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## Review

# Multiple unexplained fractures in infants and child physical abuse

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## ABSTRACT

When an infant presents with X-rays showing multiple unexplained fractures in various stages of healing (MUFVSH), the child is usually diagnosed with child abuse based on criteria of the Academy of Pediatrics' Committee on Child Abuse and Neglect (AAPCCAAN). Almost always, the infant is subsequently removed from the home and civil or criminal proceeding commence. It may be that healing infantile rickets or other poorly understood metabolic bone disorders of infancy are responsible for these x-rays. Activated vitamin D is a seco-steroid hormone, whose mechanism of action is genetic regulation. Lack of it can result in musculoskeletal defects known as rickets. Low calcium can also cause rickets. However, it is clear that experts for the state believe that the x-rays in these cases are so definitive as to be pathognomonic for child abuse. Therefore, if the caregivers deny abusing their infants, experts following American Academy of Pediatrics' Committee on Child Abuse and Neglect, guidelines are essentially claiming that x-rays showing multiple unexplained fractures in various stages of healing are lie detector tests. However, it is not widely appreciated that the gold standard for the diagnosis of rickets is a bone biopsy, not x-rays, as radiologists miss biopsy proven rickets 80% of the time; that is, 4 out of 5 infants with rickets will have normal x-rays. In this article we provide reports of two cases and their outcomes. We discuss information about healing infantile rickets and an example of common sense medical conclusions in these cases. This information could lead to a significant reduction in the number of innocent parents having their infant removed or sent to prison.

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## Contents

1. Introduction	00
2. Case presentations	00
2.1. Infant number one	00
2.2. Infant number two	00
3. Discussion	00
4. Conclusion	00
Conflict of interest	00
Funding source	00
Financial disclosure	00
References	00

*Abbreviations:* 25(OH)D, 25-hydroxyvitamin D; AAPCCAAN, American Academy of Pediatrics' Committee on Child Abuse and Neglect; CPS, child protective services; CML, classical metaphyseal lesion; MUFVSH, multiple unexplained fractures in various stages of healing; TPN, total parental nutrition.

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## 1. Introduction

There are few subjects as contentious as child abuse. On the one hand, no one wants child abusers to have custody of an infant. On the other hand, no one wants innocent parents wrongly separated from their infant or sent to prison. Every year in the United States, infants are shot, stabbed, drowned or suffocated; we do not mean to deny the occurrence of child abuse. We limit our contentions to

multiple fractures in infants under the age of 6 months in which there are no other clear signs of abuse. The American Academy of Pediatrics' Committee on Child Abuse and Neglect (AAPCCAN) has issued guidelines for the evaluation of children with multiple unexplained fractures, concluding they are almost always due to abuse [1].

However, common sense questions still need answering: Why would abusive parents repeatedly seek medical care for the infant they abused? How can trauma severe enough to fracture bones not leave a bruise? Why would chest trauma severe enough to fracture ribs not also result in lung damage? Why wouldn't blunt chest trauma cause some inwardly angulated rib fractures instead of all perfectly aligned fracture ends? Wouldn't parents who beat their infant severely enough to cause multiple fractures show evidence of psychopathology? Do infants who are beaten severely enough to cause multiple fractures show fear in the presence of the abuser? How often do the eyewitnesses to parental/infant interactions report the parents were concerned and loving parents?

## 2. Case presentations

### 2.1. Infant number one

African American parents repeatedly brought their four-month-old winter-born breast-feeding infant to medical professionals due to an unexplained swelling over the left clavicle and failure to thrive. His pediatrician had never prescribed or recommended the supplemental 400 IU/day of vitamin D that the American Academy of Pediatrics recommends for all infants, especially breast feeding infants.

An x-ray of the left clavicle found a fracture as well as multiple nondisplaced rib fractures. A skeletal survey was done and the radiologist reported it revealed additional non-displaced multiple rib fractures, including multiple nondisplaced posterior rib fractures in various stages of healing as well as a questionable classic metaphyseal lesion (CML) of the distal right femur. X-rays of his long bones showed questionable mild demineralization but no other fractures. The hospital radiologist reported there were no frayed epiphyses or metaphyseal widenings. Nursing notes indicated that either parent could successfully console the infant and he showed no fear being around either parent. History and physical examination revealed a history of excessive head sweating but no bruising anywhere on his body or evidence of internal injuries. The infant's initial 25-hydroxy-vitamin D [25(OH)D] level was 13 ng/ml and his alkaline phosphatase (AP) was elevated at 886 IU/L. After repeated requests by the parent's experts, Child Protective Services (CPS) obtained serum calcium, phosphorous and PTH (all normal) but they were not done until the then bottle-feeding infant had been in child protective services for 6 months.

