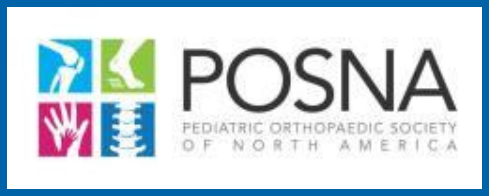
Femur Shaft Fractures
Under 10 years old

5th Annual SLAOTI Meeting
Sao Paolo, Brazil
October 12-14, 2017

Richard M Schwend MD
Professor Orthopaedics and Pediatrics
Director of Research
Children's Mercy Hospital
Kansas City MO, USA
rmschwend@cmh.edu

Disclosures

- K2M Consultant
- Medtronic Consultant
- POSNA President and BOD member
- AAP Immediate Past Chair and Section on Orthopaedics Executive Committee
- Project Perfect World Board of Directors.
- Miracle Feet Medical Advisory Board.



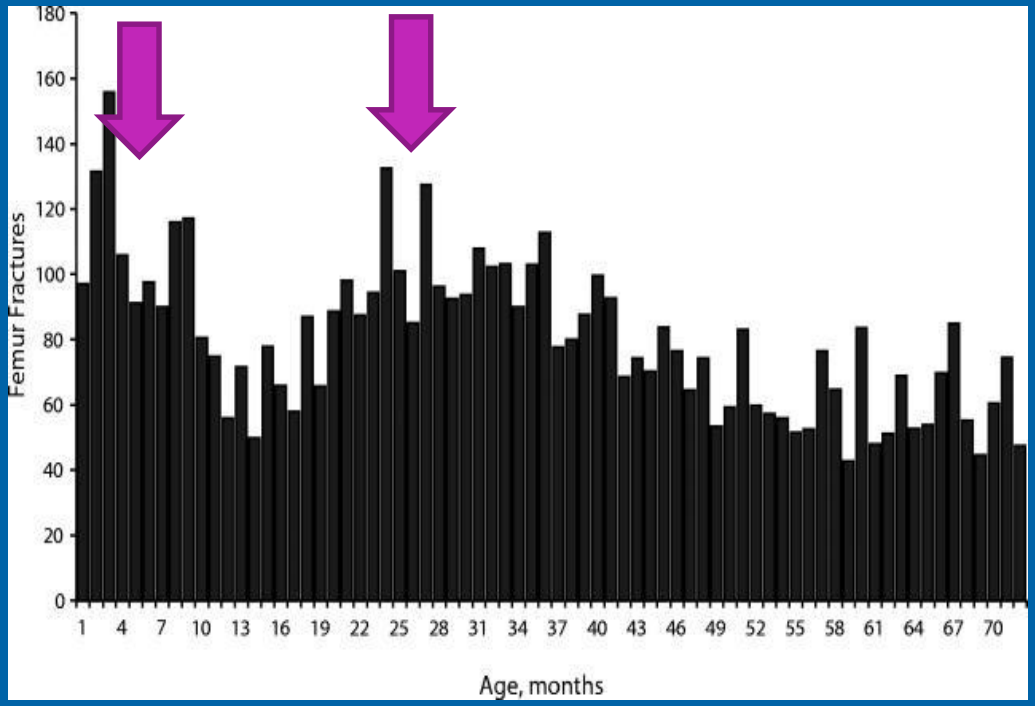
Children's Mercy
KANSAS CITY

Key Points

- Femur fracture in a child before walking age is suspicious for non-accidental trauma
- Most common femur fracture type in a child is closed, transverse, and non-comminuted
- Adolescents have adult-like mechanism for femur fracture (high energy) and associated injuries are common
- Treatment varies by age, weight, and fracture pattern. Typically non surgical <5 yo.

Children's Mercy KANSAS CITY

Epidemiology. 0-6 years of Age



- Peak incidence during infancy and 2.3 years of age.
- 2.6 times more common in boy, usually from a fall.
  - Hedlund R 1986

Estimated number of femur fractures among children in the US by month of age. Brown et al 2004, from Kids inpatient Data base 1997.

Children's Mercy KANSAS CITY

Pediatric Bone

- Bone plasticity allows internal organ damage without obvious fracture.

- Both material and structural properties change with growth

- Weaker: less strength in bending than adult bone.
- Less stiff
- Absorbs more energy before breaking
- Plastic deformation
- Lower mineral and more fibrous- greenstick fractures.
    - Currey and Butler 1975

