

Is it sensible for radiologists (general & expert) to attempt to date fractures?

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Is it Sensible for Radiologists to Attempt to Date Fractures?

- ▶ I have no Conflicts of Interest to Declare

Physical Abuse: Fractures

- ▶ Fractures are the second most common injury after cutaneous trauma (bruising/burns/scratches)- recorded in up to 55% of children who have been physically abused
- ▶ The majority of children are under 3 years age, 50% under 1 year
- ▶ Less than 10% of abusive fractures are in children over 5 years
- ▶ Fractures may be solitary or multiple and may affect the appendicular or axial skeleton
- ▶ The long bones (80%), rib (7%) and skull (7%) fractures are the commonest sites



The Role of the Radiologist: Fracture Dating

- ▶ In the context of suspected physical abuse (SPA) the timing of the fracture is often critical
- ▶ Histories are often inaccurate or absent & injuries are frequently unwitnessed
- ▶ In this context, radiologists are often asked to date fractures:
 - ▶ By clinicians to support or question the veracity of the account provided by the carer/s
 - ▶ where multiple fractures- to confirm fractures of different ages
 - ▶ To assist the court in legal decision making re optimum placement of the child, identification/exclusion of potential perpetrators

Radiological Fracture Dating

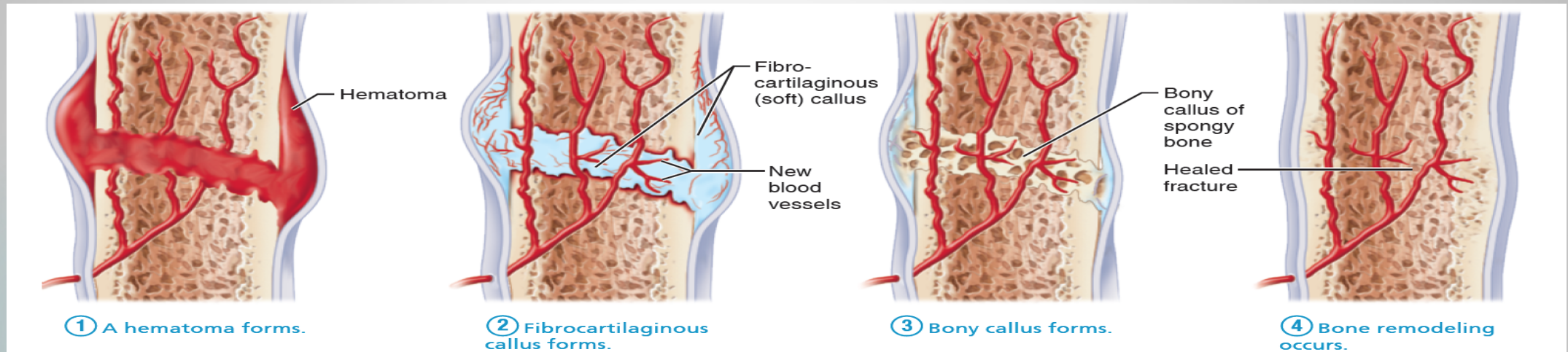


Fig. 2 Radiographs of the clavicle in three different patients show the evolution of *callus matrix* with fracture age. **a** *Soft callus* formation in a 12-day-old

Soft Tissue Swelling

SPNBF

Soft Callus

Intermediate

Hard Callus

Bridging & bone remodeling

Fracture Dating: The Evidence

Radiologic Features	Cumming 1979	Yeo & Reed 1994	O'Connor & Cohen 1998	Islam et al 2000	Offiah & Hall 2009	Halliday et al 2011	Prosser 2012	Warner et al 2017
	Newborns Clavicle, humerus, femur fractures	1-14 yrs Femur 10 pts < 4yrs		1-17 yrs Forearm 18% children 0-4y (mean 8ys)	< 2 yrs Long bones	14d-44 m (median 5m) Multiple long bones	0-6 yrs (mean 4.8yrs) Long bones	< 1 year Long bones 40 infants
Fracture Gap Widening				4-6w (56%) (2-8w)	> 7d			
SPNBF	9-10d (7-11d)	1-3w mean 11d	10-14d	4-7w (100%) Earliest 14d	7-10d	11 days (>90%) (4-11d)	22d (>40%) (15-35d)	9+ days (7-130 days)
First Callus	7 d (9-10d)	1-3w	14-21d	4-7w (100%)	1-6w	(4-11d)	22-35d	9—14 days (9-130 days)
Mature Callus			14-21d	13w (90%)		20-106d	>/= 22d	
Bridging		2.6w (1.5-3.7w)		13w (50%)		All at 20+ days Earliest 13d	>36d	15-51 days (15-130)
Remodelling		8w	1yr (3-24m)	9w (50%)			>36d (5 + wks)	> 51 days

The Evidence: Why the variation in time scales?

