she's on her changing table." "The fractures must have happened when I folded his. Legs against his stomach, I did it several times, I did it when he cried from colic. I would lose my temper, take him by the legs and pull them up to his shoulders."	
Differing statements regarding CML and SDH in children with both types of injury	
"I held him in front of me, I was holding him under the arms, I don't remember, I didn't shake him for long, just one back-and-forth, and then I set him down hard in his bed. He was on the changing table; I squeezed his legs together, there was no hematoma; I don't understand." "I shook my son several times, may be ten times; I was irritated by his crying. As for the fractures, that must have happened when I folded his legs against his stomach and I took his legs and pulled them up to his shoulders." "I shook him hard several times because he didn't want to eat and I was tired. I picked him up; I held him in front of me and shook him. I changed him on the changing table. I turned him over quickly, his arm must have gotten stuck and twisted it."	
Repeated violence	
"I would wedge his arm under his back and hold his back flat with my arm so that he couldn't move. I did it all the time." - "I'd say that in the end it was happening almost daily." "Once or even twice a week; it depended on how I was feeling and how she was eating." "It had become like a habit. at night, I would do it." "I admit being violent with my daughter when I handled her while dressing her or caring for her daily."	

¹Some cases involved multiple circumstances or mechanisms, as described by the perpetrator (total >100%).

The confessions indicated (Table 9) that the mechanism of the CML in all cases was “abusive, violent, and intentional.” The confessions described “excessive stress on the joints defined as ‘indirect skeletal forces’ with ‘torsion, traction, violent compression (or crushing), and forced movements (crossing the arms, folding the legs up over the abdomen, separating the thighs)’.” The circumstances during which the violent acts most often occurred were diapering (44%), dressing or undressing (30%), crying (22%) or feeding (15%). The study included excerpts from some of the confessions, but not all. Excerpts from the confessions detailed the abusive acts further:

“I would yank her around and pull her thighs out to the side in an inappropriate way to put on her diaper.”

“I would push the diaper changing movements too far... I would grab one leg in each hand and lift them up. His legs would be straight and I’d push them as far as they would go toward his head. This put a lot of stress on his knee joints. Let’s just say that most of my actions involved the joints ...

Sometimes I twisted his ankles in and out. I would take his heel and turn his foot side to side”

“I twisted their ankles while I was undressing them ... I did it to their wrists, too ... I grabbed her wrist and pulled it upward.”

“I would grab her by the shins hard and pull on her legs to stretch them out so I could put on her clothes. I would hold her legs straight out by putting one hand on her foot and the other on her thigh in order to put on her pants or onesie. The movements were not appropriate. I’ve used force to hold her leg. I’ve also yanked on her legs to pull her toward me when she’s on her changing table.”

"The fractures must have happened when I folded his legs against his stomach, I did it several times, I did it when he cried from colic. I would lose my temper, take him by the legs and pull them up to his shoulders."

In the confessed cases with SDH the perpetrators also confessed "violent shaking and clearly differentiated between the circumstances and mechanisms of the shaking and those of the CMLs". From the admissions, the following statements were excerpted:

"I held him in front of me ... under the arms ... I didn't shake him for long, just one back-and-forth, and then I set him down hard in his bed. He was on the changing table; I squeezed his legs together, there was no hematoma; I don't understand."

"I shook my son several times, maybe ten times ... As for the fractures, that must have happened when I folded his legs against his stomach and I took his legs and pulled them up to his shoulders."

"I shook him hard several times because he didn't want to eat and I was tired. I picked him up; I held him in front of me and shook him. I changed him on the changing table. I turned him over quickly, his arm must have gotten stuck and I twisted it."

The violence was described as recurrent (67%) and in those cases, it was described as "habitual," "daily," "all the time," or "several times a week for several weeks." The violence was mostly described as "having caused crying immediately after "a cracking" sound and a loss of limb mobility from violent handling."

Further, the authors also compared infants with SDH to those without, and concluded that CMLs of the shoulder were significantly more frequent ($p= 0.03$) in those with subdural hematoma, and fractures of different ages were significantly more common in those without subdural hematoma ($p= 0.03$).

The study concluded that acts described as “abusive, violent, and intentional” by the perpetrator, consisting of “excessive stress on the joints defined as ‘indirect skeletal forces’ with ‘torsion, traction, violent compression (or crushing), and forced movements (crossing the arms, folding the legs up over the abdomen, separating the thighs)’” can cause CMLs in infants. Further, the violent acts were frequently described as recurrent, and a high proportion of the study cases with CML (73 %) had concomitant or previous injuries.

Obviously however, the “no confession” group is not a control group for estimating diagnostic accuracy. Calculation of the diagnostic accuracy would need a matched, non-abused group for comparison. Also complicating the comparison between the groups is that the study did not report any demographic differences between the two groups, but regarded the entire cohort as one group regardless of confession status. From the definition of “no confession” it is not clear if it consisted only of cases where the suspected perpetrator did not provide any explanation at all, and/or of cases where explanations were inconsistent, and/or of cases with a confessions with explanations which the authors found to be “not acceptable” (such as “injuries blamed on falls, accidental impact, games, actions of another child under 5 years of age, or handling by the radiographers”). If the latter group was included, there is no definition of an “accepted” explanation and a “not accepted” explanation.

The study design with inclusion only of cases referred to the authors from the courts results in a high risk of selection bias, especially since there is no description how the authors were selected by the courts. Also, it was not reported whether the courts were criminal courts and/or administrative courts.

Included study – low quality: Carty and Pierce, 2002

Only one more study had included more than 10 cases of admitted physical abuse. Carty and Pierce (2002) reported from a large cohort of suspected non-accidental injuries (N=467) referred for a radiological opinion from 1984 through 1996. Both locally presented patients, patients referred for second opinion, and legal cases were included. 78 cases (17 % of the entire cohort) with “admission or

guilty plead" were reported. CMLs were not reported specifically, only injuries under the broad term "metaphyseal fractures" and the study was therefore excluded in the CML review. Rib fractures were reported in 154 cases. 82 % of the entire cohort was under 1 year of age.

This study was deemed to have low quality, with several factors lowering the quality. The main factor affecting the quality was that rib fractures were reported from the entire cohort of suspected abuse, and were not specifically reported from the group of "admission or guilty plead", which made up only 17 % of the entire cohort. Therefore, it was uncertain how many cases with rib fractures that actually were admitted. For a large group of the cohort the abuse diagnosis was based on "agreed" and "disputed medical evidence" (76 %) and for a small group the abuse diagnosis could not be established (7 %). Both those groups were also included in the group from which rib fractures were reported (however, no rib fractures were found in the group of accidental injuries (3%)). Including cases where the diagnosis is based on agreed or disputed medical evidence results in a high risk of incorporation bias. Rib fractures are, as described in the Background section, regarded as "highly specific for abuse" and therefore there is a high risk for circular reasoning since the conclusion of abuse in cases of rib fractures very well could be based on the presence of those rib fractures. Carty and Pierce (2002) reported, that all study cases had "additional features" of non-accidental injuries. However, they did not further describe what kind of features this was, and to what extent the diagnosis of abuse was based on the presence of rib fractures. The authors comment in the discussion that the pattern of injury and outcome were the same when the diagnosis was based on admissions as when the diagnosis was based on agreed medical evidence, except that the incidence of shaking was higher in the admission group. The authors meant this supported the validity of making the diagnosis based on injury pattern in the face of denial. However, assuming that the diagnosis of abuse is correct only because the injuries are similar to admitted cases, does not address the critical question about diagnostic accuracy and causality. The study does not compare rib fractures between an abused and non-abused group, and therefore the diagnostic accuracy cannot be estimated.

Further, the authors did not report what "admission" or "guilty plead" actually meant, or under what circumstances the confessions were obtained, and it is not stated if the confession included acts that potentially could explain the rib fractures.

Moreover, this study does not reflect a general population, the local population or the population of legal cases, but represents a mixture of cases referred to the authors, and hence the risk of selection bias is high.

The authors stated themselves that the study was a narrative observational account, not an epidemiological study, and reflected "personal experience" - and the description of their study is appropriate. In summary, the above stated weaknesses deemed the study to have low quality.

Other studies with admitted cases of physical abuse

Two studies had 5 or more cases of admitted abuse and therefore did not meet the inclusion criteria, but deserve to be mentioned because of the focus on admissions.

Leestma (2005) reported 5 cases of rib fractures in admittedly shaken infants. Besides not fulfilling the inclusion criteria regarding the minimum number of observations, the study design was questionable — the study comprised a compilation of selected cases published in English literature with admittedly shaken infants. Further, the study did not have a control group and therefore did provide an estimation of diagnostic accuracy.

Bulloch et al. (2000) reported 7 cases of rib fractures (22 % of the infants diagnosed with abuse), where the police obtained a confession of abuse. No details of the confessions were given. In the other included cases, the abuse diagnosis was based on other injuries and/or lack of explanation. In 38% of the cases of alleged abuse the diagnosis was established on multiple fractures, some with different stages of healing, and no history of trauma or no mechanism believed to be of sufficient magnitude to cause rib fractures. 18% of the cases

were diagnosed based on no history of trauma/no mechanism believed to be of sufficient magnitude to cause rib fractures, normal follow up and exclusion of birth injuries and no clinical and/or radiographic signs of bone fragility. The risk of incorporation bias is high when such a large share of the study cases was based on exclusion of other diagnoses, and the diagnosis of abuse was based on what the assessors arbitrarily believed was of “sufficient magnitude” to cause rib fractures.

Grading of evidence

This systematic literature review resulted in the following graded evidence:

- There is *limited scientific evidence* that CMLs can be caused by abuse.
- There is *insufficient scientific evidence* on which to determine the diagnostic accuracy of CMLs to be caused by abuse.
- There is *insufficient scientific evidence* that rib fractures can be caused by abuse and therefore also *insufficient scientific evidence* on which to determine the diagnostic accuracy of rib fractures to be caused by abuse.

Limited scientific evidence (low evidence according to the GRADE system) means that the strength of evidence is based on studies of high or moderate quality with factors that weaken an overall appraisal (SBU, 2018).

Insufficient scientific evidence (very low evidence according to the GRADE system) means that scientific evidence is absent, available studies have low quality, and/or that studies of similar quality report conflicting results (SBU, 2018).

5. Discussion

The results of this systematic review

The most interesting result is not the actual results of the only article with moderate quality, but the almost total lack of moderate and high-quality studies within the field with the reference test admitted, witnessed or video recorded physical abuse.

Using the criteria established early in the project it was found that there is *insufficient scientific evidence that rib fractures are caused by physical abuse*. This conclusion might seem ridiculous, since there is nothing controversial in the statement that blunt force trauma can cause rib fractures. A study in the BMJ from 2003 (Smith and Pell, 2003) made a humorous point of the focus on high quality studies in evidence-based medicine by conducting a systematic review to determine whether parachutes are effective in preventing major trauma related to gravitational challenges. They concluded that there were no randomised control studies to support the idea that the usage of parachutes prevented major trauma, and suggested that “*everyone might benefit if the most radical protagonists of evidence based medicine organised and participated in a double blind, randomised, placebo controlled, crossover trial of the parachute*”. Their study clearly shows that not everything needs to be proven through high quality scientific studies. The statement that blunt force trauma can cause rib fractures in infants is clearly such a statement. However, “blunt trauma” and “physical abuse” are two different entities, and may not be mixed up. Also, the degree of trauma needed to cause a fracture is of course of importance in this context. Can “normal handling” of the infant cause fractures? It is indeed interesting to find that when the strict PIRO criteria are applied, including infants ≤ 12 months of age, and ≥ 10 observations with rib fractures from admitted, witnesses or video recorded abuse, *no* such study was identified!

When it comes to the *diagnostic accuracy* of CMLs and rib fractures to be caused by physical abuse, the role of high-quality studies is definitely of great importance. As mentioned in the introduction, there are several reasons to push for high, robust and reliable diagnostic accuracy. Firstly, both overdiagnosis and underdiagnosis of abuse may have serious and far-reaching consequences, and

the diagnosis therefore must be as accurate as possible. Secondly, the judgement in alleged abuse cases often depend solely on the available medical evidence, without any other evidence that can direct an investigation based on flawed medical evaluation back on track. Lastly, a high and robust accuracy will lower the risk of emotional stress influencing decision making. Therefore, it is not enough to be able to say that injuries *can* be caused by abuse, but it is necessary to be able also to state *how certain* this conclusion is in a specific case.

The primary aim of this systematic literature review was to answer the question: “With what certainty can it be claimed that rib fractures or classical metaphyseal lesions in infants are attributed to physical abuse?” The answer is that there is *limited scientific evidence* that CMLs can be caused by abuse, but, that the scientific evidence is *insufficient to determine the diagnostic accuracy of both CMLs and rib fractures*.

The results clearly point toward an unfortunate lack of unbiased studies within the research field which will be discussed later. However, one study of moderate quality has been identified, which first will be discussed further.

The results of the only study deemed as having moderate study quality Adamsbaum et al., 2019

This study was assessed as having moderate quality, which means that there were factors making the study prone to a moderate degree of bias. Its results will now be discussed in detail, specifically commenting upon the risks of bias.

According to Adamsbaum and co-authors (2019), CMLs can be seen after physical abuse, and the denominator of the violence described in the confessions seems to be that it was “abusive, violent, and intentional” in the eyes of the perpetrator, as quoted by the authors. Not all admissions were quoted, and it is therefore not revealed what was stated in each case, but it must be assumed that the chosen quotes are representative of the admissions in general. Interestingly, the study did *not* conclude that the CMLs were caused by a shaking mechanism, which previously has been a mechanism frequently used in explaining these lesions (Kleinman et al., 1986). Even when shaking was confessed, the

circumstances and mechanisms of the shaking and those of the CML clearly differed. The mechanism of causing the CML was described as “excessive stress on the joints defined as ‘indirect skeletal forces’ with ‘torsion, traction, violent compression ... and forced movements’”, such as yanking and pulling the arms and legs, forceful bending and pushing of the legs, and twisting ankles and wrists. The force used is of course hard to interpret from the admissions, and would probably be hard to estimate just from a description from of a confession noted weeks or months after the event.

However, the distinction between *normal handling* versus *an accidental event* versus *an abusive act* as cited in the confessions is not obvious. In one case the mechanism to cause the CML is described as follows: “*I changed him on the changing table. I turned him over quickly, his arm must have gotten stuck and I twisted it.*” This description obviously does not exclude a situation during normal handling of a baby, and bears no sign of an intentional act (“abuse”). Further, the degree of violence described does not seem to be very different in character when compared to the CMLs reported to be caused by *accidental* or by *normal handling* of a baby such as when placing an intravenous catheter (Burrell et al., 2015), casting treatment for clubfoot (Grayev et al., 2001) and uncomplicated caesarean section (O’Connell and Donoghue, 2007).

In addition, the authors do not report what differential diagnosis have been considered or how extensive the process of excluding condition effecting bone quality and metaphyseal features have been. The low proportion of laboratory assessments in the cohort (16%) implies that exclusion of differential diagnoses was not prioritised. Moreover, the fact that 12 % of the cases were born prematurely (>32 and <37 weeks from last menstrual period) and the special differential diagnostics considerations this implicates have also not been commented on. Preterm birth infants have a decreased bone mineralization at birth which normalises during the first year of birth, and hence the risk of fractures is increased several months after birth (Flaherty et al., 2014). In conclusion, the paper does not present a clear distinction between “*violent and intentional trauma*” and *accidental or normal handling* of the baby, and an extra dimension to this problem is introduced by lack of commenting on considerations of differential

diagnoses that affect bone quality. Adamsbaum and co-authors underscore the importance of the high recurrence of trauma in the confessed cases. The possible effect and importance of repeated trauma seems to be a knowledge gap that needs to be investigated further.

Several problems are raised due to the authors way of defining “no confession”, which is not clear. The definition of the no confession group was “no confessions or the explanations of the injuries changed over time (injuries blamed on falls, accidental impact, games, actions of another child under 5 years of age, or handling by the radiographers).” This definition does not clarify whether no confession means that the perpetrator did not know how the CML occurred/did not supply any explanation *or* if no confession means that the authors simply did not accept some explanation, for instance, “injuries blamed on falls, accidental impact, games, actions of another child under 5 years of age, or handling by the radiographers”. If the latter interpretation was applied, the authors seem to already know the answer to the question how CMLs occur before starting the study, namely by “abusive, violent, and intentional” acts, and not for instance “accidental impact”. However, the statement that the radiographer caused the CML cannot automatically be excluded based on the preconceived notion that this is an unacceptable explanation; to my knowledge the only witnessed CML occurred under placement of an intravenous catheter (Burrell et al., 2015) and this is similar to handling by a radiographer. If the group of no confessions partly consists of “confessions” that the authors do not accept, they partly fail to address the full scope of the aim of their study, to “use legal statements by perpetrators to gain new insights into the causative mechanism of CML”. If including only what they themselves consider “acceptable” statements, other mechanism for CMLs than those being “abusive, violent, and intentional” in the eyes of the perpetrator will be hidden. The lack of an adequate control group is also a compromising factor. Further, the data for the two groups, confession and no confession, was not reported separately but as one amalgamated group. No differences between the groups were reported, but all parameters were not unambiguously reported as identical, which makes it difficult to scrutinize the reported data. The authors do not discuss the implication of the no confession group, and do not discuss if the perpetrators were guilty of abuse, but simply did not confess or that the no

confession group supplied alternative trauma mechanisms for CMLs. The study would have gained a lot by exploring the no confession group further, and divided the no confession into consistent unacceptable and inconsistency statements.

The confessions were all obtained from legal proceedings or investigations; none of the suspected perpetrators confessed in the early stages during the infant's hospitalisation. The authors included only confessions that were consistent, but it is not reported when in the investigation the confession emerged or under what circumstances. This methodology, i.e. using confessions obtained late in the investigation process, implies a risk of false or distorted confessions for several reasons. Firstly, a late confession can be associated with aggressive inquiry techniques, such as the Reid technique (Kassin et al., 2010). The Swedish Court of Appeal, acquitted a suspect father who had previously confessed to have shaken his infant resulting in the triad and rib fractures, after scrutinising the confession and finding that the interrogation technique had provoked a false confession (The Swedish court of Appeal for Southern Norrland, case no B 679-15; (The Swedish Court of Appeal for Southern Norrland, 2015). Secondly, the judicial practicing of plea bargaining implies a high risk of false confession. Plea bargain has been practiced in France on severe crimes since 2011, but is not practised for crimes including violence against persons if the crime stipulates a sentence not less than 5 years of prison, nor if the crime is murder or manslaughter (J-F Michard, 2019, personal communication, 9th September 2019) Although it seems unlikely that plea bargain has been practised in the cases of this present study, but the authors do not comment on this. Obviously, however, Adamsbaum and co-authors have made an effort to search for real confessions. This aspect cannot, however, be fully evaluated.

In summary the study has some compromising flaws, and does not help in answering the question about diagnostic accuracy but it supplies evidence for what kind of trauma mechanism that can cause CMLs.

Limitations of the present systematic review

A more appropriate way of conducting the literature search could have been to perform a new, similar search as the Swedish traumatic shaking report carried out in 2015. (An identical search would not have been possible since for instance the MeSH words have changed since 2015). Such a search would probably have captured a few more articles about general fractures and abuse, and would have covered more journals, since Embase and Cochrane library were not searched after 2015. However, this master thesis was limited in time, and the lack of resources required ruled out a more extensive search. However, since a meticulous manual search was carried out in the reference lists of the full text papers, there is a good chance that all important articles were identified.

Further, scrutinizing abstracts from the second search in June 2019 was conducted by the author only. This could influence the articles retrieved in full text, but the second search yielded only 739 abstracts, whereas the literature search in the Swedish report on traumatic shaking yielded 3773 abstracts. Many of the articles captured in the supplementary second search were captured already in the previous, first search. Also, the risk of missing key articles seems to be low since the author was by far the most generous to include papers for full text assessment.

The project could perhaps have benefitted from adding an expert in paediatrics and an expert in paediatric radiology. In this way different view of the articles could have been explored in more detail, and lowered the risk of bias due to similarities in scientific views. However, in a master dissertation with both limited resources and time, this was not realistic. A compromise was to use two assessors, at least giving two different views on the abstracts and articles. A question fair to ask is if both assessors have had equal opportunity to influence the outcome, or if one of them have been more influential. Following the SBU manual and the advocated steps have facilitated the assessments and kept the focus on the scientific methodology. Discussion about individual articles followed independent evaluation, and the checklist facilitated consideration of all important aspects prior to discussions. The possible effect of different level of seniority between the

authors (board certified specialist versus board certified specialist and professor in forensic medicine) was also reduced by following the advocated methodology, addressing the issue in advance, and a non-hierarchic working climate. Since the author also was in charge of the entire project as well as the final report, the relative seniority of the assessors was levelled out.

Prior reviews

Four previous systematic literature reviews were identified, three regarding the diagnostic accuracy of rib fractures in infants and children (Kemp et al., 2008, Williams and Hardcastle, 2006, Paine et al., 2019, Royal College of Paediatrics and Child Health, 2018), and one regarding the diagnostic accuracy of CMLs (Royal College of Paediatrics and Child Health, 2018). These reviews were not submitted to structural appraisal by the author, such as AMSTER (Shea et al., 2017), but the reference tests were compiled and the included studies were read in full text (Table 10). The reason for focusing on the reference tests, and not the synthesis of the review, was that the crucial question identified in this present systemic review is that the highest risk of biases is introduced when accepting papers using a reference test with low reliability, hence resulting in a metanalysis of no value.

All four systemic reviews included a large variety of reference test, and they all ranked the quality of the referenced test from highest rank implication a higher level of confidence for abuse to a low rank, implying a lower level of confidence. However, none of the reviews included only the highest rank, but also reference tests of low rank.

Table 10. Previous systematic reviews.

Review	Objective Rib or CML	Included studies Reference test for abuse
(Kemp et al., 2008)	To “systematically review published studies to identify the characteristics that distinguish fractures in children resulting from abuse and those not resulting from abuse, and to calculate a probability of abuse for individual fracture types.”	7 studies included in meta-analysis 1 study ranked 1-2 (Bulloch et al., 2000) <i>1= Abuse confirmed at case conference or family, civil, or criminal court proceedings; admitted by perpetrator; or witnessed abuse</i> <i>2=Abuse confirmed by stated criteria including multidisciplinary assessment</i> 2 studies ranked 2 (Cadzow and Armstrong, 2000, Barsness et al., 2003) <i>2=Abuse confirmed by stated criteria including multidisciplinary assessment</i> 1 study ranked 3 (Schweich and Fleisher, 1985) <i>3=Abuse defined by stated criteria</i> 3 studies ranked 4 (Thomas, 1977, Garcia et al., 1990, Strouse and Owings, 1995) <i>4=Abuse stated but no supporting detail given</i>
(Williams and Connolly, 2004)	A systematic review to answer the question: “In children undergoing chest radiography [patients] are rib fractures on plain radiographs [test] specific for non-accidental injury [outcome]?” Rib fractures	(No studies were ranked 5, 5=suspected abuse) No meta-analysis conducted 10 studies included in narrative analysis (no meta-analysis conducted) (Barsness et al., 2003, Carty and Pierce, 2002, Bulloch et al., 2000, Cadzow and Armstrong, 2000) (Leventhal et al., 1993, Garcia et al., 1990, King et al., 1988, Schweich and Fleisher, 1985, Merten et al., 1983, Thomas, 1977) All included studies: “non independent reference standard” “To the authors’ knowledge there is no nationally or globally agreed gold standard diagnostic tool for the diagnosis of non-accidental injury. As a result, the various studies use a variety of criteria against which the performance of radiological rib fracture in the diagnosis of non-accidental injury is assessed. A further weakness of the selected gold standards is the inclusion of the test being validated (chest x ray) within the gold standard test. “

(Royal College of Paediatrics and Child Health, 2018)	Systematic literature review aiming to answer amongst other questions: "Which fractures are indicative of abuse?".	Rib fractures 4 studies included in meta-analysis (Pandya et al., 2009, Barsness et al., 2003, Cadzow and Armstrong, 2000, Strouse and Owings, 1995) 15 more studies mentioned in a narrative analysis (Cosway et al., 2015, Worlock et al., 1986, Leventhal et al., 1993, Darling et al., 2014, Garcia et al., 1990, Schweich and Fleisher, 1985, Barber et al., 2013, Gipson and Tobias, 2006, Ng and Hall, 1998, Smeets et al., 1990, Bulloch et al., 2000, Feldman and Brewer, 1984, Smith et al., 1980, Thomas, 1977, Barber et al., 2015)
Rib fractures and CML	Ranking was used to indicate level of confidence that abuse taken place. Included: Ranking 1-3 was included. 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	Excluded: Rank of abuse 4 or 5 or mixed rank where relevant cases cannot be extracted. Single case reports. 4=Abuse stated but no supporting detail given 5=Suspected abuse <i>(Comment: It is not reported what rank the individual studies obtained. It is unclear if the inclusion and exclusion criteria also were applied on the narrative analysis since two of the articles apparently are single case reports.)</i>
CML: "Metaphyseal fractures" including CML <i>(Comment: Including general metaphyseal fractures such as CML, Salter Harris fractures and "bucket fracture" (not bucket-handle fractures), and it is hard to understand what conclusions are for CML only.)</i>	No meta-analysis conducted	Narrative analysis included 17 studies (Ryznar et al., 2015, Thackeray et al., 2016, McClelland and Heiple, 1982, Worlock et al., 1986, Pandya et al., 2009, Leventhal et al., 1993, Kowal-Vern et al., 1992, Barber et al., 2015, Coffey et al., 2005, Thomas et

	al., 1991, Beals and Tufts, 1983, Kleinman et al., 1995, Kleinman et al., 2011, Kleinman and Marks, 1996a, Kleinman and Marks, 1998, Kleinman and Marks, 1996b, Kleinman and Marks, 1996c) “The criteria for the ranking of abuse was lower for the section on metaphyseal lesions, which relied on case studies of rarer fracture types, some of which have lower abuse ranking.”
(Paine et al., 2019) To “estimate the prevalence of abuse in young children presenting with rib fractures and to identify demographic, injury, and presentation-related characteristics that affect the probability that rib fractures are secondary to abuse.” Rib fractures	10 studies included. Different studies included in different combinations of compilations and narrative analysis. 1 study ranked 1 (Cadzow and Armstrong, 2000) <i>1=Abuse confirmed at case conference or family, civil, or criminal court proceedings; admitted by perpetrator; or witnessed abuse</i> 1 study ranked 3a (Bulloch et al., 2000) <i>3a=Abuse defined using specific stated case-based criteria</i> 0 study ranked 2 <i>2=Abuse confirmed by stated criteria including multidisciplinary assessment. Assessment by multidisciplinary hospital-based child protection team as part of routine clinical care did not qualify as multidisciplinary assessment.</i> 2 study ranked 3b (Darling et al., 2014, Leventhal et al., 2007) <i>3b=Abuse including cases of likely or probable abuse defined by specific stated case-based criteria</i> 5 studies ranked 4 (Barsness et al., 2003, Garcia et al., 1990, Leventhal et al., 2008, Pandya et al., 2009, Strouse and Owings, 1995) <i>4=Abuse stated but no supporting detail given as to how a determination of abuse was made [includes studies relying on International Classification of Diseases, Ninth Revision and E-codes for abuse in administrative data sets and studies relying on diagnoses of abuse made by clinical teams without providing specific criteria by which those diagnoses were made.]</i> 1 study ranked 5 (Lucas-Herald et al., 2012) <i>5=Suspected abuse without supporting detail</i>

As can be seen in Table 10 regarding the systematic reviews on rib fractures, Kempe et al., (2008) included studies with the lowest ranking “Abuse stated but no supporting detail given” which is a critically low standard of a reference test. As many as 43 % of the studies were included on this criterion. Williams and Connolly (2004) ranked all included studies 3a: “no independent reference standard”; in the description clearly pointing out that the index test was part of the reference test, making all the included studies prone to incorporation bias. The review by the Royal College of Paediatrics and Child Health (2018) included studies on the following criteria: “Abuse confirmed at case conference or civil or criminal court proceedings or admitted by perpetrator”, “Abuse confirmed by stated criteria including multidisciplinary assessment” and “Abuse defined by stated criteria” which represents a higher standard of reference test than the other systematic reviews. However, both case conferences and multidisciplinary assessments provide risk of incorporation bias as will be discussed below. Unfortunately, this study did not report the rank of the individual studies, which makes the study hard to scrutinise. In the narrative analysis, single case reports were included, which according to the exclusion criteria was not acceptable, and therefore ranking of the individual studies would have been desirable to fully evaluate the review. Paine et al, (2019) included 50% of the studies on the criterion “Abuse stated but no supporting detail given as to how a determination of abuse was made” which is similar to Kempe’s lowest rank, and this must also be considered as a critically low standard for a reference test. This paper included also a study with an even lower rank, the criterion “Suspected abuse without supporting detail”.

The only identified systematic review regarding CMLs is the review by the Royal College of Paediatrics and Child Health (2018). Unfortunately, this review does not focus on CMLs exclusively, but include all metaphyseal fracture types, and it is structurally difficult to distinguish what conclusions concern CMLs and what conclusions concern other fracture types. Also, the “criteria for the ranking of abuse was lower for the section on metaphyseal lesions, which relied on case studies of rarer fracture types, some of which have lower abuse ranking.” As for the rib fractures section, the authors did not rank individual studies based on quality, but apparently also case studies were included.

Using a reference test such as “abuse stated but no supporting detail given” is highly problematic from a quality point of view and excluding studies with such a reference test seems uncontroversial from a scientific point of view, even if no previous systematic review has arrived at this conclusion. Hence, reference tests with a higher rank need to be discussed in more detail.

An example of a representative study using multidisciplinary assessment is the study by Barsness et al., (2003), which is included in all of the above-mentioned systematic reviews. Barsness and co-authors studied the prevalence of rib fractures in an abused and a non-abused group of children below 3 years of age. The reference test for abuse was consensus statements of the Child Advocacy and Protection team, a statement which was said to be multifactorial and based on all clinical, physical, psychosocial, and historic information available to the group at the time of evaluation. The basis for the team’s statement thus included the imaging findings of one or more rib fractures. Barsness and co-authors discussed that this means a “potential bias”, but meant that the evaluation was multifactorial and never solely based on the rib fracture/s. However, 29 % of the children with alleged abusive rib fractures had only one fracture, which raises question on exactly what further information the statement was based on. The authors meant that it would have been “unethical” to withhold imaging information when “making such an important clinical determination” – hence, obviously realising that rib fractures were important for the final conclusion – proving that circular reasoning indeed took place! The study is representative of how studies of child abuse are conducted, i.e. with a high risk of incorporation bias. The Barsness study is frequently cited, and numerous reviews, systematic or non-systemic and guidelines (Flaherty et al., 2014, Offiah et al., 2009, Maguire et al., 2009) have used the results for underscoring that rib fractures are highly specific for abuse. The calculated positive predictive value (PPV) of 95 % also needs to be commented, since the PPV is calculated for “a rib fracture” and not for a child with rib fracture/s. The PPV for a child with one or more rib fractures is lower, 82 % (Ricci, 2004), but since the figures are based on circular reasoning – which excludes or reduces the number of false positives and false negatives, and hence

represents “trimming” - a form of scientific misconduct, these figures are anyway not reliable.

The criterion “abuse confirmed at case conference or family, civil, or criminal court proceeding” were by Kempe et al., (2008) the Royal College of Paediatrics and Child Health (2018) and Paine et al, (2019) ranked as the highest reference test quality (together with witnessed or admitted abuse). However, no study only using this criterion was identified during this systematic review (see Appendix 5 for details about exclusion of individual studies). The criterion itself is also associated with risk of incorporation bias, because the case conference, family, civil, or criminal court proceeding is a type of multidisciplinary assessment, and relies in cases of suspicious abuse of infants largely on the medical assessment and hence not “the truth”, only a reflection of how the medical findings are interpreted by the responsible physician, thus mirroring the general opinion of how rib fracture or CMLs occur.

The criterion “abuse defined by stated criteria” is a criterion which has medium high rank quality, approximately the same quality as multidisciplinary assessment, and the quality is deemed higher when both references tests are combined. A representative study exemplifying a “criterion based” reference test is Leventhal et al., (2007). These authors studied if the proportion of fracture rated as abusive in children <36 months increased over a 24-year period. Each case was rated on a 7-point likert-scale which consisted of three levels of confidence of abuse and unintentional injury, respectively (definite, likely, and questionable), and an unknown group. Each level was defined by explicit criteria, the assessments were made individually by two clinicians and two radiologists, and the final conclusion was based on a consensus statement. The three levels of abuse and unintentional injury were collapsed into one abuse group and one unintentional injury group for the final analysis. However, the good intention of ranking the confidence of the fracture being caused by abuse, collapsing all levels into one group does result that apart from high quality reference tests such as eyewitness, also a positive skeletal survey, an inconsistent history, a changing history or inappropriate delay in seeking care, would conclude a fracture to be abusive. Especially considering that infants often do not have any symptoms, or only mild symptoms when

diagnosed with rib fractures or CMLs (Paterson and Monk, 2014), the uncertainty of basing the abuse diagnosis on “inappropriate delay in seeking” is very obvious. Even if the study design is scientifically sound, its results do not automatically become accurate if the actual criteria on which the abuse diagnosis is based on are unreliable.

Sometimes additional injuries are used as a criterion for establishing the abuse diagnosis. The study by Bulloch et al. (2000) discussed under the Results section is a good example of this. The study is, however, better than many others, relatively extensively describing what kind of injuries that were encountered, and not grouping severe injuries such as liver laceration with simple injuries such as single bruises. There are nevertheless reasons to be careful when establishing an abuse diagnosis on the presence of other lesions. For instance, it was found that there is *insufficient scientific evidence* on which to assess the diagnostic accuracy of the triad in identifying traumatic shaking (Elinder et al., 2018), and basing the abuse diagnosis on the triad as Bulloch et al. does is obviously inaccurate.

In the present review the reference test admitted, witnessed or video recorded physical abuse was chosen. This reference test is not unproblematic as was discussed under the section: The results of the only study deemed as having moderate study quality Adamsbaum et al., 2019. But the test is independent, and the risk of incorporation bias and circular reasoning is significantly lower.

Historical reflections and the importance of differential diagnosis

What is interesting to notice is the early focus metaphyseal lesions, which was mentioned by Silverman (1953), Caffey (1957), and in the key article by Kemp and colleagues (Kempe et al., 1962). Rib fractures were also early mentioned as a sign of physical abuse (Silverman, 1953). Especially Kempe and colleagues presented little doubt about the cause of multiple fractures, especially with metaphyseal and epiphyseal lesions, subdural haematoma and soft tissue injuries in different combinations. However, they supplied a theory based on anecdotal findings, and did not support the theory with any scientific evidence on, for instance, the finding of metaphyseal lesions. In fact, the diagnosis of abuse was a

diagnosis of exclusion. Times have changed, and so the scientific methodologies, and these papers do not stand out as different from other papers from that era, but what is interesting is what happened afterwards and how the scientific community has handled this theory.

Another aspect that must be mentioned is that much of the earliest work – but also much of what has been published until today – has been done by clinically active doctors and not by forensically or scientifically trained professionals. The focus of the paediatrician is clearly to protect the child rather than being judicially impartial and evaluating what can be proven beyond reasonable doubt in a criminal court setting. This is particularly clear in the influential key article by Kempe and colleagues (1962) which ends: *“the bias should be in favour of the child’s safety; everything should be done to prevent repeated trauma, and the physician should not be satisfied to return the child to an environment where even a moderate risk of repetition exist.”*

The focus on protecting the child is paramount for a clinical doctor. Not protecting a child would be against the principles of a clinician, and in many countries suspicion of abuse is mandatory to report to the social services. Over-reporting of suspicion is however not punishable. But, *suspicion* of abuse must of course never be sufficient to convict a suspect. The early research within the field – as well as most research published until today – is thus influenced by the clinical personnel’s obligation to protect their patients, not to act as an impartial expert in the judicial system. When researchers later uncritically accept the biased judgements and publications lacking sound scientific evidence, made by the early clinical paediatrician and radiologist, or by a multidisciplinary group with the same goal, the subsequent scientific studies will by default suffer from a high risk of bias because of the more or less hidden values at stake.

A parallel to sudden infant death syndrome (SIDS) is appropriate to draw. The SIDS diagnosis is a diagnosis of exclusion and one of the most used definition of SIDS is “the sudden unexpected death of an infant <1 year of age, with onset of the fatal episode apparently occurring during sleep, that remains unexplained after a thorough investigation, including performance of a complete autopsy and review

of the circumstances of death and the clinical history” (Krous et al., 2004). The mechanism of SIDS is not known, and if no other cause of death can be established the diagnosis is by default SIDS. This has similarities with rib fractures and CMLs; if no other explanation can be found, the default diagnosis is abuse. In SIDS this is acceptable, when no one is blamed to have caused the death, but it definitely raises questions in the diagnosis of child abuse. Can an abuse diagnosis be an exclusion diagnosis, with for instance rib fracture and CMLs as the only findings, when no other evidence is available? This systematic review has not found evidence to support such a conclusion. The hypothesis behind the mechanism of SIDS is the “triple-risk model” that postulates that SIDS results from the intersection of three overlapping factors: “(1) a vulnerable infant” for instance abnormal medullary serotonergic system; “(2) a critical developmental period”, and “(3) an exogenous stressor(s)” such as prone sleeping or smoking in the environment. Absence of one of these factors lowers the risk of SIDS. A similar model could be explored for fractures in infancy. (1) A vulnerable developmental age shortly after birth, (2) an intrinsic vulnerability, for instance mild forms of osteogenesis imperfecta, and a combination of (3) exogenous stressor such as prematurity, multigestational pregnancy, mild Vitamin D deficiency, in combination with normal or slightly rougher handling of the baby - or an accidental event. Approximately 95 % of SIDS cases are between 1 and 5 months of age (Krous, 2014), very similar to the peak age of CMLs and rib fractures, as well as of the triad.

There is still need for great caution when diagnosing abuse. Rib fractures and CMLs are said to be highly specific of abuse, but there are several problems. Firstly, to distinguish abusive trauma from accidental trauma, secondly to exclude any condition that makes the skeleton more fragile, thirdly to achieve a detailed and impartial documentation of the event. Sometimes additional injuries can guide the evaluation, but in most cases, there is a need for an extensive investigation considering differential diagnoses. Excluding all causes of a fragile skeleton known *today* is, however, not enough. Science will always continue to advance; e.g. 15 years ago several types of OI were not yet discovered (Palomo et al., 2017).

Future studies

Further studies should aim at large cohorts of admitted cases and will probably need international multicentre studies to achieve a high enough power. A critical multidisciplinary assessment of all evaluable evidence by clinical and scientific experts is until further probably the best method for a high-quality assessment before reaching a court decision, but can of course never be regarded as “the truth”. A court decision should also definitely not be used in scientific studies as a reference test, because of the high risk of incorporation bias. The wide-spread use of video recording technology, e.g. the growing use of so-called nanny cams will offer possibilities to capture events in an objective way, not previously available. Interestingly, the Working Group on Human Asphyxia has gathered filmed hangings from around the world, and in this way enabled unprecedented insight of the hanging process (Sauvageau et al., 2010). A similar strategy of an international working group on child abuse, collecting video recorded events, could offer the same type of unprecedented insights.