The infant was the product of an uncomplicated 39-week gestation weighing 6 pounds four ounces. The mother used a phosphate binder and antacid, calcium carbonate, on a daily basis the last two months of her pregnancy. The infant was discharged the day after his birth to the care of his parents. He never required total parental nutrition (TPN) and had no gastrointestinal procedures. However, his growth and development showed he was not gaining enough weight with breast-feeding and he failed to follow faces with his eyes. The mother had a 25(OH)D of 14 ng/ml five months after her infant had been taken out of the home.

The states' experts interpreted his x-rays as showing no evidence of rickets or other metabolic bone diseases. Osteogenesis Imperfecta was ruled out. Radiology, endocrinology and pediatric child abuse experts at an academic medical center tested for other rare causes of multiple fractures, such as Ehlers-Danlos syndrome, scurvy, copper deficiency, genetic rickets, Menkes' syndrome, biliary atresia, propionic acidemia, myofibromatosis, congenital

syphilis, and congenital cytomegalovirus infection, which were all negative. They diagnosed child physical abuse, stating they saw no evidence of frayed epiphyses, metaphyseal widening or significant demineralization; they opined there was a CML on the right distal femur. CPS removed the infant from his home. Repeat x-rays done 6 weeks after the infant was removed from the home and on formula showed multiple healing fractures and no new fractures.

The parents moved to have their son returned home but CPS refused. The state hired the three academic experts described above while the parents hired radiology and endocrinology experts, and a forensic psychiatrist (JJC).

The defense's forensic psychiatrist testified he found no evidence of psychopathology or any mental illness in the parents. All eyewitnesses to the parent's interactions with the infant in and around the time of the alleged abuse testified the parents were excellent parents and never abusive. The parents' radiological expert diagnosed multiple fractures due to healing infantile rickets. He testified the right distal humerus epiphysis was frayed. The states' expert stated the CML proved child abuse per AAPCCAN diagnostic guidelines. The court accepted the six expert reports into evidence, heard testimony, and subsequently returned the infant to the parents, commenting that the lack of bruising, lack of internal trauma, lack of angulated fractures, lack of psychopathology in the parents and the parent's character witnesses as the basis of his judgement. The infant was then started on 2000 IU/day of vitamin D and 250 mg of calcium for three months and began thriving. X-rays done at age 10 months showed no fractures or evidence of rickets.

### 2.2. Infant number two

The infant was the product of a normal 40-week pregnancy and delivery with the exception of the mother using large amounts of calcium carbonate as an antacid for the last three months of her pregnancy. He weighed 5 pounds 6 ounces at birth and was discharged the next day. He never required TPN and had no known medical problems. His pediatrician did not prescribe or recommend vitamin D supplements.

Over the course of the two months after the birth of their winter-born infant, the parents, who were European-American, repeatedly brought their breast-feeding infant to the attention of medical personnel for fussiness, not eating well and failure to thrive. He completed a course of ampicillin for a suspected ear infection but that did not help his fussiness. At ten weeks of age the parents brought the infant to the emergency room for unexplained swelling over the left upper leg.

X-rays revealed a spiral fracture of the left femur and a skeletal x-ray survey revealed multiple fractures, including non-displaced posterior rib fractures, in various stages of healing. The radiologists stated there was no evidence of rickets. Two areas of bluish brown discolorations of the skin were noted on the infant's left hand, which was charted as a bruise by one of the nurses. However, no bruises were present over any of the fracture sites. Physical exam showed no evidence of internal injury, lungs or otherwise. Other than excessive sweating of the head, the rest of the infant's history and exam were normal.

The infant's 25(OH)D level was 12 ng/ml and his AP was elevated at 446 U/L. Serum CA and phosphorous were within normal limits. Two hospital radiologists ruled out metabolic bone disease and diagnosed child abuse based solely on the x-rays. They opined there was a CML on the distal right tibia. Child protective services had the infant removed from the home. The parents claim no physician interviewed or examined them, other than to accuse them of abuse.

After the infant was removed from the home, the child was referred to a tertiary academic medical center where serum

phosphorus and PTH were normal. Genetic testing for osteogenic imperfecta and other rare causes of metabolic bone disease were negative. A radiologist and pediatric child abuse expert agreed with the diagnosis of child abuse and opined that such fractures as these could only be due to child abuse.

