

Paediatric forearm fractures manipulated in the emergency department: incidence and risk factors for re-manipulation under general anaesthesia

Shaye Seefried, Kim Chin-Goh, Vahe Sahakian, Nicholas Lightfoot, Matthew Boyle

ABSTRACT

AIM: Re-manipulation of paediatric forearm fractures under general anaesthetic may be required following inadequate closed reduction under conscious sedation. Manipulation under general anaesthetic carries significant inherent risks and is preferably avoided. We assessed one institution's experience with paediatric forearm fracture reduction and investigate the incidence of re-manipulation under general anaesthetic of fractures initially managed under conscious sedation without fluoroscopy.

METHOD: All paediatric forearm fractures presenting to the children's emergency department of our national children's hospital between 1 January 2019 and 30 June 2019 were studied. Radius and ulna fractures were categorised according to fracture location (distal third, middle third, proximal third), any associated injury, and any plan to proceed to the operating room that was documented prior to manipulation in the emergency department. Univariate and multivariate statistical analysis was carried out to test for differences between discrete and continuous data and odds ratios were calculated.

RESULTS: Three-hundred and nine patients presented during the study period with 267 being eligible for analysis. Fifteen point seven percent (42/267) required fracture manipulation in the operating theatre following initial reduction in the children's emergency department. Independent risk factors associated with significantly higher rates of failed reduction under conscious sedation ($p < 0.001$ – 0.004) were patients who had a delay in presentation to hospital, were older, or had a non-distal fracture site.

CONCLUSION: There are higher rates of re-manipulation under general anaesthetic in children presenting to the emergency department of our national children's hospital with forearm fractures than seen in comparative international studies. Risk factors which predict an inadequate initial reduction and interventions to improve this are discussed.

Forearm fractures are among the most common injuries in children, accounting for 45% of all childhood fractures and 62% of upper limb fractures.¹ Treatment upon presentation to the emergency department (ED) routinely involves the use of procedural sedation, closed reduction, and casting. Subsequent re-manipulation under general anaesthetic (GA) is at times required when the initial reduction is inadequate. However, it is well understood that manipulation under GA carries significant anaesthetic, psychological, financial, and environmental risk, and the need for this intervention should therefore be minimised wherever possible.^{2–5}

Previously, Lee et al. found that repeat fracture reduction and the need for subsequent operative treatment was required in 8.4% of paediatric forearm fractures initially managed without fluoroscopic guidance.⁷ This same study showed that under

fluoroscopic guidance re-manipulation rates fell to only 2%.⁷ This equates to around a 76% reduction in trips to theatre with use of the C-arm.

Kuman et al. showed that in a general ED setting without fluoroscopic guidance repeat reductions were required in 30.8% of forearm fractures.⁶ In comparison, only 7.2% of forearm fractures in the study who underwent closed reduction with mini C-arm fluoroscopic assistance required re-manipulation.⁶ Similar to the results of Lee et al., this equates to around a 77% reduction in trips to the theatre with use of fluoroscopic guidance.

At our national children's hospital, all paediatric forearm fractures are reduced in the ED under conscious sedation without the use of fluoroscopy. The adequacy of the reduction is judged clinically and on post-procedure radiographs, which are reviewed by the treating paediatric orthopaedic surgeon. If there is inadequate reduction or

alignment on the post-procedural radiograph, the patient is starved and transferred to the operating room for further fracture management under general anaesthesia. There has been anecdotal concern about the rates of subsequent re-manipulation under general anaesthesia in the current working model.

The purpose of this study is to assess the efficacy of conscious sedation in the children's ED in appropriately managing paediatric forearm fractures. The primary outcome is the percentage of patients who required unscheduled transfer to the operating room for further care. Secondary outcomes were the indication for transfer to the operating room, the procedure performed, and the hospital length of stay.

Methods

Ethics approval from the local institutional ethics review committee was obtained.

Patients who presented to our national children's hospital in Auckland, New Zealand with isolated upper limb injuries and radiographic evidence of a fracture of the radius, ulna or both between 1 of January and 30 of June 2019 were retrospectively identified and were eligible for study inclusion. Patients were excluded if after initial X-ray review a plan was in place for transfer to the operating room for emergent or semi-emergent fracture management, if conscious sedation was unable to be safely provided in the children's ED, or if there were concurrent fractures of the supracondylar distal humerus, olecranon or the radial neck. Patients with Monteggia pattern fracture-dislocations were also excluded due to the high likelihood of requiring operative management.

The electronic data warehouse maintained by the healthAlliance was queried to identify patients presenting with forearm fracture within the study period. Study data were obtained from review of electronic charts, radiographs and procedural records. Fractures were classified by bone and by fracture location.