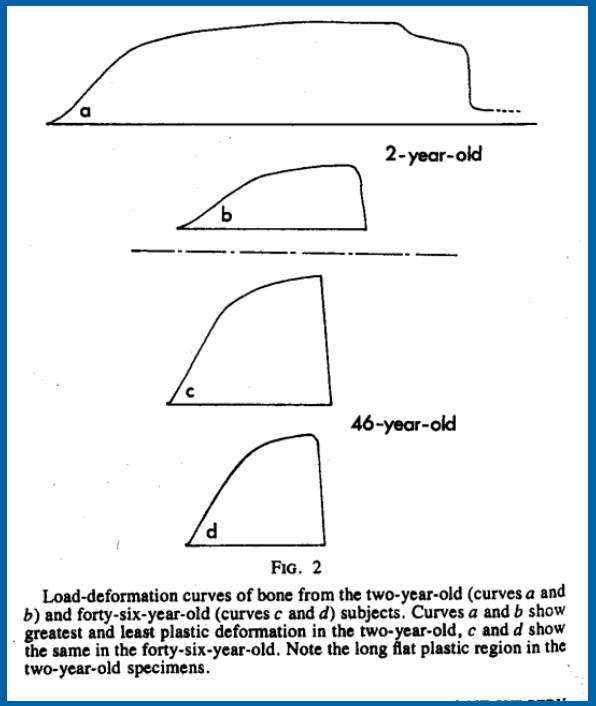
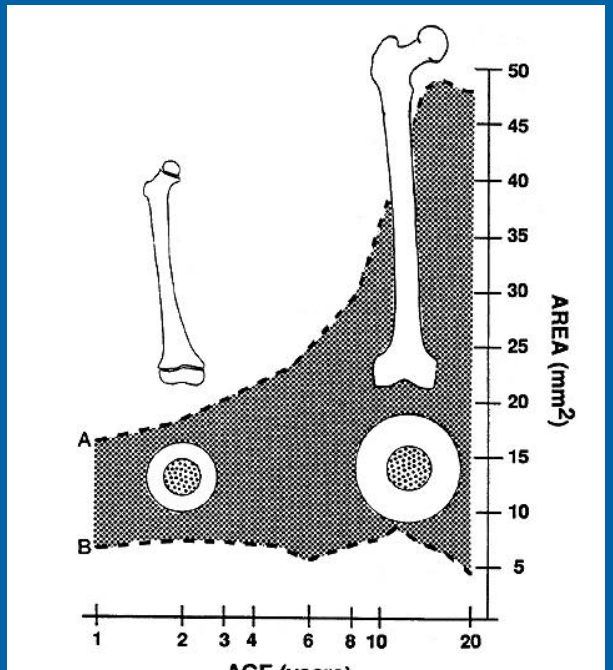


FIG. 2

Load-deformation curves of bone from the two-year-old (curves *a* and *b*) and forty-six-year-old (curves *c* and *d*) subjects. Curves *a* and *b* show greatest and least plastic deformation in the two-year-old, *c* and *d* show the same in the forty-six-year-old. Note the long flat plastic region in the two-year-old specimens.