However, to be able to determine the diagnostic accuracy of a specific finding, not only a reliable reference test for abuse is necessary, but also an appropriate non-abused matched control group, which also is complicated. Often in studied encountered the control group is not age matched with the study group, often consisting of accidentally injured, considerably older children (Larimer et al., 2013, Pandya et al., 2009, Valvano et al., 2009, Garcia et al., 1990)

Also, the prevalence of both CMLs and rib fractures in a general non-abused population is not known. Some efforts have been done trying to determine the prevalence of CMLs; for instance, one study (Eide et al., 2019) found only one CML in the studied population of 408 healthy children under 2 years of age radiographed at an emergency department. However, this study is a good example of bias; The authors studied a population that does not nearly match the age group of infants with CMLs and suspected abuse. Of the 408 children studied, only 3 were younger than 6 months, only 31 were between 6 and 12 months, and the total mean age was 18 months. Hence, the age when CMLs is said to be most specific and common is severely underrepresented. The only CML that was

identified, was also not attributed to trauma and was found in an 11 months old boy, which means that 1 out of 34 infants below 12 months of age demonstrated an occult CML not attributed to trauma. The same problem is seen in studies surveying the prevalence of rib fractures in a general infant population. Problems encountered here are for instance that the X-rays taken on clinical indications are not as extensive as a skeletal survey, for instance lacking oblique view (Ruest et al., 2019). Furthermore, the clinical question will affect the detection of rib fractures when not expected (Sagar et al., 2012). Hopefully, additional detection methods without radiation hazards will develop. Much has happened with the MRI technique and the capacity and rapidity of the machines is quickly improving.

Further, studies to evaluate inter- and intra-reliability between radiologists as well as between histopathologists, and incorporating blind testing of differential diagnoses such as rickets, would supply the scientific community valuable knowledge in the controversies of infant fractures and rickets. Similar blind tests could be performed on radiologists to evaluate how many rib fractures in infants or CMLs that are missed when the clinical question is not abuse.

Animal and biomechanical studies, including finite element method studies, has been performed, but must be further improved to add knowledge to the mechanism of trauma for both rib fractures and CMLs among infants.

Final words

In conclusion, performing studies on physical child abuse is difficult which is one of the few things all researchers within this field seem to agree on. For ethical reasons, randomised, controlled trials are of course not possible to pursue, and creating alternative high-quality studies within the field of physical child abuse is a challenge. The challenge is mainly caused by the difficulties in finding a good enough reference test for abuse, but also by findings such as rib fractures and CMLs, being so uncommon findings on the whole, and needing large cohorts to be identified.

Difficulties to perform studies in the field of physical child abuse is, however, no excuse to compromise the methodological standard, and less so to accept limited scientific evidence as good enough for judicial proceedings. On the contrary, the far-reaching consequences of both over-diagnosis and under-diagnosis demand high scientific standards. Having scrutinised the entire field of research regarding rib fractures and CMLs in infants, and their possible correlations with physical child abuse, the lack of high-quality studies, and the presence of polemic and emotional argumentation dominating the field, is striking. As a whole, the scientific field would benefit to focus more on the scientific methodology instead of focusing on defending existing paradigms, protecting one's own standpoints, or engaging in the emotional aspects and consequences of individual cases. Science grows by being questioned, discussed and improved, and improving the methodological issues within the field of child abuse research would benefit all parties – not least the child and its family. Very few people actually deny that child abuse exists, but what needs to be explored is what the diagnostic accuracy of different symptoms and signs are. In a perfect world, questioning studies would be welcomed, since it would drive the science further and expand the knowledge by improving further studies. The aim of researchers on both sides of the osseous injuries/SBS/AHT/abuse controversy, both those called “denialists” and those called “believers”, must ultimately be the same, i.e. to be able to state with a high degree of certainty whether a certain injury or combination of injuries is caused or not caused by abuse. Acknowledging the flaws in most existing studies and acknowledging the difficulties in conducting high quality studies within this field seems to be a golden opportunity for researcher with different views to come together and create a basis for the missing high-quality research.

Unfortunately, the field seems to be deeply divided, and the research sprung from either side of the controversy, deeming to prove one's own standpoint. Max Planck stated: *“new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it”* (cited in Hull et al., 1978). Maybe this is the necessity of the science of physical child abuse, that a new generation of researchers explore the field, not personally bound to previous research and preconceived ideas, and looking with an open mind at the existing

scientific evidence, acknowledging both the “denialists” wish for better methodology and the “believers” consideration of the difficulties in conducting sound science. And not caring about the polemic, but conducting the necessary research to find more reliable answers to the question: “With what certainty can it be claimed that rib fractures or classical metaphyseal lesions in infants are attributed to physical abuse”.

6. References

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7. Appendices

Appendix 1. Search strategy: The Swedish traumatic shaking report, October 2015 (SBU, 2016)



Appendix to report

Traumatic shaking – a
systematic review, report no
255E

1 (6)

Cinahl via EBSCO 15 October 2015

Search terms		Items found
Population: infants		
1.	(MH "Infant") OR (MH "Infant, High Risk") OR (MH "Infant, Hospitalized") OR (MH "Infant, Newborn") OR (MH "Infant, Large for Gestational Age") OR (MH "Infant, Low Birth Weight") OR (MH "Infant, Postmature") OR (MH "Infant, Premature") OR (MH "Infant, Small for Gestational Age") OR (MH "Infant, Very Low Birth Weight")	126,854
2.	TI (baby OR babies OR infant OR infants OR infancy OR newborn OR new-born OR preterm* OR "Very young child*")	38,151
3.	1 OR 2	136,674
Population: persons with subdural hematoma/ retinal hemorrhage/ cerebral edema/ rib fractures or classic metaphyseal lesion		
4.	(MH "Hematoma, Subdural") OR (MH "Hematoma, Subdural, Acute") OR (MH "Hematoma, Subdural, Chronic") OR MH "Eye Hemorrhage" OR (MH "Cerebral Edema") OR (MH "Fractures") OR (MH "Rib Fractures") OR (MH "Tibial Fractures")	11,428
5.	("subdural haemorrhage*" OR "subdural haematoma*" OR "subdural hematoma*" OR "retinal hemorrhage*" OR "intraocular bleeding*" OR "vitreous hemorrhage" OR "brain swelling" OR "cerebral oedema*" OR "cerebral edema*" OR "brain oedema*" OR "brain edema*" OR "Rib fracture*" OR "long bone fracture*" OR "Classic Metaphyseal Lesion" OR "metaphyseal fracture*" OR "metaphyseal chip fracture*" OR triad)	3,692
6.	4 OR 5	13,639
Cause of the injury: accidental/non-accidental		
7.	(MH "Child Abuse") OR (MH "Diagnosis, Differential") OR (MH "Diagnostic Errors") OR (MH "Failure to Diagnose") OR (MH "Accidental Falls") OR (MH "Accidents, Home") OR (MH "Accidents, Traffic")	64,424
8.	(Accident* OR unintentional OR nonaccident* OR non-accident* OR abus* OR inflicted OR noninflicted OR non-inflicted OR suspect* OR "differential diagnos*" OR misdiagnosed OR underdiagnosed OR presumptive OR probable OR intentional OR "odds of abuse")	121,639
9.	7 OR 8	152,779
Shaken baby		
10.	MH "Shaken Baby Syndrome"	315
11.	("shaken baby" OR "children who are shaken" OR "shaken impact syndrome" OR "repetitive shaking" OR "Shaking-related" OR "Shaking infant trauma" OR "Infant head trauma" OR "shaken babies" OR "shaken child" OR "shaken children" OR "shaken impact syndrome" OR "shaken infant*" OR "manually inflicted shaking" OR "shaking baby" OR "Battered child syndrome" OR "infant head trauma" OR "Infant TBI" OR "Infant shaking" OR "Abusive head trauma" OR "Abusive head injur*" OR "inflicted traumatic brain injury")	455
12.	10 OR 11	455
Combined sets (infants with accidental/non-accidental head injuries OR Shaken baby syndrome)		
13.	6 AND 9	2,065
14.	12 OR 13	2,427
15.	3 AND 14	598
16.	15 AND Limiters - Peer Reviewed	517

The search result, usually found at the end of the documentation, forms the list of abstracts.

AB = Abstract

AU = Author

DE = Term from the thesaurus

MH = Term from the "Cinahl Headings" thesaurus

MM = Major Concept

TI = Title

TX = All Text. Performs a keyword search of all the database's searchable fields

ZC = Methodology Index

* = Truncation

" " = Citation Marks; searches for an exact phrase

Search terms		Items found
Population: shaken baby syndrome		
1.	"Shaken Baby Syndrome"[MeSH]	6
2.	("shaken baby" OR "children who are shaken" OR "shaken impact syndrome" OR "repetitive shaking" OR "Shaking-related" OR "Shaking infant trauma" OR "Infant head trauma" OR "shaken babies" OR "shaken child" OR "shaken children" OR "shaken impact syndrome" OR "shaken infant" OR "shaken infants" OR "manually inflicted shaking" OR "shaking baby" OR "Battered child syndrome" OR "infant head trauma" OR "Infant TBI" OR "Infant shaking" OR "Abusive head trauma" OR "Abusive head injury" OR "abusive head injuries" OR "inflicted traumatic brain injury" OR "inflicted traumatic brain injuries"):ti,ab,kw	13
3.	1 OR 2	CDSR/0 DARE/1 Central/ 10 CRM/0 HTA/0 EED/2

The search result, usually found at the end of the documentation, forms the list of abstracts.

[AU] = Author

[MAJR] = MeSH Major Topic

[MeSH] = Term from the Medline controlled vocabulary, including terms found below this term in the MeSH hierarchy

[MeSH:NoExp] = Does not include terms found below this term in the MeSH hierarchy

Systematic[SB] = Filter for retrieving systematic reviews

[TI] = Title

[TIAB] = Title or abstract

[TW] = Text Word

* = Truncation

" " = Citation Marks; searches for an exact phrase

CDSR = Cochrane Database of Systematic Review

CENTRAL = Cochrane Central Register of Controlled Trials, "trials"

CRM = Method Studies

DARE = Database Abstracts of Reviews of Effects, "other reviews"

EED = Economic Evaluations

HTA = Health Technology Assessments

Embase via Elsevier 15 October 2015

Search terms		Items found
Population: infants		
1.	infant/de OR baby/de OR high risk infant/de OR hospitalized infant/de OR newborn/de OR newborn death/	5,178
2.	baby:ti OR babies:ti OR infant:ti OR infants:ti OR infancy:ti OR neonate*:ti OR newborn:ti OR 'new born':ti OR preterm*:ti OR neonatal:ti OR 'very young child':ti OR 'very young children':ti	349,056
3.	1 OR 2	352,306
Population: persons with subdural hematoma/ retinal hemorrhage/ cerebral edema/ rib fractures or classic metaphyseal lesion		
4.	'subdural hematoma'/de OR 'retina hemorrhage'/de OR 'brain edema'/de OR 'rib fracture'/de OR 'flail chest'/de OR 'tibia fracture'/de OR 'epiphysis'/de OR 'brain ischemia'/de OR 'brain hemorrhage'/exp	235,293
5.	((subdural NEXT/1 haemorrhage*) OR (subdural NEXT/1 haematoma*) OR (subdural NEXT/1 hematoma*) OR (retinal NEXT/1 hemorrhage*) OR (intraocular NEXT/1 bleeding*) OR (vitreous NEXT/1 hemorrhage*) OR "brain swelling" OR (cerebral NEXT/1 oedema*) OR (cerebral NEXT/1 edema*) OR (brain NEXT/1 oedema*) OR (brain NEXT/1 edema*) OR (Rib NEXT/1 fracture*) OR ('long bone' NEXT/1 fracture*) OR "Classic Metaphyseal Lesion" OR (metaphyseal NEXT/1 fracture*) OR ('metaphyseal chip' NEXT/1 fracture*)):ti,ab	32,746
6.	4 OR 5	244,806
Cause of the injury: accidental/non-accidental		
7.	"child abuse"/de OR "differential diagnosis"/de OR "diagnostic error"/de OR "falling"/de OR "home accident"/de OR "accident"/de OR "traffic accident"/de OR "multiple trauma"/de OR 'accidental injury'/de OR 'birth injury'/de OR 'traumatic brain injury'/de	511,210
8.	accident*:ti OR unintentional:ti OR nonaccident*:ti OR (non NEXT/0 accident*):ti OR abus*:ti OR inflicted:ti OR noninflicted:ti OR 'non inflicted':ti OR suspect*:ti OR misdiagnosed:ti OR underdiagnosed:ti OR presumptive:ti OR probable:ti OR intentional:ti OR differential:ti OR trauma:ti	302,731
9.	7 OR 8	751,930
Shaken baby		
10.	(shake* NEAR/2 (baby OR babies OR child OR children OR impact OR infant)):ti,ab OR (shaking NEAR/2 (baby OR babies OR children OR impact OR infant* OR repetitive OR "manually inflicted")):ti,ab OR (Shaking-related OR "Infant head trauma" OR "Battered child syndrome" OR "infant head trauma" OR "Infant TBI" OR "Abusive head trauma" OR (Abusive head NEXT/0 injur*) OR "inflicted traumatic brain injury"):ti,ab	1,562
Combined sets		
11.	6 AND 9	20,953
12.	10 OR 11	17,507
13.	3 AND 12	1,033

/de= Term from the EMTREE controlled vocabulary

/exp= Includes terms found below this term in the EMTREE hierarchy

/mj = Major Topic

:ab = Abstract

:au = Author

:ti = Article Title

:ti:ab = Title or abstract

* = Truncation

" " = Citation Marks; searches for an exact phrase " " = Citation Marks; searches for an exact phrase

Search terms	Items found
Population: infants	
1. "Infant"[Mesh]	963323
2. Baby[ti] OR babies[ti] OR infant[ti] OR infants[ti] OR infancy[ti] OR newborn[ti] OR new-born[ti] OR preterm*[ti] OR Very young child*[ti] OR ((Baby[tiab] OR babies[tiab] OR infant[tiab] OR infants[tiab] OR newborn[tiab] OR new-born[tiab]) NOT Medline[SB])	237441
3. 1 OR 2	1033776
Population: persons with subdural hematoma/ retinal hemorrhage/ cerebral edema/ rib fractures or classic metaphyseal lesion	
4. Hematoma, Subdural[MeSH] OR Retinal Hemorrhage[MeSH] OR Brain Edema[MeSH] OR Brain injuries[MAJR] OR ("Hemorrhage"[Mesh:NoExp] AND (Brain[MeSH:NoExp] OR "Eye"[Mesh:NoExp])) OR "Fractures, Bone"[Mesh:NoExp] OR "Tibial Fractures"[Mesh] OR Epiphyses/injuries[MeSH] OR "Rib Fractures"[Mesh]	128585
5. subdural haemorrhage*[tiab] OR subdural haematoma*[tiab] OR subdural hematoma*[tiab] OR retinal hemorrhage*[tiab] OR intraocular bleeding*[tiab] OR vitreous hemorrhage[tiab] OR brain swelling[tiab] OR cerebral oedema*[tiab] OR cerebral edema*[tiab] OR brain oedema*[tiab] OR brain edema*[tiab] OR Rib fracture*[tiab] OR long bone fracture*[tiab] OR Classic Metaphyseal Lesion[tiab] OR metaphyseal fracture*[tiab] OR metaphyseal chip fracture*[tiab]	25679
6. 4 OR 5	140274
Cause of the injury: accidental/non-accidental	
7. Child Abuse[MeSH] OR Diagnosis, Differential[MeSH] OR Diagnostic Errors[MeSH] OR Accidental Falls[MeSH] OR Accidents, Home[MeSH] OR Accidents[MeSH] OR "Multiple Trauma"[Mesh]	656491
8. Accident*[ti] OR unintentional[ti] OR nonaccident*[ti] OR non-accident*[ti] OR abus*[ti] OR inflicted[ti] OR noninflicted[ti] OR non-inflicted[ti] OR suspect*[ti] OR differential diagnos*[ti] OR misdiagnosed[ti] OR underdiagnosed[ti] OR presumptive[ti] OR probable[ti] OR intentional[ti] OR odds of abuse[ti]	126896
9. 7 OR 8	731115
Shaken baby	
10. "Shaken Baby Syndrome"[Mesh] OR shaken[ti] OR shaken baby[tiab] OR children who are shaken[tiab] OR shaken impact syndrome[tiab] OR repetitive shaking[tiab] OR Shaking-related[tiab] OR Shaking infant trauma[tiab] OR Infant head trauma[tiab] OR shaken babies[tiab] OR shaken child[tiab] OR shaken children[tiab] OR shaken impact syndrome[tiab] OR shaken infant*[tiab] OR manually inflicted shaking[tiab] OR shaking baby[tiab] OR Battered child syndrome[tiab] OR infant head trauma[tiab] OR Infant TBI[tiab] OR Infant shaking[tiab] OR Abusive head trauma[tiab] OR Abusive head injur*[tiab] OR shaking injur*[tiab]	3062
Combined sets: persons with accidental/non-accidental head injuries OR Shaken baby syndrome	
11. (6 AND 9) OR 10	17164
12. 3 AND 11	4175

The search result, usually found at the end of the documentation, forms the list of abstracts.

[MeSH] = Term from the Medline controlled vocabulary, including terms found below this term in the MeSH hierarchy

[MeSH:NoExp] = Does not include terms found below this term in the MeSH hierarchy

[MAJR] = MeSH Major Topic

[TIAB] = Title or abstract

[TI] = Title

[AU] = Author

[TW] = Text Word

Systematic[SB] = Filter for retrieving systematic reviews

* = Truncation

Search terms		Items found
Population: infants		
1.	SU.EXACT("Infants") OR SU.EXACT("Premature Infants") OR subject("Neonates")	15,970
2.	TI((baby OR babies OR infant OR infants OR infancy OR neonate* OR neonatal OR newborn OR new-born OR preterm* OR "Very young child" OR "very young children"))	12,188
3.	1 OR 2	19,932
Population: persons with subdural hematoma/ retinal hemorrhage/ cerebral edema/ rib fractures or classic metaphyseal lesion		
4.	subject("Brain") OR subject("Traumatic Brain Injury") OR subject("Head Injuries")	10,504
5.	ALL(((retinal OR intracranial OR cerebral OR subdural OR intraocular OR vitreous) NEAR/2 (hemorrhage OR haemorrhage* OR haematoma OR bleeding*)) OR ((Cerebral OR brain) NEAR/2 (oedema* OR edema* OR swell*)) OR ((Head OR brain) NEAR/1 (trauma OR injury)))	1,507
6.	ALL("Rib fracture*" OR "long bone fracture*" OR "Classic Metaphyseal Lesion" OR "metaphyseal fracture*" OR "metaphyseal chip fracture*" OR triad)	1,907
7.	TI("head trauma" OR "brain injury" OR "head injury")	592
8.	4 OR 5 OR 6 OR 7	12,840
Cause of the injury: accidental/non-accidental		
9.	subject("Injuries") OR subject("Trauma") OR subject("Child Abuse") OR subject("Family Violence")	38,970
10.	ALL(Accident* OR unintentional OR nonaccident* OR non-accident* OR abus* OR inflicted OR noninflicted OR non-inflicted OR suspect* OR differential OR misdiagnosed OR underdiagnosed OR presumptive OR probable OR intentional OR trauma)	154,286
11.	9 OR 10	160,621
Shaken baby		
12.	if("Shaken Baby Syndrome")	32
13.	TI(Shaken) OR ALL("shaken baby" OR "children who are shaken" OR "shaken impact syndrome" OR "repetitive shaking" OR "shaking event" OR "Shaking-related" OR "Shaking infant trauma" OR "Infant head trauma" OR "shaken babies" OR "shaken child" OR "shaken children" OR "shaken impact syndrome" OR "shaken infant" OR "shaken infants" OR "manually inflicted shaking" OR "shaking baby" OR "Battered child syndrome" OR "infant head trauma" OR "Infant TBI" OR "Infant shaking" OR "Abusive head trauma" OR "Abusive head injury" OR "abusive head injuries" OR "inflicted traumatic brain injury" OR "inflicted traumatic brain injuries")	137
14.	12 OR 13	146
Combined sets		
15.	8 AND 11	2,056
16.	15 OR 14	2,137
17.	3 AND 16	138

The search result, usually found at the end of the documentation, forms the list of abstracts.

AB = Abstract

AF = Author affiliation

All = Performs a keyword search in most of the database's searchable fields, except full text

AU = Author

SU.EXACT = Term from the Sociological thesaurus

SU.EXACT.EXPLODE = Includes terms found below this term in the Sociological thesaurus

TI = Title

* = Truncation

" " = Citation Marks; searches for an exact phrase

? = Wildcard, used to replace any single character either inside or at the right end of a word

Search terms		Items found
Population: infants		
1.	TITLE (baby OR babies OR infant OR infants OR infancy OR neonate* OR neonatal OR newborn OR new-born OR preterm* OR "Very young child" OR "very young children")	359,779
Population: persons with subdural hematoma/ retinal hemorrhage/ cerebral edema/ rib fractures or classic metaphyseal lesion		
2.	TITLE-ABS("subdural haemorrhage*" OR "subdural haematoma*" OR "subdural hematoma*" OR "retinal hemorrhage*" OR "intraocular bleeding*" OR "vitreous hemorrhage" OR "brain swelling" OR "cerebral oedema*" OR "cerebral edema*" OR "brain oedema*" OR "brain edema*" OR "Rib fracture*" OR "long bone fracture*" OR "Classic Metaphyseal Lesion" OR "metaphyseal fracture*" OR "metaphyseal chip fracture*" OR triad) OR TITLE("head trauma" OR "brain injury" OR "head injury")	92,366
Cause of the injury: accidental/non-accidental		
3.	TITLE(Accident* OR unintentional OR nonaccident* OR non-accident* OR abus* OR inflicted OR noninflicted OR non-inflicted OR suspect* OR differential OR misdiagnosed OR underdiagnosed OR presumptive OR probable OR intentional OR trauma)	437,335
Shaken baby		
4.	TITLE(Shaken) OR TITLE-ABS("shaken baby" OR "children who are shaken" OR "shaken impact syndrome" OR "repetitive shaking" OR "Shaking-related" OR "Shaking infant trauma" OR "Infant head trauma" OR "shaken babies" OR "shaken child" OR "shaken children" OR "shaken impact syndrome" OR "shaken infant" OR "shaken infants" OR "manually inflicted shaking" OR "shaking baby" OR "Battered child syndrome" OR "infant head trauma" OR "Infant TBI" OR "Infant shaking" OR "Abusive head trauma" OR "Abusive head injury" OR "abusive head injuries" OR "inflicted traumatic brain injury" OR "inflicted traumatic brain injuries")	1,935
Combined sets		
5.	2 AND 3	5,710
6.	4 OR 5	7,260
7.	1 AND 6	793
8.	7 AND limit to: articles & reviews	576

The search result, usually found at the end of the documentation, forms the list of abstracts.

TITLE-ABS-KEY = Title or abstract or keywords

ALL = All fields

PRE/n = "precedes by". The first term in the search must precede the second by a specified number of terms (n).

W/n = "within". The terms in the search must be within a specified number of terms (n) in any order.

***** = Truncation

" " = Citation Marks; searches for an exact phrase

LIMIT-TO (SRCTYPE , "j" = Limit to source type journal

LIMIT-TO (DOCTYPE , "ar" = Limit to document type article

LIMIT-TO (DOCTYPE , "re" = Limit to document type review

Appendix 2. Search strategy: Rib fractures and CML, June 2019

PubMed 10th June 2019

Search terms		Items found
Population: infant		
1.	"Infant"[Mesh]	
2.	Baby[tiab] OR babies[tiab] OR infant[tiab] OR infants[tiab] OR newborn[tiab] OR new-born[tiab] OR preterm*[tiab] OR Very young child*[tiab]	
3.	1 OR 2	
Index test: rib fractures		
4.	"Rib Fractures"[Mesh] OR Rib fracture*[tiab]	
Combined sets: infant with rib fractures		
5.	3 and 4	384

[Mesh] = The NLM controlled vocabulary thesaurus used for indexing articles for PubMed. Includes terms found below this term in the MeSH hierarchy

[tiab] = Title or abstract

*= Truncation

Search terms		Items found
Index test: CML		
1.	metaphyseal lesion*[tiab] OR metaphyseal fracture*[tiab] OR metaphyseal chip fracture*[tiab] OR bucket handle fracture*[tiab] OR bucket-handle fracture* OR corner fracture*[tiab]	580

[tiab] = Title or abstract
 *= Truncation

Appendix 3. Checklist relevance

Checklist Relevance Assessment

Overall assessment:	Relevant Continue with quality assessment ☐	NOT Relevant ☐
----------------------------	---	---

Author:

Publication year:

Title:

Name of reviewer:

Study design	Yes	No	
Is the study design relevant according to the inclusion criteria (e.g. cohort or case-control)?	☐	☐	
Is the article a review?	☐	☐	
Correlation between outcome and abuse	Yes	No	No information
Does the study explore the correlation between outcome and abuse?	☐	☐	☐
Addressed questions	Yes	No	No information
Is the addressed question relevant?	☐	☐	☐
Is the inclusion criteria in the study relevant in respect to the addressed questions?	☐	☐	☐
Is the exclusion criteria in the study relevant in respect to the addressed questions?	☐	☐	☐
Population	Yes	No	No information
Is the studied population relevant?	☐	☐	☐
Is the studied population clearly described/defined?	☐	☐	☐
Is the method for selecting “patients” to the study relevant?	☐	☐	☐

Appendix 4. Checklist quality

Checklist Quality Assessment

Instructions: The assessment is primarily concerning the quality of the study, which means the risk for bias. The alternative “unclear” should be used when the information is not retrievable from the text. The alternative N/A is used when the question is irrelevant. Specify under comments.

Overall assessment:	High Quality	Moderate quality	Low quality
	☐	☐	☐

Author:

Publication year:

Title:

Name of reviewer:

1. Type of study				
	Yes	No	Unclear	N/A
A. Prospective cohort? Comment below	☐	☐	☐	☐
B. Retrospective case-control? Comment below	☐	☐	☐	☐
C. Cross-sectional study? Comment below	☐	☐	☐	☐
D. Case serie? Comment below	☐	☐	☐	☐
E. Other type, specify below	☐	☐	☐	☐
Comments:				
A.				
B.				
C.				
D.				
E.				

2. Focus of the study				
	Yes	No	Unclear	N/A
A. Rib fractures	☐	☐	☐	☐
B. Classic metaphyseal lesions	☐	☐	☐	☐
C. Combination	☐	☐	☐	☐
D. Other type, specify below	☐	☐	☐	☐
Comments:				
A.				
B.				
C.				
D.				

3. Abuse				
	Yes	No	Unclear	N/A
A. Is it specifically stated how the child was physically abused?	☐	☐	☐	☐
B. If yes, is the definition for abuse adequate?	☐	☐	☐	☐
C. What kind of abuse is included in the definition	☐	☐	☐	☐
C1) Shaking	☐	☐	☐	☐
C2) Grabbing	☐	☐	☐	☐
C3) Punching	☐	☐	☐	☐
C4) Combination	☐	☐	☐	☐
C5) Other, specify below	☐	☐	☐	☐
D. Who alternative how was the diagnosis of abuse established?				
D1) Confession by perpetrator, specify below	☐	☐	☐	☐
D2) Witnessed abuse, specify below	☐	☐	☐	☐
D3) Video recorded abuse	☐	☐	☐	☐
D3) Perpetrator found guilty in court	☐	☐	☐	☐
D4) Assessment by medical/social personnel (including multidisciplinary team) specify below	☐	☐	☐	☐
D5) Other injuries, specify below	☐	☐	☐	☐
D6) Criteria, specify below	☐	☐	☐	☐
D7) Other, specify below				
Comments:				
A.				
B.				
C.				
D.				

4. Selection Bias				
	Yes	No	Unclear	N/A
A. Is the studied group selected adequately (e.g. not based on biased selection)?	☐	☐	☐	☐
B. If groups are compared, is this done adequately? Specify the comparison below.	☐	☐	☐	☐
C. Is the size of the studied group and the control group adequate? (More than 10 persons in the abuse group)	☐	☐	☐	☐
D. Is the age in the studied group/control group adequate (according to PIRO: range, mean or median age ≤ 12 months)?	☐	☐	☐	☐
E. Was the composition of the compared groups equally enough?	☐	☐	☐	☐
Comments:				
A.				
B.				
C.				
D.				
E.				

5. Detection Bias				
	Yes	No	Unclear	N/A
A. Were the persons who evaluated the outcome <i>impartial</i> ?	☐	☐	☐	☐
B. Were the persons who evaluated the outcome <i>blinded</i> ?	☐	☐	☐	☐
C. Is the outcome measured in an adequate way/with defined methods?	☐	☐	☐	☐
D. Has the outcome been measured at reasonable timepoints? (In relationship to birth or trauma event?)	☐	☐	☐	☐
E. In the cases where more than one observer participated, was the agreement between them acceptable?	☐	☐	☐	☐
F. Have the statistical methods used been reported adequately?	☐	☐	☐	☐

Appendix 5. Excluded studies

Record no	Study	Reason for exclusion 1	Reason for exclusion 2	Reason for exclusion 3 and 4	Focus of study
2202	Tsai A, McDonald AG, Rosenberg AE, Gupta R, Kleinman PK. 2014. Erratum to: High-resolution CT with histopathological correlates of the classic metaphyseal lesion of infant abuse, <i>Pediatric Radiology</i> , 44(9), 1190.	Not relevant study design: Erratum			
2203	Barber I, Perez-Rossello JM, Wilson CR, Kleinman PK. 2015. The yield of high-detail radiographic skeletal surveys in suspected infant abuse. <i>Pediatric Radiology</i> , 45(1), 69-80.	Not relevant PIRO, outcome Objective: To determine the diagnostic yield of high-detail radiographic skeletal surveys in suspected infant abuse.	Not relevant PIRO, reference test "skeletal surveys performed for suspected child abuse"		CML + Rib
2208	Wood JN, Fakeye O, Feudtner C, Mondestin V, Localio R, Rubin DM. 2014. Development of guidelines for skeletal survey in young children with fractures, <i>Pediatrics</i> , 134(1), 45-53.	Not relevant PIRO, outcome Objective: To "develop guidelines for performing initial skeletal survey (SS) in children <24 months old with fractures, based on available evidence and collective judgment of experts from diverse pediatric specialties".	Not relevant study design: Consensus statement/guidelines for skeletal surveys	Other: A systematic review is performed as a basis for the development of guidelines, but the results of the review are not reported in the article.	CML + Rib
2224	Lindberg DM, Berger RP, Reynolds MS, Alwan RM, Harper NS. 2014. Yield of skeletal survey by age in children referred to abuse specialists. <i>The Journal of Pediatrics</i> , 164(6): 1268-1273.e1.	Not relevant PIRO, outcome Objective: To "determine rates of skeletal survey completion and injury identification in different age ranges for children <60 months in a large, multicentre cohort of children who underwent subspecialty evaluation for concerns of child physical abuse."	Not relevant PIRO, reference test "children who underwent subspecialty evaluation by a child abuse physician (CAP) for concerns of physical abuse"		CML + Rib
2238	Tsai A, McDonald AG, Rosenberg AE, Gupta R, Kleinman PK. 2014. High-resolution CT with histopathological correlates of the classic metaphyseal	Observations (<10) 5 cases	Not relevant PIRO, outcome Objective: "High-resolution CT imaging and histologic correlates were employed to (1) characterize the normal infant anatomy surrounding the chondro-	Not relevant PIRO, reference test "Long bone specimens from five fatally abused infants, three boys and two girls, ranging in age from 1.3 months	CML

	lesion of infant abuse. <i>Pediatric Radiology</i> , 44(2), 124-140. S		osseous junction, and (2) confirm the 3-D model of the CML previously inferred from planar radiography and histopathology.	to 9 months (average age: 3.6 months), whose skeletal survey showed definite or suspected CMLs, were studied postmortem to assist the medical examiner in determining the cause/ manner of death. " (No description how the diagnosis "fatally abused" was established).	
2242	Paauze DR, Paauze DK. 2013. Emergency management of blunt chest trauma in children: an evidence-based approach. <i>Pediatric Emergency Medicine Practice</i> , 10(11), 1-22; quiz 22-23.	*Not accessed.			
2243	Ayoub DM, Hyman C, Cohen M, Miller M. 2014. A critical review of the classic metaphyseal lesion: traumatic or metabolic? <i>American Journal of Roentgenology</i> , 202(1), 185-196.	Non-systematic review (No description how articles were searched or included)	Not relevant PIRO, outcome Objective: To "review the hypothesis that classical metaphyseal lesions represent traumatic changes in abused infants and compare these lesions with healing rickets."		CML
2252	Swischuk LE. 2013. What is different in children? <i>Seminars in Musculoskeletal Radiology</i> , 17(4), 359-370.	Not relevant PIRO outcome, population, index test, reference test. Objective: Fractures in infants and children are very different from fractures in adolescents and adult. "This article deals with those differences and also attempts to emphasize how to diagnose fractures in infants and children when they are very subtle."	Non-systematic review (No description of literature search and inclusion criteria)		
2273	Larimer EL, Fallon SC, Westfall J, Frost M, Wesson DE, Naik-Mathuria BJ. 2013. The importance of surgeon involvement in the evaluation of non-accidental trauma patients. <i>Journal of Pediatric Surgery</i> , 48(6), 1357-1362.	Not relevant PIRO, reference test "were coded by a dedicated trauma registry nurse as having NAT as the mechanism of injury. All other patients were considered to be injured accidentally".			Rib fractures

2281	Deye KP, Berger RP, Lindberg DM. 2013. Occult abusive injuries in infants with apparently isolated skull fractures. <i>The Journal of Trauma and Acute Care Surgery</i> , 74(6), 1553-1558.	Other: Not relevant PIRQ, outcome Objective: Determine rates of screening for occult abusive injuries, rates of injury identification and rate of reporting to CPS among infant younger than 12 months who presented with an apparently isolated skull fracture.	Not relevant PIRQ, reference test "CAPs recorded their ultimate level of concern for abuse according to a previously published 7-point rating scale for the likelihood of abuse, with 1 representing "definitely not inflicted injury" and 7 representing "definite inflicted injury" (see Appendix).21 (Lindberg et al 2007: 7 points equal "Definite inflicted injury" and includes the criteria "Unexplained posterior rib fractures, metaphyseal fractures, characteristic retinal hemorrhages"	Observations (<10) 2 cases with rib fractures, 5 cases of CML.	CML + Rib
2304	Paterson CR, Monk EA. 2013. Temporary brittle bone disease: association with intracranial bleeding. <i>Journal of Pediatric Endocrinology & Metabolism</i> , 26(5-6), 417-426.	Not relevant PIRQ, reference test "In conclusion our review of 20 young infants with both unexplained fractures and intracranial bleeding provides strong evidence that non-accidental injury was unlikely in these cases. We found that many of these patients had inadequately investigation at the time of presentation to exclude underlying metabolic disorder. We provide an indicator of the differential diagnosis of a combination of fractures and intracranial bleeding together with the principal relevant investigations. " "child abuse seemed unlikely as a cause of the fractures as in no case was there clinical evidence of injury commensurate with fracturing, as some patients had fractures while in hospital and as metaphyseal lesions, when present, were often symmetrical in distribution."	Differential diagnosis: Temporary brittle bone disease/ metabolic bone disease	No relevant PIRQ, outcome Objective: To "report on 20 patients, the pattern of whose fractures was similar to that of other patients with temporary brittle bone disease but who also had evidence of subdural bleeding. We will explore the possible cases of this combination."	CML + Rib
2317	Fassier A, Gaucherand P, Kohler R. 2013. Fractures in children younger than 18 months. <i>Orthopaedics & Traumatology, Surgery & Research</i> , 99(1 Suppl), S160-70.	Non-systematic review (No description how articles were searched or included)			

2320	Greeley CS, Donaruma-Kwoh M, Vettimattam M, Lobo C, Williard C, Mazur L. 2013. Fractures at diagnosis in infants and children with osteogenesis imperfecta. <i>Journal of Pediatric Orthopedics</i> , 33 (1), 32-36.	Not relevant PIRQ, outcome Objective: To "characterize the fracture patterns and the clinical information relied upon by clinicians at the time of diagnosis in a sample of infants and children with OI."	Not relevant PIRQ, reference test Diagnosis of OI	Differential diagnosis: OI	Rib fracture
2325	Lucas-Herald A, Butler S, Mactier H, McDewitt H, Young D, Ahmed SF. 2012. Prevalence and characteristics of rib fractures in ex-preterm infants. <i>Pediatrics</i> , 130(6), 1116-1119.	Not relevant PIRQ, reference test All infants born < 37 weeks gestation with rib fractures on chest radiography up to 1 year of age. Rib fractures attributed to thoracotomy surgery excluded. Non-accidental injury was suspected in 4 of 26 cases. 1 was diagnosed with metabolic bone disease. No clear description how abuse was excluded. No clear description if the suspected non-accidental injury was truly non-accidental injury and how that was established.	Not relevant PIRQ, outcome Objective: To "extend the limited data that are currently available by describing the prevalence and characteristic features of rib fractures in ex-preterm infants."	Differential diagnosis: Prematurity.	Rib fracture
2329	Lee JJ, Gonzalez-Izquierdo A, Gilbert R. 2012. Risk of maltreatment-related injury: a cross-sectional study of children under five years old admitted to hospital with a head or neck injury or fracture. <i>PLOS One</i> , 7(10), e46522.	Not relevant PIRQ, index test Thoracic fractures (rib, sternum and thoracic spine)	Not relevant PIRQ, reference test "The primary outcome measure, maltreatment-related injury admission, was defined as the presence of any code from two exclusive clusters of ICD-10 codes recorded as a diagnostic code in the child's electronic discharge record (Table S1). [10, 11] The most specific cluster contained codes for maltreatment syndrome or assault. The second cluster contained codes that reflected investigation for undetermined intent or concerns about the child's adverse social circumstances. Both clusters of codes were used together to define the main outcome measure, maltreatment-related codes. These maltreatment-related ICD-10 codes were selected to be consistent with 'alert' features listed in UK national guidance from NICE (National Institute of Clinical Excellence) that should prompt the clinician to 'consider' or 'suspect' child maltreatment and take further action. [1] These codes therefore reflect clinical concern about possible maltreatment but do not reflect a definitive diagnosis of abuse. They identify children who should be investigated further, and who require further assessment and information sharing. This classification reflects clinical reality where the cause of injury may not be known for certain until sometime after admission, if at all. To exclude these children from the analysis would bias estimates of predictive values, increasing estimates in the most suspicious injuries and decreasing them in less clear cut cases. To assess the	.	