The parents moved to have the infant returned to their care. They searched the Internet and found multiple cases similar to theirs were due to rickets. The mother had her 25(OH)D tested and it was 14 ng/ml. The parents retained a radiologist, a pediatrician, an orthopedist, and myself (JJC) as experts. The state hired a pediatric radiologist and a pediatric child abuse expert as consultants, both of whom followed AAPCCAN guidelines.

The infant's treating pediatrician testified that the discoloration on the left hand were Mongolian spots, not bruises. He testified the parents seemed loving and caring and the infant was never uncomfortable in the presence of his parents. In fact, all eyewitnesses to the parents' interactions with the infant reported the parents were never abusive. The parent's radiologist testified that the fractures and CML were due to rickets while the state's radiologist said the x-rays were proof of abuse. Neither parent showed evidence of psychopathology on forensic psychiatric examination (JJC).

The experts hired by the parents diagnosed multiple fractures due to healing infantile rickets. The states' experts all diagnosed child abuse per AAPCCAN diagnostic guidelines concluding that, with x-rays such as these, child abuse was the only possibility. A hearing was held where expert reports were allowed, extensive expert testimony was heard, and the court promptly returned the infant to the parents, again citing common sense reasoning for releasing the child.

The infant was then started on 3000 IU/day of vitamin D3/day together with 250 mg of calcium and began to thrive. At age 12 months his x-rays showed no evidence of fractures, or of rickets. The excessive sweating of the infant's head was no longer present. His 25(OH)D after being on 3000 IU/day for 3 months was 28 ng/ml.

### 3. Discussion

Rickets is characterized by impaired mineralization and bone formation of the growth plates of growing children caused by a variety of disorders, the most frequent of which may be vitamin D deficiency but calcium deficiencies appears to be a close second. Research has shown that rickets occurs with vitamin D levels that are similar to our two cases [2,3]. However, it is likely that calcium deficiencies cause as many cases of rickets as do vitamin D deficiency in children not on formula or breast milk. Whatever the cause, the incidence of rickets is increasing dramatically [4].

Normal bone growth requires building blocks such as calcium, phosphate and vitamin D as well as magnesium, boron and other trace elements. Deficient intake of minerals can result in deficient mineralization of the growth plates. The mineralization defects can be classified as hypocalcemic rickets caused by calcium deficiency and/or hypophosphatemic rickets caused by phosphate deficiency and/or vitamin D deficient rickets, whose active metabolite is a secosteroid hormone with multiple receptor sites on bone. In fact, calcium, vitamin D, parathyroid hormone and phosphorus interact in such a way that deficiencies of one are often associated with disorders of the others.

The causes range from dietary inadequacies, absence of sunlight, and inherited metabolic abnormalities. Maintenance of physiologically normal serum calcium and phosphorus levels require complex interactions between vitamin D, the kidneys, the gastrointestinal tract, parathyroid hormone and bone calcium regulating hormones such as vitamin D and parathyroid hormone, as well as hormones controlling phosphorus homeostasis, such as

fibroblast growth factor-23. In newborns, calcium, phosphorus, magnesium and trace elements balance must necessarily be positive in order to provide the requisite building blocks for growth and maturation.

In a modern-day study, fractures in young children have not been associated with vitamin D deficiency but none of these children were diagnosed with rickets [5]. However, fractures have historically been a complication of rickets [6,7]. In 1921, Park and Howland found spontaneous multiple rib fractures in 22 children with rickets, the majority also exhibiting multiple extremity fractures [8]. Also, old medical textbooks, including *Brenner's Practice of Pediatrics*, have repeatedly stressed that fractures are a complication of rickets [9,10].

Many practitioners may not know that infantile rickets is becoming more common due to widespread vitamin D deficiency [11]. In children with severe vitamin D deficiencies, low 25(OH)D alone may cause rickets [12]. In older rachitic infants, who are off the breast and bottle, inadequate calcium intake may be as important as are low vitamin D levels [13,14]. For example, older rachitic children (6–30 months) respond best to a combination of calcium and vitamin D than either alone [15]. However, this paper restricts itself to infantile rickets, infants who would either be on the bottle or breast-fed and therefore assumedly have adequate calcium and phosphorus intake.

