

Pediatric elbow fractures: a new angle on an old topic

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Received: 2 March 2015 / Accepted: 13 July 2015 / Published online: 28 July 2015
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Abstract

Background The three most common elbow fractures classically reported in pediatric orthopedic literature are supracondylar (50–70%), lateral condylar (17–34%), and medial epicondylar fractures (10%), with fractures of the proximal radius (including but not limited to fractures of the radial neck) being relatively uncommon (5–10%). Our experience at a large children's hospital suggests a different distribution.

Objective Our goals were (1) to ascertain the frequency of different elbow fracture types in a large pediatric population, and (2) to determine which fracture types were occult on initial radiographs but detected on follow-up.

Materials and methods Review of medical records identified 462 children, median age 6 years and interquartile range for age of 4–8 years (range 0.8–18 years), who were diagnosed with elbow fractures at our institution over a 10-month period. Initial and follow-up radiographs were reviewed in blinded fashion independently by two experienced pediatric

musculoskeletal radiologists to identify fracture types on initial and follow-up radiographs.

Results The most common fractures included supracondylar ($n=258$, 56%), radial neck ($n=80$, 17%), and lateral condylar ($n=69$, 15%). Additional fractures were seen on follow-up exams in 32 children. Of these, 25 had a different fracture type than was identified on initial radiographs. The most common follow-up fractures were olecranon ($n=23$, 72%), coronoid process ($n=4$, 13%) and supracondylar ($n=3$, 9%). Olecranon fractures were significantly more common on follow-up radiographs than they were on initial radiographs ($n=33$, 7%; $P<.0001$). Twenty-six children had more than one fracture type on the initial radiograph. The most common fracture combinations were radial neck with olecranon ($n=9$) and supracondylar with lateral condylar ($n=9$).

Conclusion Supracondylar fractures are the most frequent elbow fracture seen initially, followed by radial neck, lateral condylar, and olecranon fractures in a distribution different from what has been historically described. The relatively high frequency of olecranon fractures detected on follow-up speaks to their potentially occult nature. Careful attention to these areas is warranted in children with initially normal radiographs.

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Keywords Children · Elbow · Fracture · Radiography

Introduction

Fractures involving the elbow in children are common, comprising 5–10% of all pediatric fractures [1–4]. In a large series of more than 2,500 fractures in children, 235 involved the elbow [4]. Because of the unique anatomy of the elbow in the growing child and the propensity for complications,

prompt recognition and timely management of pediatric elbow fractures are essential.

Supracondylar fractures are universally recognized to be the most common type of pediatric elbow fracture, with a reported frequency of 50–70%; lateral condylar fractures have been historically reported as the second most common, varying from 17% to 34% [1, 2, 4–8]. Some of the earlier reports found medial epicondyle fractures to be the third most common elbow fracture in children, with a frequency of 8–11%; radial neck fractures and olecranon fractures were less frequent, occurring in 5–7% [4, 5, 8]. A relatively more recent publication reviewed 589 pediatric elbow fractures and reported radial neck fractures as the second most frequent fracture behind supracondylar fractures, with an incidence of 14%, at least double that previously reported [7]. Lateral condyle fractures followed closely as third in frequency, with an incidence of 12% [7]. We also encountered radial neck and olecranon fractures more often than the historical reports.

Our study had two purposes: first, to determine the relative frequency of pediatric elbow fractures in a large children's hospital and to compare that to historical data; second, because elbow fractures can be occult on initial radiographs, we sought to identify the relative frequency of fracture types detected on follow-up radiographs.

Materials and methods

This retrospective study was performed at our tertiary pediatric hospital with institutional review board approval. The radiology department record-search program was used to identify reports that contained the terms “elbow” and “fracture” in patients from birth to 18 years of age from October 2010 to July 2011. This search identified a group of 525 patients. We excluded those with non-accidental trauma or an underlying metabolic bone disorder such as osteogenesis imperfecta. We also excluded patients with no identifiable fracture on radiographs, isolated elbow joint effusion without follow-up radiographs, and joint effusion without fracture on follow-up radiographs. This yielded a study population of 462 patients.