		robustness of our findings, we repeated analyses using the more specific set of codes for maltreatment syndrome or assault (Table S1, results in figures S1 and S2). " Table S1: 1. Maltreatment - Maltreatment syndromes - Perpetrator of neglect and other maltreatment syndromes 2. Assault - Assault by bodily force - Other types of assault 3. Undetermined cause - Events of undetermined intent - Blood alcohol and blood-drug tests - Examination and observation following other inflicted injury - Examination and observation for other reasons: request for expert evidence 4. Adverse social circumstances - Neonatal withdrawal symptoms from maternal use of drugs of addiction - Problems related to social environment - Problems related to negative life events in childhood - Other problems related to upbringing - Other problems related to primary support group - Problems related to other legal circumstances - Problems related to lifestyle (Except Z72.0 Tobacco use) - Problems related to care-provider dependency - Health supervision and care of foundling - Health supervision and care of other healthy infant and child - Family history of mental and behavioural disorders - Personal history of other mental and behavioural disorders - Personal history of other physical trauma - Personal history of other specified risk factors, not elsewhere classified			
2349	Laskey AL, Stump TE, Hicks RA, Smith JL. 2013. Yield of skeletal surveys in children </= 18 months of age presenting with isolated skull fractures. <i>The Journal of Pediatrics</i> , 162(1), 86-89.	Not relevant PIRQ, outcome Objective: To "measure the yield of a skeletal survey in children ≤18 months old presenting with isolated skull fractures without significant intracranial injury". The primary outcome measure of this study was the results of	Not relevant PIRQ, reference test Not relevant for the study design.	Observation <10 (5 cases with rib fractures, CML not mentioned)	Rib fracture

		the skeletal survey. Abuse or not abuse not outcome.		
2355	Piteau SJ, Ward MG, Barrowman NJ, Plint AC. 2012. Clinical and radiographic characteristics associated with abusive and nonabusive head trauma: a systematic review. <i>Pediatrics</i> , 130(2), 315-323.	Systematic review Objective: To "systematically review the literature to determine which clinical and radiographic characteristics are associated with abusive head trauma (AHT) and nonabusive head trauma (NAHT) in children".		CML + Rib
2361	Ismail MF, al-Refaie RI. 2012. Chest trauma in children, single center experience. <i>Archivos de Bronconeumologia</i> , 48(10), 362-366.	Not relevant PIRO, population All paediatric patients, mean age 9.2 +/- 4.9 years	Not relevant PIRO, outcome "Our objective was to evaluate the experience in our center regarding closed or penetrating pediatric chest trauma, their diagnosis, different treatment techniques and the clinical results obtained in these cases in our emergency hospital department, which is a tertiary reference center." Abuse not mentioned as a cause of injury.	Not relevant PIRO, reference test Abuse not relevant. Data on injury mechanism from "patients medical file" at emergency center.
2362	Tsai A, Coats B, Kleinman PK. 2012. Stress profile of infant rib in the setting of child abuse: A finite element parametric study. <i>Journal of Biomechanics</i> , 45(11), 1861-1868.	Not relevant study design: Biomechanical Objective: To "identify the material properties that most influence the infant rib stress response during abusive chest compression, and ascertain whether changes in chest compression depth significantly alter patterns of stress. These findings will provide preliminary data that can direct future research for predicting rib fracture in children".		Rib fracture
2397	Sagar M, Shukla S, Bradley-Dodds K. 2012. Nonaccidental trauma presenting with respiratory distress and pleural effusion. <i>Pediatric Emergency Care</i> , 28(1), 61-63.	Case report: 1 case, multiple rib fractures in infant, attributed to non-accidental trauma, presenting with respiratory distress and pleural effusion.	Not relevant PIRO, reference test (admitted, witnessed or video recorded)	Rib fracture
2401	Meiville JD, Lukefahr JL, Clarke EA. 2012. First rib fractures in abused infants: a report of three cases. <i>Clinical Pediatrics</i> , 51(5), 426-430.	Case report: 3 cases, first rib fractures, attributed to child abuse.	Not relevant PIRO, reference test (admitted, witnessed or video recorded)	Rib fracture

2406	Diaz-Olivarrieta C, Garcia-Pina CA, Loredo-Abdala A, Paz F, Garcia SG, Schilmann A. 2011. Abusive head trauma at a tertiary care children's hospital in Mexico City. A preliminary study. <i>Child Abuse & Neglect</i> , 35(11), 915-923.	Not relevant PIRQ, reference test "In our study, children met AbHT (Abuse Head Trauma, <i>my comment</i>) diagnostic criteria when they displayed intracranial and intraocular injuries without an apparent cause or injury mechanism consistent with their clinical profile. A stronger AbHT diagnosis was given when external injuries were present. The severity of injuries and diagnostic accuracy (greater than 90%) were measured using a standardized questionnaire (Loredo-Abdalá et al., 2003). Members of the research team confirmed each AbHT diagnosis by consensus. Participants who met AbHT diagnostic criteria were considered cases, and those who did not were included in the accidental head injury (Achi) comparison group." None in the Achi had rib fractures or CML.	Observations (<10) Only 4 (31 %) and 3 (23 %) of 13 in Abusive Head Trauma (AbHT) group had rib fractures and metaphyseal lesions, respectively, and none in the accidental head injury group.		CML + Rib
2425	Botash AS, Sils IN, Welch TR. 2012. Calciferol deficiency mimicking abusive fractures in infants: is there any evidence? <i>The Journal of Pediatrics</i> , 160(2), 199-203.	"Commentary" : Calciferol deficiency (Vitamin D) and child abuse	Non-systematic review (No description on how articles were searched and included)		
2431	Kemp AM. 2011. Abusive head trauma: recognition and the essential investigation. <i>Archives of Disease in Childhood. Education and practice edition</i> , 96(6), 202-208.	Non-systematic review (No description how articles were searched or included)	Clinical guidelines , "best practise"		Rib fracture
2434	Kleinman PK, Perez-Rossello JM, Newton AW, Feldman HA, Kleinman PL. 2001. Prevalence of the classic metaphyseal lesion in infants at low versus high risk for abuse. <i>AJR. American Journal of Roentgenology</i> , 197(4), 1005-1008.	Not relevant PIRQ, reference test Low risk group: "A text search was performed of radiology reports on all infants (< 1 year old) undergoing skeletal survey because of skull fractures identified on head CT between 1999 and 2009. The CT reports were reviewed for the presence of skull fractures and their characteristics as well as associated intracranial abnormalities.	Observation <10 (9 cases)		CML

		Medical records, including the emergency department notes, consultations, and inpatient records were reviewed. Cases were classified using categories outlined in a recent study by Wood et al. [11]. Inclusion criteria in the low-risk group are detailed in Table 1 " " TABLE 1: Inclusion Criteria for Low-Risk Group Criteria - Skull fracture noted on head CT - Skeletal survey [12] - Child protection team or emergency department social worker consultation - History of a fall - Short fall (< 3 feet) - Long fall (> 3 feet) - Other (e.g., fall with parent landing on child) - No significant intracranial injury (focal extraaxial blood underlying fracture site excluded) No risk factors for abuse Absent or inconsistent history of injury Presence of other suspicious injuries - Delay in care > 72 hours - Previous child protective service involvement "During the same 10-year period, a search of radiology reports and hospital child protection team (CPT) consultations was performed to identify infants at high risk for abuse. Inclusion criteria were all of the following: subdural hematoma, retinal hemorrhages, skeletal injuries (other than classic metaphyseal lesions and skull fractures), and determination of abuse by the CPT and state child protective services. " HIGH-RISK GROUP "During the same 10-year period, a search of radiology reports and hospital child protection team (CPT)		
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		consultations was performed to identify infants at high risk for abuse. Inclusion criteria were all of the following: subdural hematoma, retinal hemorrhages, skeletal injuries (other than classic metaphyseal lesions and skull fractures), and determination of abuse by the CPT and state child protective services."		
2446	Uhl M, Geiger J, Strohm PC. 2011. [Skeletal trauma during the growing period. Radiological diagnostics] Skelettraumatologie im Wachstumsalter Radiologische Diagnostik. <i>Der Radiologe</i> , 51(8), 719-734; quiz 735-736.	Non-systematic review (No description how articles were searched or included)	Not relevant PIRO, index test	
2447	Maguire SA, Kemp AM, Lumb RC, Farewell DM. 2011. Estimating the probability of abusive head trauma: a pooled analysis. <i>Pediatrics</i> , 128(3), e550-64.	Systematic review Objective: To "determine which combinations of clinical features assist in distinguishing abusive head trauma (AHT) from nonabusive head trauma".	Not relevant PIRO, reference test (i) Abuse confirmed at case conference or civil, family, or criminal court proceedings or admitted by perpetrator or independently witnessed, or (ii) Abuse confirmed by stated criteria, including multidisciplinary assessment	CML + Rib
2451	Singh Kocher M, Dichtel L. 2011. Osteogenesis imperfecta misdiagnosed as child abuse. <i>Journal of Pediatric Orthopedics. Part B</i> , 20(6), 440-443.	Not relevant PIRO, outcome Objective: To "review the medical and social aspects of a case series of children with OI who were misdiagnosed with child abuse".	Not relevant PIRO, index test Rib fractures present but no statistics.	Rib fracture
2456	Gabaeff SC. 2011. Challenging the pathophysiologic connection between subdural hematoma, retinal hemorrhage and shaken baby syndrome. <i>Western Journal of Emergency Medicine</i> , 12(2), 144-158.	Non-systematic review (No description how articles were searched or included)		CML
2466	Matlung SE, Bilo RA, Kubat B, van Rijn RR. 2011. Multicystic encephalomalacia as an end-stage finding in abusive head trauma.	Observations (<10) 2 cases with CML and 2 cases with posterior rib fractures	Not relevant PIRO, outcome Objective: To report multicystic encephalomalacia as end stage finding of abusive head trauma.	CML + Rib

	<i>Forensic Science, Medicine, and Pathology</i> , 7(4), 355-363.				
2468a	Schilling S, Wood JN, Levine MA, Langdon D, Christian CW. 2011. Vitamin D status in abused and nonabused children younger than 2 years old with fractures. <i>Pediatrics</i> , 127 (5): 835-41.	Not relevant PIRO, reference test "The diagnosis of nonaccidental injury was made by the child protection team, independent of this study. The diagnosis used standard criteria, including history, physical examination findings, laboratory and imaging results, and consultation with other subspecialists, and was based on American Academy of Pediatrics guidelines. (24) Children were classified as abused if 1 or more of the following criteria were met: (1) In addition to fracture, other unexplained nonskeletal injuries (cutaneous, intracranial, or abdominal) were identified; (2) no history of trauma was provided to explain a fracture in a nonambulatory child; and (3) no history of trauma was provided to explain multiple fractures in an ambulatory or nonambulatory child. Bruising or swelling over fracture sites and small isolated extraaxial hemorrhages underlying skull fractures were not considered additional injuries."			"Metaphyseal fracture" + Rib
2468b	Schilling S, Wood JN, Levine MA, Langdon D, Christian CW. 2011. Errata Vitamin D status in abused and nonabused children younger than 2 years old with fractures <i>Pediatrics</i> . 128(3):593.	Other: Erratum to Schilling et al (2015)			
2479	Bixby SD, Abo A, Kleinman PK. 2011. High-impact trauma causing multiple posteromedial rib fractures in a child. <i>Pediatric Emergency Care</i> , 27(3), 218-219.	Case report: 1 case, 13-month-old with posterior rib fractures attributed to high-impact trauma.	Not relevant PIRO, population		Rib fracture
2486	Hong TS, Reyes JA, Moineddin R, Chiasson DA, Berdon WE, Babyn PS.	Not relevant PIRO, outcome Objective: To determine the additional value of	Not relevant PIRO, reference test "Based on autopsy findings, causes of	Mechanism of trauma not studied.	Rib fracture

	2011. Value of postmortem thoracic CT over radiography in imaging of pediatric rib fractures. <i>Pediatric Radiology</i> , 41(6), 736-748	postmortem thoracic CT compared with radiography in detecting paediatric rib fractures, and fracture healing, using autopsy findings as a gold standard.	death included respiratory complications (n = 4), blunt force trauma (n = 2), traumatic brain injury (n = 2), cardiovascular complications (n = 8), drowning (n = 3), falls from heights (n = 4) and metastatic disease (n = 1). In 32 patients, no definitive cause of death was established. At the time of data analysis, based on autopsy findings and medical history, neglect or abuse was confirmed in two children and suspected in seven; fractures were detected in three of these children. Based on a review of medical records, 49 out of 56 children underwent CPR within 24 h prior to death."		
2490	Duffy SO, Squires J, Fromkin JB, Berger RP. 2011. Use of skeletal surveys to evaluate for physical abuse: analysis of 703 consecutive skeletal surveys. <i>Pediatrics</i> , 127 (1), e47-52.	Not relevant PICO, outcome Objective: "To describe (1) the number of SSS performed over time, (2) the reasons children who underwent an SS presented to the hospital, (3) the reasons an SS were performed, and (4) the proportions of SSS that resulted in the identification of unsuspected fractures. For the subset of patients with positive SS results, we also sought to describe how often the SS results influenced directly the decision to make a diagnosis of abuse."	Not relevant PICO, index test	Not relevant PICO, reference test "Each case in which the SS results were positive was classified as definite abuse, probable abuse, possible abuse, or not abuse on the basis of the conclusion of the Children's Hospital of Pittsburgh child protection team (CPT). Use of the findings of a CPT to define whether an injury is attributable to abuse is a commonly used standard (13-15) and one that our group used in previous studies. (16-18) The CPT was consulted in every case in which there was a positive SS result, and there was no disagreement within the CPT about the classification of abuse for any of the subjects in the study. For purposes of analysis, children with definite	.

			abuse or probable abuse had a diagnosis of abuse; children with possible abuse or no abuse had no diagnosis of abuse. Our decision to subcategorize in this way was based on data from a previous study by our group that evaluated the cost of child maltreatment (19). In this study, children with possible abuse were most similar to subjects with no abuse, whereas subjects with probable abuse were most similar to subjects with definite abuse."	
2506	Spring A. 2011. Temporary brittle bone disease versus suspected non-accidental skeletal injury. <i>Archives of Disease in Childhood</i> , 96(5), 411-3.	Non-systematic review (No description how articles were searched or included)		
2512	Maguire S. 2010. Which injuries may indicate child abuse? <i>Archives of Disease in Childhood. Education and practice edition</i> , 95(6), 170-177.	Non-systematic review (No description how articles were searched or included)		Rib fractures
2515	Pandya NK, Baldwin K, Kamath AF, Wenger DR, Hosalkar HS. 2011. Unexplained fractures: child abuse or bone disease? A systematic review. <i>Clinical Orthopaedics and Related Research</i> , 469(3), 805-812.	Systematic review Objective: To "determine which bone diseases most commonly mimic CAN (Child abuse and neglect, <i>my comment</i>): (2) what types of osteogenesis imperfecta (OI) are most commonly confused with CAN and why; and (3) what specific findings in OI and bone disease render a mistaken diagnosis of CAN more likely."		CML
2517	Mulpuri K, Slobogean BL, Tredwell SJ. 2011. The epidemiology of nonaccidental trauma in children. <i>Clinical Orthopaedics and Related Research</i> , 469(3), 759-767.	Systematic review Objective: "(1) what is the general incidence of NAT (Non-accidental trauma, <i>my comment</i>): (2) what factors are intrinsic to the abused child, family, and society; and (3) what orthopaedic injuries are common in NAT?"		CML + Rib

2523	Perez-Rossello JM, Connolly SA, Newton AW, Zou KH, Kleinman PK. 2010. Whole-body MRI in suspected infant abuse AJR. <i>American Journal of Roentgenology</i> , 195(3), 744-750.	Not relevant PIRQ, outcome Objective: To "examine the utility of whole-body MRI (WB-MRI) in the detection of skeletal and soft tissue injuries in suspected infant abuse".	Not relevant PIRQ, reference test "All the patients (N=21, <i>my comment</i>) were being evaluated by the hospital's child protection services team, composed of pediatricians, radiologists, and social workers. Infants who were referred to the child protection team were presented by caretakers with a mechanism of injury that could not explain the clinical and radiologic findings in the patient. Injuries that raised suspicion for physical abuse were subdural hemorrhages, cerebral edema, retinal hemorrhages, and highly specific fractures for abuse such as classic metaphyseal lesions, rib fractures and multiple fractures, and different stages of healing. The child protection team and the department of social services conducted an evaluation of the child's home. In our series of cases, the child protection team concluded 20 infants had been physically abused. One infant initially was thought abused and while in foster care was diagnosed with osteogenesis imperfecta."	No statistics on how many infants with fractures, only number of rib fractures and CMLs.	CML + Rib
2531	Adamsbaum C, Grabar S, Mejean N, Rey-Salmon C. 2010. Abusive head trauma: judicial admissions highlight violent and repetitive shaking. <i>Pediatrics</i> , 126 (3), 546-555.	Observations (<10) 5 cases with rib fractures, 3 with CML			
2550	Dwek JR. 2011. The radiographic approach to child abuse. <i>Clinical Orthopaedics and Related Research</i> , 469(3), 776-789.	Systematic review Objective: "I detail the radiographic imaging of the more characteristic of the highly specific injuries, discuss the major issues that relate to some moderate- or low-specificity injuries, and describe several diseases that mimic abuse."			

2551	Leventhal JM, Martin KD, Asnes AG. 2010. Fractures and traumatic brain injuries: abuse versus accidents in a US database of hospitalized children. <i>Pediatrics</i> , 126(1), e104-15.	Not relevant PIRQ, index test	Not relevant PIRQ, reference test "Child abuse was defined by using an ICD-9-CM code for abuse (code 995.5) or an E-code for assault (codes E960 – E969). Cases whose only abuse definitions were for emotional or psychological abuse (code 995.51), nutritional neglect (code 995.52), or sexual abuse (code 995.53) were not counted as abuse. Accidental injuries included 3 main groups, that is, (1) accidental falls (codes E880–E888), (2) other accidents (eg, struck by a falling object or against an object or person) (codes E916–E928), and (3) motor vehicle accidents (MVAs) and related accidents (codes E810–E829). The remaining cases with injuries were classified in the following groups: (1) cases with no E-codes, (2) cases with a fracture with unspecified cause (code E887), (3) cases in which it was not determined whether the injury was accidental or intentional (codes E980–E989), and (4) cases in which the coding indicated a birth injury (code 767) or an underlying medical condition, such as osteogenesis imperfecta (code 756.51) or rickets (code 268.0)."		.
2555	Paterson CR. 2010. Bone disorders that cause fractures and mimic non-accidental injury. <i>Acta Paediatrica</i> , 2010; 99 (9): 1281-2.	Letter to editor			
2575	Jenny C. 2010. Multiple unexplained fractures in infants - the need for clear thinking. <i>Acta Paediatrica</i> , 99 (4): 491-3.	Commentary			

2576	Spivack BS, Otterman GJ. 2010. Does temporary brittle bone disease exist? Not by the evidence offered. <i>Acta paediatrica</i> , 99 (4): 486.	Letter to editor			
2582	Drubach LA, Johnston PR, Newton AW, Perez-Rossello JM, Grant FD, Kleinman PK. 2010. Skeletal trauma in child abuse: detection with 18F-NaF PET. <i>Radiology</i> , 255(1), 173-181.	Not relevant PIRQ, outcome Objective: To evaluate the sensitivity of fluorine 18-labelled sodium fluoride (18 F-NaF) positron emission tomography (PET) for assessment of skeletal trauma in pediatric patients suspected of having been abused and to compare the diagnostic performance of this examination with that of high-detail skeletal survey.	Not relevant PIRQ, reference test "These examinations were performed as part of the evaluation of skeletal trauma in pediatric patients who were suspected of having been abused and were referred by our hospital's child protection team."		CML + Rib
2587	Alexander R, Barr RG, Block R, Case M, Chadwick DL, Holmgren B, Jenny C, Leventhal JM, Levin A, Reece R, Wheeler P, Barr M. 2010. Evidence outweighs belief. <i>Minnesota Medical</i> , 2010; 93 (1): 5-6.	Letter to editor			
2595	Jayakumar P, Barry M, Ramachandran M. 2010. Orthopaedic aspects of paediatric non-accidental injury. <i>The Journal of Bone and Joint Surgery. British volume</i> , 92 (2): 189-95.	Non-systematic review (No description how articles were searched or included)			CML + Rib
2599	Marcovitch H, Mughal MZ. 2010. Cases do not support temporary brittle bone disease. <i>Acta Paediatrica</i> , 99 (4): 485-6.	Letter to editor			
2602	Degraw M, Hicks RA, Lindberg D. 2010. Incidence of fractures among children with burns with concern regarding abuse. <i>Pediatrics</i> , 125 (2): e295-9.	Not relevant PIRQ, population <5 years of age	Not relevant PIRQ, reference test Included in the study was children who underwent subspecialty evaluation because of concern for physical abuse. Consultation was considered to have occurred if a child abuse consultant had performed any of the following: (1) written a note in the medical record, (2) performed a physical examination, or (3) recommended	Not relevant PIRQ, outcome Objective: Determine the prevalence of fractures in children referred for subspecialty abuse because of burns.	CML + Rib

			diagnostic or therapeutic management. All subjects undergoing consultation were included, regardless of the ultimate level of concern regarding abuse.		
2614	Ravichandiran N, Schuh S, Bejuk M, Al-Harthi N, Shoudice M, Au H, Boutis K. 2010. Delayed identification of pediatric abuse-related fractures. <i>Pediatrics</i> , 125 (1): 60-6.	Not relevant PIRQ, outcome Objective: The primary objective of this study was to determine how frequently abusive fractures were missed by physicians during previous examinations. A secondary objective was to determine clinical predictors that are associated with unrecognized abuse.	Not relevant PIRQ, reference test Fractures were determined to be abusive when at least 1 of the following criteria was met: (1) confession of intentional injury by an adult caregiver; (2) inconsistent/inadequate history provided; (3) inappropriate delay in seeking medical care; (4) associated inadequately explained injuries; (5) in the absence of bone disease, presence of fractures uncommon for accidental injury and frequently reported in abusive injury (eg, metaphyseal limb fractures, posterior rib fractures not caused by birth trauma); and (6) witness to abuse came forward. A case was considered "recognized" when a referral to local child protection authorities was made the first time the child presented to a physician with the index fracture(s). This is in contrast to "missed" when the child had at least 1 physician encounter for the index fracture(s) before the visit when the abuse was confirmed. In all missed cases, the signs and symptoms compatible with a fracture and/or a radiograph diagnosis were present at the initial visit, but the possibility of abuse was not raised. Thereafter, 21 of the following occurred: (1) the child improved clinically but experienced repeat trauma and the HSC SCAN team	Not relevant PIRQ, index test	.

			found the previous fracture(s) abusive; (2) recognition of red flags and referral to the SCAN team at a routine follow-up for the index fracture(s) led to recognition of abuse; (3) the child's continued symptoms resulted in repeat unscheduled visits and a referral to the SCAN team with recognition of the index fracture(s) as abuse-related; (4) the index radiographs initially read as normal by the primary treating physician were found by a radiologist to have a fracture that required a repeat visit, when the suspicion for abuse was raised; (5) the perpetrator later confessed or a witness came forward; and/or (6) abuse was suspected in a sibling and review of the patient's fractures yielded abuse as the cause. The determination of missed versus recognized cases was made independent of the knowledge of potential predictors. "		
2628	Erfurt C, Hahn G, Roesner D, Schmidt U. 2009 [Pediatric radiological diagnostics in suspected child abuse]. <i>Der Radiologe</i> , 49 (10): 932, 934-41.	Non-systematic review (No description how articles were searched or included)		Rib fracture	
2635	Love JC, Sanchez LA. 2009. Recognition of skeletal fractures in infants: an autopsy technique. <i>Journal of Forensic Sciences</i> , 54 (6): 1443-6.	Not relevant PIRQ (outcome) Objective: "This article describes an autopsy technique that enables the pathologist to grossly examine the ribs, scapulae, and long bones, including the costal osseous junctions (COJ), increasing the likelihood of fracture recognition. "		CML + Rib	
2636	Strouse PJ. 2009. Vitamin D deficiency vs. child abuse: what do we know now and where do we go? <i>Pediatric Radiology</i> , 39(10): 1033.	Editorial			

2638	Pandya NK, Baldwin K, Wolfigruber H, Christian CW, Drummond DS, Hosalkar HS. 2009. Child abuse and orthopaedic injury patterns: analysis at a level I pediatric trauma center. <i>Journal of Pediatric Orthopedics</i>, 29(6), 618-625.	Not relevant PIRQ, reference test "Patients were included in the SCAN database (Suspected Child Abuse and Neglect database, <i>my comment</i>) if hospital personnel determined that the patient was a victim of abuse or neglect. The SCAN team consisted of an independent team of physicians, nurses, and social workers with advanced training in child abuse that examined these children in the emergency room and made the determination if the patients should be included in the SCAN database as a victim of abuse (and subsequently activated mechanisms for child protective services at the time of evaluation). Patients were included in the general trauma database if they presented to the emergency room and were hospitalized with organ system trauma that necessitated an evaluation from the hospital's trauma service, died in the emergency department as a result of their traumatic injuries, or were initially seen in the emergency department and transferred to another trauma center for management of traumatic injuries" "Patients were included in the study as a child abuse case by membership in the SCAN database. Patients were included in the study as a control (accidental) trauma case if they were found in the general trauma database, and were also not found in the SCAN database. Patients were excluded from the study if ... adequate determination could not be made if the case represented child abuse or accidental injury due to incomplete medical records".			Rib fracture
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2639	Lee EY, Kritsaneeapaiboon S, Zurakowski D, Arellano CM, Strauss KJ, Boiselle PM. 2009. Beyond the pulmonary arteries: alternative diagnoses in children with MDCT pulmonary angiography negative for pulmonary embolism. <i>American Journal of Roentgenology</i> , 193 (3): 888-94.	Not relevant PIRQ (all) Objective: To "determine the frequency and types of alternative diagnoses identified in children with clinically suspected but excluded PE".				Rib fracture
2646	Miller M. 2009. The death of temporary brittle bone disease is premature. <i>Acta Paediatrica</i> , 98 (12): 1871-3.	Commentary on Paterson (2009)				
2652	Paterson CR. 2009. Vitamin D deficiency rickets and allegations of non-accidental injury. <i>Acta Paediatrica</i> , 98 (12): 2008-12.	Case report: 4 cases of fractures, including CML and rib fractures, attributed to rickets.				CML + Rib
2654	Lubicky JP, Feinberg JR. 2009. Fractures and amputations in children and adolescents requiring hospitalization after farm equipment injuries. <i>Journal of Pediatric Orthopaedics</i> , 29(5), 435-8.	Not relevant PIRQ, outcome Objective: To "report the incidence of children requiring hospitalization for orthopaedic trauma after injury secondary to farm equipment accidents."	Not relevant PIRQ, population 0-20 years, with two sub groups, <12 and >12 years.	Not relevant PIRQ, reference test "children with diagnostic codes for fractures, excluding skull fractures, or amputations and a diagnostic code indicating the external cause of injury to be agricultural machine-related (E919.0) were culled".	Observations <10 (Approximately 8 infants < 1 year)	Rib fracture
2660	Maguire S, Pickerd N, Farewell D, Mann M, Tempest V, Kemp AM. 2009. Which clinical features distinguish inflicted from non-inflicted brain injury? A systematic review. <i>Archives of Disease in Childhood</i> , 94(11), 860-867.	Not relevant PIRQ, reference test 1. Abused confirmed at case conference or civil, family or criminal court proceedings or admitted by the perpetrator, or independently witnessed. 2. Abuse confirmed by stated criteria including multi-disciplinary assessment.	Not relevant PIRQ, population	Systematic review Objective: To investigate "What are the clinical features that distinguish inflicted from non-inflicted brain injury?".		Rib fracture
2663	Boele van Hensbroek P, Mulder S, Luijckx JS, van Ooijen MR, Goslings JC. 2009. Staircase falls: high-risk groups	Not relevant PIRQ, population 0-91 year, subgroup < 5 years	Not relevant PIRQ, reference test "For the purpose of this study, two injury databases were combined". "The	Not relevant PIRQ, outcome Objective: To "describe the epidemiology and injury		Rib fracture

	and injury characteristics in 464 patients. <i>Injury</i> , 40(8), 884-889.		trauma mechanism was manually confirmed (MRVO and PBvH) in the medical records of all selected patients. Several relevant variables (e.g., height of the fall, alcohol intoxication and suspicion of child abuse) were not recorded in either database. These data were retrieved from the medical records." Child abuse: "Of the 109 children (i.e., <18 years old), 77 children (71%) were evaluated for child abuse. In three children (4%), the suspicion of child abuse was raised. In one of these cases the attending paediatrician was notified to further evaluate the case."	pattern amongst patients with staircase falls reporting to the A&E department of a hospital and to compare these data with those available at the national level. In doing so, we attempted to gain further insight into the problem of staircase falls thereby helping to create a guide for future prevention programmes".	
2666	Weber MA, Risdon RA, Offiah AC, Malone M, Sebire NJ. 2009. Rib fractures identified at post-mortem examination in sudden unexpected deaths in infancy (SUDI). <i>Forensic Science International</i> , 189(1-3), 75-81.	Not relevant PIRO, reference test "Further specific details were extracted from the database for infants in whom rib fractures were identified, including whether the fractures were identified radiologically prior to the autopsy, the number and distribution of the fractures, comments on radiological and histopathological dating of the fractures, as well as the presence of other associated abnormalities suggestive of NAI detected at post-mortem examination. For the purposes of this study, NAI was defined as the presence of demonstrable injuries not explained by the clinical history, the suspicion having been raised either at clinical presentation or by the pathologist at the time of the post-mortem examination, and was not based on the outcomes of medicolegal or criminal proceedings. Deaths in which the injuries were deemed insufficiently severe			Rib fracture

		to account for the sudden death of the infant were classified as 'undetermined.' "			
2680	Kleinman PK, Sarwar ZU, Newton AW, Perez-Rossello JM, Rebello G, Herliczek TW. 2009. Metaphyseal fragmentation with physiologic bowing: a finding not to be confused with the classic metaphyseal lesion. <i>AJR. American Journal of Roentgenology</i> , 192(5), 1266-1268.	Not relevant PIRO, population <3 years: first documentation mean age: 18 months, range 15-26 months.	Not relevant PIRO, outcome Objective: To "describe the varied appearance of metaphyseal fragmentation associated with physiologic bowing and to estimate their frequency among children undergoing radiographic evaluation".	Not relevant PIRO, reference test Differential diagnosis. Normal variants of metaphysis.	Rib fracture
2687	Bullock DP, Koval KJ, Moen KY, Carney BT, Spratt KF. 2009. Hospitalized cases of child abuse in America: who, what, when, and where. <i>Journal of Pediatric Orthopedics</i> , 29(3), 231-237.	Not relevant PIRO, index test rib + sternal fracture in one subgroup, CML not mentioned	Not relevant PIRO, reference test "Cases coded for child abuse were defined as any patient within the population of interest who had been given at least 1 specific ICD-9 code for child abuse (995.5x) or a Supplementary Classification of External Causes of Injury and Poisoning code (E Codes) identifying a perpetrator of child abuse (E967.x). (13) Cases of accidental injury were defined as any patient within the population of interest who did not have either mode of coding for child abuse present."	Not relevant PIRO, population Inclusion <18 years. Subgroup <1 year, but no statistics on specific fractures in this age group.	.
2708	Feldman KW. 2009. The bruised premobile infant: should you evaluate further? <i>Pediatric Emergency Care</i> , 25(1), 37-39	Case report: 3 cases of infants with bruising, 2 with rib fractures +1 suggestive CML, 1 haemophilia			Rib fracture
2717	Oral R, Yagmur F, Nashefsky M, Turkmen M, Kirby P. 2008. Fatal abusive head trauma cases: consequence of medical staff missing milder forms of physical abuse. <i>Pediatric Emergency Care</i> , 24(12), 816-821.	Not relevant PIRO, outcome Objective: "Missed diagnosis of child abuse may lead to chronic abuse with potential for death. This paper reports 3 such cases."	Observations (<10) 3 cases, cases missed diagnosis of abusive head trauma with fatal outcome, 1 with multiple rib fractures, 1 CML.	Not relevant PIRO, reference test "convicted of involuntary manslaughter". (One case admitted, but not the cases with skeletal fractures.) "The University of Iowa Children's Hospital Child Protection Consultation Team database was reviewed for cases with AHT who were younger than 4	CML + Rib

			years and admitted to the hospital between January 1, 2004 and December 31, 2006. Thirty-eight cases were identified. These cases were diagnosed with AHT by the hospital's Child Protection Consultation Team consisting of a child abuse specialist, a social worker, an attending physician from the pediatric intensive care unit (PICU), a pediatric neurologist/neurosurgeon, and a pediatric radiologist. In all the cases, the diagnosis was substantiated as AHT by the Child Protection Services (CPS). To determine the rate of missed diagnosis of abusive trauma in the past medical history of the cases before their most recent admission, a retrospective review of the following records was performed: (1) electronic and paper documentation notes for the last admission, (2) local/regional multidisciplinary team meeting minutes, and (3) local medical records of previous hospitalizations or emergency department (ED) visits provided to the team by CPS. " "Three of these cases (7.9%) had a fatal outcome. The details of the course of child abuse in these 3 fatal cases are reported in this paper."	
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2724	Tsuji M, Hirata H, Hasegawa M, Uchida A. 2008. An infant with unexplained multiple rib fractures occurring during treatment in a neonatal intensive care unit. <i>The Turkish Journal of Pediatrics</i> , 50(4), 377-379.	Case report: 1 case, multiple rib fractures without superficial injury during car in neonatal intensive care unit attributed to temporary brittle bone disease.			Rib fracture
2728	Valvano TJ, Binns HJ, Flaherty EG, Leonhardt DE. 2009. Does bruising help determine which fractures are caused by abuse? <i>Child Maltreatment</i> , 14(4), 376-381.	Not relevant PIRQ, reference test "Bruises and fractures were categorized by location (right or left: hand, forearm, proximal arm, foot, foreleg, and proximal leg; pelvis, torso, head/neck). Torso fractures were further classified as clavicle, scapula, rib, or vertebral, and pelvic fractures were classified as pelvic bone or vertebral. Each fracture was also categorized by type (e.g., transverse, spiral/oblique, metaphyseal). Written summaries for each case, excluding information on bruising, were prepared by one investigator (TV) and reviewed by a child abuse expert (DL or EF) to assign cause of injury. Using previously developed criteria (including history inconsistent with injury, multiple injuries, injuries indicative of abuse, sibling abused, perpetrator admission, eyewitness; Strait et al., 1995; Thomas, Rosenfield, Leventhal, & Markowitz, 1991) modified to exclude consideration of the existence of bruises, the experts assigned children to one of three groups, namely, abused, indeterminate, and nonabused. Both experts reviewed 11% of the chart summaries for internal consistency and achieved 100% agreement."			"Metaphyseal fractures" + Rib
2734	van Rijn RR, Bilo RA, Robben SG. 2009. Birth-related mid-posterior rib fractures in neonates: a report of	Non-systematic review (No description how articles were searched or included)	Case report: 4 cases, posterior rib fractures in infants, attributed to birth trauma		Rib fracture

	three cases (and a possible fourth case) and a review of the literature. <i>Pediatric Radiology</i> , 39(1), 30-34.				
2744	Kemp AM, Dunstan F, Harrison S, Morris S, Mann M, Rolfe K, Datta S, Thomas DP, Sibert JR, Maguire S. 2008. Patterns of skeletal fractures in child abuse: systematic review. <i>BMJ</i> , 337:a1518.	Systematic review Objective: "To systematically review published studies to identify the characteristics that distinguish fractures in children resulting from abuse and those not resulting from abuse, and to calculate a probability of abuse for individual fracture types".			Rib fracture
2745	Kelloff J, Hulet R, Spivey M. 2009. Acute rib fracture diagnosis in an infant by US: a matter of child protection. <i>Pediatric Radiology</i> , 39(1), 70-72.	Case report: 1 case, infant with multiple rib fractures attributed to abuse, diagnosed with ultrasound.			Rib fracture
2746	Keller KA, Barnes PD. 2008. Rickets vs. abuse: a national and international epidemic. <i>Pediatric Radiology</i> , 38(11), 1210-1216.	Commentary on O'Connell & Donoghue (2007)			CML + Rib
2747	Chesney RW. 2008. Rickets or abuse, or both? <i>Pediatric Radiology</i> , 38(11), 1217-1218.	Commentary on Keller & Barnes (2007)			
2748	Slovic TL, Chapman S. 2008. Evaluating the data concerning vitamin D insufficiency/deficiency and child abuse. <i>Pediatric Radiology</i> , 38(11), 1221-1224.	Commentary on O'Connell & Donoghue (2007) and Keller & Barnes (2007)			CML + Rib
2749	Jenny C. 2008. Rickets or abuse? <i>Pediatric Radiology</i> , 38(11), 1219-1220.	Commentary on Keller & Barnes (2007)			
2755	Peters ML, Starling SP, Barnes-Eley ML, Heisler KW. 2008. The presence of bruising associated with fractures. <i>Archives of Pediatric and Adolescent Medicine</i> , 162(9), 877-881.	Not relevant PIRQ, reference test "Infants and children were eligible for inclusion if they had been admitted to the hospital with a formal consult made to the inpatient medical child abuse and neglect consultation service and subsequently were determined to have been abused. Determination of the presence or absence of abuse was made by the hospital-based	Not relevant PIRQ, index test "Metaphyseal fractures"; not clarified if this is equivalent to CML, limited statistics on rib fractures - only number of fractures.		"Metaphyseal fractures" + Rib

		multidisciplinary team for each study site." (ONE admitted)			
2756	Leventhal JM, Martin KD, Asnes AG. 2008. Incidence of fractures attributable to abuse in young hospitalized children: results from analysis of a United States database. <i>Pediatrics</i> , 122(3), 599-604.	Not relevant PICO, reference test Kids' inpatients database includes most states in the US. "Child abuse was identified by the presence of an E-code for assault (codes E960 –E969) or the ICD-9-CM diagnosis code for child maltreatment syndrome (code 995.5). In addition, we used E-codes to categorize the cause of fractures, as follows: falls, motor vehicle accidents, other accidents (eg, colliding with a person or object), uncertain whether the injury was accidental or intentional, bone abnormalities, metabolic abnormalities, birth trauma, or no injury E-code.			Rib fracture
2758	Dedout F, Guilbeau-Frugier C, Capuani C, Sevely A, Joffre F, Rouge D, Rousseau H, Telmon N. 2008. Child abuse: practical application of autopsy, radiological, and microscopic studies. <i>Journal of Forensic Sciences</i> , 53(6), 1424-1429.	Case report: 1 case, illustrates the valuable assistance rendered by multisliced computed tomography (MSCT) and magnetic resonance imaging (MRI) to diagnose abuse when a child has died under unclear circumstances.	Not relevant PICO, population	Not relevant PICO, reference test	Rib fracture
2766	Mok JY. 2008. Non-accidental injury in children--an update. <i>Injury</i> , 39(9), 978-985.	Non-systematic review (No description how articles were searched or included)			
2768	Kleinman PK. 2008. Problems in the diagnosis of metaphyseal fractures. <i>Pediatric Radiology</i> , 38 Suppl, 3S388-94.	Non-systematic review (No description how articles were searched or included)			
2776	Wootton-Gorges SL, Stein-Wexler R, Walton JW, Rosas AJ, Coulter KP, Rogers KK. 2008. Comparison of computed tomography and chest radiography in the detection of rib fractures in abused infants. <i>Child Abuse & Neglect</i> , 32(6), 659-663	Not relevant PICO, outcome Purpose: To compare computed tomography (CT) and chest radiography (CXR) in the evaluation of rib fractures in abused infants.	Not relevant PICO, reference test Search in the medical record database for child abuse. "The study group included all infants less than 12 months of age who had confirmed non-accidental trauma and who had both of the following: (1) a two-view (frontal and lateral) chest radiography	Only statistics on how many rib fractures, location and stage, not how many in each case/infant.	Rib fracture