A National Medicine of Library search for “healing infantile rickets” revealed no useful references except for a recent paper in which four experts stated that healing infantile rickets has a much different radiological presentation than classic rickets, one that is often mistaken for child abuse [16]. We do know that, using uterine ultrasound, about one-third of modern day fetuses (19 week) in Southampton, England, have rickets, as evidenced by the classic finding of widening at the end of the femur [17]. They found signs of rickets were common in fetuses whose mothers had 25(OH)D levels less than 20 ng/ml, and even saw evidence of rickets in some fetuses whose mothers had 25(OH)D levels between 20 and 30 ng/ml, probably due to maternal calcium deficiency. Perhaps an ultrasound study could be done on a cohort of newborns to discover the incidence of multiple unexplained fractures in various stages of healing (MUFVSH) infants or newborns but the parents of any such cohort must be informed about and protected from CPS. Small ultrasound studies of newborns have been done but they were not total body scans looking for the prevalence of multiple fractures [18]. It might be feasible to do a case series of bone ultrasounds at birth, before the infant leaves the hospital, and any found would not be due to parental abuse. However, such a study would require several thousand infants as the incidence of multiple fractures and rickets is probably rare. Such an x-ray study could not be done due to radiation exposure.

Craniotabes, which is a softening and ping pong ball-like quality of the skull, is common in rickets and is present in 22% of otherwise normal Japanese newborns; a high percentage of the Japanese infants with craniotabes had rickets [19].

Little is known about healing infantile rickets in the modern age; modern radiology training appears to no longer emphasize it. However, in 1942, Clements performed one of the largest known prospective analyses of healing infantile rickets [20]. Nearly half of all of the full-term infants that Clements studied developed subclinical rickets. The prevalence increased after the first month, peaked in the third month and disappeared by eight months. In other words, it is self-limiting. In 1952, American pathologists found that 83% of infants who died from other causes had histological rickets [21]. As recently as 1958, even in sunny Israel, histological rickets was present in 17% of deceased infants, the majority of cases occurring in infants younger than six months [22]. Some think clinicians frequently miss infantile rickets as it is self-healing [23].

We were shocked to find that different radiologists can both look at the same x-rays and come to starkly different conclusions. For example, two radiology Professors at Stanford University diagnosed multiple fractures due to rickets on several infants, and concluded that there is a “national and international epidemic” of infantile rickets [24]. However, two other board certified radiologists looked at the same x-rays and diagnosed child abuse, not rickets [25]. The same thing occurred in our two cases; the same x-rays were interpreted as rickets by the defense and child abuse by the states’ radiologists.

As far as the modern medical diagnosis of rickets goes, it has been assumed that the gold standard is radiological. However, a recent study of 41 infants who died of sudden infant death syndrome found that only 7% of bone biopsy proven rickets was picked up by pediatric radiologists [26]. That is, two academic pediatric radiologists missed over 93% of biopsy proven rickets when looking at x-rays [27]!

Another more recent study of a group of 52 children who died of various causes reported histological rickets in 10 children with vitamin D levels less than 10 ng/ml but premorbid x-rays missed the rickets 70% of the time [28]! In the same study, eight infants with vitamin D levels between 10 and 20 ng/ml had histological rickets but premorbid radiology was normal in 100% of these children. Three of the infants had fractures. Again, in this study, radiologists missed biopsy-proven rickets more than 80% of the time [29]! It should be noted that most vitamin D deficient radiological rickets occur when vitamin D levels are less than 10 ng/ml but this is probably not accurate for rickets caused by a concomitant deficiency of calcium and/or phosphorous. If other trace elements in bone (or magnesium deficiency) cause rickets, they have not been studied.

A German study of bone biopsies of 675 adult cadavers dying from other causes found that 169 cadavers had adult rickets (osteomalacia) on bone biopsy but it was not found on X-rays [30]. These three studies imply radiologists routinely miss infantile rickets.

However, one study found no histopathological evidence of rickets in nine allegedly abused infants [31]. Another histopathological study of 3 allegedly abused infants found no radiological evidence of rickets [32]. In these last two studies the diagnosis of “abused” is problematic. To know if abuse occurred for sure, a free confession or reliable eyewitness is necessary. If 80% of rickets is missed on radiographs, as virtually all the autopsy studies show, then radiologists most stop believing radiographs are the gold standard for the diagnosis of rickets and bone biopsies – read by a pathologist experience in infantile rickets – needs to be done before the infant is removed from the home.

CMLs are considered the sin qua non of abuse by AAPCCAN members but a small and growing group of radiologists think they may be due to rickets.<sup>16</sup> One of the alleged mechanisms of injury for the CML is twirling the infant around by his feet, which has never been observed or documented and strikes us as unlikely behavior for an abuser. Also, CMLs seldom bleed even though they occur in the highly vascular epiphyses. Nor do CMLs form calluses or a periosteal reaction, which would be expected if they were fractures. In fact, different groups have seen CMLs in newborns after uncomplicated cesarean sections, before the infants left the hospital [33,34].