Blinded review of initial elbow radiographs was performed independently by two experienced pediatric musculoskeletal radiologists (both with at least 15 years of experience). These radiographs were evaluated for presence and type of fractures (supracondylar and variants, lateral condyle, radial neck, medial epicondyle, olecranon, medial condyle, or coronoid process) and presence or absence of joint effusion. In patients with follow-up

radiographs within 7 days to 4 weeks of the initial radiographs, the first follow-up elbow radiographs were also independently evaluated after the initial radiographs had been reviewed for identification of any additional fractures or signs of healing (sclerosis or periosteal reaction). An additional fracture was defined as a lucent fracture line, sclerosis or periosteal reaction at an anatomical location separate from any fracture diagnosed on the initial radiographic study. Discrepant interpretations were resolved by consensus review by the two radiologists.

All analyses were performed using SAS® (version 9.3; SAS Institute, Cary, NC). Demographic variables were summarized as medians and ranges for non-normally distributed variables and as percentages for categorical variables. Because 11% of the patients had more than one fracture type, a dichotomous variable was generated for each fracture type. For each specific fracture, the dichotomous variable was set to “yes” if the specific fracture was observed on the patient's radiograph and “no” otherwise. For each fracture type, the proportion of fractures observed was calculated two ways using the FREQ procedure. The denominator for the first calculation was the total number of fractures and for the second the total number of patients in the study. The binomial test in the FREQ procedure was used to assess differences in proportions between the classically referenced proportions and our observed proportions where the total number of patients was the denominator. The binomial test was also used to compare the proportion of fracture types between initial and follow-up radiographs. All tests were two-sided and reported *P*-values are not adjusted for multiple testing. *P*-values ≤ 0.05 were considered statistically significant.

Results

The study population of 462 pediatric patients consisted of an equal gender distribution (231 females/231 males). The children ranged in age from 8 months to 18 years, with an interquartile range of 4–8 years of age (median 6 years). A total of 510 fractures were diagnosed (Table 1), 478 (94%) on initial radiographs and 32 (6%) only on follow-up radiographs. Of the 478 fractures diagnosed on initial radiographs, most — 255 (53%) — were supracondylar. Next in frequency were radial neck fractures at 79 (17%), followed by lateral condylar at 68 (14%), olecranon at 33 (7%) and medial epicondyle fractures at 27 (6%). Of the 20 miscellaneous fractures seen on initial or follow-up radiographs, coronoid process fractures were most frequent ($n=12$) followed by T-type intercondylar fractures ($n=5$). When the number of patients with a specific fracture type was compared to

Table 1 Total fractures in 462 patients

Fracture	Total fractures	Initial + FUfractures	Percentage of total fractures	Percentage of patients (95% CI)	Historical findings	P-value ^a
Supracondylar	258	255+3	50.6%	55.8 (51.3, 60.4)	60%	0.0682
Radial neck	80	79+1	15.7%	17.3 (13.9, 20.8)	5–10%	<.0001
Lateral condyle	69	68+1	13.5%	14.9 (11.7, 18.2)	17–34%	0.2374
Olecranon	56	33+23	11.0%	12.1 (9.2,15.1)	5–7%	<.0001
Medial epicondyle	27	27+0	5.3%	5.8 (3.7, 8.0)	10%	0.0029
Coronoid	12	8+4	2.4%	2.6% (1.4, 4.5)		
Miscellaneous	8	8+0	1.6%			
TOTAL	510	478+32				

CI confidence interval, FU found only on follow-up radiographs

^a Percentage of patients with specific fracture type was compared to percentages reported historically [1, 2, 4–8]

historical data, radial neck and olecranon fractures were seen significantly more often than might be expected (radial neck, 17% versus 5–10%; olecranon, 12% versus 5–7%; $P<0.0001$ for both) [1, 2, 4–8]. Lateral condylar fractures were seen less often than might be expected at (15% versus the 17–34% based on historical data, though the difference was not statistically significant) [1, 2, 4–8]. Looking at the entire population, medial epicondyle fractures occurred significantly less often than historically ($P=0.0029$). However, all 27 medial epicondyle fractures occurred in patients age 7 or older, as would be expected from the normal timing of the appearance of the ossification center on radiographs. Separate evaluation of the 193 patients age 7 and older, who had a total of 208 fractures, showed the incidence of medial epicondyle fractures was 14%, not significantly different from the 10% reported historically ($P=0.06$) (Table 2). Overall, the relative distribution of initial fracture types varied with age and skeletal maturity, as illustrated in Fig. 1.