			(CXR) and a computed tomography (CT) scan of either the abdomen or chest obtained at clinical presentation; and (2) documentation of at least one rib fracture by either method." (No description how non-accidental trauma was confirmed).		
2783	Ribe JK, Changsri C. 2008. A case of traumatic osteomyelitis in a victim of child abuse. <i>The American Journal of Forensic Medicine and Pathology</i> , 29(2), 164-166.	Case report: 1 case, infant with multiple fractures, including multiple lateral and costochondral junction fractures, chronic subdural hematoma, osteomyelitis and bronchopneumonia attributed to child abuse.			Rib fracture
2785	Drubach LA, Sapp MV, Laffin S, Kleinman PK. 2008. Fluorine-18 NaF PET imaging of child abuse. <i>Pediatric Radiology</i> , 38(7) 776-779	Case report: 1 case, infant of suspected abuse with multiple fractures including CML and rib fractures, visualised by Fluorine-18 NaF PET-scan.			CML + Rib
2801	Hansoti B, Beattie TF. 2008. Limb fractures and nonaccidental injury in children less than 24 months of age. <i>European Journal of Emergency Medicine</i> , 15(2), 63-66.	Not relevant PIRO, index test	Not relevant PIRO, reference test "five patients being referred for child-protection investigation, all of whose names were entered into the child-protection register. All the remaining fractures were considered to have a genuine accidental aetiology. To our knowledge, no child has subsequently had child abuse diagnosed." "In all five referred patients, the main cause of concern was that no convincing cause could be found for the injury rather than for the actual fracture type."		.
2822	Miller M. 2008. Another perspective on the cause of metaphyseal fractures. <i>Pediatric Radiology</i> , 38(5), 598-599; author reply 600.	Letter to editor: Reply on O'Connell & Donoghue (2007) #2890			CML
2834	Hansen KK, Prince JS, Nixon GW. 2008. Oblique chest views as a routine part of skeletal surveys performed for possible physical abuse--is this practice worthwhile?	Not relevant PIRO, outcome Objective: To "evaluate the utility of oblique chest views in the diagnosis of rib fractures when used as a routine part of the	Not relevant PIRO, reference test "To identify cases we reviewed the child protection team database for possible physical abuse consults that had skeletal surveys performed and		Rib fracture

	<i>Child Abuse & Neglect</i> , 32(1), 155-159.	skeletal survey performed for possible physical abuse".	interpreted at Primary Children's Medical Center. "Those with rib fractures were selected. "Comprehensive evaluation by the multidisciplinary child abuse team had diagnosis 'abuse' in 21 of these cases and 'not abuse' in 1 case with metabolic bone disease. These cases was included in analysis of the two-view versus for view chest series as a diagnosis of 'abuse' or 'not abuse' is not relevant to the radiographic interpretation of rib fractures."		
2851	Arkader A, Friedman JE, Warner WC, Jr., Wells L. 2007. Complete distal femoral metaphyseal fractures: a harbinger of child abuse before walking age. <i>Journal of Pediatric Orthopedics</i> , 27(7), 751-753.	Not relevant PIRO, index test Complete distal femoral metaphyseal fracture, corner fractures excluded.	Not relevant PIRO, reference test "The mechanism of injury and the past medical history, including previous hospitalizations and pediatrician notes, were carefully reviewed, and all suspicious cases underwent evaluation by the suspected child abuse or neglect (SCAN) team or social worker. The diagnosis of child abuse was made based on the criteria developed by the respective state (Child Protective Services Law). Each institution has a regulatory policy to attend to all criteria required for child abuse diagnosis." "All children, whose described mechanism of injury was doubtful, were screened by the SCAN team or social worker. Results of the initial inquiry demonstrated that the mechanism of injury was attributed to 10 children (50%) having confirmed history of abuse (eg, caregiver admitted the abuse, previous suspicion, or history of abuse), whereas 5 (25%) children were considered to be highly suspicious for		.

			suffering abuse. The 5 suspicious cases of seemingly nonaccidental or intentional injuries involved scenarios such as the child falling with a parent, a parent tripping over the child, or the child falling from the parent's lap. The remaining 5 children (25%) had acceptable accidental mechanism of injury and were not subjected to additional screening. Those acceptable causes included birth trauma (1), fall from sister's lap (1), fall from a swing, (1), fall from the bed (1), and a motor vehicle accident (1). A summary of these results, including the treatment, is organized and can be found in Table 1. Of the 20 fractures, 15 (75%) were believed to have been caused by child abuse. Among the 9 children older than 1 year old (ie, past walking age) who had a complete distal femoral metaphyseal fracture, none showed any signs of child abuse. All of the fractures were caused by typical injury-related accidents."		
2855	Walsh J, Reardon W. 2008. Job syndrome masquerading as non-accidental injury. <i>Archives of Disease in Childhood</i> , 93(1), 65-67.	Case report: 1 case, multiple fractures including 2 rib fractures in infant with Jobs syndrome.		Rib fracture	
2878	Loder RT, Feinberg JR. 2007. Orthopaedic injuries in children with nonaccidental trauma: demographics and incidence from the 2000 kids' inpatient database. <i>Journal of Pediatric Orthopedics</i> , 27(4), 421-426	Not relevant PIRQ, reference test "Data for this study was culled from the 2000 KIDS database using the International Classification of 6 Diseases, Ninth Revision, Clinical Modification(ICD-9-CM) codes for musculoskeletal and related injuries (Table 1) and the supplemental codes for identification of the perpetrator of abuse (E967). Children having the E967 code on discharge are, as best as can be	Not relevant PIRQ, index test Statistics only for fractures in rib and sternum, CML not mentioned.	Rib fracture	

		ascertained, definite victims of child abuse as determined by the appropriate hospital channels (eg, child protection team) in concert with the county/state Child Protective Service agency for each of the hospitals. By selecting only the children with this E967 code, potential or questionable cases of child abuse are excluded, making this data set as accurate and clean as possible and consisting only of abused children. " "This KIDS database includes a sampling of all hospital discharges for patients younger than 21 years during the year 2000." 45 % "Unspecified" perpetrator.		
2886	Lane WG, Dubowitz H. 2007. What factors affect the identification and reporting of child abuse-related fractures? <i>Clinical Orthopaedics and Related Research</i> , 461:219-461:225.	Not relevant PIRO, outcome Objective: Survey to examine how skilled orthopaedist are to identify abuse-related fractures and make appropriate child protective service reports, and if the decision is influenced by the orthopaedist training, or race/socioeconomic status of the child.		Rib fracture
2888	Leventhal JM, Larson JA, Abdo D, Singarachari S, Takizawa C, Miller C, Goodman TR, Schwartz D, Grasso S, Ellingson K. 2007. Are abusive fractures in young children becoming less common? Changes over 24 years. <i>Child Abuse & Neglect</i> , 31(3), 311-322.	Not relevant PIRO, population <36 months (but median age for abused group <1 year).	Not relevant PIRO, reference test "To distinguish between abusive and accidental injuries, each case was rated using a seven-point scale. The scale (Table 1) consisted of three levels of confidence for abuse (definite, likely, and questionable), three levels of confidence for unintentional injury (definite, likely, and questionable), and a middle category of unknown. Each level was defined by explicit criteria that were developed prior to performing any review of records (Thomas, Rosenfield, Leventhal, & Markowitz, 1991). In the analysis, the three levels of abusive ratings were	Rib fracture

			collapsed into one (“abuse”) and the three levels of unintentional injury were collapsed into one (“unintentional”). In addition, to provide a more conservative definition of abuse, analyses also were conducted by defining abuse to include only the definite or likely categories of abuse and unintentional injury to include only the definite or likely categories of unintentional injury. Each case was rated independently by two clinicians. When disagreements occurred, the case was discussed and a consensus was agreed upon. One clinician was a child abuse expert and rated the cases in all three time periods. The second clinician was a different person in each time period. Two pediatric radiologists reviewed each radiograph or CT scan and described the fracture and rated the likelihood of abuse using a scale similar to the one shown in Table 1. To minimize bias in the reading of radiographs, the radiologists were provided with a limited history (e.g., 10-month-old fell down the stairs in a walker) and the child’s age, but no information about the child’s demographics or who brought the child for care. When the radiologists disagreed on the description or rating, the case was discussed and a consensus was developed. The cases from each time period were rated by a different set of two pediatric radiologists. The final ratings presented in this paper were based on	
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			a consensus of the clinicians' and radiologists' ratings. When disagreements occurred, the case was discussed and a consensus rating was agreed upon. In some cases, an agreement could not be reached, and these cases were rated as "unknown." Table 1: Criteria used by clinicians to distinguish abuse from unintentional injuries <i>Definite abuse:</i> Eyewitness. Positive skeletal survey. Physical findings (e.g., bruises or burns). <i>Likely abuse:</i> Original doctors called injury abuse and history inconsistent. History not sufficient for injury and/or history of accident change. <i>Questionable abuse:</i> History inconsistent. History for accident changes. Inappropriate delay in seeking care. <i>Questionable unintentional injury:</i> Isolated incident, social worker/physician no suspicion of abuse, history somewhat inconsistent with extent of injury, but consistent with type of injury. History somewhat inconsistent with extent of injury, social worker/physician no suspicion of abuse, neglect involved Isolated incident, no suspicion of abuse, story not known. <i>Likely unintentional injury:</i> Consistent story, social worker/physician no suspicion of abuse, isolated injury. Consistent story, no suspicion of abuse, neglect involved. Minimal but	
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			consistent story, social worker/physician no suspicion of abuse, isolated incident. <i>Definite unintentional injury</i> : Motor vehicle accident. Multiple witnesses (e.g., police report, ambulance at scene). Pedestrian hit by automobile.		
2890	O'Connell A, Donoghue VB. 2007. Can classic metaphyseal lesions follow uncomplicated caesarean section? <i>Pediatric Radiology</i> , 37(5), 488-491.	Case report : 3 cases, neonates with CML of distal femur attributed to uncomplicated Caesarean section.			CML
2908	Nyweide K, Feldman KW, Gunther DF, Done S, Lewis C, Van Eenwyk C. 2006. Hypocalciuric hypercalcemia presenting as neonatal rib fractures: a newly described mutation of the calcium-sensing receptor gene. <i>Pediatric Emergency Care</i> , 22(11), 722-724.	Case report : 1 case, multiple lateral and anterior rib fractures attributed to birth trauma, in infant with familial hypocalciuric hypercalcemia (FHH) due to mutation in calcium sensing receptor (CaSR) gene.			Rib fracture
2914	Buonuomo PS, Ruggiero A, Zampino G, Maurizi P, Attina G, Riccardi R. 2006. A newborn with multiple fractures as first presentation of infantile myofibromatosis. <i>Journal of Perinatology: official Journal of the California Perinatal Association</i> , 26 (10), 653-5.	Case report : 1 case, multiple "metaphyseal radiolucent lesions" of the long bone and pathological fracture of the femur in a newborn attributed to infantile myofibromatosis.	Not relevant PIRO, index test Metaphyseal radiolucent lesions of the long bone		.
2923	Jenny C. 2006. Evaluating infants and young children with multiple fractures. <i>Pediatrics</i> , 118(3), 1299-1303.	Other : Consensus statement	Non-systematic review (No description on how articles were searched and included)	Other: Consensus statement/guidelines Committee on Child Abuse and Neglect	CML + Rib
2931	Paterson CR, McAllison SJ. 2006. Classical osteogenesis imperfecta and allegations of nonaccidental injury. <i>Clinical Orthopaedics and Related Research</i> , 452:260-452:264.	Other : Case series (N=12 patients) with osteogenesis imperfecta initially diagnosed as non-accidental injury.	Not relevant PIRO, reference test "Four patients had been evaluated using skin biopsies and fibroblast cultures. Three patients had decreased Type I collagen. 15 One of the patients had a mutation detected by polymerase chain reaction and	Observations (<10) Of 12 patients with OI 2 had multiple rib fractures, 1 had "metaphyseal" fracture of the radius (infants). In another table (Table 3) 6 "metaphyseal" fractures were reported.	"Metaphyseal fractures" + Rib

			conformation-sensitive gel electrophoresis sequencing. However, the abnormal findings did not prevent legal proceedings. In one patient (Patient 3) with negative collagen findings, there is now no doubt regarding the accuracy of the diagnosis of osteogenesis imperfecta." One patient was diagnosed by abnormal sclera, large anterior fontanel, wormian bones, and head shape typical for OI. Not clear how the diagnosis was established in all cases.	Differential diagnosis: OI	
2932	Kemp AM, Butler A, Morris S, Mann M, Kemp KW, Rolfe K, Sibert JR, Maguire S. 2006. Which radiological investigations should be performed to identify fractures in suspected child abuse. <i>Clinical Radiology</i> , 61(9), 723-736.	Systematic review: Objective: To "determine the optimal radiological investigations that should be performed to detect fractures in suspected physical abuse and which children should be investigated."			
2944	Maguire S, Mann M, John N, Ellaway B, Sibert JR, Kemp AM. 2006. Does cardiopulmonary resuscitation cause rib fractures in children? A systematic review. <i>Child Abuse & Neglect</i> , 30 (7), 739-751	Systematic review: Objective: "There is a diagnostic dilemma when a child presents with rib fractures after cardiopulmonary resuscitation (CPR) where child abuse is suspected as the cause of collapse. We have performed a systematic review to establish the evidence base for the following questions: (i) Does cardiopulmonary resuscitation cause rib fractures in children? (ii) If so, what are the frequency and characteristics of these fractures that may help to distinguish them from rib fractures caused by physical abuse?"			Rib fracture
2956	Williams R, Hardcastle N. 2006. Best evidence topic reports. Tibial fractures in very young children and child abuse. <i>Emergency Medicine Journal</i> : 23(6), 473-474.	Systematic review: Objective: To "establish whether tibial fractures in very young children are associated with child abuse." (CML not mentioned)			

2957	Gipson CL, Tobias JD. 2006. Flail chest in a neonate resulting from nonaccidental trauma. <i>Southern Medical Journal</i> , 99(5), 536-538.	Case report: 1 case, multiple fractures including left side rib fractures causing flail chest in an infant, attributed to physical child abuse.			Rib fracture
2984	Durani Y, DePiero AD. 2006. Images in emergency medicine. Fracture of left clavicle and left posterior rib due to birth trauma. <i>Annals of Emergency Medicine</i> , 47(2), 210, 215.	Case report: 1 case, 1 posterior rib fracture and 1 clavicle fracture in newborn attributed to birth trauma			Rib fracture
2988	Anilkumar A, Fender LJ, Broderick NJ, Somers JM, Halliday KE. 2006. The role of the follow-up chest radiograph in suspected non-accidental injury. <i>Pediatric Radiology</i> , 36(3), 216-218.	Not relevant PIRO, outcome Objective: To "evaluate the value of the follow-up chest radiograph in suspected non-accidental injury."	Not relevant PIRO, reference test "all children less than 2 years of age who were being investigated for suspected NAI and underwent follow-up chest radiography.		Rib fracture
2992	Fong CM, Cheung HM, Lau PY. 2005. Fractures associated with non-accidental injury--an orthopaedic perspective in a local regional hospital. <i>Hong Kong Medical Journal</i> , 11 (6): 445-51.	Not relevant PIRO, population Mean age: 5 years and 5 months, range: 3 months - 15 years.	Not relevant PIRO, reference test "children admitted to the United Christian Hospital ... with a clinical diagnosis of child abuse" and bone fractures. "All victims of child abuse in our hospital were managed by a team led by a designated Medical Coordinator on Child Abuse—a senior medical officer or above from the Department of Paediatrics and Adolescence. Other members of the team included orthopaedic surgeons, ward nurses, medical social workers, clinical psychologists, the Child Protective Services Unit from the Social Welfare Department, and the Child Abuse Investigation Units of the police in certain cases. Case conferences were conducted in most instances to establish whether the case was one of child abuse and to determine case management, bearing in mind the best interests of the child.(24) A dedicated	Observation <10 (7 cases rib, 3 cases "metaphyseal fractures")	Rib fracture + "metaphyseal fractures"

			group of multi-disciplinary professionals who can devise a comprehensive individual management plan for each child is very beneficial."		
3005	Ghahreman A, Bhasin V, Chaseling R, Andrews B, Lang EW. 2005. Nonaccidental head injuries in children: a Sydney experience. <i>Journal of Neurosurgery</i> , 103(3 Suppl), 213-218.	Not relevant PIRO, reference test "The diagnosis of nonaccidental head injury had been established following investigations by a multidisciplinary Child Protection Team, which consisted of detailed family interviews, multidisciplinary medical and surgical assessments of all injuries, an ophthalmological examination, and exclusion of underlying diseases and accidental injuries".	Not relevant PIRO, outcome Objective: To "evaluate the demographic features, socioeconomic factors, clinical and radiological findings, and progress and outcome of patients with nonaccidental head injury in an Australian population.		Rib fracture
3014	Leestma JE. 2005. Case analysis of brain-injured admittedly shaken infants: 54 cases, 1969-2001. <i>American Journal of Forensic Medicine and Pathology</i> , 26(3), 199-212.	Observation (<10 cases) 5 cases rib fractures	Not relevant study design Review of previously published case reports		Rib fracture
3019	Trinavarat P, O'Charoen P. 2004. Child abuse: radiographic findings at King Chulalongkorn Memorial Hospital. <i>Journal of the Medical Association of Thailand = Chotmaihet thangphaet</i> , 87 Suppl 2S175-8.	Not relevant PIRO, reference test "The diagnoses of abuse were made by the Suspected Child Abuse and Neglect team of the hospital, considering physical examination, psycho-social history, and result of laboratory and radiographic investigation. The sexual abuse, neglect and inconclusive cases were excluded."	Observations (<10) Only 1 case < 1 year with rib fracture (2 more patients >1 year with rib fractures). 2 patients had "metaphyseal fractures". Exact age not stated but a range between 2 and 65 months.		Rib fracture
3035	Cabrerizo de Diago R, Urena-Hornos T, Conde-Barreiro S, Labarta-Aizpun J, Pena-Segura JL, Lopez-Pison J. 2005 [Shaken baby syndrome and osteogenesis imperfecta]. <i>Reviews Neurology</i> , 40 (10): 598-600.	Other: Language Spanish			
3043	Asirdizer M, Zeyfeoglu V. 2005. Femoral and tibial fractures in a child with myelomeningocele. <i>Journal of</i>	Case report: 1 case, 22 months old with femoral and tibial fractures attributed to myelomeningocele.			

	<i>Clinical Forensic Medicine</i> , 12 (2): 93-7.			
3054	Moineau G, Plint A. 2005. Tibial fractures possibly linked to use of a baby stationary activity center. <i>Pediatric Emergency Care</i> , 21 (3): 181-3.	Case report: 1 case, 9 months old with tibial bucket deformity possibly linked to use of a baby stationary activity center.	Not relevant PIRO, index test (buckle deformity, not bucket-handle fracture)	
3056	Spitzer SG, Luomo J, Noel LP. 2009. Isolated subconjunctival hemorrhages in nonaccidental trauma. <i>Journal of AAPOS: the official publication of the American Association for Pediatric Ophthalmology and Strabismus</i> , 9 (1): 53-6.	Case report: 3 cases, infants with subconjunctival hemorrhages, 2 with multiple rib fractures, attributed to chest compression/non-accidental injury.	Not relevant PIRO, reference test	Rib fracture
3061	H V Essen, Schlickewei W, Dietz HG. 2005 [Child abuse]. <i>Der Unfallchirurg</i> , 108 (2): 92-101.	Non-systematic review (No description how articles were search or included)		
3070	Chang DC, Knight V, Ziegfeld S, Haider A, Warfield D, Paidas C. 2004. The tip of the iceberg for child abuse: the critical roles of the pediatric trauma service and its registry. <i>The Journal of Trauma</i> , 57 (6), 1189-1198; discussion 1198.	Not relevant PIRO, reference test "Child abuse cases and their perpetrators were identified by External Injury Codes (E-codes) in the range of 967.0 to 967.9, as defined in the <i>International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)</i> . ICD-9-CM diagnosis codes were examined at the integer level, ignoring any digits after the decimal points. The different digits were used only to specify a more precise description of any injury, such as open versus closed fractures, or contusions with or without loss of consciousness."	Not relevant PIRO, index test (No statistics on rib fractures in <1 year group. Grouped together with sternum, larynx and trachea.)	Rib fracture
3089	Gorincour G, Dubus JC, Petit P, Bourliere-Najean B, Devred P. 2004. Rib peristernal reaction: did you think about chest physical therapy? <i>Archives of Disease in Childhood</i> , 89(11), 1078-1079.	Not relevant PIRO, population <2 years	Observations (<10) 6 cases, with lateral rib fractures/peristernal reaction attributed to physiotherapy.	Rib fracture

3090	Morad Y, Avni I, Benton SA, Berger RP, Byerley JS, Coffman K, Greeley CS, Gustavson EE, Levitt CJ, Lenane A, Topley J, Levin AV. 2004. Normal computerized tomography of brain in children with shaken baby syndrome. <i>Journal of AAPOS: the official publication of the American Association for Pediatric Ophthalmology and Strabismus</i> , 8(5), 445-450.	Observations (<10) 5 cases with rib fractures	Not relevant PIRQ, outcome Objective: To "characterize the clinical presentation and clinical course of shaken baby syndrome (SBS) with normal cranial computerized tomography (CT) on admission and to suggest further diagnostic procedures in such circumstances".	Not relevant PIRQ, reference test Diagnosis of SBS was based on the presence at least two of the following criteria: (1) abnormal neurological examination; (2) skeletal injury consistent with SBS; (3) retinal hemorrhages; and (4) history of child abuse that included shaking with or without blunt head trauma or an inadequate history to explain the observed injuries. We excluded children that were believed to suffer from other forms of child abuse without evidence of SBS. All children were evaluated by multidisciplinary child abuse teams at the hospital where the diagnosis was made.	Rib fracture
3103	Keenan HT, Runyan DK, Marshall SW, Nocera MA, Merten DF. 2004. A population-based comparison of clinical and outcome characteristics of young children with serious inflicted and noninflicted traumatic brain injury. <i>Pediatrics</i> , 114(3), 633-639.	Not relevant PIRQ, reference test Inflicted traumatic brain injury (TBI). "The definition of the outcome, serious or fatal TBI, required evidence, through computed tomography (CT)/magnetic resonance imaging (MRI) or pathology, of intracranial injury including any type of intracranial hemorrhage, shear injury, lacerations, or contusions. Children with skull fractures but no evidence of intracranial injury were excluded. Inflicted TBI required evidence of TBI as defined above, accompanied by a confession documented in the medical record or a medical and child protective services determination that the injury was inflicted. The medical and social services evaluations were performed by the treating team at each hospital or, in the	Not relevant PIRQ, outcome Objective: To "compare inflicted and noninflicted TBI in terms of presenting complaints, clinical features, and hospital outcomes".		Rib + "meta-physal fracture"

		case of deaths, by the Office of the Chief Medical Examiner's (OCME's) forensic pathologists. Cases in which the cause was undetermined were reviewed by 2 of the authors (H.T.K. and D.K.R.), and a determination of cause was made in the manner described below. A witnessed injury was an injury in which >1 person reported that they saw the injury occur." Unknown cause classification: "When no social service or medical information was contained about injury cause in the medical record, the project coordinator prepared an abstract of the case for review by 2 of the investigators (H.T.K., D.K.R.), adapting the method of Stier et al. (14) The abstract included a summary of each case; a description of the cause of injury as presented by the caregiver to the treating physicians; and a description of the injuries, including specific findings such as metaphyseal fractures, retinal hemorrhages, and old injuries found on long-bone studies. Demographic information such as race, gender, referring hospital, and socioeconomic status were not included. Child age was included in the summary as the likelihood of certain reported events are developmentally linked. Each reviewer independently classified the case as inflicted or noninflicted. Intent was determined for 2 cases in this manner. A mechanism was set up to jury any cases in which the 2 investigators did not agree, but the procedure never was required."			
3112	Swischuk LE, Hernandez JA. 2004. Frequently missed fractures in children (value of comparative	Other: Pictorial essay describing (1) plastic bending fractures, (2) hairline fractures, (3) impaction fractures, (4) epiphyseal-	Not relevant PIRQ, index test	Non-systematic review (No description how articles were searched and included.)	

	views). <i>Emergency Radiology</i> , 11(1), 22-28.	metaphyseal Salter-Harris fractures, and (5) subtle angled buckle fractures.		
3119	Lantz P. 2004. Junk science and glass houses. <i>Pediatrics</i> , 114(1), 330; discussion 330.	Letter to editor		
3144	Ricci LR. 2004. Positive predictive value of rib fractures as an indicator of nonaccidental trauma in children. <i>The Journal of Trauma</i> , 56(3), 721; author reply 721-722.	Letter to editor: Reply on Barsness et al (2003)		Rib fracture
3183	Sirilin CB, Brown MA, Deutsch R, Andrade-Barreto OA, Fortlage DA, Hoyt DB, Casola G. 2003. Screening US for blunt abdominal trauma: objective predictors of false-negative findings and missed injuries. <i>Radiology</i> , 229(3), 766-774.	Not relevant PIRQ, outcome, population, index test, reference test Objective: Diagnostic accuracy for ultrasound screening of abdomen.		
3195	Bowley DM, Loveland J, Pitcher GJ. 2003. Tibial fracture as a complication of intraosseous infusion during pediatric resuscitation. <i>The Journal of Trauma</i> , 55(4): 786-7.	Case report: 1 case, tibial fracture in a 2-year-old attributed to intraosseous needle.		
3197	Miller ME. 2003. The lesson of temporary brittle bone disease: all bones are not created equal. <i>Bone</i> , 33(4), 466-474.	Editorial		
3210	Maroteaux P, Le Merrer M. 2003. [Battered or brittle child?] <i>Archives de pédiatrie: organe officiel de la Société française de pédiatrie</i> , 10(8), 679-680.	Editorial		
3222	Barsness KA, Cha ES, Bensard DD, Calkins CM, Partrick DA, Karer FM, Strain JD. 2003. The positive predictive value of rib fractures as an indicator of nonaccidental trauma in children. <i>The Journal of Trauma</i> , 54(6), 1107-1110.	Not relevant PIRQ, reference test "The child Advocacy and Protection (CAP) team (two pediatricians, two social workers, and one physician assistant) evaluated all children with injuries suspicious for NAT, and the decision of the CAP team determined which children were victims	Not relevant PIRQ, population <3 years	Rib fracture

		of abuse. This determination was multifactorial and based on all clinical, physical, psychosocial, and historic information available to the group at the time of patient evaluation."		
3226	Listman DA, Bechtel K. 2003. Accidental and abusive head injury in young children. <i>Current Opinion in Pediatrics</i> , 15(3), 299-303.	Non-systematic review (No description how articles were search or included)		
3227	Smith J. 2003. Shaken baby syndrome. <i>Orthopedic Nursing</i> , 22(3), 196-203; quiz 204-5.	Non-systematic review (No description how articles were search or included) Objective: To summarize issues related to clinical presentation, diagnosis, risk factors, and interventions for health care professionals regarding shaken baby syndrome.		.
3233	Rubin DM, Christian CW, Bilaniuk LT, Zazyczny KA, Durbin DR. 2003. Occult head injury in high-risk abused children. <i>Pediatrics</i> , 111 (6 Pt 1), 1382-1386.	Not relevant PIRQ, outcome Objective: To "estimate the prevalence of occult head injury in a cohort of abused children with high-risk skeletal and soft-tissue injuries. The secondary aim was to describe characteristics of the head injured population and to explore risk factors that might be associated with the presence of an occult head injury" High-risk criteria included: multiple fractures, rib fractures, facial injuries and < 6 months.	Not relevant PIRQ, reference test Children under 2 years of age admitted to an urban children's hospital between January 1998 and December 2001 with injuries suspicious for child abuse were eligible for this study if they had a normal neurologic examination on admission. Subjects were selected if they met 1 of the following "high-risk" criteria: rib fractures, multiple fractures, facial injury, or age <6 months. Subjects were excluded if they had a history of neurologic dysfunction, seizures, respiratory arrest, or if their initial physical examination revealed scalp injury.	Not relevant PIRQ, index test (rib fracture part of the reference test)
3239	Renton J, Kincaid S, Ehrlich PF. 2003. Should helical CT scanning of the thoracic cavity replace the conventional chest x-ray as a primary assessment tool in pediatric trauma?	Not relevant PIRQ, outcome Objective: To "examine what additional information TCT (Thoracic Computed Tomography) provides in the initial trauma evaluation, how frequently it	Not relevant PIRQ, population <18 years. Range: 7 months to 18 years.	

	An efficacy and cost analysis. <i>Journal of Pediatric Surgery</i> , 38(5), 793-797.	results in a change in clinical management, and as a cost/benefit analysis".			
3242	Mandelstam SA, Cook D, Fitzgerald M, Ditchfield MR. 2003. Complementary use of radiological skeletal survey and bone scintigraphy in detection of bony injuries in suspected child abuse. <i>Archives of Disease in Childhood</i> , 88(5), 387-390.	Not relevant PIRO, outcome Objective: To compare the effectiveness of radiological skeletal survey and bone scintigraphy for the detection of bony injuries cases of suspected child abuse.	Not relevant PIRO, reference test Children with "discharge diagnosis of non-accidental injury at the Royal Children's Hospital" (No further information given).	No statistics on number of cases , only number of CMLS (N=20).	CML + Rib
3249	Klotzbach H, Dellling G, Richter E, Sperhake JP, Puschel K. 2003. Post-mortem diagnosis and age estimation of infants' fractures. <i>International Journal of Legal Medicine</i> , 117(2), 82-89.	Not relevant PIRO, outcome Objective: To "develop a reliable scheme for diagnosing and dating infants' fractures in the course of an autopsy"	Case report: 3 cases, multiple fractures, including rib fractures, attributed to child abuse.		CML + Rib
3250	Ricci L, Giantis A, Merriam P, Hodge S, Doyle T. 2003. Abusive head trauma in Maine infants: medical, child protective, and law enforcement analysis. <i>Child Abuse & Neglect</i> , 27(3), 271-283.	Not relevant PIRO, reference test "selected as likely abuse related using the following criteria: the presence of intracranial trauma such as extraaxial blood and/or parenchymal injury plus one or more of the following: admitted or witnessed assault, inconsistent history, suspicious bruises, suspicious fractures, or extensive retinal hemorrhages. Determination of inconsistency in the history and/or suspiciousness of the injuries were made by the primary author (LRR) using a model similar to Duhaime et al. (1992). " "Child protective service (CPS) records were reviewed by one of the authors (PM) and the following information was collected: prior CPS history, family constellation, risk factors (substance abuse, prior abuse allegations, child abuse in the caretaker's childhood, domestic violence, mental illness, history of unrealistic expectations, history of attachment disorder), history of child	Not relevant PIRO, outcome Aim: To "identify the medical, psychosocial, and criminal justice characteristics of inflicted head trauma in Maine children"	Observations (<10) Rib fractures were seen in 3 children and "metaphyseal fractures" in 2 children. (Age for these not stated)	Rib fracture + "metaphyseal fractures"

		stressors (such as colic or feeding difficulties), whether abuse was substantiated, whether a perpetrator was identified, whether a triggering event occurred, and the final disposition of the child. Law enforcement records were reviewed by one of the authors (TD) and the following information was collected: whether or not a perpetrator was identified, perpetrator demographics; previous criminal history of the perpetrator; whether criminal prosecution was attempted and the results of that prosecution, whether there was a confession, and what, if any, were the identified impediments to investigation." "In 16 of 20 cases (80%), the hospital identified the child as a victim of abuse. Two children (10%) who died prior to diagnostic assessment at the medical facility were later identified by the medical examiner as abused. Of the two misidentified cases (10%), one appeared to be a result of medical providers feeling that the family presented well even though the injuries were suspicious, and the other the result of the providers believing the history of an accidental injury." Child protective services "CPS in Maine investigated 18 of the 20 cases (90%)." "CPS substantiated abuse in 18 cases (90%). In two cases abuse could not be substantiated. In one there were conflicting medical opinions, while in the other the medical providers said that the child had not been abused." "Law enforcement identified a perpetrator in 15 of 19 cases (79%)" "In 4		
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		of the 19 cases (21%), a perpetrator confessed to injuring the child. One child was shaken because of apparent jealousy, one was shaken because of crying, one was shaken because of a toileting accident and one child was slammed down in anger. Thirteen cases (68%) were prosecuted. Two individuals (15%) were found guilty at trial while 7 (54%) pled guilty, 3 (23%) were acquitted, and 1 died prior to trial. Law enforcement noted the following barriers to investigation: there was a delay notifying police in 6 of the 20 cases (30%), there were multiple possible suspects in 10 cases (50%), and there were conflicting medical expert opinions in 3 cases (15%). " Not stated if the cases with rib fractures or "metaphyseal fractures" were confessed or had pled guilty.		
3263	King WJ, Mackay M, Sirnick A. 2003. Shaken baby syndrome in Canada: clinical characteristics and outcomes of hospital cases. <i>Canadian Medical Association Journal</i>, 168(2), 155-159.	Not relevant PIRQ, outcome Objective: To describe the key characteristics and outcomes of children admitted to hospital with Shaken Baby Syndrome in Canada.	Not relevant PIRQ, reference test Cases of Shaken Baby Syndrome (SBS) "that were reported to the child protection teams at 11 tertiary care pediatric hospitals". "In this study, SBS was defined as any form of intracranial, intraocular or cervical spine injury as a result of a substantiated or suspected shaking, with or without impact, in a child aged less than 5 years. We relied on the diagnosis assigned by the physician responsible for child protection at each hospital and/or that recorded on the discharge summary. These health care providers are responsible for managing cases of suspected child maltreatment, working in association with community	CML + Rib

			child welfare authorities and the police. The diagnosis of SBS made according to the records at the treating hospital was accepted as noted. ICD-9 codes (1988 to March 1996 — 995.5, E967.0, E967.1, E967.9; April 1996 to 1998 — 995.55, 995.54, E967.0, E967.9) were also examined at each hospital to confirm that we had identified all cases. "		
3272	Nassogne MC, Sharrard M, Hertz-Pannier L, Armengaud D, Touati G, Delonlay-Debeney P, Zerah M, Brunelle F, Saudubray JM. 2002. Massive subdural haematomas in Menkes disease mimicking shaken baby syndrome. <i>Child's Nervous System</i> , 18(12), 729–731.	Case report: 1 case, infant with Menke's disease with massive subdural haematoma and bilateral metaphyseal spurs on distal femur.			CML?
3279	Kleinman PK, O'Connor B, Nimkin K, Rayder SM, Spevak MR, Belanger PL, Getty DJ, Karellas A. 2002. Detection of rib fractures in an abused infant using digital radiography: a laboratory study. <i>Pediatric Radiology</i> , 32(12), 896–901.	Not relevant PIRO, outcome Objective: To "assess the diagnostic performance of film-screen versus digital radiography, using charge couple device (CCD) technology, in the detection of rib fractures in infants abuse".	Observations (<10) 1 case, infant with rib fractures attributed to abuse (inflicted head injury)		Rib fracture
3284	Banaszkiewicz PA, Scotland TR, Myerscough EJ. 2002. Fractures in children younger than age 1 year: importance of collaboration with child protection services. <i>Journal of Pediatric Orthopedics</i> , 22(6), 740–744.	Not relevant PIRO, index test	Not relevant PIRO, outcome Objective: To analyze variance in abuse diagnosing of fractures in staff clinicians, orthopaedic register, and a designated doctor in child protection (consultant paediatrician).	Not relevant PIRO, reference test "To determine the likelihood of abuse, case notes were reviewed independently by two investigators, which allowed a three-tier analysis of possible abuse to be made. The first tier consisted of the initial assessment by staff clinicians, the second by an orthopaedic registrar researching the subject, and the third by a designated doctor in child protection (consultant	

			paediatrician). The same information was available to all three groups, thereby reducing the possibility of any bias entering the study. Using the simplified criterion of Thomas et al. (19) (Table 1), patients were classified into one of seven categories: definite abuse, likely abuse, suspicious, likely accident, definite accident, neglect, or unknown cause." "TABLE 1. Criteria used by investigators to distinguish abuse from accidental injury <i>Definite Abuse</i> Positive skeletal survey Witnessed episode of abuse <i>Likely Abuse</i> Severe injury, mechanism of causation does not adequately explain nature injury, and either Varying history Late presentation Previous history social services involvement Suspicious History not sufficient for injury/unexplained fracture, and either Varying history Late presentation Previous history social services involvement <i>Likely Accident</i> Consistent story, no suspicious features <i>Definite Accident</i>	
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			Multiple witnesses Neglect Accident suggests parental neglect <i>Unknown Cause</i> Medical records suggest diagnosis of abuse not considered Modified from Thomas et al. (19)"	
3294	Boal DK. 2002. Metaphyseal fractures. <i>Pediatric Radiology</i> , 32(7), 538-9.	Letter to editor: Reply on Grayev et al (2001) 3362, Miller (2001) 3295		CML
3295	Miller M. 2002. Fractures during physical therapy. <i>Pediatric Radiology</i> , 32(7), 536-537.	Letter to editor: Reply on Grayev et al (2001) 3362		CML
3312	Starling SP, Heller RM, Jenny C. 2002. Pelvic fractures in infants as a sign of physical abuse. <i>Child Abuse & Neglect</i> , 26(5), 475-480.	Case report: 2 cases, pelvic fractures in infants, with multiple fractures including rib fractures and metaphyseal fractures, attributed to physical abuse.	Unsystematic review (No description how articles were searched and selected.)	Rib fracture
3317	Sibert JR, Payne EH, Kemp AM, Barber M, Rolfe K, Morgan RJ, Lyons RA, Butler I. 2002. The incidence of severe physical child abuse in Wales <i>Child Abuse & Neglect</i> , 26(3), 267-276.	Not relevant PIRO, index test	Not relevant PIRO, outcome Objective: 1) To determine the incidence of severe physical child abuse in Wales. 2) To determine the incidence of all physical abuse in babies. 3) To investigate the extent the Child Protection Register records abuse.	
3356	Hicks R. 2001. Relating to methodological shortcomings and the concept of temporary brittle bone disease. <i>Calcified Tissue International</i> , 68(5), 316-319.	Letter to editor: Reply on Miller and Hangartner (1999)		
3360	Grant P, Mata MB, Tidwell M. 2001. Femur fracture in infants: a possible accidental etiology. <i>Pediatrics</i> , 108(4), 1009-1011.	Not relevant PIRO, index test Salter Harris II fracture	Case report: 2 cases, infants with Salter Harris II fractures.	

3362	Grayev AM, Boal DK, Wallach DM, Segal LS. 2001. Metaphyseal fractures mimicking abuse during treatment for clubfoot. <i>Pediatric Radiology</i> , 31(8), 559-563.	Case report: 8 cases, metaphyseal injuries, including CML, in infants undergoing casting treatment for clubfoot.			CML
3401	Belfer RA, Klein BL, Orr L. 2001. Use of the skeletal survey in the evaluation of child maltreatment. <i>The American Journal of Emergency Medicine</i> , 19(2), 122-124.	Not relevant PIRO, outcome Objective: To (1) determine the incidence of clinically unsuspected fractures detected by skeletal survey, and (2) identify high-risk groups of children that would benefit from skeletal surveys.	Not relevant PIRO, reference test "all children admitted to CNMC over a 30-month period with a diagnosis of alleged physical abuse was performed. All patients were evaluated by the multi-disciplinary Division of Child Protection team"	Only occult fractures reported	Rib fracture
3411	Skellern CY, Wood DO, Murphy A, Crawford M. 2000. Non-accidental fractures in infants: risk of further abuse. <i>Journal of Paediatrics and Child Health</i> , 36(6), 590-592.	Not relevant PIRO, index test	Not relevant PIRO, reference test "Subjects were classified as non-accidental if medical staff were alerted by historical or radiological findings, and child protection medical staff concurred on further assessment. Factors considered in this decision were: if (i) an admission was made that the injuries had been deliberately inflicted; (ii) the injuries were not compatible with the clinical history; (iii) historical account of the injury varied; (iv) there was a lack of any explanation for injuries; (v) there were accompanying physical signs of abuse or neglect such as bruises, burns, nutritional deprivation; (vi) the fracture types had high specificity for child abuse, e.g. rib and metaphyseal fractures; and (vii) other fractures were detected on skeletal survey". The suspected non-accidental group was further classified on the basis of the SCAN team investigation outcome as founded, unfounded, or indetermined (i.e. suspicious of abuse or unable to be investigated)."		

