

# The Racket About Rickets: Confronting the Metabolic Bone Disease Defense at Trial

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## Case Introduction

- 3 month old boy presents to Pediatric Intensive Care Unit at our children's hospital
- Altered mental status and seizures
- Required CPR at home; no EMS called
- Mother tells medical providers history of water being poured over his head, followed by difficulty breathing while in father's care



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## Injuries

- Head CT showed bilateral subdural hemorrhages and **bilateral skull fractures**
- Skeletal survey showed:
  - Healing classic metaphyseal fractures of the distal femurs bilaterally
  - Bilateral classic metaphyseal fractures of the proximal humeri
  - Bilateral skull fractures
  - Left radius fracture
  - Left ulna fracture
- Ophthalmology: Bilateral retinal hemorrhages



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## Laboratory Results

- **Vitamin D: 13.7 (deficiency range)**
- PTH: 210.6 (high)
- Phosphorous: 5
- Magnesium: 2
- Calcium: 8.6 (range 8.5 to 11)



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## Child Physical Abuse

Our diagnosis



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## Rickets

Defense diagnosis




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## Fractures Basics

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- Long bone
  - Transverse
  - Oblique
  - Spiral
- Classic Metaphyseal Fractures (or Lesions)
- Rib
- Skull
- Hands, feet
- Scapula
- Vertebral




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## When to be concerned?

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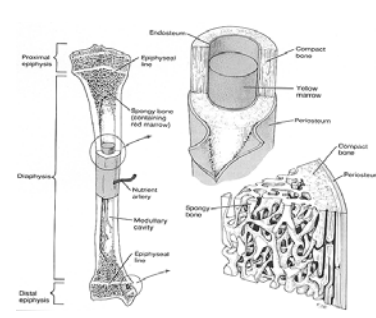
- Is the child ambulatory?
  - Crawling, pulling to a stand, scooting, walking
  - Accidental injuries are less likely if the child cannot ambulate
- Is there a history?
  - If so, does the mechanism match the injury?
- Children are not little adults
  - Developmental stages are very important



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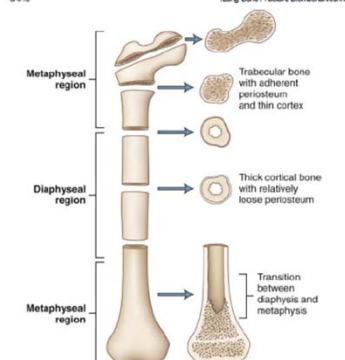
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## Bone structure



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## Long Bone Fracture Biomechanics/Introduction




**FIGURE 35-1** Illustration of bone architecture.  
 (From Pierce MC, Bertocci GE, Vogeley E, et al: Evaluating long bone fractures in children: a biomechanical approach with illustrative cases. *Child Abuse Negl* 2004;28:305-324.)

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## Long Bones

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- Humerus, radius, ulna, femur, tibia, and fibula
- <https://askabiologist.asu.edu/bone> anatomy




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## Biomechanical Considerations

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Straining stress	Occurs when a force is applied perpendicular to the long axis of a structure or object causing tension on one side and compression on the other.
Biomechanical material properties	Characterizes a material and defines how a material will respond to exposure to physical phenomena (e.g., force, acceleration). Modulus of elasticity is an example of a material property.
Biomechanics	Study of response of biological tissue to physical phenomena such as force, acceleration, pressure, etc.
Compression	Stress created by compressing or "squeezing" an object or structure.
Deformation	Change in size or shape of an object due to application of force. Deformation can be elastic or permanent.
Elasticity	Material is said to be elastic if it deforms under stress (e.g., external forces), but then returns to its original shape when the stress is removed. Often described through modulus of elasticity, E, which is the ratio of stress to strain and can be thought of as defining the stiffness of a material.
Force	Application of which tends to cause a body or object with mass to accelerate, change position, or child shape. (Force = Mass × Acceleration)
Fracture	Failure of structure such that it is unable to support or withstand the applied load.
Fracture threshold	Level of force or stress above which a fracture will occur.
Load	Describes the application of forces or moments to a body or object.
Moment	The tendency of a force to produce body or object rotation when applied at a perpendicular distance (moment arm) from the axis of rotation.[3] (Moment = Force × Moment Arm)
Shear stress	Stress produced when force application is aligned with the surface of a body or object. <i>Pressure is usually associated to the radial length of a body or object [3].</i>



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### Types of Long Bone Fracture

- Spiral fractures: torsion or twisting
- Transverse: bending or direct blow to the extremity
- Oblique: Compression and rotation
- Comminuted: Complex

Cooperman D, Merten D. *Skeletal Manifestations of Child Abuse*. *Child Abuse: Medical Diagnosis and Management*, AAP, 2009.