On initial radiographs, 26 patients had more than one fracture. The most common combinations seen in these

patients were (1) radial neck fracture with olecranon fracture ($n=9$) (Fig. 2), one of whom also had a medial epicondyle avulsion fracture; and (2) supracondylar fracture combined with lateral condylar fracture ($n=9$) (Fig. 3). Of the other eight patients, five had an olecranon fracture with either a supracondylar or lateral condylar fracture, and the other three had combined coronoid process with lateral condyle ($n=1$), olecranon with coronoid process ($n=1$), or medial epicondyle with radial neck fractures ($n=1$).

Of the 32 fractures seen only on follow-up radiographs (Table 3), 25 were in patients who already had at least one fracture on initial radiographs and 2 were in patients with elbow dislocation and no fracture seen on initial radiographs; 5 others had no fracture seen on initial radiographs but subsequently had a fracture identified on follow-up (3 supracondylar, 1 olecranon [Fig. 4] and 1 radial neck). Four of these last five had only a joint effusion seen on initial radiographs; the olecranon fracture, however, lacked an effusion initially. The remaining 27 fractures (84%) identified only on follow-up

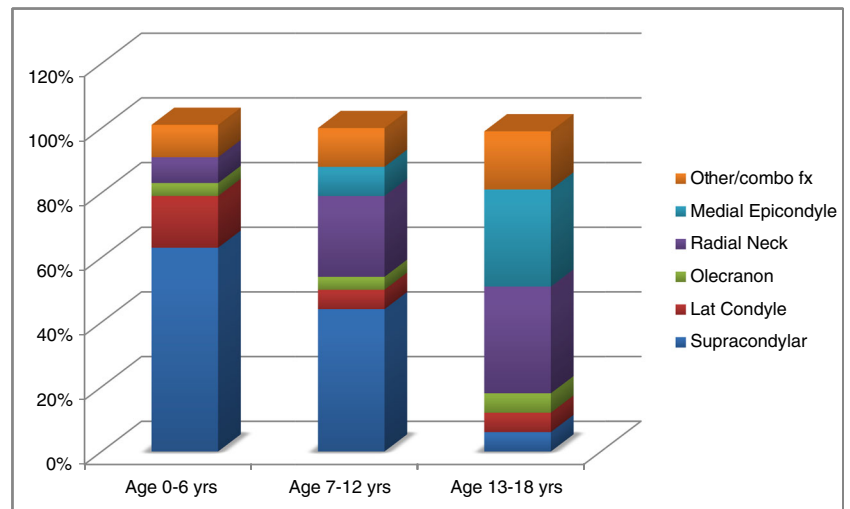
Table 2 Total fractures in 193 patients age 7–18 years

Fracture	Total fractures	Initial + FU	Percentage of total fractures	Percentage of patients (95% CI)	Historical findings	P-value ^a
Supracondylar	76	74+2	36.5%	39.4% (32.4, 46.7)	60%	<.0001
Radial neck	53	52+1	25.5%	27.5% (21.3, 34.3)	5–10%	<.0001
Lateral condyle	15	14+1	7.2%	7.8% (4.4, 12.5)	17–34%	0.0006
Olecranon	21	13+8	10.1%	10.9% (6.9, 16.2)	5%	0.0002
Medial epicondyle	27	27+0	13.0%	14.0% (9.4, 19.7)	10%	0.0647
Coronoid	8	5+3	3.8%	4.2% (1.8, 8.0)		
Miscellaneous	8	8+0	3.8%	4.2% (1.8, 8.0)		
Total	208	193+15				

CI confidence interval, FU found only on follow-up radiographs

^a Percentage of patients with specific fracture type was compared to percentages reported historically [1, 2, 4–8]

Fig. 1 Graph shows relative distribution of initial major elbow fracture types seen in each pediatric age group



radiographs involved the proximal ulna (23 olecranon and 4 coronoid process fractures). Of the 23 olecranon fractures seen on follow-up, 11 had a visible fracture line