Children's Mercy KANSAS CITY

12 years

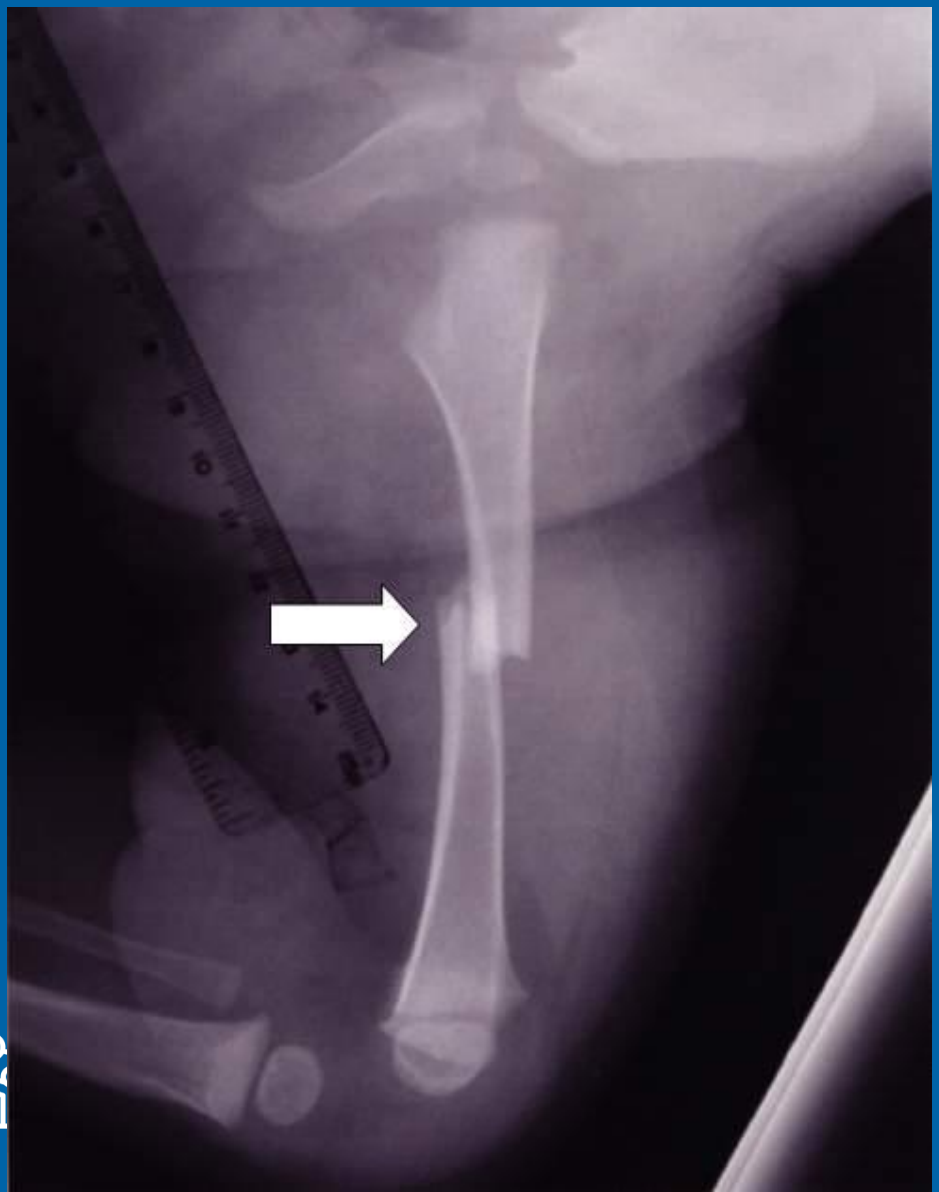
22 month

Children's Mercy
KANSAS CITY

Classification

- Patterns-transverse, oblique, spiral, comminuted
- Stability
  - Length stable (transverse, some oblique)
  - Length unstable (long spiral, comminuted
- Open vs Closed- Use Gustillo, modified

Transverse fractures



- 10 fold higher associated energy
  - 2nd story window
  - Hit by car
- common fx in child abuse
- High association with concomitant brain injury
- Piglet model: faster bending loads

Treatment- By Age and Pattern

Age	Weight	Fracture Stability (Length Stable vs. Unstable*)	Treatment Options
< 6 mo	Any	Any	Pavlik harness Spica Cast
6 mo – 5 yrs	Any	Stable and Most unstable	Spica cast
	Any	Some unstable	90/90 traction à spica cast Flexible nails (controversial)
5 – 11 yrs.	< 49 kg	Stable	Flexible intramedullary nailing
	Any	Unstable	Submuscular bridge plate vs. External fixation
	> 49 kg	Any	Submuscular bridge plate vs. External fixation vs. Rigid trochanteric entry nail (in older children, but controversial)