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### Bone Fracture Biomechanisms

FIGURE 35-5 Type of stress depends upon the characteristics of force application

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### Transverse Fracture

FIGURE 33-8 A transverse fracture is a fracture line that runs horizontal to the bone long axis (arrow).

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### Spiral Fracture

13-6 A 2-w-week-old infant imaged for a history of "not moving an extremity" that was swollen on clinical examination radiographic confirmation of a right spiral femur fracture, the caretakers then offered a "new story" of dropping the

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### Buckle Fracture


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### Spiral Fracture

JRE 33-7 Long bone spiral fracture. Note the complete separation of fracture fragments and the length of the fracture line (arrows).

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### Oblique Fracture



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### Metaphyseal Fractures


- Highly concerning for inflicted injury
- Not produced by usual accidents of infancy.
- Require violent traction and twisting.
- Example: a child is forcefully snatched by the leg such that it twists and pulls.

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### CML



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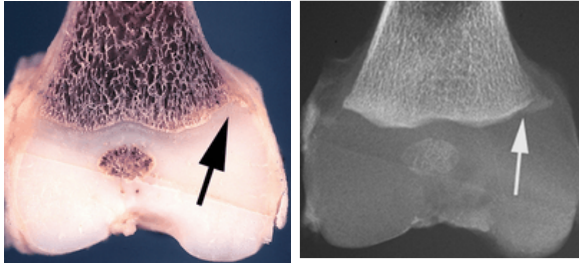
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### CML



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### Rib Fractures

- 90% of children with abuse rib fractures are less than 2 years of age
- 80% are located at the posterior ribs
- In healthy children, they are rarely due to accidents
- Violent shaking or lateral compression of chest
- Ribs difficult to break because of increased compliance

Cooperman D, Merten D. *Skeletal Manifestations of Child Abuse*. Child Abuse: Medical Diagnosis and Management. AAP, 2009.

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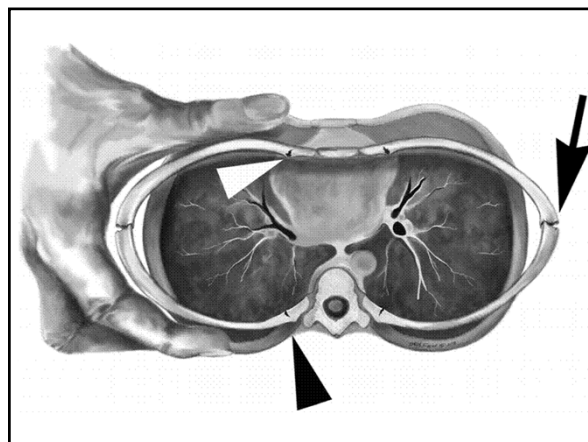
### Rib Fractures



FIGURE 33-23 Classic posterior rib fractures with bulbous callus formation at the costovertebral junction at multiple adjacent levels (white arrows). Lateral margin rib fracture with callus on the right is also present (black arrow).

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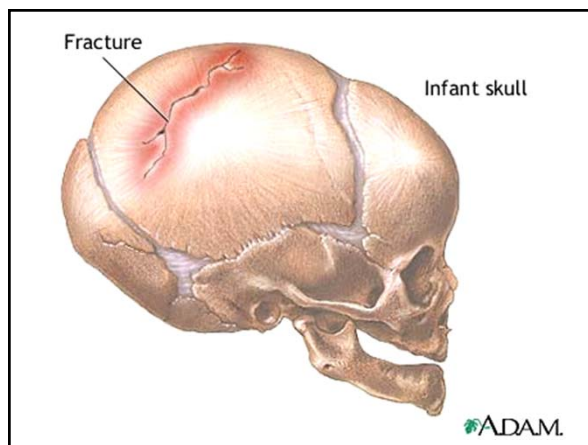
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### Skull Fractures

