



## Original Paper

## Dating fractures in infants

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## ARTICLE INFORMATION

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**AIM:** To document the timing of the appearance of the radiological features of fracture healing in a group of infants in which the date of injury was known and to assess the degree of interobserver agreement.

**MATERIALS AND METHODS:** Three paediatric radiologists independently assessed 161 images of 37 long bone fractures in 31 patients aged 0–44 months. The following features were assessed: soft-tissue swelling, subperiosteal new bone formation (SPNBF), definition of fracture line, presence or absence of callus, whether callus was well or ill defined, and the presence of endosteal callus.

**RESULTS:** Agreement between observers was only moderate for all discriminators except SPNBF. SPNBF was invariably seen after 11 days but was uncommon before this time even in the very young. In one case SPNBF was seen at 4 days.

**CONCLUSION:** With the exception of SPNBF, the criteria relied on to date fractures are either not reproducible or are poor discriminators of fracture age.

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## Introduction

A recent systematic review of the radiological dating of fractures in children<sup>1</sup> highlighted the lack of published evidence in this area. Only three primary research studies of adequate quality were identified, which, when taken together, included data on 189 children, only 56 of whom were younger than 5 years. The majority of children suffering non-accidental fractures are younger than 3 years and 50% of fractures occur in children under 1 year.<sup>2</sup> Therefore, there are few published data available for the age group most at risk for non-accidental injury (NAI) and the dating of these fractures, which can be so crucial to the future of the child and their family, is based on the radiologist's personal experience. Some guidance is also offered in

text books,<sup>2</sup> but this is again based on the experience of the authors rather than primary research.

The area is further complicated by the multiplicity of terms used to describe fracture healing and the lack of clear definitions. The terms hard and soft callus are often used when describing radiographic features of fracture healing, but these are in fact histological terms with no clearly defined radiological equivalent.

The purpose of the present study was to identify the timing of the radiological features of fracture healing in a group of infants in whom the date of injury was known. The study group consisted of infants investigated for suspected NAI who had sustained long bone shaft fractures. These fractures are invariably symptomatic, and it is often possible to narrow the date of injury down to a 24 h period due to the testimony of parties other than the immediate carers and/or suspected perpetrators. Metaphyseal fractures have not been included as they are frequently less symptomatic and it is not possible to accurately identify the date of injury. The level of interobserver agreement for the presence of the radiological features of fracture healing was also assessed.

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## Materials and methods

Records of all children investigated for NAI at the local hospital and all children referred to one of the paediatric radiologists for an expert opinion regarding suspected NAI were reviewed. A total of 119 patients with long bone fractures were identified between July 1998 and December 2009. Eighty-eight patients were excluded, 33 had metaphyseal rather than shaft fractures, and in six patients the images were not available for review. In 47 patients it was not possible to definitely identify the date of injury from the history. Two patients were withdrawn because all observers considered the injuries to represent a re-fractures of the radius and ulna. This study was approved by the local research ethics committee.

A group of 31 patients with long bone shaft fractures in whom the date of injury could confidently be identified remained. The date of injury was ascertained from the testimony of third parties other than the suspected perpetrators or by confession of the perpetrator (Table 1). All three observers reviewed the history available. Patients were only included in the study if all observers were confident that the date of injury had been established. The patients' ages range between 14 days and 44 months, the median age was 5 months (Fig 1). Thirty-seven fractures were identified. The fracture sites are listed in Table 2. All fractures were treated after the first radiograph, which usually involved immobilization. Patients were all removed to a place of safety as soon as the fracture was identified. None of the patients were known to have a co-existent head injury, which, it has been suggested, may affect the features of fracture healing.<sup>3,4</sup> The majority of the images were conventional radiographs but some of the more recent cases were DICOM images.

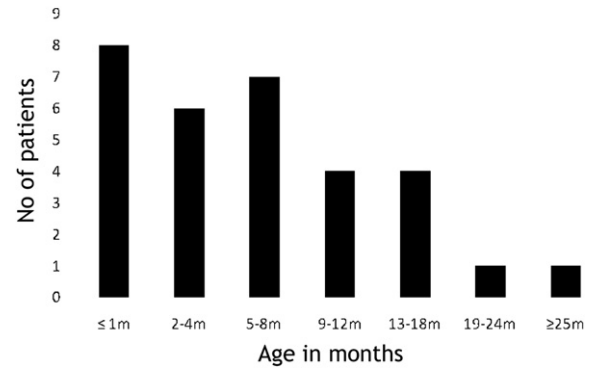
As the study was retrospective, the timing of the radiographs was dictated by clinical need and was therefore variable. The distribution is shown in Fig 2. The day of injury was recorded as day 0.

A total of 161 radiographic assessments were made. The radiographs were anonymized and randomized. Each was independently assessed by each of three observers for features of fracture healing. Levels of agreement between each pair of observers were assessed using Cohen's kappa coefficient and classified as either poor (less than 0.2), fair (0.2–0.4), moderate (0.4–0.6), good (0.6–0.8), or very good (0.8–1). Radiographs were assessed for the following features, which are widely used in clinical practice to assess the age of fractures: blurring of the soft-tissue planes, subperiosteal new bone formation (SPNBF), definition of fracture line, presence of callus, definition of callus, and endosteal callus. For each category radiographs were

**Table 1**

Features in the history establishing the date of injury.

Accepted accidental fall	4
Seen by health visitor or general practitioner earlier in day	3
Behavioural change noted by independent family/friends	16
Confession by carer	5
Symptomatic on return from nursery	3



**Figure 1** Age range of the 31 subjects.

excluded if one or more observer felt the quality of the image was too poor to assess that feature on the radiograph. For example, due to the presence of a plaster cast.

## Results

### Blurring of soft-tissue planes

Assessment of soft-tissue swelling was hampered by the quality of the radiographs and the presence of plaster casts. In 72 assessments one or more observer felt that the radiographs were too poor to make a comment on blurring of the soft tissues; therefore, these were excluded. A total of 89 assessments were then compared. Kappa scores between all three pairs of observers ranged between 0.41 and 0.66 (moderate to good agreement). In only 56 assessments did all three observers agree. In the cases where there was consensus, soft-tissue blurring was seen in three out of nine cases on the day of injury and in 80% of images between 1–10 days (Fig 3). Soft-tissue swelling was not seen in any of the agreed assessments after 10 days, although some observers identified blurring as late as 34 days.

### SPNBF

All radiographs were considered to be of adequate quality to assess this feature; therefore, the total number assessed for agreement was 161. Kappa scores between the three pairs of observers ranged between 0.83 and 0.96, very good in all cases. All observers agreed in a total of 150 assessments (Fig 4). SPNBF was seen on all radiographs taken at 11 days and beyond, with the exception of a fibula fracture imaged at 37 and 78 days, which had healed. SPNBF was seen before 11 days on only two radiographs in

**Table 2**

Sites of the 37 fractures.

Fracture site	Number
Femur	12
Humerus	15
Tibia	2
Fibula	2
Radius	3
Ulna	3

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