While defining non-acceptable reductions depends on the patient's skeletal maturity and fracture location, in this study for distal fractures <20 degrees angulation were deemed acceptable. For midshaft and proximal fractures, <15 degrees angulation for patients under age 10, and <10 degrees angulation for those over age 10, were deemed acceptable. A delay in presentation was indicated in instances where patients presented

to other facilities initially and then came to our national children's hospital over 24 hours after injury. No delay was defined as when patients presented directly to our hospital on the day of injury or soon after (<24 hours).

Statistical analysis

Information was stored in a Microsoft Excel spreadsheet and statistical analyses were completed using SPSS Version 27. Testing for the normal distribution was through the Shapiro–Wilk test with a two-tailed p-value of <0.05 being indicative of non-normally distributed data. Patient, procedural and outcome data are reported as number (percentage) or median (interquartile range [IQR]) as appropriate for categorical and continuous data, respectively. Fisher's exact test or a Chi-squared test with an appropriate Yate's continuity correction or the Mann–Whitney U test were used to test for differences between discrete and continuous data, respectively. Odds ratios with 95% confidence intervals (CIs), comparing different fracture parameters to a reference group, were calculated. When appropriate, to detect a trend or an association between categorical data, the Cochran–Armitage test for a trend was used. Across all statistical tests, a two-tailed p-value of <0.05 defined statistical significance. Binary logistic regression was used to identify patient and fracture-related variables, which were associated with the need for fracture management in the operating room. A model was built using backward elimination with odds ratios (ORs) and associated 95% CIs being reported. Model performance was assessed through the R-squared and Hosmer–Lemeshow statistics.

Results

Between 1 of January and 30 of June 2019, 309 patients presented to the children's ED with forearm fractures. Whilst at our national children's hospital attempts are made to reduce all forearm fractures as long as it is safe to do so, in the ED, without fluoroscopy at the surgeon's discretion including 100% displaced or off-ended fractures, a total of 42 patients were excluded from further analysis. Thirteen patients were excluded, as fracture manipulation under GA was planned due to sedation being unavailable in the children's ED, and 29 patients were, due to additional fractures, excluded from the study. There were 14 patients with supracondylar fractures, 13 patients with Monteggia fractures/dislocations and two patients

with radial neck fractures. Of those who were excluded from further analysis, 32 (76.2%) went to the operating theatre for fracture management.

Of the 267 patients included for analysis, 15.7% (42/267) required fracture re-manipulation in the operating theatre following management in the children's ED. The baseline demographic features and details surrounding the fractures sustained are further summarised in Table 1. Those who required fracture management under GA were older (10.2 vs 8.0 years old; $p=0.03$), and were more likely to have experienced a delay in presentation for fracture management ($p=0.001$), and also spent a greater period of time in hospital ($p<0.001$).

There were no differences in the total number of fractures sustained, both for the radius ($p=0.31$), ulna ($p=0.21$) and both bones combined ($p=0.16$) with most fractures being non-segmental. Those who required fracture management under GA were less likely to have sustained a distal radius fracture ($p=0.02$) and more likely to have sustained a midshaft radius fracture ($p=0.02$). Overall, patients who sustained non-distal fractures (proximal or mid-shaft) of the radius and/or ulna were more likely to require fracture manipulation under GA (45.2% v 25.3%; $p=0.01$).

Univariate comparisons, expressed as ORs with 95% CIs are shown in Table 2. When compared with those with an isolated distal radius fracture, children with an isolated midshaft radius fracture were more likely to require treatment in the operating theatre (OR 13.9 (3.1–62.4); $p<0.00$). Those with non-distal fractures of either the radius or ulna were significantly more likely to require operative treatment than those with isolated distal fractures (OR 2.7 (1.3–5.3); $p=0.006$). Although, the crude odds ratios increased progressively with an increase in the number of fractures sustained, due to insufficient patient numbers there were no significant differences observed when compared to patients with one fracture ($p=0.24$).

Multivariate logistic regression was completed to determine the demographic and fracture-related predictors of patients requiring subsequent fracture management under general anaesthesia (summarised in Table 3). Using backwards elimination and after nine steps, the predictors identified were delay in presentation to hospital (OR 12.9; $p=0.001$), non-distal fracture site (OR 7.5; $p=0.001$) and increasing patient age (OR 1.3; meaning every year of age increases the chance of manipulation under GA by 13%; $p=0.004$). The Nagelkerke R-squared statistic was 0.228, and the Hosmer–Lemeshow test revealed no evidence of poor model fitting ($p=0.93$).