- Caused by a direct blow to the head or and impact on a static object
- When to be concerned
  - Linear skull fracture are often accidental
    - Children can obtain simple, linear fractures from short falls
    - May result in epidural hematoma
  - But your skull should not look like an egg you just cracked to bake a cake
    - That's a problem

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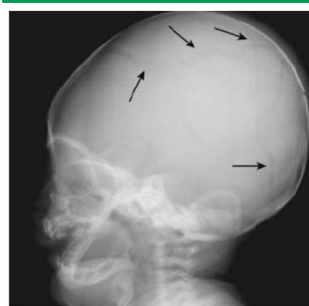
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RE-33-25 Simple skull fracture (white arrows) in the temporal-parietal area from a documented accidental fall. Note how thin the fracture line is. Normal coronal sutures are also seen (black arrows).

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## Differential diagnosis of skeletal trauma

- Obstetric trauma
- Osteopenia of prematurity
- Nutritional and metabolic
- Infection
- Neuromuscular defects
- Skeletal dysplasia
  - Osteogenesis imperfecta
  - Hypophosphatasia
  - Osteopetrosis

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## Rickets

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## What is Rickets?

- Let's start with vitamin D
  - Obtained from diet
  - Photosynthesis
    - 7-dihydrocholesterol-> cholecalciferol (vitamin D3)
    - Dependent on sun exposure, latitude, pollution, season, skin pigmentation (Caucasian more)
  - Sources:
    - 80% from photosynthesis
    - Fish, egg, fortified milk, supplements
    - Breast milk content is low and requires supplementation
      - Up until 3 months of age, have reserves from in utero

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## Vitamin D Deficiency

- NO CONSENSUS on what is vitamin D deficiency in children, but there are some general guidelines
  - 10 ng/ml- overt deficiency
  - 11 ng/ml- 20 ng/ml- deficiency
  - 21 ng/ml- 30 ng/ml- insufficiency
  - > 30 ng/ml- optimum
- Primary cause of rickets

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## Rickets Defined

- “Clinical syndrome associated with insufficient endochondral calcification of the growth plates of the long bones, resulting in deformation and impaired growth.”
- Associated with osteomalacia
  - Failed mineralization of trabecular and cortical bone.

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## Signs and Symptoms

- Early signs
  - Low calcium
  - High parathyroid hormone (PTH)
  - Our patient
  - Under age 6 months, low calcium can cause:
    - Seizures
    - Tetany
    - Stridor
    - Apnea
- Intermediate
  - Normal calcium, high PTH
  - Poor bone mineralization

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### Skeletal changes

- Bowing of long bones
- Enlargement at ends of long bones
- Delayed closure of fontanelles
- Frontal and parietal bossing
- Soft skull bones
- Posterior skull flattening
- Rachitic rosary
- Delayed motor skills and muscled weakness

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### Diagnosis

- To diagnose rickets, you need...

#### CLINICAL AND RADIOGRAPHIC EVIDENCE!!

- Fractures are possible in rickets, but are relatively uncommon

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<http://mediphotos.blogspot.com/2011/11/appearance-of-rachitic-rosary-by-photos.html>

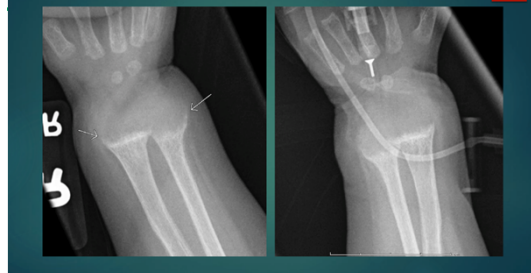
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#### Bilateral wrists



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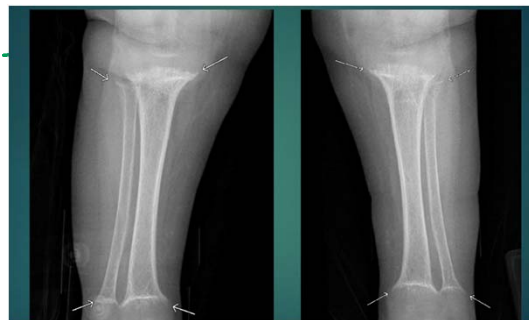