3418	Cadzow SP, Armstrong KL. 2000. Rib fractures in infants: red alert! The clinical features, investigations and child protection outcomes. <i>Journal of Paediatrics and Child Health</i> , 36(4), 322-326.	Not relevant PIRO, reference test "Rib fractures were considered to be non-accidental if this was the conclusion reached by the Child Protection Unit and the affiliated Suspected Child Abuse and Neglect (SCAN) Team, composed of a Royal Children's hospital child protections paediatrician and social worker, in addition to representatives from the Department of Families Youth and Community Care (DFYCC) and Police Child Abuse Investigation Unit. This conclusion was made after full and frank discussion, in which the patterns of current injury, past injury or abuse history, and social history, were considered."			Rib fracture
3439	Bulloch B, Schubert CJ, Brophy PD, Johnson N, Reed MH, Shapero RA. 2000. Cause and clinical characteristics of rib fractures in infants. <i>Pediatrics</i> , 105(4), E48.	Not relevant PIRO, reference test "Child abuse was diagnosed whenever the infant had additional injuries specific or indicative of abuse. These included injuries attributable to shaken baby syndrome, such as subdural hemorrhages or retinal hemorrhages, unexplained internal injuries, or other fractures considered specific for abuse. Child abuse was also diagnosed whenever there had been a confession by the perpetrator. A presumptive diagnosis of child abuse was made in all remaining cases when the history given by the caretaker was not plausible to explain the injuries and when accidental trauma, bone fragility, and birth trauma had been ruled out. Accidental injury was diagnosed whenever the history of trauma was plausible and likely to have caused the rib fractures. Plausible histories included falls from heights greater than 6 feet or falls while in the arms of a caregiver. Motor			Rib fracture

		vehicle collisions and direct blows of sufficient force were also considered plausible histories causing accidental fractures depending on associated historical events and whether independent observers witnessed the injuries. Rib fractures attributable to birth injury were diagnosed when the radiographs that were obtained while the newborn was still hospitalized revealed acute fracture. To further exclude birth trauma, hospital records were reviewed for type of delivery, infant size, and a record of difficult or complicated delivery. Clinical findings, such as tachypnea and irritability during the newborn period, were also used as indications of possible birth trauma. Bone fragility was then considered a possible cause in all remaining cases. The criteria used for making the diagnosis of bone fragility were: 1) diagnosis by a geneticist, or 2) a clinical picture consistent with a bone dysplasia including additional accidental fractures or bruising when the child was placed in a safe environment. Telephone contact with the child's primary care physician, review of any subsequent radiographs, as well as data from the medical record were used to investigate this second criterion."				
3442	Gunther WM, Symes SA, Berryman HE. 2000. Characteristics of child abuse by anteroposterior manual compression versus cardiopulmonary resuscitation: case reports. <i>The American Journal of Forensic Medicine and Pathology</i>, 21 (1): 5-10.	Case report: 2 cases, multiple rib fractures and internal thoracic or abdominal blunt force injury in infants attributed to squeezing of the chest. One case admitted by perpetrator.				Rib fracture

3457	Kocher MS, Kasser JR. 2000. Orthopaedic aspects of child abuse. <i>Journal of the American Academy of Orthopaedic Surgeons</i> , 8(1), 10-20.	Non-systematic review (No description how articles were searched or included)		
3461	DiScala C, Sege R, Li G, Reece RM. 2000. Child abuse and unintentional injuries: a 10-year retrospective. <i>Archives of Pediatrics & Adolescent Medicine</i> , 154 (1), 16-22.	Not relevant PIRQ, index test	Not relevant PIRQ, reference test "The NPTR is a database that contains information about many aspects of pediatric trauma, its causes, and its consequences. Data are voluntarily contributed to the NPTR by pediatric trauma centers or children's hospitals with pediatric trauma units." "We extracted from the NPTR the following 2 groups of children injured by blunt trauma and consecutively reported to the registry by more than 70 participating hospitals between January 1, 1988, and December 31, 1997: (1) all cases reported to the NPTR as an established case of child abuse and (2) all cases reported to the NPTR as an established case of unintentional injury. The distinction between child abuse and unintentional injury was made at the treating hospital and was not questioned. All cases reported as suspected child abuse were excluded."	.
3496	Miller ME. 1999. Temporary brittle bone disease: a true entity? <i>Semin Perinatology</i> , 23 (2): 174-82.	Not relevant PIRQ, reference test "Of the 33 cases of infants with multiple, unexplained fractures, 26 were considered to be consistent with TBBD based on the following criteria: (1) Parents and caregivers denied wrongdoing at the time of presentation and throughout the investigation by authorities; (2) There was no apparent episode of trauma to explain the fractures; (3) There was no external skin	Differential diagnosis: Temporary brittle bone disease	

		injury such as bruising at the time of presentation or at prior health care visits; (4) Further evaluation showed no other evidence of systemic findings that would indicate child abuse - -no retinal hemorrhages, no subdural hematomas, no visceral organ damage; (5) Radiographs showed no evidence of metabolic bone disease and apparent normal bone density; (6) When done, results of laboratory studies evaluating for metabolic bone disease such as serum calcium and phosphorus and collagen analysis to evaluate for OI were normal."		
3511	Sinal SH, Stewart CD. 1998. Physical abuse of children: a review for orthopedic surgeons. <i>Journal of the Southern Orthopaedic Association</i> , 7(4), 264-276.	Non-systematic review (No description how articles were searched and included)		
3517	Tzioumi D,Oates RK. 1998. Subdural hematomas in children under 2 years. Accidental or inflicted? A 10-year experience. <i>Child Abuse and Neglect</i> ; 22 (11): 1105-12.	Not relevant PIRQ, reference test Patients were assigned to three different diagnostic groups: (1) Nonaccidental injury [NAI]; (2) accidental injury; and (3) nontraumatic, secondary to a disease process. The patients were assigned to each group using the diagnosis that had been recorded in their medical records. All the children in the NAI group had been evaluated by the hospital Child Protection Team and the diagnosis of nonaccidental injury had been confirmed. This nonaccidental injury group was further subclassified into: "impact" or "shaking" injury.	Observations (<10) Only 4 cases with rib fractures in NAI group, 0 in accidental	Rib fracture
3521	Youmans DC, Don S, Hildebolt C, Shackelford GD, Luker GD, McAlister WH. 1998. Skeletal surveys for child abuse: comparison of interpretation using digitized images and screen-	Not relevant PIRQ, outcome Objective: To compare child abuse detection using screen-film radiographs and their digitized images displayed on a computer workstation.	Not relevant PIRQ, reference test "Twenty consecutive child abuse patients with at least one fracture (mean age 187 days, range 38-540 days) were identified from the records	No statistics on number of CML and rib fractures were detected, or number of individuals with fractures. CML + Rib

	film radiographs. <i>American journal of Roentgenology</i> , 171 (5): 1415-9.		of the Department of Clinical Social Work at our children's hospital for the period from February 1992 to November 1994. These clinically proven child abuse cases were diagnosed by a combination of history, physical examination, radio-graphic findings, and social work history. Twenty consecutive control subjects were chosen from skeletal surveys performed during the same time period mean age 172 days, range, 32-436 days). In 16 of these subjects, the skeletal survey was obtained as part of a workup for child abuse; investigation (similar to that of our diagnosed cases) concluded that no evidence of child abuse was present. In one patient each, the reason for the skeletal survey was suspected dysplasia, Schwartz-Jampel syndrome, metabolic disorder, and metastases."		
3529	Kleinman PK. 1998. Shaken babies. <i>Lancet</i> , 352 (9130): 815-6.	Reply on Editorial			
3531	Ng CS, Hall CM. 1998. Costochondral junction fractures and intra-abdominal trauma in non-accidental injury (child abuse). <i>Pediatric Radiology</i> , 28 (9): 671-6.	Case report: 3 cases, costochondral junction fractures in infants and toddlers attributed to abuse.			
3551	Lancon JA, Haines DE, Parent AD. 1998. Anatomy of the shaken baby syndrome. <i>The Anatomical Record</i> , 253 (1): 13-8.	Non-systematic review (No description how articles were searched or included)			
3562	Thomsen TK, Elle B, Thomsen JL. 1997. Post-mortem radiological examination in infants: evidence of child abuse? <i>Forensic Science International</i> , 90 (3): 223-30.	Observations (<10) (study part) 2 cases with abnormal skeletal survey (1 case consistent with rickets, 1 case "cupplings" of the ulnar bones).	Not relevant PIRQ, outcome (study part) Objective: To examine "the value of post-mortem radiography in infants with sudden unexplained death."	Case report: 1 case, multiple fractures including CML and rib fractures and subarachnoid haemorrhage after admitted abuse.	CML + Rib

3568	Kleinman PK, Marks Jr SC. 1998. A regional approach to the classic metaphyseal lesion in abused infants: the distal femur. <i>American Journal of Roentgenology</i> , 170 (1): 43-7.	Not relevant PIRQ, outcome Objective: The purpose of this study was to analyze the spectrum of morphologic alterations of the classic metaphyseal lesion involving the distal femur of abused infants and to identify features that aid in radiologic diagnosis and assessment of healing.	Not relevant PIRQ, reference test "died with evidence of inflicted skeletal injury". "The characteristic of the population studied and methodology have been presented in detail (3)". (3=#3664.) "The histologic material of 10 age-matched normal distal femur was reviewed for comparison with the pathologic material". Not stated how the diagnosis abuse was established. From #3664: "The autopsy report or the death certificate data were reviewed. This information was often supplemented with data supplied by investigative authorities or revealed at trial. A total of 31 infants (average age 3 months, range 3 weeks to 10.5 months) with inflicted skeletal injuries were identified. The findings of these infants form the basis of this study. Head trauma was the cause of death in 18 infants. One infant each died of asphyxiation, liver laceration, and dehydration. One infant showed mild cardiomegaly and was diagnosed with hypertrophic cardiomyopathy. In the remaining nine cases, a specific cause of death could not be determined and the diagnoses were listed as sudden infant death syndrome (SIDS), undetermined, or pending."		CML
3571	Lazoritz S, Baldwin S, Kini N. 1997. The Whiplash Shaken Infant Syndrome: has Caffey's syndrome changed or have we changed his syndrome? <i>Child Abuse & Neglect</i> , 21(10), 1009-1014.	Not relevant PIRQ, reference test "This study was a retrospective review of all children under the age of 3 admitted to Children's Hospital of Wisconsin between January 1, 1990 and June 30, 1995 who were identified as having a subdural hematoma caused by other than accidental means after the completion of	Not relevant PIRQ, outcome Objective: The aim of this study is to examine the data used by John Caffey in his description of the Whiplash Shaken Infant Syndrome and compare it with recent data in an attempt to determine whether the syndrome that he described has changed, or if we	Not relevant PIRQ, population <3 years	Rib fracture

		a complete multi-disciplinary investigation. Excluded were any children with a documented accidental etiology for their hemorrhage. Included were infants where there was no history of trauma, a history of minor trauma, or a history that was determined to be untrue after investigation. Data was collected from medical records and from radiological findings on 71 patients."	have changed his syndrome into what we now call The Shaken Infant Syndrome.	of rib fractures (fresh or healing)	
3602	Beatty JH. 1997. Orthopedic aspects of child abuse. <i>Current Opinion in Pediatrics</i> , 9 (1): 100-3.	Non-systematic review (No description how articles were searched or included)			CML + Rib
3605	Abilin DS, Sane SM. 1997. Non-accidental injury: confusion with temporary brittle bone disease and mild osteogenesis imperfecta. <i>Pediatric Radiology</i> , 27(2), 111-113.	Non-systematic review (No description how articles were searched or included)			
3606	Chapman S, Hall CM. 1997. Non-accidental injury or brittle bones. <i>Pediatric Radiology</i> , 27(2), 106-110.	Non-systematic review (No description how articles were search or included)			
3607	Kleinman PK, Schlesinger AE. 1997. Mechanical factors associated with posterior rib fractures: laboratory and case studies. <i>Pediatric Radiology</i> , 27(1), 87-91.	Not relevant study design 1) Cadaver study simulating operative sternotomy found fractures on the first rib at or medial to the costotransverse process. 2) Animal study (rabbit) found no rib fractures on CT following digital sternal compression of the chest on firm surface but rib fractures on the head and neck of the ribs after digital gripping around the thorax and compression antero-posteriorly 3) 2 case report , posterior rib fractures after high energy trauma	Observations (<10) 2 cases	Not relevant PIRQ, population	Rib fracture
3611	Kleinman PK, Marks Jr SC. 1996. A regional approach to the classic metaphyseal lesion in abused infants: the proximal humerus. <i>American Journal of Roentgenology</i> , 167(6), 1399-1403.	Not relevant PIRQ, outcome Objective: The purpose of this study was to systematically analyze the spectrum of morphologic alterations of the classic metaphyseal lesion (CML) involving the proximal humerus of abused infants and	Not relevant PIRQ, reference test "Characteristic of the population studied and methodology have been presented in detail (3)". (3=#3664.) "The histologic material of 10 age-matched normal proximal humeri was	Observation <10 (4 infants with 7 proximal CMLs)	CML

		to identify radiologic features that aid in the diagnosis and assessment of healing.	reviewed for comparison with the pathologic material". Not clearly stated how the diagnosis abuse was established. From #3664: "The autopsy report or the death certificate data were reviewed. This information was often supplemented with data supplied by investigative authorities or revealed at trial. A total of 31 infants (average age, 3 months; range, 3 weeks to 10.5 months) with inflicted skeletal injuries were identified. The findings of these infants form the basis of this study. Head trauma was the cause of death in 18 infants. One infant each died of asphyxiation, liver laceration, and dehydration. One infant showed mild cardiomegaly and was diagnosed with hypertrophic cardiomyopathy. In the remaining nine cases, a specific cause of death could not be determined and the diagnoses were listed as sudden infant death syndrome (SIDS), undetermined, or pending."		
3620	Cramer KE. 1996. Orthopedic aspects of child abuse. <i>Pediatric clinics of North America</i> . 43(5), 1035-1051.	*Not accessed			
3621	Kleinman PK, Nimkin K, Spevak MR, Rayder SM, Madansky DL, Shelton YA, Patterson MM. 1996. Follow-up skeletal surveys in suspected child abuse. <i>American Journal of Roentgenology</i> . 167(4), 893-896.	Not relevant PIRQ, outcome Objective: To "assess the additional yield of a repeat skeletal survey in identifying and dating skeletal injury for cases in which child abuse was strongly suspected".	Not relevant PIRQ, reference test "skeletal surveys performed for suspected abuse. A repeat skeletal survey was recommended if the number, type, and age of the fractures present pointed strongly to abuse; if the radiologic appearance of the fracture did not appear consistent with the history provided; or if additional imaging data (e.g., cranial CT) or clinical findings strongly indicated		CML + Rib

			abuse. In all cases, a referral was made to the Department of Social Services." "infants and toddlers strongly suspected of being physically abused on the basis of findings on the initial skeletal survey, other imaging studies, history, or physical examination underwent a follow-up examination approximately 2 weeks after the initial examination".	
3627	Kleinman PK, Marks SC, Jr., Ninkin K, Rayder SM, Kessler SC. 1996. Rib fractures in 31 abused infants: postmortem radiologic-histopathologic study. <i>Radiology</i> , 200(3), 807-810.	Not relevant PIRO, reference test "infants ...who died with inflicted skeletal injuries" "In September 1995, we reported the postmortem findings in the skeleton of 31 abused infants (17 girls, 14 boys; age range 3 weeks to 10 ½ months; mean age 3 months); the imaging techniques were described in detail (9)." (9=#3364) From #3364: "The autopsy report or the death certificate data were reviewed. This information was often supplemented with data supplied by investigative authorities or revealed at trial. A total of 31 infants (average age 3 months; range 3 weeks to 10.5 months) with inflicted skeletal injuries were identified. The findings of these infants form the basis of this study. Head trauma was the cause of death in 18 infants. One infant each died of asphyxiation, liver laceration, and dehydration. One infant showed mild cardiomegaly and was diagnosed with hypertrophic cardiomyopathy. In the remaining nine cases, a specific cause of death could not be determined and the diagnoses were listed as sudden infant death syndrome (SIDS), undetermined, or pending. An analysis of the skull fractures proved		Rib fracture

		problematic. Thirteen infants had skull fractures, but it was not possible to calculate the number of fractures in individual cases, as fractures were often complex, extending into and across sutures. For this reason, they were excluded from the numerical analyses. "		
3639	Kleinman PK, Marks Jr SC. 1996. A regional approach to classic metaphyseal lesions in abused infants: the distal tibia. <i>AJR. American Journal of Roentgenology</i> , 166(5), 1207-1212.	Not relevant PIRQ, outcome Objective: The purpose of this study was to analyze systematically the spectrum of morphologic alterations of classic metaphyseal lesions (CMLs) involving the distal tibia of abused infants and to identify features that assist in the radiologic diagnosis and assessment of healing.	Not relevant PIRQ, reference test "The characteristics of the population studied and the methodology used were presented in detail previously (3)" (3=#3664) "Histologic material from 10 age-matched, normal distal tibias was reviewed for comparison with pathologic material." Re #3664: Not clearly stated how the diagnosis abuse was established. "The autopsy report or the death certificate data were reviewed. This information was often supplemented with data supplied by investigative authorities or revealed at trial. A total of 31 infants (average age 3 months, range 3 weeks to 10.5 months) with inflicted skeletal injuries were identified. The findings of these infants form the basis of this study. Head trauma was the cause of death in 18 infants. One infant each died of asphyxiation, liver laceration, and dehydration. One infant showed mild cardiomegaly and was diagnosed with hypertrophic cardiomyopathy. In the remaining nine cases, a specific cause of death could not be determined and the diagnoses were listed as sudden infant death syndrome (SIDS), undetermined, or pending."	CML

3650	Kleinman PK, Marks SC, Jr. 1996. A regional approach to the classic metaphyseal lesion in abused infants: the proximal tibia. <i>AJR, American Journal of Roentgenology</i> , 166(2), 421-426.	Not relevant PIRO, outcome Objective: To "systematically analyze the spectrum of morphologic alterations of the classic metaphyseal lesion (CML) involving the proximal tibia of abused infants and to identify features that aid in the radiologic diagnosis and assessment of healing".	Not relevant PIRO, reference test "The materials and methods that we used have been presented in detail [8]. " (8=#3664) In #3364: Not clearly stated how the diagnosis of abuse was established. "The autopsy report or the death certificate data were reviewed. This information was often supplemented with data supplied by investigative authorities or revealed at trial. A total of 31 infants (average age 3 months, range 3 weeks to 10.5 months) with inflicted skeletal injuries were identified. The findings of these infants form the basis of this study. Head trauma was the cause of death in 18 infants. One infant each died of asphyxiation, liver laceration, and dehydration. One infant showed mild cardiomegaly and was diagnosed with hypertrophic cardiomyopathy. In the remaining nine cases, a specific cause of death could not be determined and the diagnoses were listed as sudden infant death syndrome (SIDS), undetermined, or pending."	Observation <10? Not stated number of infants, only number of CMLs (N=17)	CML
3651	Gilliland MG, Folberg R. 1996. Shaken babies--some have no impact injuries. <i>Journal of Forensic Sciences</i> , 41(1), 114-116.	Not relevant PIRO, outcome Objective: Investigate whether shaking without direct head trauma is sufficient to inflict a lethal injury on an infant.	Not relevant PIRO, reference test "Evidence of shaking was defined as two or more of the following criteria: 1) finger marks and/or rib fractures, 2) subdural and/or subarachnoid hemorrhage, and 3) a history of vigorous shaking".	Not relevant PIRO, index test (rib fracture reference test) Not relevant PIRO, population Not stated	Rib fracture
3655	Strouse PJ, Owings CL. 1995. Fractures of the first rib in child abuse. <i>Radiology</i> , 197(3), 763-765	Not relevant PIRO, reference test "We reviewed all radiographic studies and pertinent medical records of these patients to ascertain the cause of fracture and the extent of associated injuries, and we attempted to determine a mechanism			Rib fracture

		of injury". Causes: osteopenia, child abuse, unknown, motor vehicle accident, chest tube, osteogenesis imperfecta and birth trauma. "One abused child, with 24 fractures of 14 ribs, had a history of congenital syphilis, cirrhosis, and osteopenia, which likely predisposed him to easy fracture; this child is included only under child abuse". Of children with first rib fractures (N=6), 5 were abused. "All five children had other manifestations of child abuse that contributed to the diagnosis. Four suffered severe neurological injuries with permanent sequelae. Two patients died as a result of abuse." "A history of shaking and slamming the child down was elicited from the abuser in one case ... however, the mechanism of injury remains speculative in the four other cases".		
3659	Kleinman PK, Marks Jr SC. 1995. Relationship of the subperiosteal bone collar to metaphyseal lesions in abused infants. <i>The Journal of Bone and Joint Surgery. American volume</i> , 77(10), 1471-1476.	Not relevant PIRQ, outcome Objective: To "systematically" examine "the relationship of the subperiosteal bone collar to metaphyseal lesions in abused infants".	Not relevant PIRQ, reference test "...who died with evidence of abuse". Not further information on how the diagnosis of abuse was established.	CML
3664	Kleinman PK, Marks SC, Jr., Richmond JM, Blackbourne BD. 1995. Inflicted skeletal injury: a postmortem radiologic-histopathologic study in 31 infants. <i>AJR. American Journal of Roentgenology</i> , 165(3), 647-650.	Not relevant PIRQ, reference test Abuse defined as "who died with inflicted skeletal injuries." "The autopsy report or the death certificate data were reviewed. This information was often supplemented with data supplied by investigative authorities or revealed at trial. A total of 31 infants (average age 3 months, range 3 weeks to 10.5 months) with inflicted skeletal injuries were identified. The findings of these infants form the basis of this study. Head trauma was the cause of death in 18 infants. One infant each died		CML + Rib

		of asphyxiation, liver laceration, and dehydration. One infant showed mild cardiomegaly and was diagnosed with hypertrophic cardiomyopathy. In the remaining nine cases, a specific cause of death could not be determined and the diagnoses were listed as sudden infant death syndrome (SIDS), undetermined, or pending." According to article referenced (#3962) (including 4 abused infants): "The diagnosis of abuse was based on history, clinical findings, typical skeletal lesions, determination by social service agencies, and characteristic patterns of intracranial hemorrhage, as seen by antemortem CT and by pathologic examination at autopsy"		
3680	Tröger J, Stegen P. 1995. [Child abuse. Important findings in diagnostic imaging]. <i>Der Radiologe</i> , 35(6), 401-405.	*Not accessed		
3701	Nimkin K, Kleinman PK, Teeger S, Spevak MR. 1995. Distal humeral physal injuries in child abuse: MR imaging and ultrasonography findings. <i>Pediatric Radiology</i> , 25(7), 562-565.	Not relevant PIRQ, index test Salter-Harris fracture II and III	Case reports: 3 cases, (3 month - 23 months old) distal humeral Salter-Harris fractures II and III, attributed to child abuse. Detected by magnetic resonance imaging (MRI).	
3733	Walker A, Chernoff R, Joffe A, Wilson ME. 1994. Child abuse, sudden infant death syndrome, infectious disease, and vaccinations. <i>Current Opinion in Pediatrics</i> , 6(2), 225-231.	Not relevant study design: Detailed review of a single article (Leventhal et al., 1993) #3775		
3737	Nimkin K, Teeger S, Walach MT, DuVally JC, Spevak MR, Kleinman PK. 1994. Adrenal hemorrhage in abused children: imaging and postmortem findings. <i>American Journal of Roentgenology</i> , 162 (3): 661-663.	Not relevant PIRQ, reference test "Proved child abuse". 1 case: "Child abused was later confirmed" No description how this was proven or confirmed.	Case report: 5 cases, adrenal hemorrhages (4-36 months) attributed to child abuse. 4 had rib fractures.	CML + Rib

3745	Betz P, Lieberhardt E. Rib 1994. Fractures in children--resuscitation or child abuse? <i>International Journal of Legal Medicine</i> , 106(4), 215-218.	Not relevant PIRQ, reference test Not stated how mechanism of injury was established. Cause of death: SIDS, drowning, congenital heart defects, infection, epileptic seizure, car accident, fall, traumatic asphyxia, child abuse. Not stated how the diagnosis of child abuse was established. Not stated how information about cardiopulmonary resuscitation was obtained.	Differential diagnosis: CPR	Not relevant PIRQ, outcome Objective: To determine if "rib fractures of the chest of a baby or a child can be caused by external cardiac massage". Observation <10 No group of child abuse, car accident, fall or traumatic asphyxia had more than 6 cases; ≤7 years.	Rib fracture
3753	Laor T, Jaramillo D. 1993. Metaphyseal abnormalities in children: pathophysiology and radiologic appearance. <i>American Journal of Roentgenology</i> , 161(5), 1029-1036.	Other: Pictorial essay describing metaphyseal abnormalities in children; pathophysiology and radiological appearance.	Non-systematic review (No description how articles were searched and included)		
3754	Carty HM. 1993. Fractures caused by child abuse. <i>The Journal of Bone and Joint Surgery. British volume</i> , 75(6), 849-857.	Non-systematic review (No description how articles were searched and included)			CML + Rib
3756	Conway JJ, Collins M, Tanz RR, Radkowski MA, Anandappa E, Hernandez R, Freeman EL. 1993. The role of bone scintigraphy in detecting child abuse. <i>Seminars in Nuclear Medicine</i> , 23(4), 321-233.	Not relevant PIRQ, outcome Objective: This review of diagnostic imaging in child abuse characterizes the significant differences between bone scintigraphy and X-ray evaluation, describes the advantages and disadvantages of each modality, postulates on the specific mechanism of injury producing the characteristic scintigraphic findings, and emphasizes the influence of scintigraphic studies on medical, social and legal aspects of child abuse."	Non-systematic review (No description how articles were searched and included)		CML + Rib
3768	Duncan AA, Chandry J. 1993. Case report: multiple neonatal fractures--dietary or deliberate? <i>Clinical Radiology</i> , 48(2), 137-139.	Case report: 1 case – rickets or child abuse or both?			CML + Rib

3770	Barry PW, Hocking MD. 1993. Infant rib fracture - birth trauma or non-accidental injury. <i>Archives of Disease in Childhood</i> , 68(2), 250.	Letter to editor: Case report 1 case, newborn with rib fractures attributed to birth trauma.			Rib fracture
3771	Paterson CR, Burns J, McAlilion SJ. 1993. Osteogenesis imperfecta: the distinction from child abuse and the recognition of a variant form. <i>American Journal of Medical Genetics</i> , 45(2), 187-192.	Not relevant PIRO, reference test "In 7 patients the initial clinical diagnosis was OI, usually because fractures occurred while the child was still in hospital and in these cases the parents had been informed by their medical advisers of the diagnosis and the severity of the condition since multiple fractures were often seen. In the remaining 7 patients, fractures occurred at home and the initial diagnosis was of NAI. However, as a group these cases were distinctive in that the multiple fractures occurred without evidence of trauma and more than 90 % of the fractures were found "by accident" when radiographs were carried out for other reasons. In each case there was a gross discrepancy between the radiological and evidence of injury and the superficial evidence of trauma as recorded by professionals and others outside the family at the time when supposedly the fractures occurred. The patterns of the fractures and of other clinical findings were similar whether the original diagnosis was OI or NAI and we think that this represents a distinctive disorder. "	Differential diagnosis OI, "temporary brittle bone disease".		CML + Rib
3774	Feibusch K. 1993. Handle with care: is it really child abuse?. <i>The Pharos of Alpha Omega Alpha-Honor Medical Society. Alpha Omega Alpha</i> , 56(1), 34-36.	Commentary			
3775	Leventhal JM, Thomas SA, Rosenfield NS, Markowitz RI. 1993. Fractures in young children. Distinguishing child	Not relevant PIRO, reference test For each case, three assessments were made. First two clinicians (J.M.L. and S.A.T.), one	Not relevant PIRO, outcome Not possible to retrieve statistical data on metaphyseal fractures.		Rib fracture

abuse from unintentional injuries. <i>American Journal of Diseases of Children</i>, 147(1), 87-92.	with 7 years of experience directing the hospital's child abuse team, reviewed the clinical record, including the evaluation of the injury, the child's history, and events that occurred after the injury, and used a seven-point scale with predefined criteria to rate the likelihood that the fracture was due to abuse. This rating included three levels of certainty for abuse (definite, likely, and questionable), three levels of certainty for unintentional injury (or accidents) (questionable, likely, and definite), and a middle rating of unknown. Injuries that were reported to the child protective service agency because of neglect were classified on the unintentional injury side of the scale. Each category on the seven-point scale was precisely defined. (5) For example, "definite abuse" was diagnosed only when there was (1) a witness, (2) a confession, (3) a suspicious injury with a later episode of abuse, (4) a skeletal survey with an additional fracture or fractures, or (5) other bruises, burns or organ damage suggesting that abused had occurred. "Definite unintentional injury" required a witness to a child's injury by a neutral observer, such as a police officer, or a fall that occurred at a public setting, such as a supermarket, while a rating of "likely unintentional injury" was used for cases where the injury was judged to be consistent with the history. The seventh category, "unknown," was used for cases where the medical records did not provide sufficient details to allow a judgment to be made as to how the injury occurred.	"Metaphyseal fractures" not defined (CML?)		
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3785	Kowal-Vern A, Paxton TP, Ros SP, Lietz H, Fitzgerald M, Gamelli RL. 1992. Fractures in the under-3-year-old age cohort. <i>Clinical Pediatrics</i>, 31(11), 653-659.	Not relevant PIRQ, reference test "Child abuse cases were determined and reported to the Illinois Department of Children and Family Services if any of the following criteria were met: 1) inadequate	Observation <10 (6 cases with rib fractures in total, 4 abuse cases, 2 cases motor vehicle accident (both groups mean age <1 months)		Rib fracture

		explanation of injury; 2) multiple injuries; 3) presence of classical child abuse injuries; 4 physical findings inconsistent with history. To determine if all children younger than 3 years who sustained a fracture and were seen in the emergency room (ER) were admitted, a five month period (March to July 1990) for which records were available was retrospectively reviewed. " Patients who sustained a fracture were identified and categorized according to circumstances surrounding the injury: motor vehicle passenger, motor vehicle vs pedestrian, other accident, and child abuse.			
3787	Kleinman PK, Marks SC, Spevak MR, Richmond JM. 1992. Fractures of the rib head in abused infants. <i>Radiology</i>, 185(1), 119-123	Not relevant PIRO, outcome "this report details the radiologic and histopathologic characteristics of rib head fracture in seven abused infants. The frequency of rib head versus neck fractures was determined, and the mechanism of injury of this interesting lesion was examined."	Not relevant PIRO, reference test No description how the child abuse diagnosis was established. "A review of radiological and histological material from seven abused infants who died between 1984 and 1990 was performed"	Observation <10 (N=7)	Rib fracture
3805	Moseley CF. 1992. Occult fractures. <i>Instructional Course Lectures</i>, 41361-41367.	* Not accessed			
3814	Williams RA. 1991. Injuries in infants and small children resulting from witnessed and corroborated free falls. <i>The Journal of Trauma</i>, 31(10), 1350-1352.	Not relevant PIRO, outcome, population, index test, reference test Objective: To investigate differences in injury severities in small children <3 years) in witnessed or not witnessed free falls.			
3820	Taitz LS. 1991. Child abuse and metabolic bone disease: are they often confused? <i>BMJ</i>, 302(6787), 1244.	Not relevant PIRO, reference test Infants and children "who were the subjects of proceedings for child protection (N=19) or whose parents had been charged with causing their injuries (N=3). "Additional evidence of abuse was present in 17 cases" this included injuries such as brain damage, subdural haemorrhages, multiple bruises, neglect, "multiple evidence of			Rib fracture

		abuse and neglect". 1 of 22 cases was confessed by suspected perpetrator.			
3826	Kleinman PK, Belanger PL, Karellas A, Spevak MR. 1991. Normal metaphyseal radiologic variants not to be confused with findings of infant abuse. <i>American Journal of Roentgenology</i> . 156 (4). 781-783.	Non-systematic review (No description how articles were searched and included)	Other: Pictorial essay. Normal metaphyseal variants (1) Step-off, (2) Beak, (3) Proximal Tibial Cortical Irregularities, (4) Spur.		CML
3827	Kleinman PK, Marks SC, Jr., Spevak MR, Belanger PL, Richmond JM. 1991. Extension of growth-plate cartilage into the metaphysis: a sign of healing fracture in abused infants. <i>American Journal of Roentgenology</i> , 156(4). 775-779.	Not relevant PIRO, outcome Objective: To determine if healing metaphyseal injury in abused infants is accompanied by an increase in the thickness of the growth-plate zone of hypertrophic cartilage and if radiolucent extension from the growth plate into the metaphysis correlates with this histologic indicator of healing fracture."	Not relevant PIRO, reference test "infants who died with evidence of inflicted skeletal injuries".		CML
3828	Dent JA, Paterson CR. 1991. Fractures in early childhood: osteogenesis imperfecta or child abuse? <i>Journal of Pediatric Orthopaedics</i> , 11 (2): 184-6.	Not relevant PIRO, reference test No cases of non-accidental injuries, "all fractures were attributed to accidental injury". Not stated how the diagnosis of accidental injury nor of osteogenesis imperfecta was established.	Not relevant PIRO, population < 5 years	Not relevant PIRO, index test Objective: "We report the distribution and type of long bone fractures sustained by a group of children with OI < 5 years of age and compare these findings with those from a group of normal children of similar age."	Metaphyseal fractures?
3833	Loder RT, Bookout C. 1991. Fracture patterns in battered children. <i>Journal of Orthopaedic Trauma</i> , 5(4), 428-433.	Not relevant PIRO, reference test Children reported to the Social Service for actual or suspected physical abuse, and fractures in the medical records that "were considered by the Child Protection Team at the Children's Hospital of Michigan to be definite child abuse. (This multidisciplinary team is made up of social workers, radiologist, orthopaedic surgeons, and neurosurgeons, and is led by a pediatrician.)"	Observation <10 (7 cases with CML)	Only the number of rib fractures (N=31) is stated , not the number of children/infants is stated.	CML

3843	Sperry K, Pfalzgraf R. 1990. Inadvertent clavicular fractures caused by "chiropractic" manipulations in an infant: an unusual form of pseudoabuse. <i>Journal of Forensic Sciences</i> , 35(5), 1211-6.	Case report: 1 case, infant with healing, symmetrical clavicular fractures and a healing left medial humeral epicondyle fracture attributed to chiropractic manipulation.	Not relevant PIRQ, index test		
3851	Garcia VF, Gotschall CS, Eichelberger MR, Bowman LM. 1990. Rib fractures in children: a marker of severe trauma. <i>The Journal of Trauma</i> , 30(6), 695-700.	Not relevant PIRQ, population Observation <10 (Rib fractures: 7 cases abuse, mean age 0.6 years; 7 cases crash occupants, mean age 5.3 years; 16 cases pedestrian, mean age 6.2 years; 3 cases falls, mean age 4.7 years.	Not relevant PIRQ, reference test No description of how the diagnosis of abuse was established.		Rib fracture
3852	Krishnan J, Barbour PJ, Foster BK. 1990. Patterns of osseous injuries and psychosocial factors affecting victims of child abuse. <i>The Australian and New Zealand Journal of Surgery</i> , 60(6), 447-450.	Not relevant PIRQ, population Rib fractures: mean age 17.8 months, range 0.5-24 months. "metaphyseal injury" seems to be equivalent to classic metaphyseal lesions, but this is not explicitly stated. No age stated for those with metaphyseal fractures, but all were included in the study: mean age 16 months, range 0.5-69 months.	Not relevant PIRQ, reference test Suspicion of child abuse, sufficient enough to be reported to the Dept of Community Welfare at the hospital. 20/108 cases were investigated by the police and "proven". Mother of the abused was suspected in 50 % of the cases and was "confirmed" as the offender in 3 instances. The father was suspected in 24 % of the cases and "confirmed" as the offender in 6 cases. The male "de facto" was suspected in 15% of the cases and "confirmed" in 6 cases. The offender was unknown in 11 % of the cases. By "confirmed" means that the persons were charged after Criminal Bureau investigation. In 20 cases a person was charged. (Charges not correlated to injuries in the article, my comment)		
3865	Paterson CR. 1990. Osteogenesis imperfecta and other bone disorders in the differential diagnosis of unexplained fractures. <i>Journal of the Royal Society of Medicine</i> , 83(2), 72-74.	Not relevant PIRQ, population	Not relevant PIRQ, outcome	Not relevant PIRQ, index test Not relevant study design	

3868	Magid N, Glass T. 1990. A "hole in a rib" as a sign of child abuse. <i>Pediatric Radiology</i> , 20(5), 334-336.	Case report: 2 cases, infants with cyst-like radiolucencies in ribs, at least one case attributed to child abuse.	Not relevant PIRO, reference test No description how the diagnosis of abuse was established.		
3873	Smeets AJ, Robben SG, Meradji M. 1990. Sonographically detected costo-chondral dislocation in an abused child. A new sonographic sign to the radiological spectrum of child abuse. <i>Pediatric Radiology</i> , 20 (7): 566-567.	Case report: 1 case, costo-chondral dislocation detected sonographically in an infant. Multiple fractures, including metaphyseal and posterior rib fractures, attributed to child abuse.	Not relevant PIRO, reference test No description how the diagnosis of abuse was established.		CML + Rib
3879	Rizzolo PJ, Coleman PR. 1989. Neonatal rib fracture: birth trauma or child abuse? <i>The Journal of Family Practice</i> , 29 (5), 561-563.	Case report: 1 case, rib fracture in newborn attributed to birth trauma			Rib fracture
3883	Dahlenburg SL, Bishop NJ, Lucas A. 1989. Are preterm infants at risk for subsequent fractures? <i>Archives of Disease in Childhood</i> , 64(10 Spec No), 1384-1385.	Not relevant PIRO, outcome Objective: To "test the hypothesis that premature infants, especially those under <33 weeks' gestation (the high risk group for early bone disease) are at increased risk of childhood fractures compared with infants born at full term".	Not relevant PIRO, population ≤ 5 years	Not relevant PIRO, index test	.
3891	Hobbs CJ. 1989. ABC of child abuse. Fractures. <i>BMJ</i> , 298 (6679), 1015-1018.	Non-systematic review (No description how articles were search or included)			
3894	Kleinman PK, Blackbourne BD, Marks SC, Karellas A, Belanger PL. 1989. Radiologic contributions to the investigation and prosecution of cases of fatal infant abuse. <i>The New England Journal of Medicine</i> , 320 (8): 507-11.	Not relevant PIRO, outcome Objective: To determine if improved ability to identify and date osseous lesions during autopsy (radiologically and histologically) aid the medical investigation and prosecution in fatal infant abuse.	Not relevant PIRO, reference test Not explicitly stated, but seem to be based on an overall assessment (police investigation and autopsy findings including skeletal fractures such as CML and rib fractures). Three cases had a "history of shaking".	Observation <10 (8 of 12 cases were found to be victims of abuse)	
3906	King J, Diefendorf D, Apthorp J, Negrete VF, Carlson M. 1988. Analysis of 429 fractures in 189 battered children. <i>Journal of Pediatric Orthopedics</i> , (5), 585-589.	Not relevant PIRO, reference test Children "considered by either the Social Service scan team or the municipal courts to have been battered" that was seen at the Los Angeles Hospital and had fractures.			Rib fracture
3915	Kleinman PK, Marks SC, Adams VI, Blackbourne BD. 1988. Factors	Not relevant PIRO, outcome	Not relevant PIRO, reference test		Rib fracture

	affecting visualization of posterior rib fractures in abused infants. <i>American Journal of Roentgenology</i> , 150(3), 635-658.	Objective: To provide an understanding of the factors influencing visibility of posterior rib fractures in abused infants.	The diagnosis: child abused was established "on the presence of associated skeletal abnormalities considered indicative of abuse, including metaphyseal 'bucket-handle' and 'corner' fractures of the extremities, scapular fractures, spinous process fractures, and characteristic traumatic central nervous system injury."		
3916	Nazer H, Daradkeh T, Mohamed S, Shamayleh AQ, Marei O. 1988. A diagnostic dilemma in Jordan: two child abuse case studies. <i>Child Abuse & Neglect</i> , 12(4), 593-599.	Case report: 2 cases (a 15 months old and a 3 years old) with multiple injuries, the 3 years old with rib fractures, attributed to child abuse.	Not relevant PIRQ, population		
3953	Worlock P, Stower M, Barbor P. 1986. Patterns of fractures in accidental and non-accidental injury in children: a comparative study, <i>British Medical Journal (Clinical Research ed.)</i> , 293(6539), 100-102.	Not relevant PIRQ, reference test "Children with fractures due to non-accidental injury were identified from the records of the Nottinghamshire National Society for the Prevention of Cruelty to Children special unit ... Only those children whose fractures were proved to be the result of child abuse were included; those placed on the register of children at risk because a case conference could not confirm suspicions of abuse were excluded from the study. ... The control group comprised all children aged 12 or under who presented with a fracture to the accident department of the University Hospital, Nottingham, from 1 January to 30 June 1981 and in whom abuse was excluded. These children were identified from Hospital Activity Analysis, fracture clinic records, and accident unit records."	Not relevant PIRQ, population Unclear if population is "infants" as normally defined (<1 year) or as <18 months which is used as cut-off for describing the population in the article.		CML + Rib
3960	Stöver B. 1986. [Radiologic diagnosis of the battered child syndrome].	Non-systematic review (No description how articles were searched or included)			