Children's KANSAS CITY

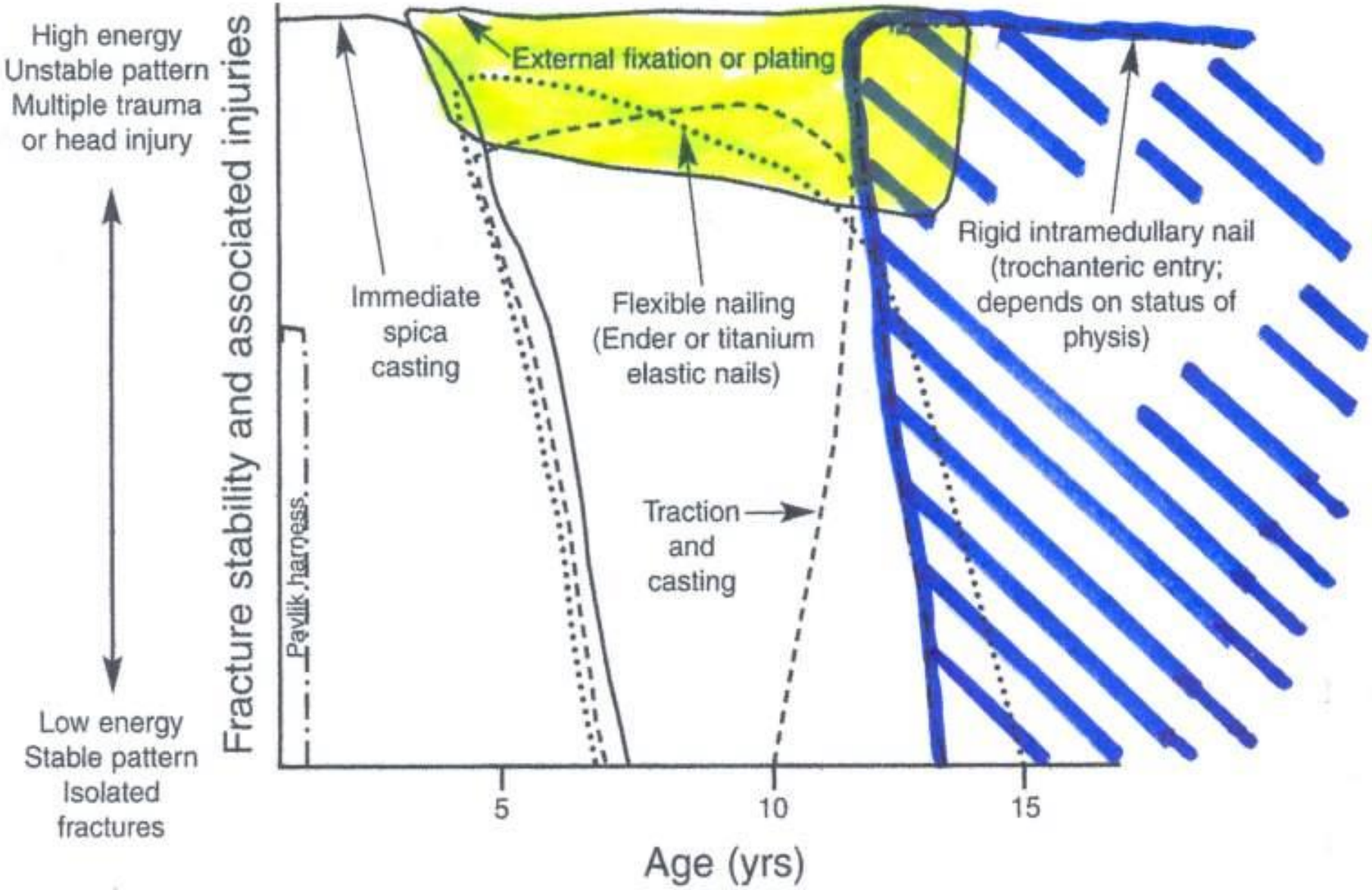


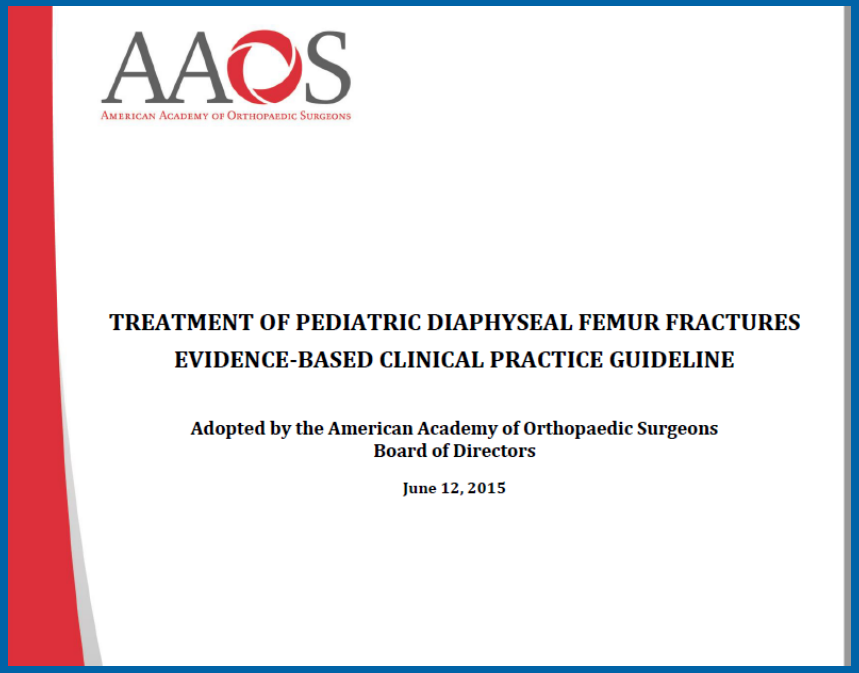
Figure 1 Treatment options for pediatric femoral fractures based on type of injury and patient age.

Flynn J, Schwend R JAAOS

The Problem

- A 22 month boy has an unwitnessed fall on a wet floor.
- He is brought promptly to the ED.
- Is this abuse?
- Incidence of abuse is 3 times that of DDH or clubfoot, but can be lethal.

What does AAOS Say?



Strength of Recommendation Descriptions

Strength	Overall Strength of Evidence	Description of Evidence Strength	Strength Visual
Strong	Strong	Evidence from two or more "High" strength studies with consistent findings for recommending for or against the intervention.	★★★★
Moderate	Moderate	Evidence from two or more "Moderate" strength studies with consistent findings, or evidence from a single "High" quality study for recommending for or against the intervention.	★★★☆
Limited	Low Strength Evidence or Conflicting Evidence	Evidence from two or more "Low" strength studies with consistent findings or evidence from a single study for recommending for or against the intervention or diagnostic test or the evidence is insufficient or conflicting and does not allow a recommendation for or against the intervention.	★★☆☆
Consensus*	No Evidence	There is no supporting evidence. In the absence of reliable evidence, the work group is making a recommendation based on their clinical opinion. Consensus recommendations can only be created when not establishing a recommendation could have catastrophic consequences.	★☆☆☆

Children's Mercy KANSAS CITY

AAOS CPG 2015

CHILD ABUSE

Strong evidence supports that children younger than thirty-six months with a diaphyseal femur fracture be evaluated for child abuse.

Grade of Recommendation: Strong ★★★★

INFANT FEMUR FRACTURE

Limited evidence supports treatment with a Pavlik harness or a spica cast for infants six months and younger with a diaphyseal femur fracture, because their outcomes are similar.

Grade of Recommendation: Limited ★★☆☆

WATERPROOF CASTING

Limited evidence supports waterproof cast liners for spica casts are an option for use in children diagnosed with pediatric diaphyseal femur fractures.

Grade of Recommendation: Limited ★★☆☆

Femur Fracture and Child Abuse

- Understand the importance of age, history, skin, fracture morphology in diagnosis child abuse.
- Realize that infants with a fracture < one year of age have a very high association for abuse.
- Remember that NOTHING is pathognomonic for abuse, so always keep an open mind
- Understand the 5 misperceptions about femur fractures.
- Recognize that other conditions can masquerade as child abuse, so always keep an open mind.

Schwend RM, Blakemore L, Lowe L. The Orthopaedic Recognition of Child Maltreatment. In Rockwood and Wilkins, ed. Fractures in Children. Seventh Edition. Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins; 2014.