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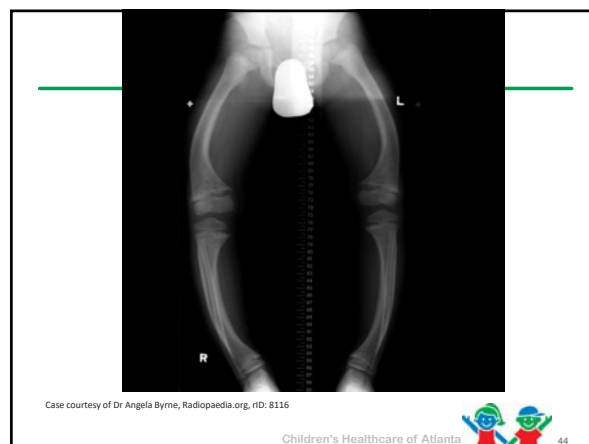


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### Literature

- McGillvery et al.
  - No bone changes in deficiency and insufficiency
  - No fractures even in children with signs of rickets
- Hutan et al
  - 42 children with nutritional deficiency in Turkey
  - No fractures
- Robinson et al
  - Australia, 11 year review
  - 5/126 children with nutritional rickets had fractures
- Mylott et al
  - Wisconsin, 10% of children with rickets had fractures

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### Literature

- Chapman et al.
  - 45 infants less than 2 year of age with rickets
  - 17.5% had fractures
    - All were ambulatory
    - All had obviously abnormal bones
    - No one who did not walk had fractures
    - No high risk fractures
- Bishop et al.
  - Vitamin D deficiency in a term infant sufficient to result in bone weakening and fracture will be accompanied by unequivocal radiological and biochemical evidence of deranged skeletal structure and homeostasis."

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### How Low Can You Go?

- 2010 Institute of Medicine Report
  - Levels below 12 ng/ml: "persons are at risk for bone deficiency"
- No hard consensus for children
- Remember that clinical AND radiographic signs are needed

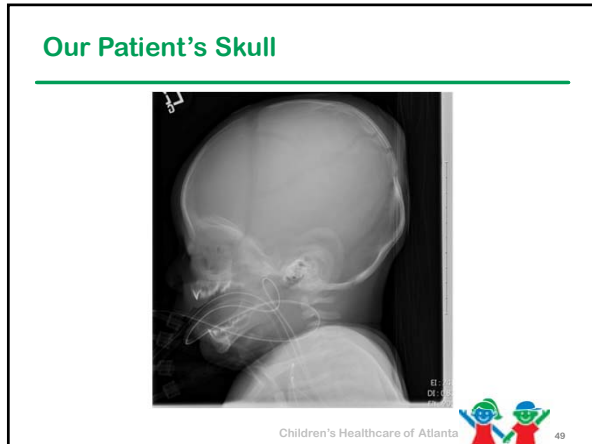
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### Rickets and Maternal Vitamin D

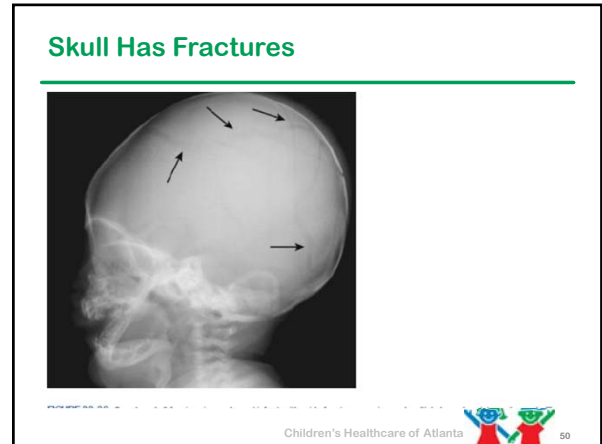
- 80% of bone mineral stores occur in 3<sup>rd</sup> trimester
- However, only extreme maternal vitamin D deficiency will affect fetus
  - Nutrition goes preferentially to fetus
- Congenital rickets occurs only in severe cases of maternal vitamin D deficiency