	<i>Monatsschr Kinderheilkd</i> , 134 (6), 322-327.				
3962	Kleinman PK, Marks SC, Blackburne B. 1986. The metaphyseal lesion in abused infants: a radiologic-histopathologic study. <i>American Journal of Roentgenology</i> , 146 (5), 895-905.	Observations (-10) 4 cases with CML	Not relevant PIRQ, reference test "The diagnosis of abuse was based on history, clinical findings, typical skeletal lesions, determination by social service agencies, and characteristic patterns of intracranial hemorrhage, as seen by antemortem CT and by pathologic examination at autopsy"	Not relevant PIRQ, outcome Objective: A radiologic-histopathologic study to determine whether the inferences that have been drawn from the radiologic findings in abused infants are accurate.	CML
3966	Thompson BM, Finger W, Tonsfeldt D, Aprahamian C, Troiano P, Hendley G, Mateer J, Stueven H. 1986. Rib radiographs for trauma: useful or wasteful? <i>Annals of Emergency Medicine</i> , 15 (3), 261-5.	Non-systematic review Objective: To examine the utility and sensitivity of radiological diagnosis of rib fracture with and without pulmonary complications in the settings of chest trauma.			Rib fracture
3980	Schweich P, Fleisher G. 1985. Rib fractures in children. <i>Pediatric Emergency Care</i> , 1 (4), 187-9.	Not relevant PIRQ, reference test Revision of charts of children admitted to the hospital, with rib fractures. No information on how the diagnosis of abuse was established. "Five children, all infants, had rib fractures from non-accidental causes... Each of these infants came to the ED without a history of significant trauma; three of the reported cases had sudden onset of respiratory distress, according to their parents." No information on how the mechanism of the rib fractures in the other groups was established. (Motor vehicle accident - passenger or pedestrian, fall from height or gunshot.)			Rib fracture
4009	Feldman KW, Brewer DK. 1984. Child abuse, cardiopulmonary resuscitation, and rib fractures. <i>Pediatrics</i> , 3(3), 339-342.	Not relevant PIRQ, reference test 3 groups: the abuse group, the cardiopulmonary resuscitation group and the incidental group. "The abused group contained 41 inpatients consecutively referred ... to the Children's Orthopedic Hospital and Medical Center child abuse			Rib fracture

		team and confirmed by them to have been abused. The cardiopulmonary resuscitation group (CRP group) contained 50 patients who had received CPR including closed-chest cardiac massage... Although the identification of children receiving CPR was undoubtedly incomplete, all who had chest roentgenogram subsequent to resuscitation were included in the review. The incidental fracture group included 22 patients who had rib fractures discovered on chest film during the same time period as that used for the CPR group. "In all cases" the abuse group, the CRP group, the incidental fracture group "abuses was diagnosed by our child abuse team on the basis of additional physical and social data." "Injuries other than rib fractures or other physical signs of neglect led to the investigation and diagnosis of child abuse in the 13 of the 14 children with the abusive rib fractures. These injuries included: other fractures in six patients, abdominal visceral injury in three, skin trauma in six, failure to thrive in three, and cardiac arrest in three."			
4019	Helfer RE, Scheurer SL, Alexander R, Reed J, Slovis TL. 1984. Trauma to the bones of small infants from passive exercise: a factor in the etiology of child abuse. <i>The Journal of Pediatrics</i>, 104 (1), 47-50.	Case report: 4 cases, infants with fractures attributed to passive exercise, 1 with rib fractures, 1 "chip fractures" and 1 with both rib and "chip" fractures.			Rib fracture + "chip fractures"
4028	Leonidas JC. 1983. Skeletal trauma in the child abuse syndrome. <i>Pediatric Annals</i>, 12 (12), 875-881.	Non-systematic review (No description how articles were searched or included)			CML + Rib
4043	Merten DF, Radkowski MA, Leonidas JC. 1983. The abused child: a	Not relevant PIRO, reference test Child abuse diagnosis established on "strong clinical evidence of abuse" (but no	Not relevant PIRO, index test (Rib OK.)	(Problems with Table II and III, epiphyseal/metaphyseal fractures mistake, mixture of	Rib fracture + "epiphyseal-

	radiological reappraisal. <i>Radiology</i> , 146 (2), 377-381.	further explanation of what this means). "An attempt was made to categorize abuse into physical, neglect/deprivation, and sexual abuse based upon the presenting history and physical examination. Clinical evidence of physical injury was present in 698" Other groups was neglect/deprivation and sexual abuse. (No further explanation of what "clinical evidence" of physical abuse means.)	CML not mentioned , but, "epiphyseal-metaphyseal" fractures which "include characteristic metaphyseal 'avulsion' fractures and 'bucket-handle' new bone formation"	number of fractures and number of patients.)	metaphyseal fractures which "include characteristic metaphyseal 'avulsion' fractures and 'bucket-handle' new bone formation."
4061	Dorst JP. 1982. Child abuse. <i>Der Radiologe</i> , 22 (8), 335-341.	Non-systematic review (No description how articles were searched or included)			CML + Rib
4067	Rosenberg N, Bottenfield G. 1982. Fractures in infants: a sign of child abuse. <i>Annals of Emergency Medicine</i> , 11 (4), 178-180.	Not relevant PIRQ, index test	Not relevant PIRQ, reference test "Suspected Abuse" "In patients with a history of fall, child abuse was suspected when there was a delay in seeking aid (3), incompatible history (2), associated physical findings (2) unusual fracture (1), and variable history (1). An unknown history of trauma was present in 20 % of the patients, all children believed to be abused"		.
4074	Tischer W, Jahrig K. 1982. [Perinatal injuries of skeletal system]. <i>Zentralblatt für Gynäkologie</i> , 104 (18), 1169-1181.	Non-systematic review (No description how articles were searched or included)			
4076	Pickett III WJ, Johnson JF, Enzenauer RW. 1982. Case report 192. Neonatal fractures mimicking abuse secondary to physical therapy. <i>Skeletal Radiology</i> , 8(1), 85-86.	Case report: 1 case of CML in newborn, attributed to physiotherapy with increased muscle tonus and contractures.			CML
4077	Galleno H, Oppenheim WL. 1982. The battered child syndrome revisited. <i>Clinical Orthopaedics and Related Research</i> , (162): 11-19.	Not relevant PIRQ, population UCLA subgroup: 7 weeks - 17 years. 50% <3 years. Second peak in adolescence (11-17	Not relevant PIRQ, reference test UCLA subgroup: Referred to the child abuse team and "clinically confirmed as victims of child abuse" ("Victims of	Not relevant PIRQ, index test Uncertain if CML were studied.	Rib + metaphyseal "Beak", "Periosteal"

		years). No information on age in the LAOH subgroup. Only 5 children with rib fractures, the age of these not stated.	"neglect or sexual molestation" was not included). (No description how they were clinically confirmed). LAOH subgroup: 15 roentgenographically diagnosed patients from Los Angeles Orthopedic Hospital. (No further description how the diagnosis of abuse was established).		or "Impaction"
4079	McClelland CQ, Heiple KG. 1982. Fractures in the first year of life. A diagnostic dilemma. <i>American Journal of Diseases of Children</i> (1960), 136(1), 26-29.	Not relevant PIRQ, reference test "The criteria for diagnosis of nonaccidental cause (child abuse) included the following: (1) history at variance with severity of injuries; (2) history details changed during interview with parent or caretaker; (3) different versions of the injury presented by various family members; (4) substantial delay in seeking medical care; (5) accompanying signs of abuse and neglect such as bruises, burns, scars, and evidences of poor general care and nutritional deprivation; (6) multiple fractures unexplained by the nature of the injury or the presence of accompanying host abnormalities." (Not stated how many criteria had to be fulfilled for diagnosis.) "The decision as to the nonaccidental cause was confirmed only after a review was made of the details of the case history and of the hospital course of the child by the Hospital Child Protection Team, consisting of senior pediatrician, social worker, and pediatric nurse with long experience with child abuse cases."	Not relevant PIRQ, index test. No clear definition of CML. Fractures in the metaphyseal area described as "metaphyseal evulsion" (2) or "metaphyseal - other" (3) Also "epiphyseal" (1). Rib fractures reported only as total amount in non-accidental group + accidental group, and the percentage who had host abnormalities such as OI, osteopenia due to nutritional problems etc.	Observation <10 only 5 fractures in the metaphyseal area.	CML?
4090	Merten DF, Kirks DR, Ruderman RJ. 1981. Occult humeral epiphyseal fracture in battered infants. <i>Pediatric Radiology</i> , 10(3), 151-154.	Case report: 2 cases, complete fracture separation of the proximal and distal humeral epiphyses in infants, attributed to battered child syndrome.	Not relevant PIRQ, index test		

4096	Smith FW, Gilday DL, Ash JM, Green MD. 1980. Unsuspected costo-vertebral fractures demonstrated by bone scanning in the child abuse syndrome. <i>Pediatric Radiology</i> , 10(2), 103-6.	Case reports: 4 cases, infants with multiple fractures, amongst other costo-vertebral fractures, diagnosed by bone scintigraphy. Fractures attributed to physical abuse.	Observations (<10)		Rib fracture
4106	Horan FT, Beighton PH. 1980. Infantile metaphysial dysplasia or "battered babies"? A reassessment of material in the Fairbank Collection. <i>The Journal of Bone and Joint Surgery. British volume</i> , 62-b (2), 243-7.	Observations (<10) 4 cases < 12 months	Not relevant PIRO, reference test	Not relevant PIRO, population	CML
4126	Garraway WM, Stauffer RN, Kurland LT, O'Fallon WM. 1979. Limb fractures in a defined population. I. Frequency and distribution. <i>Mayo Clinic Proceeding</i> , 54 (11): 701-7.	Not relevant PIRO, all Objective: To describe frequency and distribution of limb fractures in a well defined population (CML and rib fractures in infants not mentioned).			
4136	Astley R. 1979. Metaphyseal fractures in osteogenesis imperfecta. <i>The British Journal of Radiology</i> , 52(618), 441-443.	Not relevant PIRO, outcome Objective: To describe metaphyseal fractures in osteogenesis imperfecta resembling metaphyseal fractures in non-accidental injuries.	Not relevant PIRO, reference test "obvious generalized bone disease so that confusion with non-accidental injury did not occur".	Differential diagnosis: Osteogenesis imperfecta	CML
4161	Kerley ER. 1978. The identification of battered-infant skeletons. <i>Journal of Forensic Sciences</i> , 23(1), 163-68.	Case report: 3 cases, skeletal remains of infants with multiple fractures, including rib fractures.			Rib fracture
4185	Thomas PS. 1977. Rib fractures in infancy. 1977. <i>Annales de Radiologie (Paris)</i> , 20(1), 115-22.	Not relevant PIRO, reference test No description how the diagnosis of abuse was established.	Observations (<10) 6 cases of rib fractures attributed to abuse		Rib fracture
4193	Rupprecht E, Berger G. 1976. [On the differential diagnosis of multiple skeletal trauma in childhood (author's trans)]. <i>Radiologica Diagnostica</i> , 17 (5), 615-25.	Non-systematic review (No description how articles were searched or included)			CML + Rib
4204	Bartel M, Sellentin W. 1976. [Analysis of ribs and serial fractures of the ribs]. <i>Zentralblatt für Chirurgie</i> , 101(2), 77-84.	Not relevant PIRO, population Subgroup 0-10 years	Observations (<10) Approximately 8 in the age group 0-10 years		Rib fracture

4207	Rethmeier JW. 1976. Infantile cortical hyperostosis (Caffey's disease). Two case reports. <i>Radiologia Clinica</i> , 45(2-4), 251-257.	Case report: 2 cases, infants with infantile cortical hyperostosis	Not relevant PIRQ, index test		.
4247	Smith SM, Hanson R. 1974. 134 battered children: a medical and psychological study. <i>British Medical Journal</i> , 3 (5932), 666-670.	Not relevant PIRQ, all			.
4249	Akbarnia B, Torg JS, Kirkpatrick J, Sussman S. 1974. Manifestations of the battered-child syndrome. <i>The Journal of Bone and Joint Surgery. American volume</i> , 56(6), 1159-1166.	Not relevant PIRQ, reference test No description how child abuse diagnosis was established.	Not relevant PIRQ, population	Not relevant PIRQ, index test Only the number of rib fractures is stated, not the number of children. No information on CML.	Rib fractures
4256	Lauer B, Ten Broeck E, Grossman M. 1974. Battered child syndrome: review of 130 patients with controls. <i>Pediatrics</i> , 54(1), 67-70.	Not relevant PIRQ, index test	Not relevant PIRQ, population	Not relevant PIRQ, reference test "A 'battered' or 'abused' child was defined as any child under 10 years of age hospitalized because of physical injuries believed to have been caused intentionally by a parent, other household member or a regular caretaker. In screening charts we excluded uninjured children even though they may have been neglected or otherwise maltreated and we accepted the staff's decisions that the children's injuries were nonaccidental."	.
4285	George JE. 1973. Spare the rod: a survey of the battered-child syndrome. <i>Forensic Science</i> , 2(2), 129-167.	Non-systematic review (No description how articles were searched or included)			CML + Rib
4286	McRae KN, Ferguson CA, Lederman RS. 1973. The battered child syndrome. <i>Canadian Medical Association journal</i> , 108 (7), 859-860.	Not relevant PIRQ, index test	Not relevant PIRQ, population	Not relevant PIRQ, reference test	.
4288	O'Neill JA, Jr., Meacham WF, Griffin JP, Sawyers JL. 1973. Patterns of	Not relevant PIRQ, reference test No clear description how the diagnosis of abuse	Not relevant PIRQ, population		CML + "Metaphyse

	injury in the battered child syndrome. <i>The Journal of Trauma</i> , 13(4), 332-9.	was established. "Follow-up information was available on every patient, since all were reported to the Juvenile Court and followed by a caseworker. The person responsible for the injury was known in 98 of the 110 cases. In 79 instances one or both of the parents were proved or strongly suspected to be responsible for the injury; in 55 of these cases it was the mother. Older siblings were responsible five times. Baby sitters or others close to the family were at fault 14 times."	All children with physical child abuse, range 3 weeks - 11 years. "The vast majority were between the age of 6 months and 1 year." "The most common victim of child battering was under the age of 2 years".		al fragmentati on"
4312	American Academy of Pediatrics Committee on Infant and Preschool Child. 1972. Maltreatment of children. The battered child syndrome. <i>Pediatrics</i> , 50 (1), 160-162.	Not relevant study design: Consensus statement/recommendation			
4319	Hiller HG. 1972. Battered or not - a reappraisal of metaphyseal fragility. <i>The American Journal of Roentgenology, Radium Therapy, and Nuclear Medicine</i> , 114(2), 241-246.	Not relevant PIRQ, population Age not stated for study 2.	Not relevant PIRQ, reference test Study 1) Infants and children with long bone fractures "in whom no stigmata of battering were present. "As can be imagined, the type of trauma varied tremendously. At one end of the scale were patients with no known injury, and at the other were patients who had sustained severe falls from heights or been involved in automobile accidents." Study 2) All children and infants suspected of battering.	Observation <10 (0 cases with CML in study 1, 5 cases with CML study 2)	CML
4320	Caffey J. 1972. The parent-infant traumatic stress syndrome; (Caffey-Kempe syndrome), (battered babe syndrome). <i>The American Journal of Roentgenology, Radium Therapy, and Nuclear Medicine</i> , 114(2), 218-229.	Non-systematic review (No description how articles were searched or included)			
4381	Caffey J. 1970. Traumatic cupping of the metaphyses of growing bones.	Case report: 5 case, cupping of the metaphyses attributed to trauma,			.

	<i>The American Journal of Roentgenology, Radium Therapy, and Nuclear Medicine</i> , 108(3), 451-460.	including 2 cases of abuse, seen in children months to years after a manifest or suspected traumatic event.			
4465	Wurfel LJ, McCoy WT. 1965. Radiographic features of the battered child syndrome. <i>Journal of the College of Radiologists of Australasia</i> , 9(3), 220-223.	Not relevant PIRO, reference test No description how the diagnosis of abuse was established. "The radiological findings in these children were of major importance both in diagnosis and as guidance and as a guide to management."	Observation <10 (7/26 cases rib fractures, 7/26 metaphyseal fractures - no data on CML)	Not relevant index test CML: The metaphyseal fractures: "are common and occurred in the limb long bones in seven children. They included small chip fractures ... and metaphyseal rarefactions ... Avulsion of the epiphyseal-metaphyseal fragment may occur following transverse fracture with separation through the cartilaginous epiphyseal plate". This is a broader definition than that of CML.	Rib fracture
4483	Teng CT, Singeleton EB, Daeschner CW, Jr. 1964. Skeletal injuries of the battered child. <i>The American Journal of Orthopedics</i> , 6, 202-207.	Case report: 5 case (3 weeks - 15 months), with multiple fractures, including metaphyseal infarctions and rib fractures, attributed to child abuse.	Not relevant PIRO, reference test		CML + Rib
4494	Fairburn AC, Hunt AC. 1964. Caffey's "Third syndrome" – A critical evaluation ("The battered baby"). <i>Medicine, Science, and the Law</i> , 4:123-4126.	Case report: 4 cases.			Rib fracture
4503	Griffiths DL, Moynihan FJ. 1963. Multiple epiphyseal injuries in babies. ("Battered baby syndrome"). <i>British Medical Journal</i> , 2(5372), 1558-1561.	Case report: 6 infants with multiple fractures including metaphyseal lesions, rib fractures, and subdural hematoma attributed to physical child abuse.	Not relevant PIRO, reference test		CML
4509	Kempe CH, Silverman FN, Steele BF, Droegemueller W, Silver HK. 1962. The battered-child syndrome. <i>JAMA</i> , 181:17-18124.	Non-systematic review	Case report: 2 cases, (3 months, 13 months) fractures, subdural hematoma		CML
4528	Blackmore. JA 2014. Incidental finding of healing rib fractures on	Conference proceeding			Rib fracture

	chest x-ray and non-accidental skeletal injury in young children. <i>Pediatric Radiology</i> , 44S374-S375.				
4529	Frankel J, Pinggen A, Schifffmann H, Vogel M, Vlainic D, Ganschow R, Born M. 2014. Cardiopulmonary resuscitation (CPR)-related posterior rib fractures in neonates and infants following recommended changes in CPR techniques. <i>Child Abuse & Neglect</i> , 38(7), 1267-1274.	Not relevant PIRO, reference test "all infants with anterior-posterior chest radiographs after CPR". Excluded: no medical records, no chest compressions documented, CPR outside hospital, sternotomy, osteopenia, osteoporosis, other bone disease ("were excluded radiologically" (no signs of bone disease on chest radiographs) and by patient records (e.g. Ca/Crea i.U. screening), abuse ("was excluded by reference imaging before CPR or by the fact that the infant had not been discharges from hospital from birth to the time of CPR and by patients records") (<i>none excluded in this criterion</i>), accidental trauma (<i>none excluded on this criterion</i>).	Not relevant PIRO, outcome Objective: To "investigate the incidence of posterior rib fractures related to the "two-thumbs" technique in neonates and infants. If CPR-related rib fractures do occur, it will be essential to clarify whether these rib fractures differ from NAT-associated rib fractures".	Differential diagnosis: CPR	Rib fracture
4542	Paterson CR. 2014. Osteogenesis imperfecta and rib fractures in infancy. <i>Journal of Pediatric Orthopaedics</i> , 34(5), e12.	Letter to editor: Reply on Greeley et al (2013)			Rib fracture
4545	Hyman C, Miller M, Ayoub D. 2010. Evidence of metabolic bone disease in young infants with multiple fractures misdiagnosed as child abuse. <i>Journal of Bone and Mineral Research</i> , 25S140-S141.	Conference proceeding			
4559	Burge L, Shropshire DL. 2014. Embracing the grey: Advocating for patients when the story and the science don't add up. <i>Journal of Investigative Medicine</i> , 62(2), 474.	Conference proceeding			
4575	Perez-Rossello J. 2013. Update on child abuse imaging. <i>Pediatric Radiology</i> , 43S267.	Conference proceeding			

4702	Holmes Morton D. 2011. In the time of genomics: Genetic disorders and the mistaken diagnoses of child abuse, neglect, or SIDS. <i>Molecular Genetics and Metabolism</i> , 102 (3), 305-306.	Conference proceeding			
4712	Willson PM, Greiner MV, Duma EM. 2012. Posterior rib fractures in a young infant who received chiropractic care. <i>Pediatrics</i> , 130(5), e1359-e1362.	Case report: 1 infant with 2 posterior rib fractures, attributed to chiropractic care.			Rib fracture
4738	Mahomed N, Goodier M. 2012. Non accidental injury - A South African experience. <i>Pediatric Radiology</i> , 42S551-S552.	Conference proceeding			
4742	Shalaby-Rana E, Jackson AM, Hinds T, Deye K. 2012. Radiologists beware: Unusual imaging manifestations in child abuse. <i>Pediatric Radiology</i> , 42S347-S348.	Conference proceeding			
4749	Karmazyn B, Duhn RD, Jennings SG, Matthew RW, Tahir B, Hibbard R, Hicks R. 2012. Long bone fracture detection in suspected child abuse: Contribution of lateral views. <i>Pediatric Radiology</i> , 42(4), 463-469.	Not relevant PIRQ, outcome To "compare the frequency and the confidence of fracture detection in the long bone using both frontal and lateral radiographs, compared with the ACR guideline of frontal radiographs alone".	Not relevant PIRQ, reference test "we identified all skeletal surveys performed for suspicion of child abuse from". "We excluded any surveys not performed for suspected child abuse, as well as incomplete, repeat and follow-up surveys, as well as children with underlying bone disease or dysplasia". "A radiologist who did not participate in image evaluation reviewed the original radiological reports and identified 100 patients for inclusion in the study. All consecutive patients with multiple long bone fractures (N=56) were included. To decrease the bias of the radiologists reviewing the studies, the other 44 children included 2 groups of consecutive patients with a single long		CML

			bone fracture or no long bone fractures (N = 22 in each group).		
4762	Hirsh MP, McGuire MM. 2011. Good things come in small packages- unique neonatal anatomic features. <i>FASEB Journal: official publication of the Federation of American Societies for Experimental Biology</i> . 2011, 25.	Conference proceeding			
4764	Clarke NMP, Shelton FRM, Taylor CC, Khan T, Needhirajan S. 2012. The incidence of fractures in children under the age of 24 months - In relation to non-accidental injury. <i>Injury</i> , 43(6), 762-765.	Not relevant PIRQ, index test	Not relevant PIRQ, reference test "Mechanism of injury was established according to the history resulting in the injury. The fractures were then categorised into significant, insignificant and unexplained mechanism. Significant injury included falls during outdoor activities (e.g. trampoline), falls from a height over 2 ft such as stairs or being dropped, and insignificant injury included falls from sofas/beds and indoor activities." "Of 123 children who attended the ED, abuse was not suspected in 96 of the cases. Of the others, 5 patients had a report of concern filed in their medical notes, and 22 were referred to CPS. 16 children had both a report of concern filed and a CPS referral."		
4783	Martin PS, Jones MD, Maguire SA, Theobald PS, Kemp AM. 2012. Increased incidence of CPR-related rib fractures in infants - Is it related to changes in CPR technique? <i>Resuscitation</i> , 83(4), e109.	Letter to editor: Reply on Reyers et al (2011) #8096			
4833	Al-Mahroos F, Al-Amer EA, Umesh N, Alekri AI. 2011. Pattern of skeletal injuries in physically abused children. <i>Bahrain Medical Bulletin</i> , 33 (2).	Not relevant PIRQ, reference test The Child Protection Unit "reviewed all the records of child abuse and neglect. Out of 804 child abuse and neglect, 36 children were identified to have abusive skeletal injuries". "None of the children	Observation <10 (6 cases $\leq$ 1 year with rib fractures)		Rib fracture

		had a plausible history of major trauma and none had CPR before diagnosing fractures. All cases of accidental trauma or those due to metabolic disease such as osteogenesis imperfecta, osteopenia of prematurity, and rickets were excluded." "This study is based on the review of medical records, radiographs ... Only children who sustained skeletal fractures as a result of child abuse were included in the study."			
4849	Mathers D. 2011. The imperfect science of non-accidental injury diagnosis. <i>Internal Medicine Journal</i> , 4135.	Conference proceeding			
4853	Cosway B, Mathura N, Bredow M, Fraser J, Mott A, Rawlinson A, Soe N, Thyagarajan M, Kemp. 2011. A Diagnostic indicator for nai in children with rib fractures; a retrospective analysis of 52 infants. <i>Archives of Disease in Childhood</i> , 96A99.	Conference proceeding			Rib fracture
4854	Swischuk L, Surnedi M, Jadhav S, Muzzafar S. 2011. Rickets and the battered child: A possible algorithm. <i>American Journal of Roentgenology</i> , 196(5 Suppl.), A275.	Conference proceeding			
4912	De Melo AN, De Medeiros LL, Nobre RM, Neto MM, Fonseca ASM. 2010. Non-traumatic fracture of the femur in an infant with recurrent epileptic seizures - Case report. <i>Journal of Epilepsy and Clinical Neurophysiology</i> , 16(2). 77-79.	Case report: 1 case, transepiphyseal fracture (Type 1 fracture according to Delbetts) in the femur neck attributed to seizure.	Not relevant PIRO, index test		
4940	Swischuk LE, Surnedi MK, Jadhav SP, Muzzafar S. 2010. Rickets and the battered child: A possible algorithm. <i>Pediatric Radiology</i> , 40(4), 575.	Conference proceeding			

4941	Kleinman PK, Perez-Rossello JM, Newton AW, Kleinman PL. 2019. Prevalence of the classic metaphyseal lesion in infants at low versus high risk for abuse. <i>Pediatric Radiology</i> , 40(4), 567-568.	Conference proceeding			
4946	Perez-Rossello J, Newton A, Kleinman P. 2010. Prevalence of the classic metaphyseal lesion in infants at low versus high risk for abuse. <i>Pediatric Radiology</i> , 40 (6)1101-1102.	Conference proceeding			
4949	Wei C, Stevens J, Harrison S, Mott A, Warner J. 2010. Fractures in a tertiary neonatal intensive care unit in Wales. <i>Archives of Disease in Childhood</i> , 95A93.	Conference proceeding			Rib fracture
5042	Mejean N, Rey-Salmon C, Adamsbaum C. 2009. Shaken baby syndrome (SBS): Frequency of imaging patterns through a large series. <i>Pediatric Radiology</i> , 39S580.	Conference proceeding			
5098	Kaplan KM, Gruson KI, Paksima N. 2008. Bilateral humerus and corner fractures in an 18-month-old infant: A case report and review of child abuse from the resident perspective. <i>Bulletin of the NYU Hospital for Joint Diseases</i> , 66(2), 124-128.	Case report: 1 case, multiple fractures, including corner fractures, in 18 months old toddler. Parent admitted striking the toddler several times.	Not relevant PIRQ, population (18 months)		CML
5171	Carroll DM, Doria AS, Paul BS. 2007. Clinical-radiological features of fractures in premature infants - A review. <i>Journal of Perinatal Medicine</i> , 35(5), 366-375.	Non-systematic review (No description how articles were searched or included)	Other: Aimed to "review the prenatal changes and postnatal adaptations of bones in premature infants, and discuss the prevalence, etiopathogenesis and characteristics of fractures specifically encountered in the premature infant, as well as the imaging modalities available for diagnosis".		

5222	Pierce MC, Bertocci G. 2006. Fractures resulting from inflicted trauma: Assessing injury and history compatibility. <i>Clinical Pediatric Emergency Medicine</i> , 7(3), 143-148.	Case report: 3 cases with fractures attributed to non-accidental injury, 1 case confessed (CML or rib fractures not mentioned in the confessed case).	Non-systematic review	Other: Objective: This article will provide an overview of fractures resulting from inflicted trauma in young children and will address the issue of assessing injury and history compatibility. Fact-based cases are provided for illustrative purposes.	
5450	Lysack JT, Soboleski D. 2003. Classic metaphyseal lesion following external cephalic version and cesarean section. 2003. <i>Pediatric Radiology</i> , 33(6), 422-424.	Case report: 1 case with CML in proximal tibia attributed to external cephalic version for frank breech and subsequent urgent Caesarean section.			CML
5526	Sorantin E, Lindbichler F. 2002. Die nicht unfallbedingte Verletzung (battered child). <i>Der Radiologe</i> , 42(3), 210-216.	Non-systematic review (No description how articles were search or included)			
5527	Chalumeau M, Foix-I'Helias L, Scheinmann P, Zuani P, Gendrel D, Ducou-le-Pointe H. 2002. Rib fractures after chest physiotherapy for bronchiolitis or pneumonia in infants. <i>Pediatric Radiology</i> , 32(9), 644-647.	Case report: 5 infants with rib fractures after chest physiotherapy.			
5673	Ingram JD, Connell J, Hay TC, Strain JD, Mackenzie T. 2000. Oblique radiographs of the chest in nonaccidental trauma. <i>Emergency Radiology</i> , 7(1), 42-46	Not relevant PIRO, outcome Objective: To "evaluate whether the addition of oblique chest radiographs to the skeletal survey for nonaccidental trauma improved our ability to diagnose rib fractures".	Not relevant PIRO, reference test Children who underwent radiographic examination for suspected non-accidental injuries.		Rib fracture
5731	Rao P, Carty H. 1999. Non-accidental injury: Review of the radiology. <i>Clinical Radiology</i> , 54(1), 11-24.	Non-systematic review (No description how articles were searched or included)			CML + Rib
5791	Swischuk LE. 1998. Metaphyseal corner fractures in infants: A review. <i>Emergency Radiology</i> , 1998, 5(2), 103-107.	Non-systematic review (No description how articles were searched or included)			CML

5847	Bush CM, Jones JS, Cohle SD, Johnson H. 1996. Pediatric injuries from cardiopulmonary resuscitation <i>Annals of Emergency Medicine</i> , 28(1), 40-44.	Not relevant PIRQ, population <12 years: Mean age 19.0 months, range 6 hours - 12 years.	Not relevant PIRQ, reference test "records from all deceased children (<12 years old) who had been given CPR during an 8-year period (1988 through 1995). Patients with historical or physical evidence of preceding trauma were excluded. Clinical and autopsy records were abstracted for patient demographics, clinical findings, duration of CPR, persons administering CPR, and medical examiner summaries". "Two hundred sixty children were found to have undergone CPR. Of these, 49 were excluded for the following reasons: historical or physical evidence of preceding trauma or physical abuse (N=43); missing documentation of resuscitation efforts (N=4); or a medical history of bleeding diatheses (N=2)."	Not relevant PIRQ, outcome To "assess the type, rate, and severity of unanticipated complications of CPR (external cardiac compressions and ventilation) in a pediatric population. Differential diagnosis: CPR	Rib fracture
5927	Markowitz RI, Hubbard AM, Hartz MP, Bellah RD, Kessler A, Meyer JS. 1993. Sonography of the knee in normal and abused infants. <i>Pediatric Radiology</i> , 23(4), 264-267.	Not relevant PIRQ, outcome Objective: Illustrates the sonographic appearance of the normal infants' knee and correlates the radiographic abnormalities seen in child abuse with sonography. An example of neonatal rickets mimicking child abuse is also included.	Not relevant PIRQ, reference test Not stated how the diagnosis of abuse was established.	Observation <10 (3 infants with CML, 1 infant with rickets, 1 case with normal anatomy).	CML
6197	Pohl M. 1967. Differential diagnostic criteria for acquired metaphyseal changes in childhood. [German] <i>Der Radiologe</i> , 7(12), 380-382.	Non-systematic review			CML
6306	Capesius P, Van Damme W, Toutou D, Reolon M. 1977. The metaphyseal lesions of Menkes' syndrome - a case report. [French] <i>Journal Belge de Radiologie</i> , 60(4), 345-350.	Case report: 1 infant with Menkes' disease and metaphyseal changes			CML

6387	Clemetson CAB. 2006. Caffey revisited: a commentary on the origin of "shaken baby syndrome" ... Caffey J. Multiple fractures in the long bones of infants suffering from chronic subdural hematoma, <i>Journal of American physicians & surgeons</i> , 11(1), 20-21.	Other: Comment? Differential diagnosis			
6458	De Wagner B. 2011. Differential diagnosis: child abuse or bone disorder? <i>Body Cast</i> , 26 (2): 10-12.	Non-systematic review			
6535	Smurthwaite D, Wright NB, Russell S, Emmerson AJ, Mughal MZ. 2009. How common are rib fractures in extremely low birth weight preterm infants? <i>Archives of Disease in Childhood - Fetal & neonatal edition</i> , 94(2), F138-F139.	Not relevant PIRO, reference test Receiving neonatal intensive care. "Inclusion criteria for the study were ELBW who: (a) were born at our Regional Perinatal centre or transferred to the NICU within 2 weeks of life, (b) had survived for >4 weeks after birth, (c) were discharged home from NICU or died on the NICU, and (d) had a complete set of radiographs available for review"	Not relevant PIRO, outcome Objective: To establish the incidence and sites of radiologically apparent rib fractures in ELBW (extremely low birth weight, 1000 g) infants, receiving contemporary neonatal care.	Differential diagnosis: ELBW (extremely low birth weight, (<1000 g) infants)	Rib fracture
6545	Williams RL, Connolly PT. 2004. In children undergoing chest radiography what is the specificity of rib fractures for non-accidental injury? <i>Archives of Disease in Childhood</i> , 89(5), 490-492.	Systematic review Objective: To answer the structured clinical question: In children undergoing chest radiography [patients] are rib fractures on plain radiographs [test] specific for non-accidental injury [outcome]?			Rib fracture
6549	Mangurten HH, Wittert WR, McFadden J, Linn ES. 1999. Incidental rib fractures in a neonate. <i>Neonatal Intensive Care</i> , 12(7), 15-18.	Case report: 1 neonate with 2 posterior rib fractures attributed to delivery.			
6683	Ahmed SF, Franey C, McDevitt H, Somerville L, Butler S, Galloway P, Reynolds L, Shaikh MG, Wallace AM. 2011. Recent trends and clinical features of childhood vitamin D deficiency presenting to a children's	Not relevant PIRO (all) Objective: To "analyse the cases that had presented to the Royal Hospital for Sick Children and in whom vitamin D deficiency was considered the primary problem".	Differential diagnosis: Vitamin D deficiency		

	hospital in Glasgow. <i>Archives of Disease in Childhood</i> , 96(7), 694-696.				
6754	Hicks RA, Stolfi A. 2007. Skeletal surveys in children with burns caused by child abuse. <i>Pediatric Emergency Care</i> , 23(5), 308-313.	Not relevant PIRQ, outcome Objective: To determine the frequency of occult fractures in children with suspicious burns compared with children with other types of physical abuse.	Not relevant PIRQ, reference test "The method for diagnosis of physical abuse was adapted from previously described criteria. (3, 4) These include 7 diagnostic categories: definite abuse, likely abuse, questionable abuse, unknown cause, questionable accident, likely accident, and definite accident. Definite abuse was diagnosed, for example, if any of the following was present: perpetrator confession, eye-witness, positive skeletal survey, other types of injury suggestive of abuse (eg, pattern skin injuries, internal injuries), or a suspicious injury later followed by definite abuse. Likely abuse was diagnosed if the patient's presenting injury was considered suspicious for abuse by the treating physicians and the history offered was inconsistent (ie, implausible or no history, changing history, or delay in seeking care). Questionable abuse was diagnosed when an injury was not considered suspicious or was of uncertain cause and the history offered was inconsistent. For this study, the diagnosis of physical abuse was made for patients who were classified in either the definite abuse or likely abuse categories." "Patients were further classified based on whether they had at least 1 skeletal survey. Positive skeletal surveys were defined as having a fracture that was unexplained, highly specific for abuse, or associated with a perpetrator	Not relevant PIRQ, population burn injured, abused (mean 2.1 years, SD 2.0 years), 74 % <2.0 years, non-burn injured, abused (mean 1.4 years, SD 1.6 years), 59 % <2.0 years.	Rib fracture

			confession. Fractures considered highly specific for abuse were classic metaphyseal lesions, posterior rib fractures, scapular fractures, spinous process fractures, and sternal fractures. (5)"		
6758	Eckert K, Ackermann O, Schweiger B, Radeloff E, Liedgens P. 2012. Sonographic diagnosis of metaphyseal forearm fractures in children: a safe and applicable alternative to standard x-rays. <i>Pediatric Emergency Care</i> , 28(9), 851-854.	Other: Not relevant PIRQ, all Objective: To compare the sonographic and x-ray-diagnoses of suspected metaphyseal forearm fractures to evaluate and confirm the safety and applicability of ultrasound in diagnosing these fractures under routine conditions of a pediatric emergency unit.			.
6813	Wood JN, Feudtner C, Medina SP, Xianqun L, Localio R, Rubin DM. 2012. Variation in occult injury screening for children with suspected abuse in selected US children's hospitals. <i>Pediatrics</i> , 130(5), 853-860.	Not relevant PIRQ, outcome Objective: To "describe the variation across selected US children's hospitals in screening for occult fractures in children <2 years old diagnosed with physical abuse and in infants <1 year old who have injuries associated with high likelihood of physical abuse."	Not relevant PIRQ, index test	Not relevant PIRQ, reference test "The 2 study populations were: (1) children <2 years old who had a diagnosis of physical abuse; and (2) infants who had serious injuries that are frequently attributed to physical abuse. The physical abuse group included children with a diagnosis of physical abuse or assault (International Classification of Diseases, Ninth Revision, Clinical Modification [ICD-9-CM] 995.50, 995.54, 995.55 995.59, E960-E967, E968.0-E968.3, and E968.5-E968.9). The infant population included 2 subgroups: infants with TBI (traumatic brain injury, my comment) and infants with femur fractures. The TBI group included infants <1 year old with a diagnosis of TBI (ICD-9-CM 800-801, 803-804, or 851-853) in any of the 21 diagnosis	.