Children's Mercy KANSAS CITY

75% of our fatal or near-fatal victims of child abuse had a fracture or fractures in their past

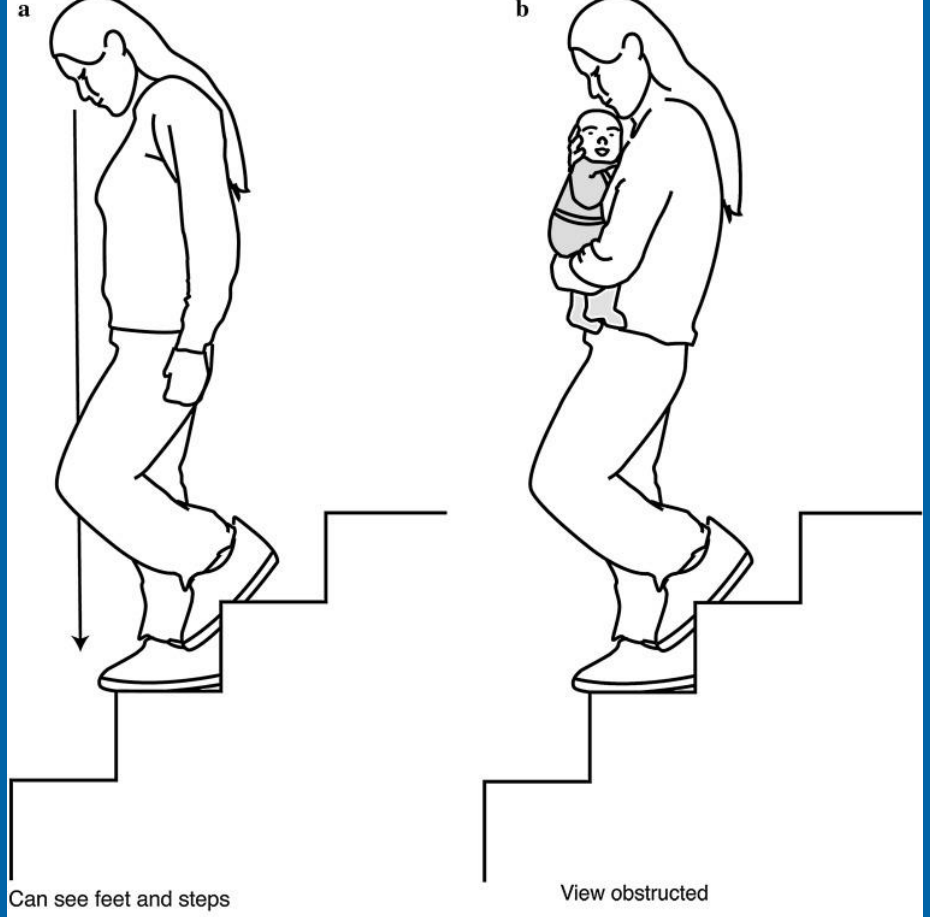
Stair falls are a common fabricated history in an attempt to account for severe and multiple injuries

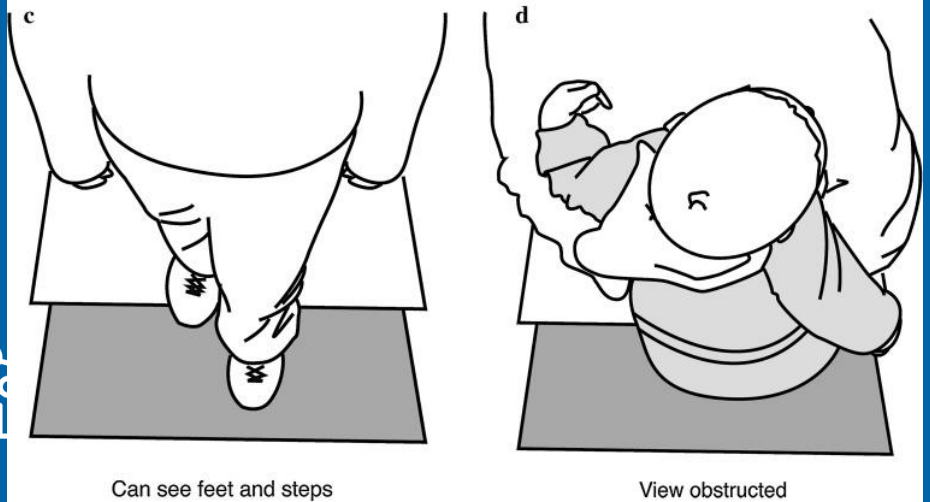
Children's Mercy KANSAS CITY

UMKC School of Medicine

BEST CHILDREN'S HOSPITALS U.S.News & WORLD REPORT RANKED IN 10 SPECIALTIES 2015-16

MAGNET RECOGNIZED AMERICAN NURSES CREDENTIALING CENTER





However, Stair falls can also be a plausible mechanism.