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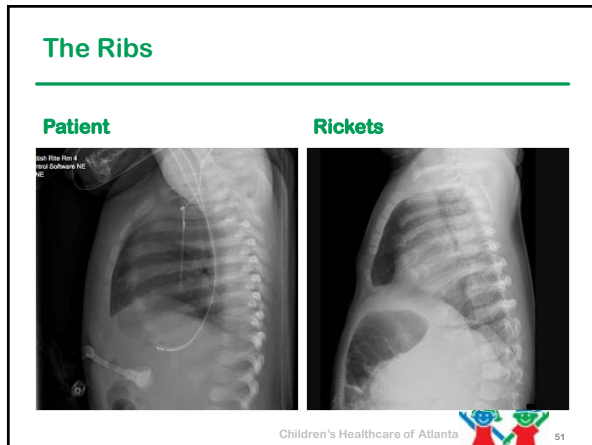




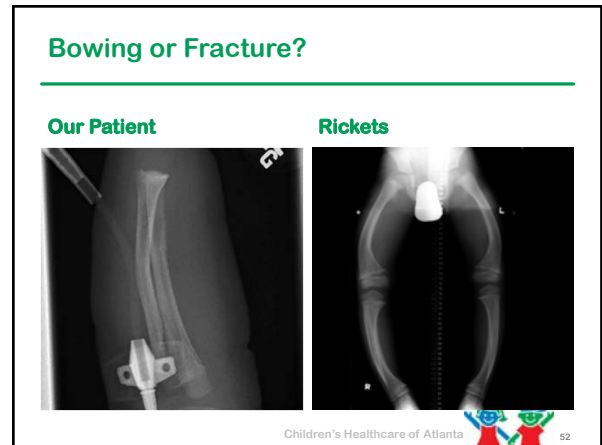
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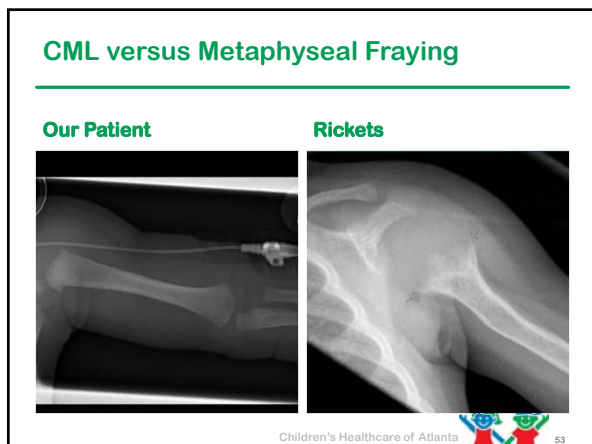
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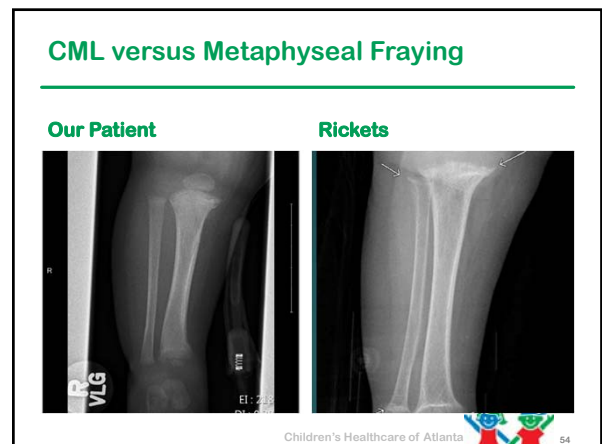
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## CML versus Metaphyseal Fraying

**Our Patient**



**Rickets**




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## CML

**Our Patient**



**Textbook CML**




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## The Myth of Temporary Brittle Bone Disease

- Disorder of infants ages 0 to 1 year
- Causes:
  - Prematurity
  - Defects in collagen
  - Reduced fetal movement
  - Vit D deficiency (infantile rickets)
  - Mineral deficiencies
  - Genetic disorders
- Not a real thing

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### Temporary brittle bone disease: association with decreased fetal movement and osteopenia.

Miller ME<sup>1</sup>, Hangartner TN.