- ▶ **Age:** Fracture healing is influenced by age
 - ▶ Bones heal at a faster rate in children compared to adults¹
 - ▶ Bones appear to heal at a faster rate in infants compared to older children²
- ▶ **Site:** Fracture healing is influenced by location
 - ▶ Forearm fractures heal faster than lower limb fractures in adults
 - ▶ Forearm fracture's appear to heal at a faster rate than tibial fractures in children²

1. An Investigation of time since injury: a radiographic study of fracture healing. KB Hufnagl.

LSU Thesis. 2005 Louisiana State University

2. A Radiographic Assessment of Pediatric Fracture Healing & Time Since Injury. C Malone et al J Forensic Sci 2011 Vol 56 No 5

Fracture Dating: The Evidence

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The Evidence: Other Factors

▶ **Plaster cast**

- ▶ Analysis limited by cast - all studies assessing long bone fractures (except Halliday)
- ▶ Negative impact inter-observer agreement

▶ **Fracture type**

- ▶ Fracture type not differentiated in some studies
- ▶ Some studies excluded displaced fractures, fractures with external fixation

▶ **Imaging**

- ▶ Different phases bone healing assessed
- ▶ Criteria for phases bone healing inconsistent



Fracture Dating: Recent Literature

Radiologic Features	Walters et al 2014	Fadell et al 2017
	Clavicle	Clavicle
	0-3 months	0-6months
	131 infants	61 infants
SPNBF	10+ days 8 days (50%) 7 days earliest	11 days (7-49 days)
Callus: First (soft)	15+ days 13 days (50%) 9days earliest (mean 18d)	11 days (11-61 days)
Callus: intermediate	(mean 25d)	
Callus Hard	(mean 42d)	
Bridging		22 days (20-63 days)
Bone Remodelling		49days (35-151 days)

► Walters et al 2014

- Demonstrated consistent pattern of fracture healing

Proposed timeframes – but questioned if applicable to all long bones & older infants/children

► Fadell et al 2017

Demonstrated predictable fracture healing

Suggest proposed timeframes which could be used to assist fracture dating - though noted SPNBF & callus slightly earlier than reported in older children (3-5y)

Fracture Dating: Recent Literature

Pediatric Radiology (2021) 51:1682–1689
<https://doi.org/10.1007/s00247-021-05038-3>

ORIGINAL ARTICLE



Validating scoring systems for fracture healing in infants and young children: pilot study

Samuel Crompton¹ • Fabrizio Messina² • Gillian Klafkowski³ • Christine Hall⁴ • Amaka C. Offiah^{1,3}

Crompton et al 2021

- ▶ **Aims:** To examine if the proposed timeframes for healing clavicular fractures can be applied to dating all fractures of suspected PA
- ▶ Children < 3 yrs with femoral fractures
- ▶ Assessed: SPNBF, callus, remodeling phases of healing

Recent Literature

Radiologic Features	Walters et al 2014	Fadell et al 2017	Crompton et al 2021
	Clavicle	Clavicle	Femur
	0-3 months	0-6months	< 33 months (mean 19m)
	131 infants	61 infants	30 children
SPNBF	10+ days 8 days (50%) 7 days earliest	11 days (7-49 days)	12 + days (83.3%) (7-11days (22%)
Callus: First (soft)	15+ days 13 days (50%) 9days earliest (mean 18d)	11 days (11-61 days)	27+ days (89.5%) (15-26 days 50%)
Callus: intermediate	(mean 25d)		
Callus Hard	(mean 42d)		
Bridging		22 days (20-63 days)	
Bone Remodelling		49days (35-151 days)	42+ days (26-37d 26.7%)

► Results

- Timeframes of SPNBF & callus lags behind birth related clavicle fractures
- Bone remodeling may be apparent earlier
- Caution suggested comparing timelines for fracture healing in clavicle vs femur
- Larger studies recommended

Literature: Summary of Timeframes

- **Concordance between studies:**
 - SPNBF - usually present by 9-14 days
 - Bone remodelling 6-7 weeks
- **No concordance:**
 - Callus (soft & mature)

