Is there benefit to concurrent x-ray imaging of the wrist, forearm and elbow in paediatric patients following a fall on the outstretched hand?

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Abstract

Introduction: Concurrent X-ray imaging of the wrist, forearm and elbow in paediatric patients following a fall on the outstretched hand (FOOSH) is intended to minimise the risk of an undetected co-occurring injury and is typically performed on patients aged 0–10 years. The purpose of this study was to explore the benefit of this strategy and to identify if age could provide evidence for imaging. Methods: A 12-month retrospective review of all X-ray examinations of the wrist, forearm and distal humerus of patients aged 0–10 years referred from the Emergency Department of Logan Hospital, Queensland was undertaken. The frequency, type and location of radiographic abnormalities and the requested examinations region of interest (ROI), referral notation and patient’s age were recorded. Analysis was made by descriptive statistics. Results: Four hundred and seventy-six examinations met the studies inclusion criteria, 4.8% (n = 23) identified an abnormality outside of the documented ROI. On review of the admission and treatment notes, 1.7% (n = 8) were deemed to have detected traumatic abnormalities as a direct outcome of concurrent imaging. No age-related evidence for imaging was identified. Conclusion: This study demonstrates limited benefit (1.7%) to concurrent imaging following a FOOSH. The results suggest that a thorough physical evaluation of the paediatric upper limb performed by the referrer is sufficient to accurately guide X-ray imaging. These findings have the potential to positively impact a reduction in the number of X-rays performed on paediatric patients and in turn contribute to limiting radiation dose. Further studies may be beneficial in verifying the study’s findings.

Introduction

Fractures of the forearm are common causes of paediatric presentations to emergency departments worldwide.1,2 The most common type of fractures in the paediatric population involve the radius and ulna (40%–50%).3,4 The incidence of distal forearm fractures has risen over the past 40 years with some studies suggesting this increase to be a result of a combination of growing sports involvement and increased body weight.3,6 The typical mechanism of injury is a fall on the outstretched hand (FOOSH), with fractures most commonly occurring in the distal third of the forearm (75%) and involving either or both the radius and ulna.3

Following a FOOSH, co-occurring injuries of the affected upper limb have been reported in children and include the elbow, hand and shoulder girdle.6,7 The most common co-occurring injury for paediatric patients with a forearm fracture is that of a supracondylar fracture of the distal humerus, reported in up to 5% of cases.7
combination of a forearm fracture and a supracondylar fracture is termed a ‘floating elbow’ and these children are at increased risk of acute compartment syndrome. Monteggia-type lesions consisting of a midshaft ulna fracture with associated anterior radial head dislocation can also be seen in children in varying forms.

Fractures causing damage to the growth plate can have a significant impact on future growth and modelling of the bone. Previous studies have shown that growth plate injuries account for 15%–30% of all paediatric bony injury with the upper limb the most likely to be affected. In addition to the risk of growth arrest, injury to the growth plate often stimulates bone repair, which can lead to limb length discrepancy, bone bridge formation between the metaphysis and epiphysis and angulation of the bone. This makes it imperative that such injuries are diagnosed early and managed promptly and appropriately. An additional challenge to clinicians investigating these injuries is that common fracture locations, types, and their patterns following a FOOSH also vary by age group.

The limited capacity for paediatric patients at early stages of development to communicate poses a further challenge to referrers during their clinical assessment. Paediatric patients are typically harder to assess and may be unable or unwilling to indicate a key site of pain or tenderness. This is most prevalent for patients below 4 years of age, with the 48–60 month mark of paediatric development typically associated with 100% intelligible speech.