Discussion

Forearm fractures are a common presentation seen in paediatric EDs. When treated with a closed reduction under procedural sedation in the ED, it is accepted that at times a subsequent re-manipulation under GA may be required. In this study of children presenting to the ED of our national children's hospital with forearm fractures, we identified disappointingly high rates of re-manipulation. Following initial closed reduction under conscious sedation, unplanned re-manipulation under GA was undertaken in almost 16% of patients. Paediatric forearm fractures can be unstable, and in general, up to 7–13% of forearm fractures treated by closed reduction are subject to re-angulation and/or displacement requiring re-manipulation before definitive union.^{1,8,9} Our rates of re-manipulation immediately following initial reduction exceed this.

The high proportion of patients requiring re-manipulation at our national children's hospital raises concerns based on the inherent anaesthetic, psychological, financial, and environmental risks associated with manipulation under GA.^{3–6} While anaesthesia-related mortality is rare, perioperative morbidity associated with GA is not uncommon.¹¹ Minor complications including postoperative nausea and vomiting, sore throat and dental damage all have negative impacts on patient experiences. Serious cardiovascular and respiratory complications associated with general anaesthesia meanwhile can have long-term repercussions resulting in permanent disability.¹⁰ Reduction under GA is also linked to a significantly longer time to manipulate, and greatly increased hospital length of stay.³ Alongside these are the emotional and mental factors of having a procedure in the operating theatre, which have been shown to result in a significantly greater negative psychological impact on paediatric patients.⁵ Additionally, the mean facility charge and cost incurred with each patient is also significantly higher with manipulation under GA compared to procedural sedation.⁴ At our institution, the average total time spent in theatre for a forearm manipulation under GA is almost 46 minutes. With operating theatre and anaesthesia time at our institution being billed at \$50.60 NZD per minute, and operating theatre staff at \$190.90 NZD per 15 minutes, this equates to an average cost of \$2,885.12 per case. By halving the rates of manipulation under GA, our hospital would have a saving of \$60,587.52 in theatre expenses alone over the six-month study period.

McQuinn and Jaarsma¹² have shown that in pae-

Table 1: Demographics.

	Entire cohort	Control	GA manipulation	p-value
Patients (%)	267 (100)	225 (84)	42 (16)	
Male (%)	151 (57)	126 (56.0)	25 (60)	0.74
Age (years)	8.3 (6.2–11.2)	8.0 (6.1–10.9)	10.2 (6.5–12.6)	0.03
Length of stay (hours)	5.3 (4.4–6.7)	5.1 (4.2–6.1)	8.5 (5.8–23.6)	<0.001
Delay in presentation (%)	10 (4)	4 (2)	6 (14)	0.001
Primary presentation to outside hospital (%)	10 (4)	4 (2)	6 (14)	0.001
Radius fracture (%)				
Bilateral	3 (1)	2 (1)	1 (2)	0.69
Left	125 (49)	106 (50)	19 (46)	
Right	127 (50)	106 (50)	21 (51)	
Radius fracture site (%)				
Distal	189 (74)	165 (77)	24 (59)	0.02
Midshaft	55 (22)	40 (19)	15 (37)	0.02
Proximal	12 (5)	9 (4)	3 (7)	0.42
Ulna fracture (%)				
Bilateral	1 (1)	0 (0)	1 (4)	0.05
Left	70 (45)	55 (43)	15 (54)	
Right	86 (55)	74 (57)	12 (43)	
Ulna fracture site (%)				
Distal	97 (62)	82 (64)	15 (54)	0.39
Midshaft	54 (34)	42 (33)	12 (43)	0.38
Proximal	8 (5)	6 (5)	2 (7)	0.63
Radius and ulna fracture (%)				
Unilateral	145 (54)	118 (52)	27 (64)	0.18
Bilateral	1 (0)	0 (0.0)	1 (2)	0.16
Non distal fracture site of either bone (%)	76 (29)	57 (25)	19 (45)	0.01
Two-tailed p-value of <0.05 used to define significance				
Values for radius and ulna fracture sites may sum to more than 100% due to patients with more than one fracture site				

Table 2: Odds Ratios.

Parameter	Failed Manipulation / Total (%)	Odds Ratio (95% CI)	p-value
Distal radius only	8/97 (8)	Comparison group	
Midshaft radius only	5/9 (56)	13.9 (3.1–62.4)	<0.001
Proximal radius only a	0/3 (0)	1.5 (0.1–31.6)	0.80
Distal ulna only a	0/5 (0)	0.96 (0.05–18.8)	0.97
Midshaft ulna only	1/4 (25)	3.7 (0.34–39.9)	0.28
Proximal ulna only a	0/3 (0)	1.5 (0.07–31.6)	0.80
Radius fractures only	13/109 (12)	Comparison group	
Ulna fractures only	1/12 (8)	0.67 (0.08–5.6)	0.71
Radius and ulna fractures	15/102 (15)	1.3 (0.57–2.8)	0.55
One radius fracture	13/107 (12)	Comparison group	
Two radius fractures a	0/2 (0)	1.4 (0.06–30.8)	0.83
One ulna fracture	1/12 (8)	0.65 (0.08–5.5)	0.70
Distal fractures only	21/189 (11)	Comparison group	
Non-distal fractures	19/76 (25)	2.7 (1.3–5.3)	0.006
One fracture site	21/189 (12)	Comparison group	

Table 3: Regression.