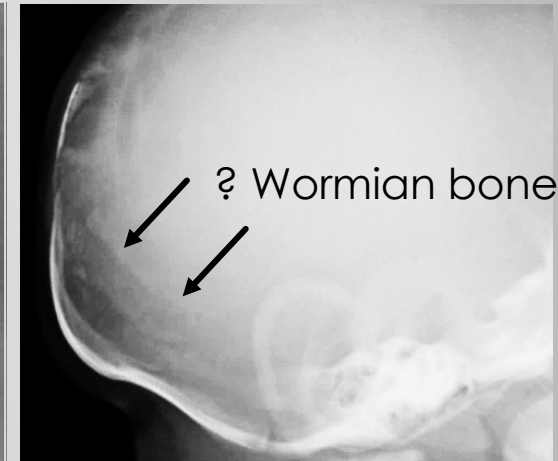
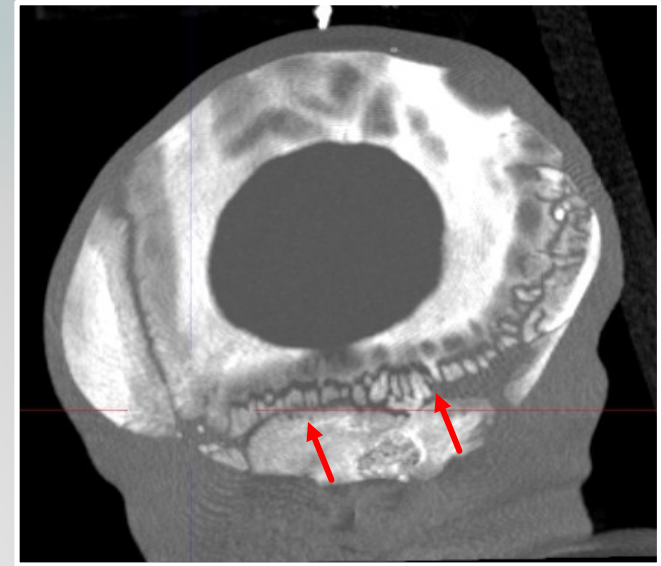
*Is it Sensible for Radiologists to
Attempt to Date Fractures?*

The 'general' Radiologist

- ▶ Dating fractures with any 'accuracy' is a difficult & complex & area - supported by very limited evidence
- ▶ In clinical practice providing a 'date' or a 'timescale' for a fracture/s is not necessary
- ▶ Differentiation of acute & healing fractures, is sufficient & invaluable
 - ▶ in identifying whether an injury is consistent with the history provided (if any)
 - ▶ in the context of multiple fractures, identifying fractures of different ages – indicates repeated episodes of trauma

Is it Sensible for Radiologists to Attempt to Date Fractures? The 'general' Radiologist

- ▶ Accurate identification of acute or healing fractures requires high quality imaging & a critical review
- ▶ The clinical paediatric radiologist plays an important role in ensuring optimum imaging & where there is doubt recommending, additional views, alternative imaging ie CT
- ▶ Error at this stage may have a significant implications for the child



13 month old girl with acute fracture RT femur, healing fracture RT tibia.
Care proceedings initiated suspected PA

Is it Sensible for Radiologists to Attempt to Date Fractures? The 'general' Radiologist

- ▶ Attempting to date fractures risks:
 - ▶ Attendance at court to justify opinion
 - ▶ an expectation of knowledge /understanding of the literature
 - ▶ discrepancy with appointed expert - culminating in expert meetings, difficult cross examinations
 - ▶ Being treated as an Expert rather than Witness of fact !

Is it Sensible for Radiologists to Attempt to Date Fractures: The 'Expert' Paediatric Radiologist

- ▶ The role of the expert witness is to assist the Court, on matters outside of their knowledge
- ▶ In the context of a child with a fracture/s due to SPA the expert is appointed to advise the court on:
 - ▶ causation
 - ▶ most likely timeframe for the fracture/s

Dating Fractures? The 'Expert' Paediatric Radiologist

- ▶ Expert opinion is expected to be evidence based - not solely based on the personal experience or knowledge of the individual
- ▶ The literature on accidental fracture dating, remains limited – only 4 studies in children < 3 yrs/age (262 children)
 - ▶ Walters 2014: Clavicle 0-3 mo
 - ▶ Warner 2017: Long bone fractures < 1 yrs
 - ▶ Fadell 2017: Clavicle fractures 0-6 mo
 - ▶ Crompton 2021: Femoral fractures < 33 mo

Dating Fractures? The 'Expert' Paediatric Radiologist

- ▶ Most experts provide opinion based on a combination of their own clinical experience (often significant) & knowledge of the published literature
- ▶ Combination of personal opinion and literature may result in:
 - ▶ Differing opinion - need for expert meetings
 - ▶ Difficult cross examination – justification of opinion
 - ▶ Derogation of the literature
 - ▶ Criticism of experts by the Court, media

What is the Alternative?

- ▶ Experts avoid 'dating fractures' & provide only broad descriptive timeframes
- ▶ This is not practical or realistic:
 - ▶ detrimental to the courts & ultimately the welfare of the child
 - ▶ risks other experts (non-radiologists) attempting to date fractures/providing opinion

Is it Sensible for Radiologists (general & expert) to attempt to date Fractures?

- ▶ At present, with respect to estimating the age of fractures in children with suspected physical abuse
 - ▶ **It is necessary to date fractures, however:**
 - ▶ **General paediatric radiologists are advised to provide only descriptive timeframes ie acute or healing fracture**
 - ▶ **Experts should provide the most likely timeframe which should be kept broad, with a clear explanation of the limitations**

Thank you

References

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