			fields in the PHIS database. Infants with only skull fractures or concussions (ICD-9-CM 800.0, 800.5, 801.0 801.5, 803.0, 803.5, 804.0, 804.5, 850, or 854) were excluded because the likelihood of abuse and occult fractures is lower among this group than among infants with more severe head injuries. (27, 39, 40) The femur fracture group included infants <1 year old with a diagnosis of femur fracture (ICD-9-CM 820–821). Given our focus on potential victims of abuse, children with an E-code for transportation accidents (E800–E848) were excluded, as were infants hospitalized following birth. Infants with a diagnosis of brain or lower extremity neoplasm (ICD-9-CM 191.0–191.9 or 170.7) that might have resulted in pathologic fractures or intracranial bleeding were excluded from the infant groups.	
6966	Jéquier S, Hanquinet S, Anooshiravani-Dumont M.2001. Non accidental skeletal and CNS trauma of infancy. <i>Medecine et Hygiene</i> , 59 (2335), 421-429.	Non-systematic review (No description how articles were searched or included)		CML + Rib
8003	Högberg U, Andersson J, Högberg G, Thiblin I.2018. Metabolic bone disease risk factors strongly contributing to long bone and rib fractures during early infancy: A	Not relevant PIRQ, reference test "diagnosed with fracture-diagnosis according to International Classification of Diseases (ICD10) were retrieved from the National Patient Register and linked to the Swedish Medical Birth Register and the		Rib fracture

	population register study. <i>PLoS One</i> . 13(12), e0208033.	Death Cause Register. "Infants with a selection of fracture diagnoses and accidental injuries, according to the 10th Swedish version of the International Classification of Diseases (ICD10), were identified. Birth-related fractures were excluded.			
		Fall accidents, W00-W19 (ICD10) (Table 1), were classified as: a) slight (<0.5 m)—fall on the same level, fall involving bed, chair or furniture; or b) moderate (>0.5–3m)—fall from being carried and from stairs and steps [1, 5, 6]. Further, for the whole sample, a selection of infant diagnoses, such as osteogenesis imperfecta (OI), Ehlers-Danlos syndrome (EDS) and maternal diagnoses, was extracted (Table 1)." "Infant abuse diagnosis (observation for suspected abuse, battered baby syndrome, maltreatment syndrome)" "Z03.8K, Y07, T74.1 Y06"			
8004	Ruest S, Kanaan G, Moore JL, Goldberg AP. 2019. The Prevalence of rib fractures incidentally identified by chest radiograph among infants and toddlers. <i>The Journal of Pediatrics</i> , 204, 208–213	Not relevant PIRQ, reference test All cases (N=5) with rib fractures on chest X-ray on medical indication (not indication of non-accidental injury or accident) reported in detail.	Not relevant PIRQ, outcome Objective: To "determine the prevalence of incidental rib fractures identified by chest radiograph (CXR) obtained for indications unrelated to accidental trauma or non-accidental trauma (NAT), and describe the histories associated with cases of incidental rib fractures and their proposed etiologies. It is hypothesized that incidental rib fractures are rare and alternative explanations for rib fractures occasionally used in a medico-legal context such as minor	Observations (<10) In total 5 cases with rib fractures	Rib fracture

			accidental trauma, undiagnosed medical conditions, and transient metabolic bone disturbances are unlikely to be the etiology of incidental rib fractures."		
8006	Raynor E, Konaia P, Freemont A. 2018. The detection of significant fractures in suspected infant abuse. <i>Journal of Forensic and Legal Medicine</i> , 60, 9-14.	Not relevant PIRO, outcome Objective: Increasingly osteoarticular pathology at the Manchester University NHS Foundation Trust (MFT) is being sent samples of bones from infants suspected of inflicted injury for histological examination, both from bones with fractures detected at autopsy or skeletal survey and from posterior ribs and long bone metaphyses (sites of significance in assessing for abusive injury) when there is no evidence of fracture on skeletal survey or autopsy. Here we report the results of an audit of the anonymised data from a series of such cases, to establish the sensitivity of skeletal survey (SS) to detect fractures and to define the medico-legal value of submitting bones for histological examination.	Not relevant PIRO, reference test Cases of suspected non-accidental injuries referred to the histology department		CML + Rib
8007	Wood JN, Henry MK, Berger RP, Lindberg DM, Anderst JD, Song L, Localio R, Feudtner C. 2019. Use and Utility of skeletal surveys to evaluate for occult fractures in young injured children. <i>Acta Paediatrica</i> , 19(4), 428-437.	Not relevant PIRO, outcome Objective: To "describe the percentage and characteristics of children aged <24 months with non-motor vehicle crash (MVC) related injuries who undergo a skeletal survey and have occult fractures".	Not relevant PIRO, reference test "The likelihood of abuse was recorded as definite abuse, probable abuse, indeterminate, probable accident, or definite accident based on the CPT's documented assessment or assessment of the primary medical team if CPT was not consulted. We collapsed the definite and probable categories for the analyses." Not stated what the criteria for the different steps in the likelihood scale were.	Not relevant population (<24 months) Not relevant PIRO, index test Only statistics for 1) how many % had rib fractures as first identified injury, 2) how many of those underwent skeletal survey and 3) how many % of those surveys were positive.	
8009	Ambrose CG, Soto Martinez M, Bi X, Deaver J, Kuzawa C, Schwartz L, Dawson B, Bachim A, Polak U, Lee B,	Biomechanical	Not relevant PIRO, outcome Objective: To "evaluate infant bone failure thresholds through		Rib fracture

	Crowder C. 2018. Mechanical properties of infant bone. <i>Bone</i> , 113, 151-160.		biomechanical loading in order to develop baseline data for infant injury mechanical analysis. These baseline data can be used for future studies such as finite element analysis of traumatic injuries or to provide control data when investigating the effects of diseases that may impact bone strength. Ultimately, mechanical strength data such as those presented here could be used to support or dismiss claims of fracture susceptibility in the context of the medicolegal investigation."		
8010	Choudhary AK, Servaes S, Slovis TL, Palusci VJ, Hedlund GL, Narang SK, Moreno JA, Dias MS, Christian CW, Nelson MD Jr, Silvera VM, Palasis S, Raissaki M, Rossi A, Offiah AC. 2018. Consensus statement on abusive head trauma in infants and young children. <i>Pediatric Radiology</i> , 48, 1048-1065.	Consensus statement	Non-systematic review (no description how articles where searched and included)		
8011	Joyce T, Huecker MR. 2019. Pediatric Abusive Head Trauma (Shaken Baby Syndrome). In <i>StatPearls [online]</i> . Treasure Island, Florida, USA:StatPearls Publishing. https://www.ncbi-nlm-nih.gov.ezproxy.its.uu.se/books/NBK499836/	Non-systematic review (No description how articles were searched or included)			
8014	Ali E, Rockman-Greenberg C, Moffatt M, Narvey M, Reed M, Jiang D. 2018. Caffeine is a risk factor for osteopenia of prematurity in preterm infants: a cohort study. <i>BMC Pediatrics</i> , 18, 9	Not relevant PIRQ, outcome Objective: "Based on existing studies we hypothesize that caffeine usage, cumulative dose or duration of usage are associated with OP. and this association exists even when con- trolled for the effects of other neonatal risk factors. The primary outcome of this study was to	Not relevant PIRQ, reference test Fractures during 12 weeks of neonatal intensive care unit. Non-osteopenic fractures excluded.	Differential diagnosis: Caffeine	

		determine the effect of the cumulative dose and the duration of caffeine on OP (osteopenia of prematurity, my comment). Other covariates of interest were included in the analysis, steroids and diuretics cumulative dose vitamin D intake, and maternal parity."		
8015	Johnson K, Derauf DC, Stetson R, Galaray P, Homme J. 2017. Keeping an open mind: cognitive bias in the evaluation of an infant with posterior-lateral rib fractures. <i>Case Reports in Pediatrics</i> , 2017, 5163094.	Case report: 1 case, posterior-lateral rib fracture in infant attributed to surgical patent ductus arteriosus repair.		Rib fracture
8016	Wootton-Gorges SL, Soares BP, Alazraki AL, Anupindi SA, Blount JP, Booth TN, Dempsey ME, Falcone Jr RA, Hayes LL, Kulkarni AV, Partap S, Rigsby CK, Ryan ME, Safdar NM, Trout AT, Widmann RF, Karmazyn BK, Palasis S. 2017. ACR Appropriateness Criteria" Suspected Physical Abuse—Child. <i>Journal of the American College of Radiology</i> , 14(S5), S338-S349.	Systematic review	Other: Consensus statement/radiological guidelines - The American College of Radiology	CML + Rib
8018	Droms RJ, Rork JF, Mclean R, Martin M, Belazarian L, Wiss K. 2017. Menkes disease mimicking child abuse. <i>Pediatric Dermatology</i> , 34(3), e132-e134.	Case report: 1 infant with Menkes disease and with 1 posterior rib fracture and metaphyseal lesions		Rib fracture
8019	Paine CW, Fakeye O, Christian CW, Wood JN. 2019. Prevalence of abuse among young children with rib fractures: A systematic review. <i>Pediatric Emergency Care</i> , 35(2), 96-103.	Systematic review Objective: To "estimate the prevalence of abuse in young children presenting with rib fractures and to identify demographic, injury, and presentation-related characteristics that affect the probability that rib fractures are secondary to abuse.		Rib fracture
8020	Wacks PW, Schoppel K, Sell P J, Guggina T. 2016. Opening Pandora's box: A chest radiograph in a 5-	Case report: 1 infant with Menkes disease and with CML and posterior rib fractures		CML + Rib

	month-old with bronchiolitis. <i>Hospital Pediatrics</i> , 6;642.			
8022	Khan NA, Lam V, Rickett A, Dickinson F. 2016. Unforeseen rib fracture findings in infant chest radiographs: evidence of non-accidental injury or simply a case of birth trauma? <i>BMJ Case Reports</i> . Published online [30 June 2016]. doi: 10.1136/bcr-2016-214651	Case report: 1 newborn with 2 rib fractures attributed to birth trauma.		Rib fracture
8023	Blackburne WB, Waddell JN, Swain MV, Alves de Sousa RJ, Kieser JA. 2016. Biomechanical investigation of impact induced rib fractures of a porcine infant surrogate model. <i>Journal of the Mechanical Behavior of Biomedical Materials</i> , 62, 588-598.	Biomechanical	Not relevant PIRO, outcome Objective: This study investigated the structural, biomechanical and fractographic features of rib fractures in a piglet model, to test the hypothesis that fist impact, apart from thoracic squeezing, may result in lateral costal fractures as observed in abused infants.	Not relevant study design: Animal model.
8024	Hirsch FW, Sorge I, Roth C, Gosemann JH. 2016. [Accident or maltreatment? Radiographic X-ray patterns in non-accidental trauma: The concept of sentinel injuries]. <i>Der Radiologe</i> , 56(5), 414-123.	Non-systematic review (No description how articles were searched or included)		
8026	Newton AW. 2016. Child maltreatment: a review of key literature in 2015. <i>Current Opinion in Pediatrics</i> , 28(3), 395-9.	Non-systematic review (No description how articles were searched or included)	Objective: Helping the general practitioner understand the evolution of research in the field of child abuse pediatrics.	.
8027	Delgado Álvarez I, de la Torre IB, Vázquez Méndez É. 2016. The radiologist's role in child abuse: imaging protocol and differential diagnosis. <i>Radiología</i> , 58 Suppl 2, 119-28.	*Not accessed		
8032	Shur N, Carey JC. 2015. Genetic differentials of child abuse: Is your case rare or real? <i>American Journal</i>	Non-systematic review (No description how articles were searched and included)	Case report: 1 infant with multiple rib fractures and normal molecular findings for COL1A1A (OI type I or V) and COL1A12 (OI type IV).	Rib fracture

	<i>of Medical Genetics. Part C, Seminars in medical genetics.</i> 169(4), 281-8.			
8033	Lindberg DM, Beaty B, Juarez-Colunga E, Wood JN, Runyan DK. 2015. Testing for abuse in children with sentinel injuries. <i>Pediatrics</i> , 136(5), 831-8.	Not relevant PIRQ, reference test "A diagnosis of abuse was defined by the assignment of any of the following ICD-9-CM codes, which have been used previously to identify recognized abuse from within the PHIS cohort (995.50, 995.54, 995.55, 995.59, E960-E967, E968.0-E968.3, and E968.5-E968.9)". (19-#6318)	Not relevant PIRQ, outcome Objective: To "determine which putative sentinel injuries are most associated with physical abuse. We performed a secondary analysis of children who were seen in the ED or inpatient wards of leading children's hospitals by using the Pediatric Health Information System (PHIS) database. We determined rates of recognized abuse among children with putative sentinel injuries.	Rib fracture
8034	Lauridsen JR, Cromblin KL. 2015. Prolonged abusive chest compressions in an infant: An occult form of child abuse: Review of hemodynamics. <i>The American Journal of Forensic Medicine and Pathology</i> , 36(4), 274-275.	Case report: 1 infant with 4 postlateral left rib fractures caused by admitted prolonged chest squeezing.		Rib fracture
8051	Fagen KE, Shalaby-Rana E, Jackson AM. 2015. Frequency of skeletal injuries in children with inflicted burns. <i>Pediatric Radiology</i> , 45(3), 396-401.	Not relevant PIRQ, population Non-accidental group with mean age 20 months, median age 17 months. Not stated how old all the children with fractures (rib or CML) were.	Not relevant PIRQ, reference test From a database of children assessed for possible abuse children with burn injuries and skeletal surveys were included. "The final diagnosis of these patients was categorized based on the appearance of the burn alone into nonaccidental, accidental or indeterminate by a child abuse pediatrician, either during patient evaluation or during review of the medical record if the child was not seen by a child abuse pediatrician. The consulting child abuse pediatricians were all part of a hospital-based child abuse team. The evaluation of a child abuse pediatrician includes obtaining a comprehensive history, a physical	Observation <10 7 with rib fractures (of whom 2 were 24 and 28 months old, respectively), 3 with CML (of whom 1 was 1 month old) in non-accidental group. CML + Rib

			examination, appropriate labs and studies, review of medical records, and discussion of evidentiary findings with law enforcement and child welfare investigators. The final diagnosis was reached based on the history, physical findings and multidisciplinary review with law enforcement or child welfare officials.		
8055	Kessel B, Dagan J, Swaid F, Ashkenazi I, Olsha O, Peleg K, Givon A; Israel Trauma Group, Alfici R. 2014. Rib fractures: comparison of associated injuries between pediatric and adult population. <i>American Journal of Surgery</i> , 208(5), 831-834.	Not relevant PIRO, population Subgroup 0-14 years.	Not relevant PIRO, reference test Mechanism classified into: driver or passenger in motor vehicle accident, pedestrian hit by car, motorcycle, bicycle, fall from height, fall (non-height, assault, other. "Data were obtained from the records of The Israeli National Trauma Registry maintained by Israel's National Center for Trauma and Emergency Medicine Research, in the Gertner Institute for Epidemiology and Health Policy Research. Records with information concerning trauma patients hospitalized in 11 hospitals, of which 6 are Level I trauma centers and 5 are Level II trauma centers, were included.	Not relevant PIRO, outcome Objective: To "analyze patterns of associated injuries in children as compared with adults, all of whom presented with rib fractures".	Rib fracture
8056	Darling SE, Done SL, Friedman SD, Feldman KW. 2014. Frequency of intrathoracic injuries in children younger than 3 years with rib fractures. <i>Pediatric Radiology</i> , 44(10), 1230-1236.	Not relevant PIRO, reference test "During this study period, children with concerns for child abuse were evaluated by the same three child abuse specialists and their diagnosis of abuse was made with the assistance and consensus of the child abuse team. Children who were found by either Child Protective Services or the courts to have been abused were also included as abused. The diagnosis of abuse was based on the sum of all available clinical and investigative information and was not based solely on			Rib fracture

		the presence of rib fractures in any patient. Only children with a confirmed diagnosis of abuse or accidental injury were studied; indeterminate cases were excluded. " Among the accidentally injured children were motor vehicle occupants, pedestrians hit by motor vehicles, falls from height, television fell on one child, a horse kicked one child.			
8065	Paterson CR, Monk EA. 2014. Clinical and laboratory features of temporary brittle bone disease. <i>Journal of Pediatric Endocrinology & Metabolism</i> , 27(1-2), 37-45.	Not relevant PIRO, reference test Not stated how child abuse was ruled out.	Not relevant PIRO, outcome Objective: To describe clinical and laboratory features of temporary brittle bone disease	Differential diagnosis: Temporary brittle bone disease	CML + Rib
8083	Wei C, Stevens J, Harrison S, Mott A, Warner J. 2010. Fractures in a tertiary neonatal intensive care unit in Wales. <i>Acta Paediatrica</i> , 101(6), 587-590.	Not relevant PIRO, reference test All babies admitted to a tertiary neonatal intensive care unit diagnosed with one or more fracture(s) during their inpatient stay. Babies were divided into two groups based on the assumed aetiology of the fractures: • Group1: Recognized traumatic cause. This included six cases of birth trauma [femur (n = 2), humerus (n = 1) and clavicle (n = 3)], one skull fracture from a witnessed accidental fall and three rib fractures secondary to thoracotomy [repair of tracheo—oesophageal fistula (n = 2) and removal of congenital cystic adenomatoid malformation (n = 1)]. Except for the three surgical cases, X-rays were taken for clinically suspected fractures as part of clinical care. • Group 2 included the 17 babies where there was no evidence of trauma as the cause. Fifteen of the 17 cases showed radiological evidence of osteopenia, and 2 had strong clinical suspicion of osteopenia on the basis of chronic lung disease and	Not relevant PIRO, outcome Objective: To describe the characteristics of fractures and identify associated factors in infants with fractures sustained during admission to a regional tertiary neonatal intensive care unit.	Differential diagnosis: Prematurity.	Rib fracture

		steroid therapy. All X-rays were taken as part of clinical management.		
8092	Menegazzi JJ. 2011. Infant chest compression depth needs further evaluation. <i>Resuscitation</i> , Oct;82(10):1362.	Letter to editor: Reply on Reyers et al (2011) #8096		Rib fracture
8096	Reyes JA, Somers GR, Taylor GP, Chlasson DA. Increased incidence of CPR-related rib fractures in infants--is it related to changes in CPR technique? <i>Resuscitation</i> . 2011 May;82(5):545-8.	Not relevant PIRQ, outcome Objective: To confirm the impression that frequency of CPR-related rib fractures in infant had increased after new guidelines for CPR techniques in 2005.	Not relevant PIRQ, reference test "A diagnosis of CPR related rib fractures was based on: characteristic location of the fractures (anterior, antero-lateral and/or lateral rib segments); acute nature, usually with limited periosteal haemorrhage and with no histological evidence of a cellular inflammatory response; and exclusion of other potential causes for rib fractures (e.g. MVAs, falls, etc.)"	Rib fracture
8098	Debaecker G, Dubos JP, Rakza T. 2011. [Rib fractures in the newborn]. <i>Archives de Pédiatrie: Organe Officiel de la Société Française de Pédiatrie</i> , 18(3), 342-343.	Case report: 1 newborn with 2 rib fractures.		Rib fracture
8108	Matches EW, Lew EO. 2010. Two-handed cardiopulmonary resuscitation can cause rib fractures in infants. <i>The American Journal of Forensic Medicine and Pathology</i> , 31(4), 303-307.	Case report: 5 infants with anterolateral rib fractures attributed to two-handed CPR.		Rib fracture
8112	Matches EW, Lew EO. 2010. Do resuscitation-related injuries kill infants and children? <i>The American Journal of Forensic Medicine and Pathology</i> , 31(2), 178-85.	Not relevant PIRQ, reference test "All available historical data (law enforcement, Medical Examiner investigator, Fire-Rescue reports, and relevant perimortem hospital charts and witness statements) were reviewed and the atraumatic population was then subdivided into 2 groups: (1) those with a documented history of terminal resuscitate efforts including CPR" (N=382)	Differential diagnosis Objective: To "to answer 4 questions about the pediatric population: (1) Do resuscitative efforts cause orofacial or upper airway injuries? (2) Do resuscitative efforts cause hollow or solid thoracoabdominal viscera injuries? (3) Do resuscitative efforts cause rib fractures? (4) Are injuries worse in those cases where medically	Rib fracture

		"and (2) those who did not undergo resuscitation" (N=164).	untrained individuals participate in resuscitative efforts?		
8115	Talbert D. 2010. Beads but no collar; the significance of an asymptomatic rib bone healing pattern in infants. <i>Medical Hypotheses</i> , 75(1), 82-84.	Other: Presentation of a hypothesis about how "beads" on ribs are developed			Rib fracture
8122a	Chapman T, Sugar N, Done S, Marasigan J, Wambold N, Feldman K. 2010. Fractures in infants and toddlers with rickets. <i>Pediatric Radiology</i> . 40(7), 1184-1189. Erratum in: <i>Pediatric Radiology</i> . 2010, 40(7), 1308.	Not relevant PIRQ, reference test Children <24 months were identified by two means: - Group 1 radiographic diagnosis rickets - Group 2 laboratory report elevated alkaline phosphatase at least 1.5 times normal as a possible indicator of metabolic bone disease. Radiographs within 1 months from diagnosis of rickets.	Not relevant PIRQ, population Mean age 13 months, range 2-24 months. Only 4 children < 7 months.	Not relevant PIRQ, outcome Objective: To "evaluate infants and toddlers with radiographically evident rickets and to document the frequency of injury, age of injury and types of fractures that occur within this specific population. We hypothesize that fractures in children with rickets occur in abnormal bone and can be explained by a failure of normal load-bearing of abnormal bone." Differential diagnosis: Rickets. Observation < 10 2 cases with rib fractures	Rib fractures
8122b	Chapman T, Sugar N, Done S, Marasigan J, Wambold N, Feldman K. 2010. Errata. Fractures in infants and toddlers with rickets. <i>Pediatric Radiology</i> . 40(7), 1308.	Other: Errata to Chapman et al (2010) #8122a			
8127	Paterson CR. Temporary brittle bone disease: fractures in medical care. 2009. <i>Acta Paediatrica</i> , 98(12):1935-8.	Case report: 5 cases, multiple rib fractures in infants occurring during hospitalization attributed to temporary brittle bone disease			CML (1) + Rib
8137	Noordam C, Funke S, Knoers NV, Jira P, Wevers RA, Urban Z, Morava E. 2009. Decreased bone density and treatment in patients with	Case report: 4 cases of decreased bone density in patients with inherited cutis laxa, 1 with congenital rib fracture.			Rib fracture

	autosomal recessive cutis laxa. <i>Acta Paediatrica</i> , 98(3), 490-494.				
8154	Worn MJ, Jones MD. 2007. Rib fractures in infancy: establishing the mechanisms of cause from the injuries - a literature review. <i>Medicine, Science, and the Law</i> , 47(3), 200-212.	Biomechanical	Non-systematic review (No description of literature search and inclusion criteria) Objective: To assess information regarding the various types of rib fracture and their likely mechanisms, paying particular attention to the likely forces, deflections and loading rates involved, from a biomechanical engineering perspective.		Rib fracture
8155	Dollinak D. 2007. Rib fractures in infants due to cardiopulmonary resuscitation efforts. <i>The American Journal of Forensic Medicine and Pathology</i> , 28(2), 107-10.	Not relevant PIRQ, reference test "70 consecutive medicolegal autopsies were performed on infants that died at the age range from 2 weeks to 8 months, who had no evidence of injury aside from the rib fractures to be described." Not stated if all 70 had CPR, but the 7 with rib fractures had CPR according to medical records.	Differential diagnosis Objective: To "evaluate for subtle rib fractures in infants and to better characterize resuscitation-related rib fractures that may occur in infants who died of apparent nontraumatic reasons".		Rib fracture
8160	Kaplan W, Haymond MW, McKay S, Karaviti LP. 2006. Osteopenic effects of MgSO ₄ in multiple pregnancies. <i>Journal of Pediatric Endocrinology & Metabolism</i> , 19(10):1225-30.	Not relevant PIRQ, outcome Objective: To "describe the effects of prolonged maternal treatment with MgSO ₄ in infants who were products of multiple pregnancies."	Observations (<10) 1 case with rib fractures	Not relevant PIRQ, reference test. Differential diagnosis: Osteopenia in infants after maternal treatment with MgSO ₄ .	Rib fracture
8162	Chanelière C, Moreux N, Pracros JP, Bellon G, Reix P. 2006. [Rib fractures after chest physiotherapy: a report of 2 cases]. <i>Archives de Pédiatrie: Organe Officiel de la Société Française de Pédiatrie</i> , 13(11), 1410-1412.	Case report: 2 infants with rib fractures attributed to physical therapy during bronchiolitis.			Rib fracture
8182	Hoke RS, Chamberlain D. 2004. Skeletal chest injuries secondary to cardiopulmonary resuscitation. <i>Resuscitation</i> , 63(3), 327-238.	Systematic review Objective: To "review the evidence on the incidence of rib and sternal fractures after conventional closed-chest compression in the treatment of cardiac arrest in adults			Rib fracture

		and children, and after active compression–decompression cardiopulmonary resuscitation (ACD-CPR)".			
8197	Miller M. 2003. Infants at higher risk to fracture than the general population of young infants. <i>Pediatric Radiology</i> , 33(10), 733-734.	Letter to editor: Reply on Chalumeau et al (2002), #5527			Rib fracture
8198	Loneragan GJ, Baker AM, Morey MK, Boos SC. 2003. From the archives of the AFIP. Child abuse: radiologic-pathologic correlation. <i>Radiographics</i> , 23(4), 811-845.	Non-systematic review (No description how articles were searched or included)			CML + Rib
8222	Sewell RD, Steinberg MA. 2000. Chest compressions in an infant with osteogenesis imperfecta type II: No new rib fractures. <i>Pediatrics</i> , 106(5), E71.	Case report: 1 newborn with OI and several rib fractures who underwent chest compression without any additional rib fractures			Rib fracture
8235	Hartmann RW Jr. Radiological case of the month. 1997. Rib fractures produced by birth trauma. <i>Archives of Pediatrics & Adolescent Medicine</i> , 151(9), 947-948.	Case report: 2 neonates with posterior rib fractures, attributed to birth trauma.			Rib fracture
8256	Spevak MR, Kleinman PK, Belanger PL, Primack C, Richmond JM. 1994. Cardiopulmonary resuscitation and rib fractures in infants. A postmortem radiologic-pathologic study. <i>JAMA</i> , 272(8), 617-618.	Not relevant PIRQ, reference test Medical records with information on CPR. "We then excluded nine infants dying with evidence of child abuse. Although a child manifesting isolated acute rib fractures as a result of abuse would have been included in the study, we encountered no such infant".	Differential diagnosis Objective: To "determine the incidence of rib fractures visible at autopsy or with postmortem radiographs after cardiopulmonary resuscitation (CPR) in infants younger than 1 year".		Rib fracture
8281	Nakayama DK, Ramenofsky ML, Rowe MI. 1989. Chest injuries in childhood. <i>Annals of Surgery</i> , 210(6), 770-775.	Not relevant PIRQ, population Subpopulation 0-4 years	Not relevant PIRQ, reference test No description how the diagnosis of abuse, or other mechanisms, were established.	Not relevant PIRQ, outcome Outcome: To characterize the scope and consequences of childhood chest injuries.	Rib fracture
8337	Keipert JA. 1970. Rickets with multiple fractured ribs in a premature infant. <i>The Medical Journal of Australia</i> , 1(13), 672-675.	Case report: 1 premature infant with multiple rib fractures attributed to rickets.			Rib fracture

9001	Akinseye ON, Yazdani R, Tornow KA, Reeder KN, Clarke RL, Pfeifer CM. 2019. Imaging findings of Menkes disease, a radiographic mimic of abusive trauma. <i>Radiology Case Reports</i> , 14(8), 993-996.	Case report: 1 infant with Menkes disease and with metaphyseal irregularities.		CML
9002	Elde P, Djive Å, Myklebust R, Forseth KF, Nøttveit A, Brudvik C, Rosendahl K. 2019. Prevalence of metaphyseal injury and its mimickers in otherwise healthy children under two years of age. <i>Pediatric Radiology</i> . 2019 May 29. doi: 10.1007/s00247-019-04413-5.	Not relevant PIRQ, reference test All children 0-2 year examined at the Accident and Emergency department, due to an injury warranting a radiograph. All assessable metaphyses included in the images were analysed.	Not relevant PIRQ, outcome Objective: To "examine the prevalence of metaphyseal injury and its mimickers in otherwise healthy children younger than 2 years of age".	CML
9006	Keblawi SS, Wright JN, Otjen JP, Verma A, Brown EC, Ness KD, Feldman KW. 2019. Multiple Abusive Fractures in an infant with a concurrent parathyroid hormone-related peptide-secreting renal tumor: abusive fractures accompanying a parathyroid hormone-related peptide-secreting tumor. <i>Pediatric Emergency Care</i> , Apr 9, doi: 10.1097/PEC.0000000000001796.	Case report: 1 case, bone fragility in infant, with amongst other CML, caused by parathyroid hormone related peptide secreting mesoblastic nephroma.		CML
9008	Marine MB, Hibbard RA, Jennings SG, Karmazyn B. 2019. Ultrasound findings in classic metaphyseal lesions: emphasis on the metaphyseal bone collar and zone of provisional calcification. <i>Pediatric Radiology</i> , 49(7), 913-921.	Not relevant PIRQ, outcome Objective: To "analyze the US findings of known CMLs initially diagnosed by radiography".	Not relevant PIRQ, reference test All patients with skeletal surveys performed for possible child abuse and subsequent assessment for evaluation of CMLs who had a definite CML on radiographs (rickets excluded).	CML
9014	Della Grotta LM, Marine MB, Harris TL, Karmazyn B. 2019. Classic metaphyseal lesion acquired during physical therapy. <i>Clinical Imaging</i> , 54, 100-102.	Case report: 1 infant with CML in proximal tibia, and with hypertonic lower extremity due to myelomeningocele, attributed to physical therapy.		CML

9015	Tsai A, Connolly SA, Ecklund K, Johnston PR, Kleinman PK. 2019. Subperiosteal new bone formation with the distal tibial classic metaphyseal lesion: prevalence on radiographic skeletal surveys. <i>Pediatric Radiology</i> , 49(4):551-558.	Not relevant PIRQ, outcome Objective: To "(1) determine the prevalence of subperiosteal new bone formation with CMLs on anteroposterior (AP) radiographs from initial skeletal surveys, and then (2) to assess the additional diagnostic yield of lateral radiographs from the initial surveys and AP radiographs from the follow-up surveys in the detection of subperiosteal new bone formation with CMLs."	Not relevant PIRQ, reference test Suspected abuse. Foundation for concern of abuse by 1) additional fractures documented radiographically 2) hospital child protection team consults, and 3) mandate report filing for suspected abuse.		CML
9016	Costantini A, Valta H, Baratang NV, Yap P, Bertola DR, Yamamoto GL, Kim CA, Chen J, Wierenga KJ, Fanning EA, Escobar L, McWalter K, McLaughlin H, Willaert R, Begtrup A, Alm JJ, Reinhardt DP, Mäkitie O, Campeau PM. 2019. Novel fibronectin mutations and expansion of the phenotype in spondylometaphyseal dysplasia with "corner fractures". <i>Bone</i> , 121, 163-171.	Case report: 5 cases of spondylometaphyseal dysplasia with "corner fractures" caused by 5 novel missense mutation in FN1 (fibronectin gene). Clinical, radiographic and genetic findings (no infants).	Not relevant PIRQ (population)		CML
9027	Burren CP, Caswell R, Castle B, Welch CR, Hilliard TN, Smithson SF, Ellard S. 2018. TRPV6 compound heterozygous variants result in impaired placental calcium transport and severe undermineralization and dysplasia of the fetal skeleton. <i>American Journal of Medical Genetics. Part A</i> , 176(9):1950-1955.	Case report: 1 newborn with rib fractures and CML, attributed to in-utero calcium deficiency due to defect placenta calcium transfer (mutation).			
9029	Cadoff EB, Sheffer R, Wentroub S, Ovadia D, Meiner V, Schwarzbauer JE. 2018. Mechanistic insights into the cellular effects of a novel FN1 variant associated with a spondylometaphyseal dysplasia. <i>Clinical Genetics</i> , 94(5), 429-437.	Case report: 1 toddler with spondylometaphyseal dysplasia (SMD) and corner fractures	Not relevant PIR, population		

9034	Miller M, Mirkin LD. 2018. Classical metaphyseal lesions thought to be pathognomonic of child abuse are often artifacts or indicative of metabolic bone disease. <i>Medical Hypotheses</i> , 115, 65-71.	Not relevant study design: Objective: To review the histopathology in the original articles by authors Kleinman and Marks that described the specificity of the classical metaphyseal lesion for child abuse and to determine if there were any oversights in the authors' analysis.	Non-systematic review (No description of literature search and inclusion criteria)		CML
9038	Tsai A, Johnston PR, Perez-Rossello JM, Breen MA, Kleinman PK. 2018. The distal tibial classic metaphyseal lesion: medial versus lateral cortical injury. <i>Pediatric Radiology</i> , 48(7), 973-978.	Not relevant PICO, outcome Objective: To "compare medial versus lateral cortical involvement of distal tibial CMLs in a clinical cohort of infants with suspected abuse".	Not relevant PICO, reference test "All cases were evaluated by the hospital multidisciplinary child abuse team with formal reports of suspected abuse submitted to state child welfare authorities" (of the cases with distal distal tibia CML, both anteroposterior and lateral projection in initial examination and an anteroposterior projection on follow up).		CML
9039	Holick MF, Hossein-Nezhad A, Tabatabaei F. 2017. Multiple fractures in infants who have Ehlers-Danlos/hypermobility syndrome and or vitamin D deficiency: A case series of 72 infants whose parents were accused of child abuse and neglect. <i>Dermato-endocrinology</i> , 9(1), e1279768.	Not relevant PICO, reference test Diagnosis of Ehler Danlos Syndrome (EDS) and/or vitamin D deficiency based on interview with parents, when possible examination of the child, and records from Bone Health Care Clinic at Boston University Medical Campus (BUMC) and accompanied medical records from other institutions. "The following information was gathered from the records: previous diagnosis at other institutions, age in weeks, number of fracture fractures and their location (s), past medical history for Joints Hypermobility Syndrome (JHS), EDS, OI, clinical signs and symptoms of rickets and EDS, family history for EDS, laboratory results, radiology reports and images, and genetic testing results. Parent(s) were evaluated for clinical evidence of EDS. The infants of these parents, who were often accompanied by a caretaker, were also	Not relevant PICO, outcome Objective: To "increase the level of awareness that Ehlers-Danlos/hypermobility syndrome (EDS) and vitamin D deficiency are associated with infantile fragility fractures and radiologic features that may be mistakenly reported to be caused by non-accidental trauma due to Child Abuse and Neglect (CAN)."	Differential diagnosis: Ehlers-Danlos/hypermobility syndrome (EDS) and vitamin D deficiency	CML + Rib

		evaluated for clinical evidence of EDS and signs and symptoms of vitamin D deficiency and evidence for infantile rickets. " "The clinical features identified among infants with EDS who were evaluated were family history of joint hypermobility and blue/gray sclera in the infants, doughy textured skin, increased skin elasticity, soft tissue involvement, and hypermobility/flexibility (Table 2).3,4,7,36 The parenteral history of joint hypermobility was confirmed when one or both parents were evaluated in the clinic and demonstrated classic clinical signs for Ehlers Danlos/hypermobility syndrome with a Beighton score of at least 5/9 which is diagnostic for this genetic disorder.3,4,7,37 The radiological signs of rickets among infants who presented with fractures at various stages of healing at diagnosis were rachitic rosary, wide anterior fontanel(s), craniotabes, and perisutural hypomineralization (Table 3). Clinical evidence for rickets included frontal bossing and rachitic rosary. 3,4,7" "Genetic screening for OI was performed in 65%(47) of the infants; no causative variants in the COL1A1 and COL1A2 genes were found. However 4% (3) of the infants were diagnosed with OI/EDS overlap syndrome; a causative variant in the SERPINF1 gene was found in two of the cases and in the third case the diagnosis was confirmed by ultrastructural analyses of a skin biopsy. " "The biochemical findings are presented in Table 4. Serum levels of 25(OH)D were reported in 47 infants (18 § 8.5 ng/mL) and 31 of them were deficient (<20 ng/mL). "Moreover,	
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		the 25 (OH)D level was reported in 30 mothers and the mean was 21.3 ng/mL (\$ 11.7 ng/mL), and 16 of them were deficient (<20 ng/mL). Alkaline phosphatase, parathyroid hormone (PTH), calcium, and phosphorus mean values were reported Table 4."		
9047	Norrell K, Hemrikus W. 2017. The risk of assuming abuse in an infant with an isolated metaphyseal lesion: A case report. <i>JBJS case connector</i> , 7(3), e69.	Case report: 1 case, corner fracture in infant attributed to normal variant (bone spur)		CML
9051	Lee CS, Fu H, Baratang N, Rousseau J, Kumra H, Sutton VR, Niceta M, Cioffi A, Yamamoto G, Bertola D, Marcelis CL, Lugtenberg D, Bartuli A, Kim C, Hoover-Fong J, Sobreira N, Pauli R, Bacino C, Krakow D, Parboosingh J, Yap P, Kariminejad A, McDonald MT, Aracena MJ, Lausch E, Unger S, Superti-Furga A, Lu JT. Baylor-Hopkins Center for Mendelian Genomics, Cohn DH, Tartaglia M, Lee BH, Reinhardt DP, Campeau PM. 2017. Mutations in fibronectin cause a subtype of spondylometaphyseal dysplasia with "corner fractures". <i>American Journal of Human Genetics</i> , 101(5), 815-823.	Not relevant PIRO (all except CML) Objective: Describes fibronectin mutations in spondylometaphyseal (SMD) with corner fractures.	Differential diagnosis Spondylometaphyseal (SMD) with corner fractures.	CML
9052	Chen J, Ma X, Zhou Y, Li G, Guo Q. 2017. Recurrent c.G1636A (p.G546S) mutation of COL2A1 in a Chinese family with skeletal dysplasia and different metaphyseal changes: a case report. <i>BMC Pediatrics</i> , 17(1):175.	Case report: 3 cases of spondylo-epimetaphyseal dysplasia, Strudwick type.	Other: Not relevant PIRO all (except CML)	CML
9053	Tsai A, Coats B, Kleinman PK. Biomechanics of the classic metaphyseal lesion: finite element	Biomechanical	Not relevant PIRO, outcome Objective: This study focuses on the strain patterns generated from finite	CML

	analysis. 2017. <i>Pediatric Radiology</i> , 47(12), 1622-1630.		element modeling to identify loading scenarios and regions of the cortex that are susceptible to bone failure in the distal tibia and fibula in an infant.		
9065	Machol K, Jain M, Almannaï M, Orand T, Lu JT, Tran A, Chen Y, Schlesinger A, Gibbs R, Bonafè L, Campos-Xavier AB, Unger S, Superti-Furga A, Lee BH, Campeau PM, Burrage LC. 2017. Corner fracture type spondylometaphyseal dysplasia: Overlap with type II collagenopathies. <i>American Journal of Medical Genetics. Part A</i> , 173(3), 733-739.	Case report: 2 cases of spondylometaphyseal dysplasia (SMD) corner fracture type with corner fractures	Non-systematic review (no description how articles were searched and included)		CML
9069	Pfeifer CM, Hammer MR, Mangona KL, Booth TN. 2017. Non-accidental trauma: the role of radiology. <i>Emergency Radiology</i> , 24(2), 207-213.	Non-systematic review (No description how articles were searched or included)			CML + Rib
9073	Cannell JJ, Holick MF. 2018. Multiple unexplained fractures in infants and child physical abuse. <i>The Journal of Steroid Biochemistry and Molecular Biology</i> , 175, 18-22.	Case report: 2 cases with multiple fractures (amongst other post rib fractures and CML) where infantile rickets was proposed as explanation	Commentary		CML + Rib
9080a	Leaman LA, Henrikus WL, Bresnahan JJ. 2016. Identifying non-accidental fractures in children aged <2 years. <i>Journal of Children's Orthopaedics</i> , 10(4), 335-341.	Not relevant PIRQ, reference test Data obtained from charts were amongst other things "classification of possible abuse". "All cases that were submitted to the Pennsylvania Office of Children, Youth, and Families for review were considered cases of potential abuse. The decision to report the child for non-accidental trauma (NAT) evaluation was made by the pediatric emergency attending physician or the orthopedic surgeon caring for the child." "All cases reported were done so on the basis of clinical intuition, inconsistent histories,			CML

		and fracture patterns. Reporting was consistent with the American Academy of Pediatrics (AAP) clinical guidance report [20]. Due to medical-legal barriers, we do not have information regarding substantiation by the Pennsylvania Office of Children, Youth, and Families. [20]: Christian et al (2015). No		
9080b	Leaman LA, Hennrikus WL, Bresnahan JJ. 2016. Erratum to: Identifying non-accidental fractures in children aged <2 years. <i>Journal of Children's Orthopaedics</i> , 10(5), 467.	Other: Errata to Leaman et al (2016), #9080a		.
9083	Nair N, Satapathy AK, Gupta N, Kabra M, Gupta AK, Jana M. 2016. Spondylometaphyseal dysplasia corner fracture (Sutcliffe type). <i>Indian Journal of Pediatrics</i> , 83(10), 1191-1194.	Case report: 1 case with spondylometaphyseal dysplasia (SMD) and corner Fracture type (Sutcliffe)	Not relevant PIRQ, population	CML
9088	Thackeray JD, Wannemacher J, Adler BH, Lindberg DM. 2016. The classic metaphyseal lesion and traumatic injury. <i>Pediatric Radiology</i> , 46(8), 1128-33.	Not relevant PIRQ, reference test Infants in the Examining Siblings to Recognize Abuse (EXSTRA) research network which was "a prospective, observational study of 20 U.S. child abuse teams that included all children <120 months (10 years) of age who underwent subspecialty evaluation by a child abuse physician for concerns of physical abuse between Jan. 15, 2010, and April 30, 2011". "For each patient consultation, the child abuse physician was asked to rate the level of concern for abuse using a 1-7 Likert scale, with 1 indicating definitely not inflicted injury and 7 indicating definitely inflicted injury. While the primary analysis of the EXSTRA network involved household contacts such as siblings and children who shared a day care with the index child, this secondary analysis includes data only		CML

		from index children." "The ultimate determination of whether any fracture or other injury was identified (as when different radiologists disagreed) was made by the responsible child abuse physician after review of any available testing, clinical information and specialty consultation using the criterion of whether they would testify to the presence of an injury court or in the medical record. " "For this secondary analysis, we analyzed data for all subjects ≤12 months of age identified as having a CML. " (The likert scale was not used in the study)			
9098	Girschick H, Wolf C, Morbach H, Hertzberg C, Lee-Kirsch MA. 2015. Severe immune dysregulation with neurological impairment and minor bone changes in a child with spondyloenchondrodysplasia due to two novel mutations in the ACP5 gene. <i>Pediatric Rheumatology Online Journal</i> , 13(1), 37.	Case report: 1 case of spondyloenchondrodysplasia (SPENCD) and metaphyseal irregularities	Not relevant PIRQ, index test	Not relevant PIRQ, population	.
9099	Burrell T, Opfer E, Berglund L, Lowe LH, Anderst J. 2015. A witnessed case of a classic metaphyseal fracture caused during IV line placement in a child: Insight into mechanism of injury. <i>Journal of forensic and legal medicine</i> , 35:51-3.	Case report: 1 case witnessed CML caused by medical care in infant			CML
9105	Johnson K, Bradshaw K. Skeletal Aspects of Non-Accidental Injury. <i>Endocrine development</i> , 28, 247-258.	Non-systematic review (No description how articles were searched or included)			CML + Rib
9108	Thompson A, Bertocci G, Kaczor K, Smalley C, Pierce MC. 2015. Biomechanical investigation of the classic metaphyseal lesion using an immature porcine model. <i>AJR</i> .	Biomechanical	Animal model Objective: To "investigate loading conditions necessary to create a classic metaphyseal lesion using an immature porcine model".		CML