….So always keep an open mind

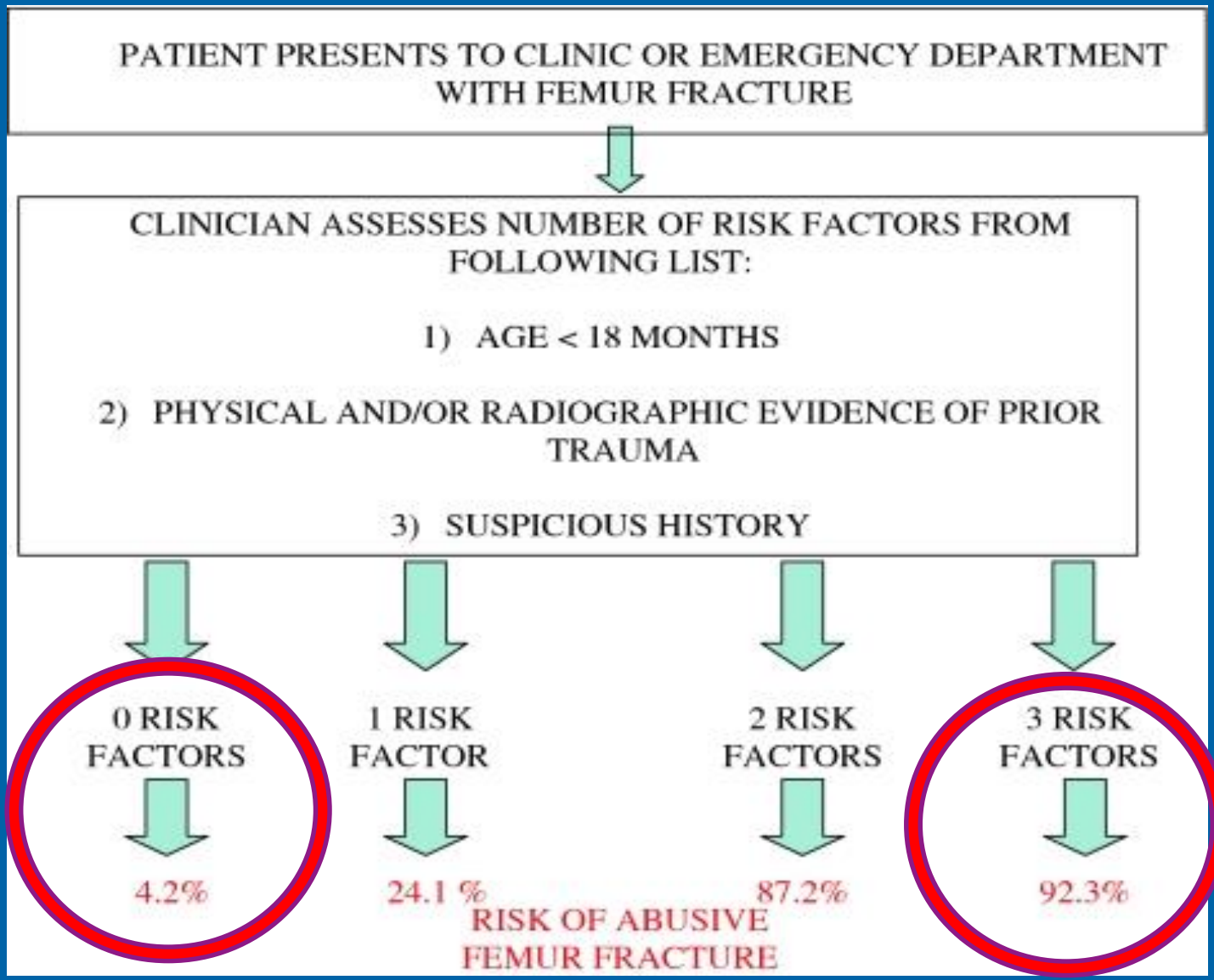
Pennock AT et al.
J Child Orthop 2014;8:77-81

4 things to remember

- Age matters- the younger the more likely
- History matters
  - *O*r the examination of the history
- Skin matters-90% of physical abuse has bruising
- Fracture morphology matters

Children's Mercy KANSAS CITY

Multiple Logistic Regression Model



Baldwin, 2011

Clin Orthop Relat Res 2011 Mar;469(3):798-804

Five Common Misperceptions

- 1. Toddlers rarely break their femurs.
- 2. Lots of force is required to break the femur.
- 3. There is a high risk of abuse when a young child has a femur fracture.
- 4. If unsure, then report it, it can't hurt.
- 5. "***Strong evidence*** supports that children younger than 36 months with a diaphyseal femur fracture be ***evaluated*** for child abuse". AAOS 2009 and 2015 CPG

Schwend RM, Werth C, Johnston A. Femur shaft fractures in toddlers and young children: rarely from child abuse. J Pediatr Orthop 2000 Jul-Aug:20(4):475-81.

Children's Mercy KANSAS CITY

Treatment 0-6 months

INFANT FEMUR FRACTURE

Limited evidence supports treatment with a Pavlik harness or a spica cast for infants six months and younger with a diaphyseal femur fracture, because their outcomes are similar.

Grade of Recommendation: Limited ★★☆☆

Children's Mercy KANSAS CITY

Treatment 6 mo - 5 years spica cast

WATERPROOF CASTING

Limited evidence supports waterproof cast liners for spica casts are an option for use in children diagnosed with pediatric diaphyseal femur fractures.