Due to the known potential for co-occurring injury, potential risks of missing an undiagnosed fracture and age-based communication limitations, many emergency referrers routinely request concurrent or additional and overlapping imaging of the forearm including both the elbow and wrist joints in paediatric patients with suspected fractures following a FOOSH. In some institutions this requirement is in place as an imaging protocol. The intention of this practice is to reduce the risk of a co-occurring and or unsuspected ipsilateral injury of the upper limb going undetected. This anecdotal imaging practice is known to be undertaken in several Australian emergency settings. Despite the use of this protocol, there is limited published evidence to support this imaging strategy. Consequently, complete imaging protocols, where undertaken as a ‘one size fits all’ examination, may be viewed as unjustified and unnecessary for the majority of paediatric patients with FOOSH-type injuries. It is known that exposure to even low doses of radiation may lead to an increased risk of cancer. Whilst extremity doses for X-ray imaging are low, babies and younger children are increasingly radiosensitive to extremity imaging compared to older children and adults because of the proportion of red bone marrow present in their long bones. Concurrent imaging of the wrist, forearm and elbow joint may represent a preventable exposure to ionising radiation, in a population that is particularly radiosensitive.

At the study site, for all patients aged 10 years and under, complete X-ray imaging of the wrist, forearm and elbow is mandatorily performed for all patients when X-ray imaging of either the wrist, forearm or elbow is requested following a FOOSH. This imaging protocol is performed irrespective of the specific region requested by the referrer. The purpose of this study was to ascertain whether concurrent X-ray imaging of the wrist, forearm and elbow is of benefit to the paediatric patient in the Australian setting by analysing the number of unexpected injuries detected due to the site’s imaging protocol. Additionally, this study sought to determine whether an evidence-based age cut off for imaging could be established.

**Methods**

Ethics approval was granted by the Metro South Human Research Ethics Committee (HREC/2018/QMS/45266) and the Charles Sturt Human Research Ethics Committee (H19127).

A retrospective, non-experimental, quantitative study design was used to identify the number of abnormalities detected due to concurrent imaging of the wrist, forearm and elbow. All X-ray examinations of the wrist, forearm and elbow of patients aged 0–10 years imaged at Logan Hospital, Queensland between 1 January 2018 and 31 December 2018 were identified using the hospital’s Radiology Information System (RIS). The review process was undertaken by one of the authors (DS) who examined the electronic medical imaging request form, X-ray imaging acquired and the radiology report through the RIS and Picture Archiving Communication System (PACS).

A two-stage identification and correlation process was then undertaken (Fig. 1). Stage one involved the identification of examinations that met three inclusion criteria.

1. The patient presented to the emergency department following a FOOSH-type traumatic injury of the upper limb (wrist, elbow or forearm).
2. The patient received concurrent imaging of the wrist, forearm and elbow as per the study site’s paediatric FOOSH imaging protocol.
3. A radiographic abnormality was documented in the findings of the radiology report.

For examinations which met the inclusion criteria, the medical imaging request form located on the RIS, which
indicated an examination code for the region requested and the examination’s clinical details for the region/s of interest was reviewed. The ROI was recorded as being either the wrist, elbow, forearm or a combination of the three.

The clinical details if present, were searched for an area of concern and a point of maximal tenderness or deformity. For example, a request for a wrist X-ray that included concern for a midshaft forearm injury in the clinical details was perceived to indicate a ROI for the radiographic examination as a wrist and forearm.

Stage two involved identification and correlation of abnormalities occurring outside of the ROI was as follows:

To identify whether an abnormality was identified because of the imaging protocol, the location of each abnormality detected was compared with the examination’s ROI as documented on the medical imaging request form. Where an abnormality was detected outside the ROI, its location was compared with the limits of anatomy included on a wrist, forearm or elbow projection. To standardise the recording of fractures involving the radius and ulna, fractures were categorised as occurring either in the distal, middle or proximal third of either bone. Technical positioning handbooks for radiography were consulted to define the anatomy reasonably expected to be included for each ROI or X-ray series. A wrist X-ray series was considered to include the distal one-third of the radius and ulna, the carpal bones and the metacarpal bones. The forearm series was considered to include the full length of the radius and ulna as well as the carpal bones and distal humerus. The elbow series was considered to include at a minimum the distal third of the humerus and the proximal third of the radius and ulna.