**Author Information**

**Abstract**  
 Infants who present with multiple unexplained fractures pose a difficult diagnostic dilemma of child abuse versus intrinsic bone disease. Temporary brittle bone disease is a recently described disease characterized by a transient bone weakness in the first year of life which presents with multiple, unexplained fractures that can be confused with child abuse. The


pediatric reports

*Pediatr Rep.* 2011 Jun 30; 3(3): e24. PMID: PMC3207312  
 Published online 2011 Oct 11. PMID: 22053288  
 doi: 10.4081/pr.2011.e24

**Temporary brittle bone disease: relationship between clinical findings and judicial outcome**

Colin R. Paterson<sup>1</sup> and Elizabeth A. Monk<sup>2</sup>

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Pediatric Health, Medicine and Therapeutics Dovepress  
open access to scientific and medical research

Open Access Full Text Article ORIGINAL RESEARCH

## Long-term follow-up of children thought to have temporary brittle bone disease

This article was published in the following Dove Press journal:  
 Pediatric Health, Medicine and Therapeutics  
 9 June 2011  
 Number of times this article has been viewed

Colin R Paterson<sup>1</sup>  
 Elizabeth A Monk<sup>2</sup>

<sup>1</sup>Department of Medicine (retired),  
<sup>2</sup>School of Accounting and Finance,  
 University of Dundee, Dundee,  
 Scotland

**Background:** In addition to nonaccidental injury, a variety of bone disorders may underlie the finding of unexplained fractures in young children. One controversial postulated cause is temporary brittle bone disease, first described in 1990.

**Methods:** Eighty-five patients with fractures showing clinical and radiological features of temporary brittle bone disease were the subject of judicial hearings to determine whether it was appropriate for them to return home. Sixty-three patients did, and follow-up information was available for 61 of these. The mean follow-up period was 6.9 years (range 1–17, median 6).

**Results:** We found that none of the children had sustained any further injuries that were thought


Paterson and Monk  
**Disclosure**  
 CRP received normal fees for investigating most of these cases and, when needed, for providing evidence in court.

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## Other Disorders to Consider

- OI
- Ehrlös Danlos
- Scurvy
- All of these have been used to explain multiple fractures in court

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## Witnesses You May Need

- Radiologist
- Geneticist
- Endocrinologist

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## References

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- Rickets photographs courtesy of Dr. Norrell Atkinson, MD, unless otherwise specified.

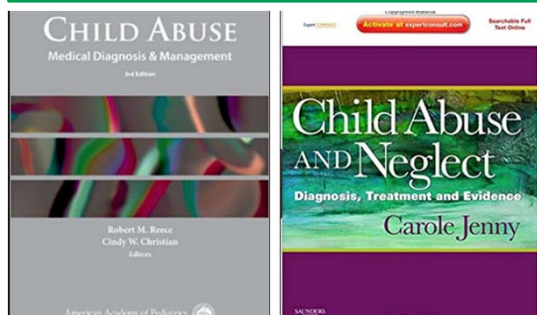
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## References



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## Rickets in the Courtroom

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Dedicated to All Better

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## Preparation Before Trial

- Familiarize yourself with the literature
  - Both Sides
  - Understand why the medical community rejects these theories
- Work with State's expert to apply literature to specific facts
  - Understanding "Possible" versus "Probable"
- Work with all medical experts on courtroom testimony
  - Role is to educate jury

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## Defense Experts

- Research the defense expert
  - Databases through Professional Organizations
  - Transcripts
  - Google – deep dive
  - News articles, including quotes
  - YouTube
  - "Scholarly" articles
  - Other beliefs they hold outside the mainstream
  - Criminal history
  - Professional license status and complaints
  - Common associates

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## Defense Experts

- Always attempt to speak with defense experts
  - Always with investigator
  - Refusal to speak can be used at trial
- Have them “educate” you
  - Don’t attempt to argue your points
  - Listen to everything they have to say
  - Ask questions for further clarification
- Will they commit to a position prior to trial?
- Follow up with State’s experts

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## Pre-Trial Motions

- Daubert / Frye Challenges
  - Argument: These medical theories are not accepted in the scientific community; therefore, they should not be presented to jury
  - Will only confuse the issues
- Always consider filing
  - Even if not successful, will educate judge on very complicated matters
  - Will increase likelihood of success when objections made during trial
  - May force sworn testimony before trial

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## Excluding the Theory

- Some courts have begun to exclude fringe medical theories:
  - State of Florida v. James Duncan; CRC94-04801CFANO
    - 6<sup>th</sup> Judicial Circuit
    - Specifically dealt with the admissibility of the rickets defense
  - State of Tennessee v. Zachary Thacker; 151-2018
    - Sumner County, Tennessee
    - This order dealt with proposed challenges to abusive head trauma science
- Copies of these orders can be sent directly to you
  - Your judge can take judicial notice

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## Mainstream Medical View

The editors of *Pediatric Radiology* have rejected contentions linking the high-specificity imaging findings of child abuse with rickets.