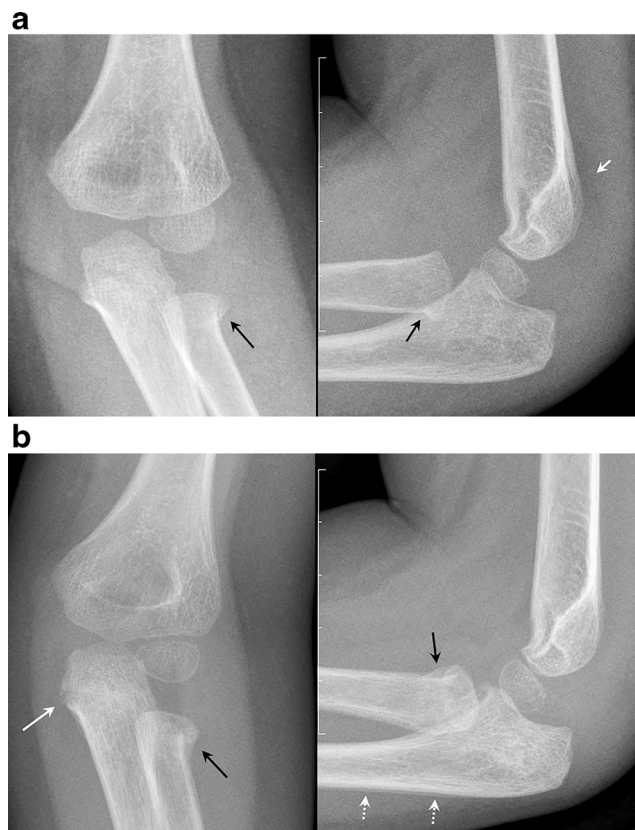


Fig. 2 Radial neck and olecranon elbow fractures in a 2-year-old with history of a fall. **a** Anteroposterior (AP) and lateral radiographs at the time of injury show a mildly angulated radial neck fracture (*black arrows*) and a posterior fat pad sign (*white arrow*). **b** Follow-up AP and lateral radiographs 4 weeks later show the healing radial neck fracture (*black arrows*) and a healing olecranon fracture that was not detected prospectively (*solid white arrow*), with periosteal reaction (*dotted white arrows*)

with periosteal new bone and 12 had periosteal new bone only.

Joint effusions were present on the initial radiographs in 422 of the 462 patients (91.3%). In the 40 patients without a joint effusion, 24 (60%) had either a radial neck ($n=15$, 37.5%) or a medial epicondyle ($n=9$, 22.5%) fracture.

Discussion

Trauma is a common indication for elbow imaging in children. Fractures in the developing pediatric elbow occur frequently and can be challenging to diagnose radiographically. Although some fractures are quite apparent, knowledge of the normal developmental appearances and the radiographic clues to injury are necessary to optimize detection of more occult fractures. Elbow fat pad displacement, particularly in the posterior olecranon fossa, indicates a joint effusion, which can be

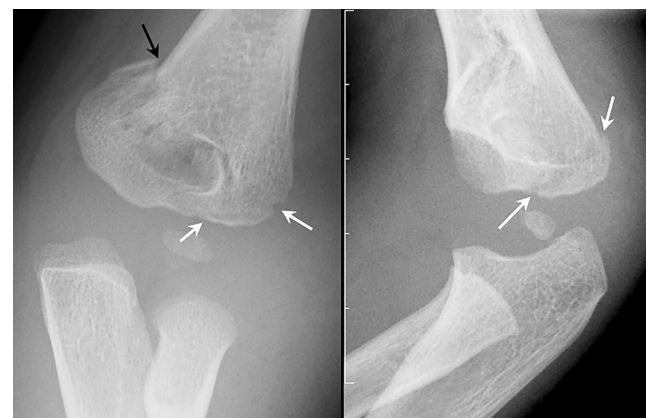


Fig. 3 Supracondylar and lateral condylar fractures in a 2-year-old boy with history of a fall. Anteroposterior and lateral projections show a supracondylar fracture (*black arrow*) and an additional fracture in the lateral condyle (*white arrows*)

Table 3 Fractures on follow-up radiographs

Fracture	Number	Percentage
Supracondylar	3	9.4%
Olecranon (total)	23	71.9%
Periosteal reaction only	12	(37.5%)
Fx line + periosteal reaction	11	(34.4%)
Radial neck	1	3.1%
Coronoid	4	12.5%
Lateral condyle	1	3.1%
Total	32	100%

Fx fracture

a helpful clue. Our study design excluded children without fracture on follow-up imaging, so the predictive value of a joint effusion was not assessed. However, the literature suggests that in children with joint effusion as the only finding on initial radiographs, identification of later occult fracture varies widely at 17–76% [9, 10]. Depending on the location of the

fracture, there may not be a joint effusion, as was seen in the minority (8%) of our patients with fractures, most frequently involving the radial neck. Radial neck fractures occur at the level of the annular ligament, which is intimately associated with the distal joint capsule attachment. The radial neck, therefore, is partly extra-articular, likely explaining the inconsistent finding of joint fluid with radial neck fractures [11].