If an abnormality was identified outside of the defined anatomic limits for the ROI, for example, in the midshaft or proximal radius or ulna, when the ROI was a wrist, this was considered to have been potentially identified due to the concurrent imaging performed.

To identify whether the abnormality detected outside of the ROI was apparent or clinically suspected prior to imaging, a retrospective review of the relevant electronic medical records pertaining to the patient’s assessment and admission was performed. An abnormality was determined to be clinically suspected and not identified because of concurrent imaging performed, if the records documented a suspected injury, obvious deformity or point of maximal tenderness at the location of the abnormality. If no evidence was found to indicate the abnormality was suspected or apparent prior to the imaging performed, then it was determined to have been detected due to the concurrent imaging protocol. Data were collated in Microsoft Excel.

**Data analysis**

Conventional descriptive statistics were used to analyse the data. Categorical variables were described using frequencies and percentages. Continuous variables were
described using median and interquartile range (IQR). Histograms were used to visualise the distributions of the measures of interest.

Results

A total of 1161 X-ray examinations involving the wrist, elbow or forearm for patients aged 0–10 years were identified. Of these examinations, 59.5% \( (n = 691) \) did not meet the inclusion criteria: no abnormality was detected 33.6% \( (n = 390) \), 19.2% \( (n = 223) \) had been performed for follow-up imaging of a known abnormality, 2.0% \( (n = 23) \) of patient presentations did not involve a FOOSH or similar mechanism of injury and 4.7% \( (n = 55) \) were excluded due to the study site’s paediatric imaging protocol not being followed.

Forty-one per cent \( (n = 476) \) of examinations met the study inclusion criteria. The median age of the patients was 6 years, and the interquartile range for the data set was 4 years (see Fig. 2). An abnormality was identified outside of the ROI in 20% \( (n = 23) \) of the included examinations. Following review of the electronic medical records for these 23 examinations, there was documented evidence in 15 to indicate that the abnormality was clinically suspected prior to imaging and, thus, was not detected as a direct outcome of the concurrent imaging performed.

The remaining eight examinations representing 1.7% of the total examinations reviewed were deemed to have demonstrated an abnormality because of concurrent imaging of the wrist, elbow and forearm. The location and types of abnormalities detected within and outside the ROI for these eight examinations are presented in Table 1.

The frequency and type of abnormalities detected as a direct outcome of concurrent imaging is presented in Figure 3 and further described in Table 1. The injury pattern of a ‘floating elbow’ as described by Roposch et al as justification for imaging the wrist, elbow and forearm was present in 7% \( (n = 29) \) of the examinations reviewed. However, all occurrences of ‘floating elbow’ within the study undertaken were detected within the ROI for the examination and not as a direct outcome of concurrent imaging.

Discussion

Concurrent imaging of the wrist, forearm and elbow in paediatric patients following FOOSH is intended to minimise the risk of a co-occurring injury from going undetected. This study identified additional findings attributable to this practice in 1.7% \( (n = 8) \) of examinations identified by the inclusion criteria.

Despite being an anecdotally accepted practice across several Australian public hospitals, there is no literature to support dedicated concurrent imaging protocols of the paediatric upper limb following trauma. A single comparable study conducted in the United States by Golding et.al sought to assess the necessity of additional X-ray imaging of the elbow in paediatric patients with a known wrist fracture. The single site’s, retrospective study involving 129 children who received additional imaging

![Figure 2. Patient age distribution for included examinations \( (n = 476) \).](image-url)
of the elbow joint found a second injury proximal to the known wrist fracture was present in 3% \((n = 4)\) of the children, all of whom exhibited physical findings of pain at the elbow. No fractures were documented in children with a negative physical clinical assessment of the elbow joint. Golding et al.\(^6\) concluded that additional radiographs of the elbow in children with distal forearm fractures were unnecessary when an appropriate physical clinical assessment was performed. Despite differences between Golding et al.\(^6\) and the current study relating to variations in the concurrent imaging protocols performed, the incidence of unexpected findings reported is comparable, 3% versus 1.7% for the current study.