**We reaffirm this position.**

CMLs are therefore highly specific for child abuse.

To deny this fact is to disregard the extensive experience and research of generations of pediatric radiologists.

*SPR Child Abuse Committee Response Regarding Classic Metaphyseal Lesion, AJR 2014; American Roentgen Ray Society*

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## Voir Dire

- Themes that may come up:
  - Fringe theories
  - Misdiagnosis by doctor
  - Seeking a second opinion
  - Healthy scientific debate
  - Doctors can make mistakes
- What type of jurors do you want?
  - Kids or no kids?
  - Science background?

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## Opening Statement

- Opening should be longer and more in depth than typical opening
  - Overview of medical science
  - Introduce mainstream medical views
  - Supported by extensive scientific proof
  - Break down complex medical concepts into real world terminology
- What will your expert say?
  - Discuss in depth
- Weave that into other facts that will come out at trial

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## Presenting the State's Expert

- What witnesses do you need?
  - Pediatric Radiologist
  - Endocrinologist
  - Geneticist
  - Child Abuse Physician
- Basics of Anatomy
  - Parts of the bone
  - How bones grow
  - What can be seen radiographically
  - Known Xrays vs. Victim's Xrays

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## Visual Aids

- Have doctors who are testifying present images of:
  - Normal X-Rays of child THAT AGE
  - Child with Rickets
- Put both on the screen and walk jury through differences
- Note: What is the capability of your courtroom presentation equipment? Need to find alternative?

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## Cross of Defense Expert

- Can you start out nice? Things you can agree on?
- Bias
  - Amount paid
  - Not hired unless find a problem
  - Who they typically testify for
  - Number of cases they accept
    - Ex: accept 90% of cases. So 90% of the time, other doctors get it wrong?
- Written Report
  - If they didn't write one, point that out
  - If they did, have they veered from it during direct?

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## Cross of Defense Expert

- Their credentials
  - What is their field
  - Ex: Pediatric radiologist far more qualified than regular radiologist in these cases
  - Get concessions on differences in training & experience
  - May also voir dire
- Ever worked in center with child abuse prevention program
  - Did they make referrals?
  - Often disagree with diagnosis?

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## Cross of Defense Expert

- Source of their opinion
  - What evidence did they review (if any)?
  - Understanding of history provided by defendant
  - Input from defense attorney?
  - What they didn't review
    - OB-GYN Records of Mother
    - Birth Records
    - Pediatric Records
  - Did not treat the patient
  - Did not speak with treating physicians
  - Did they speak with any lay witnesses

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## Cross of Defense Expert

- Constellation of Injuries
  - If multiple types of injuries
  - Have them acknowledge importance of the concept
  - Defense will attempt to treat each in a vacuum
- Does diagnosis of rickets conflict with other injuries on the child?
  - Ex: Craniotabes vs. Skull Fractures
- Do multiple defense experts contradict each other?

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### Careful What You Say...


- Read transcripts in similar cases
- Get expert to double down on a position where they have conflicting prior testimony
- Confront expert with changes in their testimony to fit the facts of a case
- Pull out quotes that could be helpful to your case
  - “Xrays are the gold standard of the diagnosis”
- Transcripts also help you anticipate the arguments defense will make

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### Cross of Defense Expert


- The Research
  - Name of Journal
  - Peer Reviewed
  - Widely Accepted in Field
  - Authors of Article, including credentials
  - Summary of the Findings
  - Methods
  - Relied upon by other reputable publications
- Are authors speaking on behalf of an entire group of doctors?

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### Cross of Defense Expert

- Research Defense Relying Upon
  - Name of journal
  - Peer reviewed? (some may be, but controversial)
  - Authors
    - Same small group that keep publishing and cite to research conducted by others in that small group?
  - Many articles have been specifically rejected by other mainstream medical articles
    - Cite to those articles
  - Have defense expert acknowledge opinion is outside the medical norm

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# Healthy Scientific Debate???

Ensure Jury Knows This Isn't Just Scientists Disagreeing

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**Association of Prosecuting Attorneys  
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