Most of the historical literature in the mid-20th century indicated that the three most common pediatric elbow fractures were supracondylar, lateral condylar and medial epicondylar fractures and that fractures of the radial neck and olecranon were fairly uncommon [4, 5, 8]. Our results do not support these historical findings. The significantly lower incidence of medial epicondyle fractures in our full study population is shown to be related to the preponderance of younger patients (median age of 6 years), because this type of fracture tends to occur after age 7 years, when the ossification center starts to appear radiographically. The incidence in the group of children in our study who were ages 7–18 years (14%) is consistent with the historical literature. Our review,

Fig. 4 Olecranon fracture in a 9-year-old who fell several days earlier and reported posterior elbow pain. **a** Initial lateral radiograph appears normal. **b** Follow-up radiograph 4 weeks later shows a sclerotic band (*black arrows*) indicating a healing non-displaced olecranon fracture not detected prospectively. **c, d** MRI. The olecranon fracture was diagnosed on MR imaging, including sagittal T1-weighted (**c**) and STIR (**d**) images obtained several days after the injury because of persistent pain. Both sequences show the low signal intensity fracture line (*black arrows*) with surrounding marrow edema signal. *STIR* short tau inversion recovery



however, highlights the significantly higher incidence of radial neck and olecranon fractures than were reported historically, more in keeping with those described by Landin and Danielsson [7]. They found a similar higher incidence of radial neck fractures (14% vs. 17% in our study) than described in older reports. However, we encountered a significantly higher number of olecranon fractures (5–7% vs. 11% in our study). Approximately 41% (23 of 56) of these olecranon fractures were detected only on the follow-up radiographs. The alteration in frequency of elbow fractures in our population as compared to older literature is likely multifactorial. We hypothesize that it reflects population differences and variation in activity levels, including the involvement of younger children in organized sports that is more common today than historically.

The mechanism of injury varies, but the most commonly described mechanism involves a fall on an outstretched hand with varus, valgus or rotational force or a combination thereof. The vectors of force and the degree of chondro-osseous development dictate the type of injury incurred. In the extended position, the olecranon becomes locked in the olecranon fossa of the distal humerus, levering against the margins of the fossa [12]. When the deforming force is valgus, the olecranon metaphysis is fractured at the joint level and can be associated with a radial neck fracture, consistent with our findings that among combination fractures the olecranon fracture is associated most commonly with radial neck fractures. The same mechanism can be associated with avulsion fractures of the medial epicondyle. When the force is varus, the olecranon fracture can be associated with a radial head dislocation (Monteggia fracture). The high incidence of olecranon fractures in our patients likely reflects this injury mechanism.

There are several limitations to our study. It is retrospective in nature and some patients with effusion but without a fracture seen on initial radiographs were lost to follow-up. This could affect the overall distribution of fracture types. It is unlikely that this would have any major effect because only three patients with effusion and without a fracture on initial radiographs did not return for follow-up imaging. In comparison, five patients with effusion and no fracture on initial radiographs who did return for imaging had no fracture on follow-up. Additionally, our population was slightly skewed to a younger age group, with a median age of 6 years, which might have affected the overall distribution of fractures. However, the effect was only shown with medial epicondyle fractures, which are known to occur in patients at least 7 years of age.

Conclusion

We have found that the distribution of elbow fractures in children is different from that described in the historical literature; specifically, radial neck and olecranon fractures are seen significantly more often than they were historically. Most important, the high incidence of olecranon fractures on follow-up radiographs speaks to their potentially occult nature. However, they are not frequently encountered in isolation on follow-up radiographs. This knowledge should help focus attention to these areas on initial and follow-up imaging studies to maximize detection of these sometimes subtle injuries.

Conflicts of interest None

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