In terms of identifying an age group for which concurrent imaging protocols may be most beneficial, the results of the study did not support variation of the current practice based on patient age. No patterns in the age, frequency or type of abnormalities detected by concurrent imaging in the eight examinations was found, although this may be a result of the small sample size. Initially, the authors hypothesised that the incidence of unsuspected injuries detected would be greatest in paediatrics below 4 years of age, where developmentally speech is not 100% intelligible.\(^{22}\) It was perceived that a reduced ability to communicate could potentially impair the accuracy of the initial clinical assessment performed and therefore that concurrent imaging would have an improved efficacy for this age group. Of the eight cases in which the protocol was deemed to have detected an unexpected abnormality, the patient’s age ranged from 1 to 9 years, with four cases involving patients aged either four or six. Based on these findings, no relationship between patient age and unexpected findings could be established, and there is insufficient evidence to support performing concurrent imaging protocols for a specific age group to increase its efficacy or value.

Whilst no specific anatomical region was associated with an increased frequency of abnormalities identified by the

| Case Number | Patient age (years) | Region of interest (ROI) on X-ray request | Location and type of abnormality detected within ROI as per Radiology report | Location and type of abnormality identified outside of ROI as per Radiology report |
|-------------|---------------------|------------------------------------------|----------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| 1           | 9                   | Wrist                                    | 1. Buckle fracture of the distal radial metaphysis  
2. Buckle fracture of the distal ulna metaphysis | 1. Elevated anterior fat pad and joint associated elbow joint effusion  
2. Transverse fracture through the junction of the proximal and mid third of the radius  
3. Transverse fracture through midshaft of the ulna |
| 2           | 4                   | Wrist                                    | No abnormality detected within the region of interest as per the Radiology report. | 1. Elevated anterior fat pad and associated elbow joint effusion  
2. Salter-Harris type 2 fracture of the distal ulna |
| 3           | 4                   | Wrist                                    | 1. Transverse fracture of the distal radial shaft with angulation  
2. Salter-Harris type 2 fracture of the distal ulna | 1. Elevated anterior fat pad and associated elbow joint effusion  
2. Impression of cortical irregularity in anterior cortex of distal humerus which may represent a supracondylar fracture |
| 4           | 6                   | Elbow                                    | 1. Elevated anterior fat pad and joint associated elbow joint effusion  
2. Impression of cortical irregularity in anterior cortex of distal humerus which may represent a supracondylar fracture | 1. Obliquely oriented fracture of the mid to proximal ulna diaphysis with displacement |
| 5           | 4                   | Wrist (Initial)                          | No abnormality detected within the region of interest as per the Radiology report. | 1. Elevated anterior and posterior fat pad-associated elbow joint effusion  
2. Cortical irregularity at anterior aspect of distal humerus suggesting a supracondylar fracture with mild dorsal displacement |
| 6           | 1                   | Wrist                                    | 1. Elevated anterior fat pad and associated small elbow joint effusion | 1. Greenstick fracture of the mid radial diaphysis with dorsal angulation |
| 7           | 6                   | Wrist                                    | 1. Incomplete fracture of the midshaft of the ulna with dorsal angulation | 2. Bowing fracture at the midshaft of the radius |
| 8           | 7                   | Wrist                                    | 1. Incomplete fracture of the midshaft of the ulna with dorsal angulation | 2. Bowing fracture at the midshaft of the radius |
practice, of the eight examinations where they were detected, none were identified in the distal radius, ulna or wrist joint. The injury pattern of a ‘floating elbow’ as described by Roposch et al. as justification for additional imaging was present in 7% \((n = 29)\) of the 476 examinations that met the inclusion criteria which is within the range of frequency reported in the same study (3% to 13%). However, all occurrences within the current study were detected within the identified ROI for the examination. This finding suggests the requested imaging based on the patient’s physical clinical assessment was sufficient to guide the imaging performed for these injuries. As a result, no evidence was found to support performing additional imaging of the elbow joint or proximal two-thirds of the radius and ulna in examinations where an abnormality was detected in the distal one-third of the radius and ulna unless clinically indicated.