It is not widely appreciated by radiologists that the gold standard for the diagnosis of rickets is a bone biopsy, not an x-ray and the pathologist that reads the bone biopsy must be knowledgeable about infantile rickets. In writing about metabolic bone disease, such as rickets, a current textbook of orthopedic pathology states, “In subtle cases absolute certainty require tissue examination.” [35] (pp. 104). The authors add, “A bone biopsy is indicated in every patient in whom a cause of fracture is

unexplained.” (pp. 127) However bone biopsy is seldom done. We must ask ourselves what is more traumatic to an infant, a few minutes of pain on its iliac crest or separation from her parents?

Osteogenesis Imperfect can be a cause of infantile fractures [36]. There are other rare metabolic bone disorders that mimic child abuse [37,38]. A recent group of radiologists complained abuse is so prevalent in radiologist’s minds, they miss metabolic bone disease [39]. More and more authors have written that child physical child abuse and healing infantile rickets are readily confused [40–42] but this is not the position of AAPCCAN [1]. In a recent review, four researchers report that CMLs, thought to be highly specific for child physical abuse by AAPCCAN are, instead, unrecognized healing infantile rickets [9]. Another oft repeated maxim of AAPCCAN experts is that abuse must have occurred as no new fractures arise while the infant is away from the caregivers. However, the above studies show infantile rickets heals spontaneously so no new fractures would be expected after CPS removes the infant from the parents. This is particularly true when an infant is removed from mother’s relatively vitamin D-poor breast milk [43], and placed on vitamin D-enriched formula in foster care.

Forty-five percent of Caucasian women residing in the northern United States are vitamin D insufficient when they give birth in spite of taking prenatal vitamins [44]. At the most, only 35% of American infants consume the daily intake of vitamin D recommended by the American Academy of Pediatrics [45]. Paradoxically, breast milk, nature’s perfect food, has almost no vitamin D in it unless the lactating mothers are sunbathing or taking 6400 IU/day of vitamin D<sub>3</sub>/day [25,46]. In modern medicine, there is a wide divergence between expert opinion and standard clinical practice in preventing and treating vitamin D deficiency [47].

Also, experts for the state often testify to statements that appear to defy medical common sense, for example: multiple traumatic rib fractures in infants occur with no internal lung injuries [1]. In the trauma literature, Garcia et al. reported that 100% of children with multiple rib fractures suffered internal injuries [48]. Other trauma experts report multiple rib fractures due to trauma sufficient to fracture multiple ribs causes death or internal injuries over 90% of the time [49]. In ninety-one children who suffered chest trauma of the type the states’ experts hypothesized in these two cases, the vast majority had internal injuries [50]. AAPCCAN guidelines state posterior rib fractures are always indicative abuse, but Wei et al. reported eight cases of posterior rib fractures in hospitalized infants who were x-rayed before they left the hospital, which excludes the possibility of the parents abusing them [51].

What happens when there is a failure to diagnose infantile rickets? Ask Ms. Chana al-Alas and Mr. Rohan Wray in the UK [52,53]. In 2012, it was only an autopsy and bone biopsy of their dead infant that cleared the couple who had been charged with abusing and murdering their infant. Ms. Chana al-Alas, who was just 16 when she became pregnant, and her partner Mr. Rohan Wray, then 19, were acquitted in December of 2013 of murdering their infant, Baby Jayden. On autopsy, the coroner did a bone biopsy and found that Baby Jayden had metabolic bone disease and multiple fractures due to infantile rickets. This disease, infantile rickets, went undetected by radiologists and pediatric child abuse experts when baby Jayden was alive. If their infant had lived, an autopsy and bone biopsy would not have been done, then felony child abuse charges against the parents would have proceeded.

#### 4. Conclusion

Fractures, including multiple rib fractures, have historically been reported in rickets. Radiologists miss rickets about 80% of the time; the gold standard for the diagnosis of rickets is a bone biopsy,



not a radiograph. However, bone biopsies are virtually never done on allegedly abused infants before they are separated from their parents. One has to ask oneself, what is more traumatic for an infant, a bone biopsy or being taken away from loving parents? Common sense medical questions need to be asked and answered in these cases. X-rays are not and should not be used as a polygraph. No one wants child abusers caring for an infant. By the same token, no one wants innocent parents deprived of their infant or incarcerated.

### Conflict of interest

JJC is president of the non-profit Vitamin D Council; receives remuneration from Purity Products and has been retained as an expert for the defense in five child physical abuse cases. MFH has nothing to declare.

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None.

### Financial disclosure

MFH has testified for the defense in a number of these cases.

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