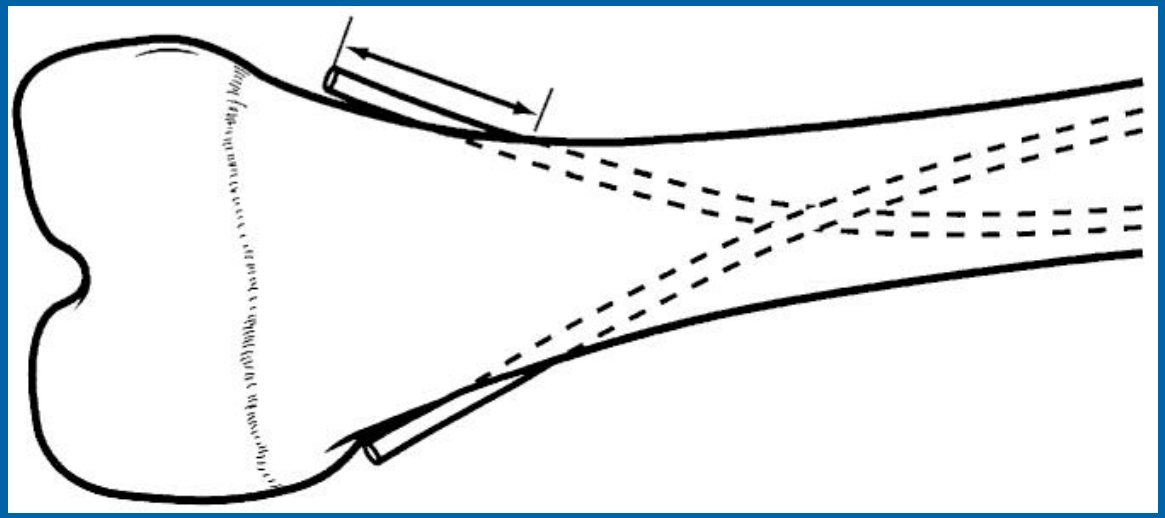
Grade of Recommendation: Limited ★★☆☆

Treatment 5-11 years

ELASTIC INTRAMEDULLARY NAILS

Limited evidence supports the option for physicians to use flexible intramedullary nailing to treat children age five to eleven years diagnosed with diaphyseal femur fractures.

Grade of Recommendation: Limited ★★☆☆



Technical tip: Proper angle of insertion

Children's Mercy KANSAS CITY

Flexible IM nails

- Hold length and alignment if there is some structural stability to the fracture pattern
- Low rate of complications if used in the proper patient population
- If >11 years old and >110 lbs, consider alternative fixation