	<i>American journal of roentgenology</i> , 204(5), W503-509.				
9120	Perez-Rossello JM, McDonald AG, Rosenberg AE, Tsai A, Kleinman PK. 2015. Absence of rickets in infants with fatal abusive head trauma and classic metaphyseal lesions. <i>Radiology</i> , 275(3), 810-821.	Not relevant PIRO, outcome Objective: To determine if radiologic and histologic changes indicative of rickets are present in cases of infant homicide with classic metaphyseal lesions (CMLs) and other skeletal injuries.	Not relevant PIRO, reference test Infant fatalities referred from the state Medical Examiner's Office for the evaluation of possible child abuse. Additional inclusion criteria were as follows: (a) The Medical Examiner determined that the infant had sustained a head injury and that the manner of death was a homicide, (b) at least one CML was evident at skeletal survey, (c) CMLs were confirmed at autopsy, and (d) non-CML fractures were also present.	Observation <10 (N=9)	CML
9127	Kepron C, Pollanen MS. 2015 Rickets or abuse? A histologic comparison of rickets and child abuse-related fractures. <i>Forensic Science, Medicine, and Pathology</i> , 11(1), 78-87.	Observations (<10) In total 4 cases, 3 abused, 1 with rickets. (1 2 years 4 months old child with rickets attributed to complications of malnutrition and asthma, compered to 2 infants 34-37 days old and 1 toddler 2 years and 6 months old with external and internal injuries suspected for abuse, death attributed to head and neck injuries, head injury and intra-abdominal injuries.)	Not relevant PIRO, reference test Abuse diagnosis based on external and internal injuries.	Not relevant PIRO, population Only 2 infants < 12 months Differential diagnoses excluded?	CML + Rib
9128	Barber J, Kleinman PK. 2014. Imaging of skeletal injuries associated with abusive head trauma. <i>Pediatric Radiology</i> , 44 Suppl 4, S613-620.	Non-systematic review (No description of literature search and inclusion criteria)			
9137	Ayoub D, Miller M, Hyman C. 2014. Reply: SPR Child Abuse Committee response regarding classic metaphyseal lesion. <i>American Journal of Roentgenology</i> , 203(2), W233.	Letter Reply on Ayoub et al (2014), #2243, #9138			
9138	Brown SD, Serveas S, Hayes LL, Society for Pediatric Radiology Child Abuse Committee. 2014. SPR Child Abuse Committee. 2014. SPR Child Abuse Committee.	Letter Reply on Ayoub et al (2014), #2243			

	Abuse Committee Response regarding classic metaphyseal lesion. <i>AJR. American Journal of Roentgenology</i> , 203(2), W232.			
9140	Kleinman PK. 2014. Classic metaphyseal lesions. <i>AJR. American Journal of Roentgenology</i> , 202(6), W603.	Letter Reply on Ayoub et al (2014), #2243, #11000, #9156		
9156	Wood BP. 2014. Commentary on "a critical review of the classic metaphyseal lesion: traumatic or metabolic?" <i>AJR. American Journal of Roentgenology</i> , 202(1), 197-198.	Letter Reply on Ayoub et al (2014), #2243		
9169	Tsai A, McDonald AG, Rosenberg AE, Stamoulis C, Kleinman PK. 2013. Discordant radiologic and histological dimensions of the zone of provisional calcification in fetal piglets. <i>Pediatric Radiology</i> , 43(12), 1606-1614.	Not relevant PIRO, outcome Objective: We systematically correlated micro-CT data with histology in piglets to explore the differing definitions of the zone of provisional calcification and to elucidate the anatomical basis for divergent definitions.		CML
9181	Baldwin KD, Scherl SA. 2013. Orthopaedic aspects of child abuse. <i>Instructional Course Lectures</i> , 62, 399-403.	Non-systematic review (No description how articles were search or included)		CML + Rib
9213	Paterson CR, Monk EA. 2011. Temporary brittle bone disease: relationship between clinical findings and judicial outcome. <i>Pediatric Reports</i> , 3(3), e24.	Not relevant PIRO, reference test Three groups: 1) judicial findings of abuse, 2) parents judicially exonerated, 3) no judicial findings		CML + Rib
9255	Johnson K. 2009. Skeletal aspects of non-accidental injury. <i>Endocrine Development</i> , 16, 233-245.	Non-systematic review (no description how articles were searched and included)		CML + Rib
9285	Kleinman PL, Zurakowski D, Strauss KJ, Cleveland RH, Perez-Rosello JM, Nichols DP, Zou KH, Kleinman PK. 2008. Detection of simulated inflicted metaphyseal fractures in a fetal pig model: image optimization and dose reduction with computed	Animal model Not relevant PIRO, outcome Objective: To prospectively determine in a foetal pig model whether diagnostic performance comparable to that of high detailed screen-film imaging can be achieved with computed radiography for the		CML

	radiography. <i>Radiology</i> . 247(2):381-390.		detection of simulated classical metaphyseal lesions (CMLs), by using Faxitron digital images as the reference standard, and whether radiation dose reduction is possible.		
9305	Walter K, Tansek M, Tobias ES, Ikegawa S, Coucke P, Hyland J, Mortier G, Iwaya T, Nishimura G, Superti-Furga A, Unger S. 2007. COL2A1-related skeletal dysplasias with predominant metaphyseal involvement. <i>American Journal of Medical Genetics. Part A</i> , 143A(2), 161-167.	Case report: 4 cases with "Type 2 collagenopathy" COL2A1 - spondylometaphyseal dysplasia, some with corner fractures			CML
9339	Sutton VR, Hyland JC, Phillips WA, Schlesinger AE, Brill PW. 2005. A dominantly inherited spondylometaphyseal dysplasia with "corner fractures" and congenital scoliosis. <i>American Journal of Medical Genetics. Part A</i> , 133A(2), 209-212.	Case report: 3 cases with spondylo-metaphyseal dysplasia (SMD) and with corner fractures	Not relevant PIRQ, population		CML
9409	Currarino G, Birch JG, Herring JA. 2000. Developmental coxa vara associated with spondylometaphyseal dysplasia (DCV/SMD): "SMD-corner fracture type" (DCV/SMD-CF) demonstrated in most reported cases. <i>Pediatric Radiology</i> . 30(1), 14-24.	Case report: 3 cases of developmental coxa vara associated with spondylometaphyseal dysplasia (SMD) and with corner fractures	Non-systematic review on 18 cases	Not relevant PIRQ, population	CML
9437	Bai M, Pearce SH, Kifor O, Trivedi S, Stauffer UG, Thakker RV, Brown EM, Steinmann B. 1997. In vivo and in vitro characterization of neonatal hyperparathyroidism resulting from a de novo, heterozygous mutation in the Ca2+-sensing receptor gene: normal maternal calcium homeostasis as a cause of secondary	Case report: 1 case of hyperparathyroidism with metaphyseal fractures			CML

	hyperparathyroidism in familial benign hypocalciuric hypercalcaemia. <i>The Journal of Clinical Investigation</i> , 99(1), 88-96.				
9471	Ikegawa S, Nagano A, Satoyoshi E. 1993. Skeletal abnormalities in Satoyoshi's syndrome: a radiographic study of eight cases. <i>Skeletal Radiology</i> , 22(5), 321-324.	Not relevant PIRQ, outcome Objective: Describe skeletal abnormalities in patients with Satoyoshi's syndrome.	Not relevant PIRQ, population	Differential diagnosis: Objective: To describe skeletal abnormalities in patients with Satoyoshi's syndrome. Observation < 10 (N=8 cases with Satoyoshi's syndrome)	CML
9580	Astley R. 1953. Multiple metaphyseal fractures in small children (metaphyseal fragility of bone). <i>The British Journal of Radiology</i> , 26(311), 577-583.	Case report: 6 cases (5 months - 2 years) with metaphyseal lesions, of which 3 also had rib fractures, without explanation			CML + Rib
10001	Health RCoPac. 2018 Child Protection Evidence: systematic review on fractures. Cardiff, UK: Cardiff University https://www.rcpch.ac.uk/sites/default/files/2018-04/child_protection_evidence_-_fractures_2018final.pdf	Systematic review Objective: "The review aims to answer four clinical questions: • Which fractures are indicative of abuse? • What is the evidence for radiological dating of fractures in children? • What radiological investigations should be performed to identify fractures in suspected child abuse? • Does cardiopulmonary resuscitation cause rib fractures in children?"			Rib fracture
10002	Silverman FN. 1953. The roentgen manifestations of unrecognized skeletal trauma in infants. <i>The American Journal of Roentgenology, Radium therapy, and Nuclear Medicine</i> , 69(3), 413-427.	Case report: 3 cases with multiple fractures including 1 case with rib fractures and 2 cases with irregular metaphysis/metaphyseal rarefaction/healing metaphyseal fractures in infants, with admitted accidents/blunt force trauma episodes in the history after inquiry.			Rib
10003	Wooley PV Jr, Evans WA Jr. 1955. Significance of skeletal lesions in	Not relevant PIRQ, reference test	Observations (<10)		Rib

	infants resembling those of traumatic origin. <i>Journal of the American Medical Association</i>, 158(7), 539-543.	1 case with "metaphyseal fragmentation about shoulders, elbows, wrists and knees", admitted "whipping, and after lie detector test expanded the statement". The other just strong suspicion based on other injuries, no explanation and social circumstances. "Finally, it will be seen that in several instances actual guilt was ascribed in court and the skeletal lesions in these cases varied in no essential detail from those seen in the group as a whole".	3 cases with rib fractures, 9 cases with metaphyseal lesions/fractures such as "Metaphyseal separation", "extensive fragmentation of about both elbows, shoulders, knees, and wrist", "metaphyseal avulsion", "metaphyseal fracture", "impaction of proximal humeral metaphysis", "metaphyseal irregularities", and "metaphyseal fragmentation". The authors describe those injuries as "The metaphyseal changes emphasized by Caffey and Astley were well represented."		
10004	Osier LK, Marks SC Jr, Kleinman PK. 1993. Metaphyseal extensions of hypertrophied chondrocytes in abused infants indicate healing fractures. <i>Journal of Pediatric Orthopedics</i>, 13(2):249-54.	Not relevant PIRO, outcome Objective: To study the correlation between radiologically documented CML with thickening of the hypertrophic zone of the cartilage of the growth plate (extension of the hypertrophied chondrocytes, EHC) in abused infants.	Not relevant PIRO, reference test Infants who died "with evidence of inflicted skeletal injuries". No further description how the diagnosis of abuse was established.		CML
10005	Dabeziez EJ, Warren PD. 1997. Fractures in very low birth weight infants with rickets. <i>Clinical Orthopaedics and Related Research</i>, Feb;(335):233-9.	Not relevant PIRO, outcome Objective: To determine the rate of rickets and fractures in very low birth weight premature infants. (The trauma mechanism, e.g. abuse, not mentioned).	Differential diagnosis Very low birth weight premature infants		Rib fracture + "metaphyseal fractures"
10006	Lindberg DM, Lindsell CJ, Shapиро RA. 2008. Variability in expert assessments of child physical abuse likelihood. <i>Pediatrics</i>. 2008 Apr;121(4):e945-53.	Not relevant PIRO, outcome In the absence of a gold standard for diagnosis of child abuse, clinicians and researchers often categorize their opinions of the likelihood of inflicted injury using several ordinal scales. The objective of this protocol was to determine the reliability of expert ratings using several of these scales.			CML + Rib
10007	Caffey J. 1957. Some traumatic lesions in growing bones other than fractures and dislocations: clinical and radiological features: The Mackenzie Davidson Memorial	Not relevant study design, lecture			

	Lecture. <i>The British Journal of Radiology</i> . May;30(353):225-38.			
10008	Kleinman PK. 1990. Diagnostic imaging in infant abuse. <i>American Journal of Roentgenology</i> , 155(4):703-12.	Non-systematic review (No description how articles were searched or included)		CML
10009	Servaes S, Brown SD, Choudhary AK, Christian CW, Done SL, Hayes LL, Levine MA, Moreno JA, Palusci VI, Shore RM, Slovis TL. 2016. The etiology and significance of fractures in infants and young children: a critical multidisciplinary review. <i>Pediatric Radiology</i> . May;46(5):591-600.	Non-systematic review (No description how articles were searched or included)	Consensus statement , amongst other the Child Abuse Committee and the Board of Directors of the Society for Pediatric Radiology	CML + Rib
10010	Offiah A, van Rijn RR, Perez-Rossello JM, Kleinman PK. 2009. Skeletal imaging of child abuse (non-accidental injury). <i>Pediatric Radiology</i> . May;39(5):461-70.	Non-systematic review (No description how articles were searched or included)		
10011	Flaherty EG, Perez-Rossello JM, Levine MA, Hennrikus WJ. American Academy of Pediatrics Committee on Child Abuse and Neglect; Section on Radiology, American Academy of Pediatrics; Section on Endocrinology, American Academy of Pediatrics; Section on Orthopaedics, American Academy of Pediatrics; Society for Pediatric Radiology. 2014. Evaluating children with fractures for child physical abuse. <i>Pediatrics</i> . 133(2), e477-e489.	Non-systematic review (No description how articles were search or included)	Consensus statement/guidelines , amongst other the American Academy of Pediatrics Committee on Child Abuse and Neglect, Section on Radiology, Section on Endocrinology, and Section on Orthopaedics, and the Society for Pediatric Radiology.	CML + Rib
10012	ACR–SPR practice parameter for the performance and interpretation of skeletal surveys in children (2017)	Guidelines , The American College of Radiology, USA.		
10013a	Christian CW; Committee on Child Abuse and Neglect, American Academy of Pediatrics. 2015. The	Non-systematic review (No description how articles were search or included)	Guidelines , Committee of child abuse and neglect	

	evaluation of suspected child physical abuse. <i>Pediatrics</i> . May;135(5):e1337-54. Erratum in <i>Pediatrics</i> . 2015 Sep;136(3):583.			
10013b	Christian CW, Committee on Child Abuse and Neglect. The Evaluation of Suspected Child Physical Abuse. <i>Pediatrics</i> . 2015;135(5):e1337-e1354. <i>Pediatrics</i> . 2015 Sep;136(3):583.	Errata to Christian et al (2015), #10013a		
10014	The Royal College of Radiologists and The Society and College of Radiographers. 2018. The radiological investigation of suspected physical abuse in children. Revised first edition. https://www.rcr.ac.uk/system/files/publication/field_publication_files/bfcr174_suspected_physical_abuse.pdf	Guidelines , The Royal College of Radiologists and The Society and College of Radiographers.		
10015	American College of Radiolog. 2006. ACR practice guidelines for skeletal surveys in children. http://www.seems.com/uploads/1/4/1/6/14162287/skel_survey_guidelines.pdf 5/720019	Guidelines , The American College of Radiology, USA.		
10016	American College of Radiolog. 2016. ACR practice parameter for the performance and interpretation of skeletal surveys in children. https://www.acr.org/-/media/ACR/Files/Practice-Parameters/Skeletal-Survey.pdf	Guidelines , The American College of Radiology, USA.		
10017	Section on Radiology; American Academy of Pediatrics. 2009. Diagnostic imaging of child abuse. <i>Pediatrics</i> . 123(5). 1430-1435.	Policy statement , American Academy of Pediatrics, Section on Radiology		
10018	Cohen MC, Offiah A, Sprigg A, Al-Adnani M. 2013. Vitamin D	Not relevant PIRO, outcome	Not relevant PIRO, reference test	Not relevant PIRO, index test

	deficiency and sudden unexpected death in infancy and childhood: a cohort study. <i>Pediatric and Developmental Pathology: the official journal of the Society for Pediatric Pathology and the Paediatric Pathology Society</i> , 16(4), 292-300.	Objective: We sought to (1) determine if there is an increased prevalence of vitamin D deficiency (VDD) in cases of sudden death in infancy and childhood; (2) establish whether there is a link between VDD and infection; and (3) assess if the level of vitamin D can be related to abnormalities in the skeletal survey and rib histology in our cohort.		
10019	Quigley AJ, Stafrace S. 2014. Skeletal survey normal variants, artefacts and commonly misinterpreted findings not to be confused with non-accidental injury. <i>Pediatric Radiology</i> , 44(1), 82-93; quiz 79-81.	Non-systematic review (No description how articles were searched or included)	Pictorial essay	CML
10020	Oestreich AE. 2018. Distinguishing child abuse fractures from rickets. <i>Pediatric Radiology</i> , Mar;48(3):305-307.	Commentary	Non-systematic review (No description how articles where searched and included)	CML
10021	Perez-Rossello JM, Feldman HA, Kleinman PK, Connolly SA, Fair RA, Myers RM, Gordon CM. 2012. Rachitic changes, demineralization, and fracture risk in healthy infants and toddlers with vitamin D deficiency. <i>Radiology</i> , Jan;262(1):234-41.	Not relevant PIRO, outcome Objective: To examine radiographic findings in children with vitamin D deficiency in comparison with biomechanical marker levels and prevalence of fractures.	Differential diagnosis: Vitamin D deficiency	.
10022	Mendelson KL. 2005. Critical review of 'temporary brittle bone disease'. <i>Pediatric Radiology</i> , Oct;35(10):1036-40.	Non-systematic review (No description how articles were searched or included)	Consensus statement , the Society for Pediatric Radiology (SPR) and European Society for Paediatric Radiology (ESPR) Board of Directors.	
10023	Price EA, Rush LR, Perper JA, Bell MD. 2000. Cardiopulmonary resuscitation-related injuries and homicidal blunt abdominal trauma in children. <i>The American Journal of Forensic Medicine and Pathology</i> , Dec;21(4):307-10.	Not relevant PIRO, index test One case of humeral fracture with multiple rib fractures and tibial metaphyseal fracture.	Not relevant PIRO, reference test	.

10024	Strait RT, Siegel RM, Shapiro RA. 1995. Humeral fractures without obvious etiologies in children less than 3 years of age: When is it abuse? <i>Pediatrics</i> , Oct;96(4 Pt 1):667-71.	Not relevant PIRO, index test	Not relevant PIRO, reference test	
10025	Thomas SA, Rosenfield NS, Leventhal JM, Markowitz RI. 1991. Long-bone fractures in young children: distinguishing accidental injuries from child abuse. <i>Pediatrics</i> , 88 (3): 471-6.	Not relevant PIRO, index test Metaphyseal fractures mentioned, but not how many. Of the fractures in the humerus "several" were Salter Harris fractures. Not stated if any of these were CML. In the fractures of the femur metaphyseal fractures were seen, but not stated how many and if any of them were CML. "Four of the 11 abused children (with humeral fractures, my comment) had other fractures on skeletal survey, either fractured ribs or multiple metaphyseal chips in other sites in different stages of healing". The text implies that CML was not included as index test.	Not relevant PIRO, reference test To determine the likelihood of abuse, each case was reviewed on three occasions: first, by two clinicians; second, by two pediatric radiologists; and third, jointly by the clinicians and radiologists to clarify disagreements and to reach a consensus. The clinicians, who included a pediatrician experienced in child abuse cases and a senior medical student, reviewed all available medical, social service, and radiological records on each case. They took into account prior histories of illness or injuries, social service evaluations, and all subsequent visits to the hospital. The pediatric radiologists were provided with a one-sentence chief complaint (eg, a 7-month old boy fell from a bed). They were not given demographic or social data (eg, the grandmother of the child said that her daughter is not a good mother). They first studied the primary fracture and then reviewed the skeletal survey when it was available. As part of their assessment, they also described the characteristics of each fracture. Finally, the clinicians and the radiologists reviewed each case together and compared their independent ratings. When disagreements occurred, the case was reviewed, and a joint assessment was made. In this paper, we present the joint ratings of all cases with fractures of the humerus or femur. Both clinicians and radiologists used a seven point scale to rate these cases; three points on the scale indicated abuse ("definite," "probable," or "possible") and three indicated accident ("definite," "probable," or "possible"). A middle category labeled "unknown" was reserved for those cases that had insufficient data in the medical record to assess the case or to reach a consensus (Tables 1 and 2).	"Metaphyseal fractures"

			Table 1. "Criteria used by the radiologists to distinguish abuse from accidents" 1. <i>Definite abuse</i>: • Serious trauma must have been involved, not reflected in history • Serious trauma must have been involved, suspicious delay in reporting • Multiple fractures found, not explained by history • Healing fractures found, not explained by history 2. <i>Likely abuse</i>: • Injury severe, history does not reflect sufficient severity 3. <i>Questionable abuse</i>: • Suspicious fractures, check history for further explanation • Suspicious delay in reporting 4. <i>Unknown cause</i> • Fracture not suspicious, story incomplete, check further 5. Questionable accident • Fracture not suspicious, story consistent, not enough details 6. <i>Likely accident</i> • Fracture not suspicious, story consistent with fracture 7. <i>Definite accident</i> • Fracture not suspicious, story consistent and thorough, witnesses
		Table 2. "Criteria used by the clinicians to distinguish abuse from accidents" 1. <i>Definite abuse</i>: • Positive skeletal survey - multiple recent fractures • Positive skeletal survey - fractures of various ages • Eyewitness • Multiple internal injuries • Physical findings - Bruises (hand, electric cord, teeth) - Suspicious or unexplained burns or scars • Sibling abused at same time • A definite intentional act causing physical harm to child • Parental fight; injury not directed at child	

			• Suspicious injury with definite later abuse 2. Likely abuse: • Original doctors called injury abuse AND history inconsistent. - History not sufficient for injury and/or. - Story of accident changes and/or family members present different versions of history and/or - Inappropriate delay in seeking care 3. Questionable abuse: • History inconsistent - History not sufficient for injury and/or - Story of accident changes and/or - Family members present different versions of history and/or - Inappropriate delay in seeking care 4. Unknown cause: • Insufficient information available in charts 5. Questionable accident: • Isolated incident, social worker/physician no suspicion of abuse, story somewhat inconsistent with extent of injury, but consistent with type of injury • Story somewhat inconsistent with extent of injury, social worker/ physician no suspicion of abuse, neglect involved • Isolated incident, no suspicion of abuse, story not known 6. Likely accident: • Consistent story, social worker/physician no suspicion of abuse, isolated injury • Consistent story, no suspicion of abuse, neglect involved • Minimal but consistent story, social worker/physician no suspicion of abuse, isolated incident • Story consistent with injury; aggressive or irresponsible behavior involved; however, injury not directly inflicted 7. Definite accident: • Motor vehicle accident • Multiple witnesses (police report, ambulance at scene) • Pedestrian hit by automobile My comment: It is not clearly stated if all 3 stages indicative of abuse "definite abuse," "likely abuse" and "questionable abuse" were classified
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			as abuse or only “definite abuse”, but the former seems to be implied by the context.	
10026	Maguire S, Mann MK, Sibert J, Kemp A. 2005. Are there patterns of bruising in childhood which are diagnostic or suggestive of abuse? A systematic review. <i>Archives of Disease in Childhood</i> . Feb;90(2):182-6.	Systematic review To "identify the evidence base and answer the question 'What patterns of bruising in childhood are diagnostic or suggestive of abuse?'"	Not relevant PIRO, reference test Ranking of the definition of child abuse. 1) Abuse confirmed at case conference or civil, family or criminal court proceedings or admitted by perpetrator. 2) Abuse confirmed by stated criteria including multidisciplinary assessment. 3) Diagnosis of abuse by stated criteria. 4) Abuse stated but no supporting detail or evidence given. 5) suspected abuse In non-abuse papers we have recorded whether factors that influence bruising were excluded, namely abuse, neurodisability, and medical conditions predisposing to bruising.	Not relevant PIRO, population .
10027	Maguire S, Moynihnan S, Mann M, Potokar T, Kemp AM. 2008. A systematic review of the features that indicate intentional scalds in children. <i>Burns</i> , Dec;34(8):1072-81.	Systematic review Objective: To "conduct a systematic review to identify distinguishing features of intentional and unintentional scalds".	Not relevant PIRO, reference test Ranking of the definition of child abuse. 1) Abuse confirmed at case conference or civil, family or criminal court proceedings or admitted by perpetrator. 2) Abuse confirmed by stated criteria including multidisciplinary assessment. 3) Diagnosis of abuse defined by criteria. 4) Abuse stated as occurring, but no supporting detail given as to how it was determined. Abuse stated simply as "suspected", no details on whether it was confirmed or not. Ranking of accidental scalds A) Scene of incident recreated or forensic police investigation of scene	Not relevant PIRO, population and index test .

			or criminal investigation ruled out abuse as a cause. B) Efforts specifically made to exclude abuse as a cause for burn through multidisciplinary investigation or social services investigation of home circumstances. C) No mention of how burn was deemed to be accidental, how abuse was excluded, or no mention that abuse was considered as possible etiology. Included only studies with a ranking of abuse of 1-3, and accidental rankings of A or B.		
10028	Caffey J. 2011. The classic: Multiple fractures in the long bones of infants suffering from chronic subdural hematoma. 1946. <i>Clinical Orthopaedics and Related Research</i> , 469 (3): 755-8.	Case report: 6 cases, infants with subdural hematoma and multiple fractures including metaphyseal fractures and cortical thickening, without signs of bone disease or history of significant trauma.			
10029	Coffey C, Haley K, Hayes J, Groner JI. 2005. The risk of child abuse in infants and toddlers with lower extremity injuries. <i>Journal of Pediatric Surgery</i> , 40 (1): 120-3.	Not relevant PIRO, index test CML not mentioned	Not relevant PIRO, reference test "If the trauma registry record for a patient indicated a diagnosis of "child abuse" or "child abuse suspected", the case was placed in the abuse category for further analysis. In our clinical experience, most of patients with an admission diagnosis of "child abuse suspected" are confirmed as abuse cases when the full clinical evaluation is completed. Furthermore, if, during the hospitalization, child abuse is definitely ruled out in a suspected abuse case, the "suspected abuse" diagnosis is deleted from the registry."	Not relevant PIRO, population	.
10030	Merten DF, Carpenter BL. 1990. Radiologic imaging of inflicted injury in the child abuse syndrome.	*Not accessed			

	<i>Pediatric Clinics of North America</i> , 37(4), 815-837.				
10031	Meller JL, Little AG, Shermeta DW. 1984. Thoracic trauma in children. <i>Pediatrics</i> , 74 (5): 813-9.	Not relevant PIRO, population (newborn -16 years)	Not relevant PIRO, reference test Not stated how diagnosis of abuse was established.	Observations (<10) Only 5 infants <1 year and 5 in total with abuse diagnosis; age for these not stated.	Rib fracture
10032	Caffey J. 1974. The whiplash shaken infant syndrome: manual shaking by the extremities with whiplash-induced intracranial and intraocular bleedings, linked with residual permanent brain damage and mental retardation <i>Pediatrics</i> , 54 (4): 396-403.	Non-systematic review (No description how articles were searched or included)			CML
10033	Kogutt MS, Swischuk LE, Fagan CI. 1974. Patterns of injury and significance of uncommon fractures in the battered child syndrome. The <i>American Journal of Roentgenology, Radium therapy, and Nuclear Medicine</i> , 121 (1): 143-9.	* Not accessed			
10034	Silverman FN. 1972. Unrecognized trauma in infants, the battered child syndrome, and the syndrome of Ambroise Tardieu. <i>Rigler Lecture. Radiology</i> , 104(2), 337-53.	* Not accessed			
10035	Ryan MP, Young SJ, Wells DL. 2003. Do resuscitation attempts in children who die, cause injury? <i>Emergency Medicine Journal</i> , 20(1), 10-12.	Not relevant PIRO, reference test 1 group CPR, 1 group no CPR	Differential diagnosis: CPR	Not relevant PIRO, outcome Objective: To determine the incidence, type, and pattern of injury related to resuscitation attempts in children who die.	Rib fractures
10036	Dokos C, Tsakalidis C, Tragiamidis A, Rallis D. 2013. Inside the "fragile" infant: pathophysiology, molecular background, risk factors and investigation of neonatal osteopenia. <i>Clinical Cases in Mineral and Bone Metabolism: the official journal of the Italian Society of Osteoporosis</i> ,	Non-systematic review (No description how articles were found or included)	Not relevant PIRO, outcome Objective: "Purpose of this review is to investigate the available data concerning neonatal osteopenia, the molecular and pathophysiological basis, the risk factors, monitoring and investigation. Therefore by elucidating neonatal osteopenia recommendations		.

	<i>Mineral Metabolism, and Skeletal Diseases</i> , 10(2), 86-90.		can be drawn to help specialists like neonatologists, orthopedics and endocrinologists to identify high risk group of neonates. "		
10037	Pierce MC, Kaczor K, Lohr D, Richter K, Starling SP. 2012. A Practical Guide to differentiating abusive from accidental fractures: An Injury plausibility approach. <i>Clinical pediatric emergency medicine</i> . 13(1), 166-177.	Non-systematic review (No description how articles were searched or included)			CML + Rib
10038	Bishop N, Sprigg A, Dalton A. 2007. Unexplained fractures in infancy: looking for fragile bones. <i>Archives of Disease in Childhood</i> . 92(3), 251-6.	Non-systematic review (No description how articles were search or included)			.
10039	Kelloge ND. American Academy of Pediatrics Committee on Child Abuse and Neglect. 2007. Evaluation of suspected child physical abuse. <i>Pediatrics</i> , 119(6), 1232-1241.	Non-systematic review (No description how articles were search or included)	<i>Guidelines</i> , Committee on Child Abuse and Neglect		
10040	Wood JN, Christian CW, Adams CM, Rubin DM. 2009. Skeletal surveys in infants with isolated skull fractures. <i>Pediatrics</i> , 123(2), e247-e252.	Not relevant PIRQ, outcome Objective: Describe the utility of skeletal surveys and the factors associated with skeletal surveys use and referral to child protective services for infants with skull fractures in the absence of significant intracranial injury.	<i>Not relevant PIRQ, reference test</i>	<i>Not relevant PIRQ, index test</i>	
10041	Alfredo Walker, Charis Kepron, Christopher M. Milroy. 2016. Are There Hallmarks of Child Abuse? I. Osseous Injuries. <i>Academic Forensic Pathology</i> , 6(4),568-590.	Non-systematic review (No description how articles were found or included)			CML + Rib
10042	O'Connor SC, Ruess L, Quinn WJ, Medina LS, Wells CN, Anderson ML. 2003. Film screen and computed radiography in the detection of classic metaphyseal lesions in an animal model of child abuse. <i>Pediatric Radiology</i> , 33, S112	Conference proceeding			

10043	Lindberg DM, Harper NS, Laskey AL, Berger RP; EXSTRA Investigators. 2013. Prevalence of abusive fractures of the hands, feet, spine, or pelvis on skeletal survey: perhaps "uncommon" is more common than suggested. <i>Pediatric Emerg Care</i> , 29(1), 26-29.	Not relevant PIRQ, reference test Secondary analysis of data from the Examining Siblings to Recognize Abuse (EXSTRA) research network. "children evaluated for concerns of physical abuse". "Subjects were eligible for inclusion regardless of the source of the referral or site of evaluation (intensive care unit, inpatient floor, emergency department, or outpatient clinic) or the ultimate level of concern for abuse."	Not relevant PIRQ, population 0-10 years, mean age or median age not stated. Age parameters for the group with fractures not stated.		CML + Rib
		This paper does not seem to have included children based on the likert scale for concern of abuse, but included <i>all</i> children with fractures.			
10044	Lindberg DM, Shapiro RA, Laskey AL, Pallin DJ, Blood EA, Berger RP; EXSTRA Investigators. 2012. Prevalence of abusive injuries in siblings and household contacts of physically abused children. <i>Pediatrics</i> , 130(2), 193-201.	Not relevant PIRQ, outcome Objective: "Siblings and other children who share a home with a physically abused child are thought to be at high risk for abuse, but rates of injury in these contact children are unknown and screening of contacts is highly variable. Our objective was to determine the prevalence of abusive injuries identified by a common screening protocol among contacts of physically abused children." Outcome: "The main outcome measure was the proportion of protocol-indicated SS that identified an abusive fracture in a contact child. Secondary outcomes included the proportions of protocol indicated physical examinations and neuroimaging that identified injuries in contacts."	Not relevant PIRQ, reference test "We defined index children as "physically abused" if they had both a high likelihood of abuse and at least 1 serious injury" Abuse in index children was established by: 1) 6 och 7 point on a 7 point likert scale AND 2) "at least one" serious injury (a) Fracture (s) b) Traumatic brain injury c) Burns > 5 % of the body d) Intra-abdominal or intrathoracic injury e) ICU admission f) Death before discharge. 6 point on the likert scale="Substantial evidence of inflicted injury": " 1) Severe injury with no offered history in a child incapable of inflicting the injury on himself or herself 2) History inconsistent with identified injuries 3) Serious injuring with changing history or history inconsistent between caregivers	Observation <10 (9 cases rib fractures, 3 cases with CML)	CML + Rib

			4) Inappropriate delay in seeking care 5) Multiple severe injuries of different age without plausible explanation. 7 point on the likert scale= <i>Definite inflicted injury</i> 1) Pattern bruises/burns 2) Unexplained posterior rib fractures, characteristic retinal hemorrhages 3) Highly suspicious injury (liver laceration, burn, pinna bruising, unexplained fracture) with definite subsequent abuse 4) Reliable eyewitness of abuse 5) Suspicious injury and concurrently abused sibling 6) Obvious injury with significant, unexplained delay in seeking care (serious burn, unresponsive child, apparent prolonged seizure)" Rating 6 or 7 means: "To a reasonable degree of medical certainty, the injuries/findings that we have described cannot plausibly be explained by accidental injury, preexisting medical illness, reasonable discipline, or benign events". "Abuse fractures in children in siblings and households contacts of physically abused children were defined as Ribs, Hand/foot, CML, Long bone, Skull."		
10051	Cosway B, Alison Mott NM, Bredow M, Fraser J, Rawlinson A, Wei C, Tnyagarajan MS, Harrison S, Kemp A. 2015. Occult rib fractures: defining the cause. <i>Child Abuse Review</i>, 24, 6-15.	Not relevant PIRQ, population <24 months	Not relevant PIRQ, reference test case conference, child protection process		Rib fractures

10052	Beals RK, Tufts E. 1983. Fractured femur in infancy: the role of child abuse. <i>Journal of Pediatric Orthopedics</i> , 3, 583-586.	Observation < 10 (Fractures not described as CML, but only 9 metaphyseal fractures [5 distal metaphysis, 4 distal metaphyseal chip fractures] in the abuse group and only 5 metaphyseal fractures [4 distal metaphysis, 1 distal metaphyseal chip fracture] in the non-abused group.	Not relevant PIRQ, reference test <u>Not abused</u> : 1. Reasonable history of cause of fracture, and 2. Appropriate timing in seeking care, and 3. Clinical examination substantiating the history. <u>Abuse suspected</u> : 1. Unreasonable history of cause of fracture to include fracture with diaper change and no history of injury, or 2. Inappropriate delay in seeking care, or 3. Physical evidence of additional trauma. <u>Abused</u> : Same as abuse, or 1. Previous known abuse, or 2. Admission of abuse, or 3. Radiological evidence of fractures at varying stages of healing, or 4. Multiple acute fractures without evidence of bone disease. Suspected abuse and abuse merged to one group.		CML
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