Four cases demonstrated additional findings in the elbow joint. These included an equivocal finding of a supracondylar fracture and three cases of elbow joint effusion as indicated by raised anterior or posterior fat pads in the elbow joint. Of these four examinations, the patient’s clinical records indicated that none received follow-up imaging or clinical assessment for these radiologic findings.

The current study identified three examinations in which mid-forearm fractures were detected where the wrist or more specifically the distal radius and ulna formed the ROI. In all three instances, the patient’s electronic documentation did not indicate that an injury was clinically suspected in the mid-forearm. Whilst a missed abnormality for any patient is important, it is noteworthy that the fractures of the radius and ulna were identified in the field of view close to the standard anatomy included on a wrist X-ray series (case numbers two and seven, Table 1). Whilst these abnormalities are important findings, there is a possibility they may not have gone undetected had concurrent imaging to the ROI not been performed. This is because it is commonplace for emergency X-ray imaging to be modified based on the patient’s clinical presentation and to subsequently include anatomy beyond the standard ROI for each projection. The proximity of the abnormalities detected to the limits of the ROI could provide limited evidence to support the practice of modified imaging to expand the routine field of view.

The findings of the current study do not support concurrent imaging of the wrist, elbow and forearm without clinical indication. They do provide evidence of an opportunity to reduce radiation exposure to a radiosensitive population, patient distress and potential costs to patients and the healthcare system. In 95.2% \((n = 453)\) of examinations reviewed, the abnormalities detected fell within the requested ROI. This finding further supports the notion that a thorough physical clinical assessment is sufficient to guide the request of X-ray imaging following a FOOSH in paediatric patients. For paediatric patients, these examinations can be considerably distressing. A reduction in the number of X-rays performed would serve to minimise the time spent mobilising the limb when the child is often in distress and in pain. Furthermore, these X-rays incur further expense to acquire, review and report.

The exclusion of 4.7% \((n = 55)\) examinations due to the imaging protocol not being followed may be a reflection of radiographers themselves not viewing the request as justified with respect to patient presentation.
not aligning with the International Commission on Radiological Protection (ICRP) definition of justification for an examination to do ‘more good than harm’. Whilst investigation of the rational for not following the study site’s protocol was outside the scope of the study, it raises questions as to the usefulness of a protocol that is not followed explicitly.

This is the only known study to retrospectively assess the value of concurrent imaging performed of the wrist, elbow and forearm as opposed to just the elbow, following a wrist injury. Limitations of the study relate to the collation of data by a single author from a single institution. Due to its retrospective nature, the number of examinations in which a co-occurring injury was detected because the referrer ordered complete imaging of the wrist, forearm and elbow in addition to the region of clinical concern cannot be determined.

**Conclusion**

The results of this study demonstrate a limited benefit of concurrent imaging of the wrist, elbow and forearm in paediatric patients following a FOOSH where there is no clinical indication for imaging outside of the region of interest. A clinically unexpected abnormality was present in only 1.7% of the examinations reviewed. The results support previous findings that a thorough clinical assessment of the wrist, forearm and elbow is sufficient to guide X-ray imaging. The findings from this study have the potential to positively impact a reduction in the number of X-rays performed on paediatric patients and in turn contribute to reducing radiation dose to this population. Future research across multiple facilities may be of benefit to verify the study’s findings.

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