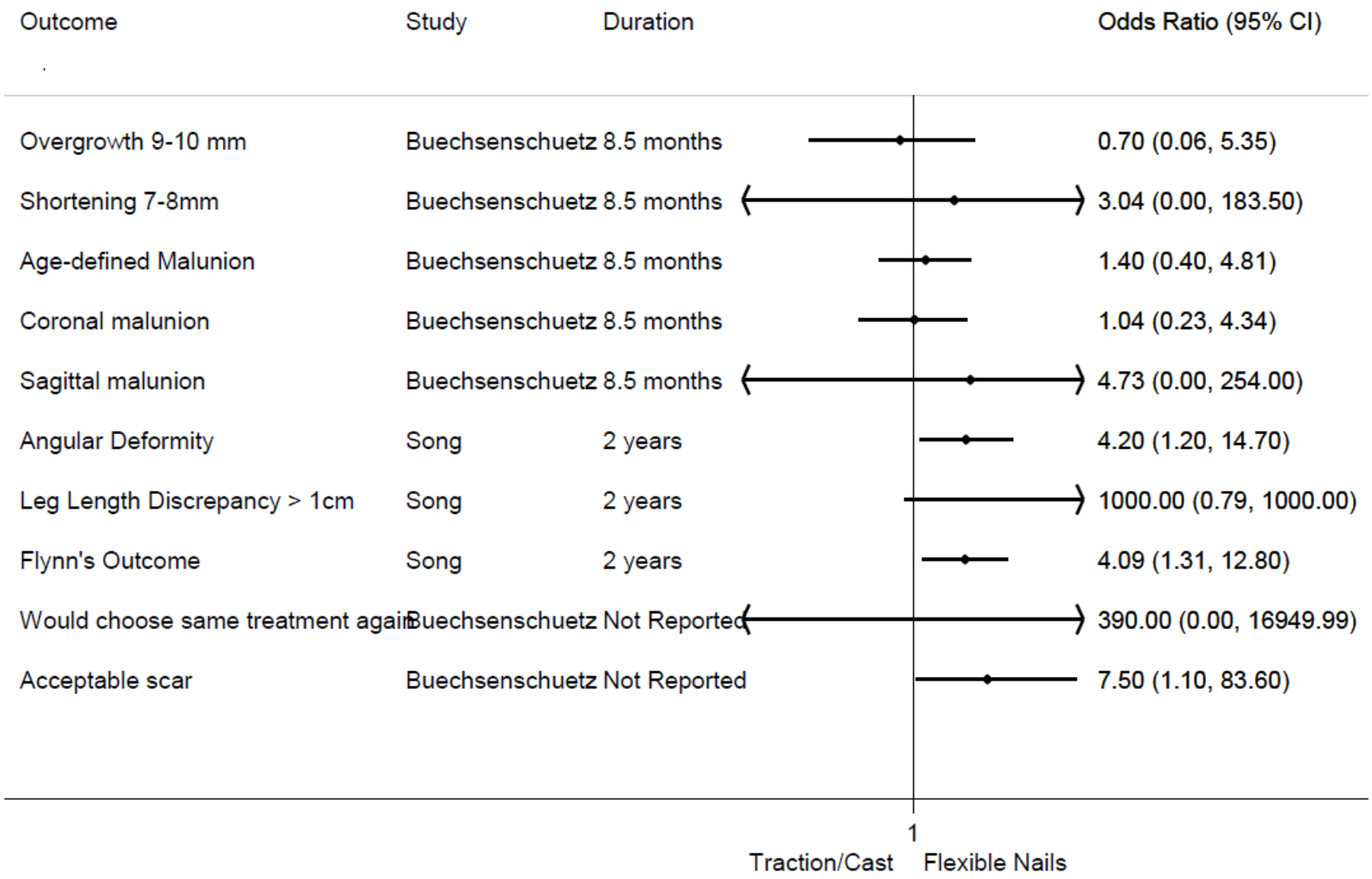
Children's Mercy KANSAS CITY

Flexible IM nails

- Technical tips:
  - Ensure sagittal plane alignment by “keeping the tips up”

Outcomes Flex Nails vs Cast

Figure 22. Flexible Nails vs. Traction & Cast - binary outcomes



Difficult Femur Fractures

- Head injury
- Open femur fracture
- Lawnmower injuries
- GSW and soft tissue loss
- Fractures near ends of bone
- Floating knee
- Associated compartment syndrome
- Child abuse

Children's Mercy KANSAS CITY

3 Reasons Why Children Die (with orthopaedic surgeons standing nearby)

- Loss of airway (Infants and Pre-school age group)
- Hemorrhagic Shock (Especially in Infants and Pre-school age group)
- Septic Shock (Any age Group)

Children's Mercy KANSAS CITY

Damage Control

- Early operative stabilization gets children off vent and out of ICU
    - Loder RT 2001
- Head injured- early femur fx care had better short-term results
    - Mendelson SA 2001
- Very relevant in pelvic trauma- early fixators but delayed definitive fixation. (Katsoulis 2006).
- In head injury- Long bone stabilization can decrease ICP
    - Tolo VT 2000

Children's Mercy KANSAS CITY

Damage Control-Fixation

- Options based on patient age, energy and multi-system involvement
    - Flynn JM 2004
- External fixator- Very useful in far-forward military environments.
- Conversion to internal fixation should be before 2 weeks.
- Flexible nails have largely replaced external fixator for the femur and at times the tibia.

Children's Mercy KANSAS CITY

Rigid IM Nail

- Lateral entry in children > 8 years old is safe and recommended
    - Gordon JE 2004
- No reported osteonecrosis or evidence of lateral growth arrest
    - Gordon JE 2003
- Small diameter rapidly inserted as means to deliver damage control
    - Higgens TF 2007

SIGN'S

global programs

199,587	321	50
PATIENTS HEALED	HOSPITALS USE SIGN IM NAILS	DEVELOPING COUNTRIES

Children's Mercy KANSAS CITY

Percutaneous Plate

- Multiple trauma, open fractures, compartment syndrome, fractures near the ends of the bone.
- Plate fixation is an excellent implant for the head injured child
    - Ward WT 1992
- Submuscular bridge plating uses longer plates, fewer screws, less soft-tissue stripping, no immobilization.
    - Kanlic EM 2004

Children's Mercy KANSAS CITY

6 yo male ATV injury

Post Op

6 months post op

Children's Mercy KANSAS CITY

Useful in situations previously external fixator was used

External Fixator

- Limited role for the femur when compared to spica cast
    - Wright JG 2005
- Refracture a risk in well reduced midshaft transverse fractures
- Randomized clinical study has not confirmed need for dynamization for femur fracture
    - Domb BG 2002

9 year old multiple trauma, unstable patient

Children's Mercy KANSAS CITY

Highly unstable fracture and need for rapid treatment

Pearl: Keep pins away from the physis and zone of injury

AAOS 2015 CPG

PAIN CONTROL

Limited evidence supports regional pain management for patient comfort peri-operatively.

Grade of Recommendation: Limited 

Children's Mercy KANSAS CITY

Acceptable shortening and angulation measurements of femur fractures based on age.

Age	Varus/Valgus (degrees)	Anterior/Posterior (degrees)	Shortening (mm)
Birth to 2 yr.	30	30	15
2 – 5 yr.	15	20	20
6 – 10 yr.	10	15	15
11 yr. to maturity	5	10	10

Adapted from Beaty JH and Kasser JR, Rockwood and Wilkins Fractures in Children, 7th Ed.(Beaty JH, 2010 #133)

Children's Mercy KANSAS CITY

Complications

- Both surgical and non surgical- shortening overgrowth and undergrowth
- Non op- skin problems,
- Surgical- infection, implant related, refracture, need to remove

Summary

- Treatment based on age and mechanism
- 0-6 mo- Evaluate for abuse, Pavlic harness
- 6 mo-5 years. Spica cast. Consider abuse in <3 years, but especially <1yo
- 5-11 years flex nails. Plates and fixators, (rigid nail) if high energy unstable