Parameter	Odds Ratio (OR)	p-value
Delay in presentation to hospital	12.9 (3.0–54.7)	0.001
Non-distal fracture	7.5 (2.4–23.8)	0.001
Age	1.13 (1.01–1.26)	0.04
Two-tailed p-value of <0.05 used to define statistical significance: Nagelkerke R-squared = 0.228 Hosmer–Lemeshow test p=0.93		

diatric forearm fractures, initial displacement and accuracy of the reduction are the primary risk factors for re-displacement.¹² A retrospective analysis of risk factors for re-displacement of diaphyseal fractures of the forearm after closed reduction by Yang¹⁰ similarly concluded that along with complete fracture, poorer reduction quality is a major risk factor in re-displacement.¹³ Clearly, ways of directly visualising the reduction at the time of initial manipulation would be advantageous to the treating physician. Fluoroscopic guidance in closed reduction under procedural sedation has been suggested as one possible improvement to decrease the risk of required re-manipulation under GA.⁶ Numerous studies have shown significant improvement in fracture alignment when assisted by fluoroscopy. Lee et al.⁷ reported that fluoroscopy use for ED reduction of paediatric forearm fractures reduced average angulation following closed reduction from 8°–6°. This same study found that this improvement in reduction quality translated into a decrease in repeat fracture displacement; only 2% of fractures reduced with fluoroscopic guidance needed subsequent surgical treatment compared to over 8% of fractures reduced without.⁷ An additional benefit in the use of fluoroscopic imaging systems in place of conventional X-ray is a reduction in radiation exposure to both patient and treating physician.^{2,7} Several studies have also suggested simple paediatric forearm fractures that are reduced and cast under fluoroscopy receive no clinical benefit from post-reduction radiographs, saving on both costs and the dose-dependent effects of cumulative radiation exposure.^{14–15}

In addition to fluoroscopic guidance, a variety of other interventions exist which may improve outcomes in closed reduction of forearm fractures. Ultrasound-guided closed reduction of forearm fractures has also been shown to have similar success rates.¹⁶ However, the time taken to evaluate the reduction is longer, is a user-dependent skill, and cannot be used once a cast is applied. Given the short action of common medications used in procedural sedation, fast and readily reproducible image guidance such as fluoroscopy may be advantageous over ultrasound.

Differences in the quality of plaster cast application and padding have also been suggested to alter the risk of re-displacement.¹⁷ Bhatia and Housden¹⁷ found that solely through improvement in plaster application skills, the rate of re-displacement of paediatric forearm fractures was reduced by 50%. This is relevant to our teaching hospital, where rotating trainee paediatric

orthopaedic surgeons result in a heterogeneity of clinical experience. With the aid of our experienced resident team of plaster nurses, all new doctors on rotation to our hospital are now formally trained in standardised forearm fracture reduction and casting.

Positioning during immobilisation has likewise been shown to influence the re-displacement of unstable forearm fractures in plaster. Immobilisation with the elbow extended may aid in maintaining reduction compared to casting with the elbow flexed and has been recommended by some authors.¹⁸ However, numerous patient impracticalities with being cast in this position, such as not being able to use a sling, preclude its utility.

This study identified several risk factors that predict the likelihood of unsuccessful reduction under procedural sedation. These were a non-distal fracture, an older child, and a delay in presentation to hospital. These independent risk factors provide the treating surgeon with a greater evidence base to draw from when discussing informed consent with a child's parents and when deciding which cases should go straight to theatre for manipulation under general anaesthesia in order to avoid unnecessary sedation and manipulation in the ED.

Our study does have some limitations. Firstly, a subset of patients presenting with forearm fractures lacked subsequent documentation from the ED concerning sedation/reduction. While this group represents a small proportion of our overall data set, complete records may have influenced our re-manipulation rates. Secondly, the study period incorporates a set rotation of trainee surgeons whose skill level may have differed from the rotation previous or subsequent and may have altered the success rate of initial manipulation. Thirdly, with casting quality related to reduction success as previously described, the inability to retrospectively grade casting quality for all individual closed reductions in this study is a limitation.

In conclusion, we found disappointingly high rates of re-manipulation of paediatric forearm fractures at our national children's hospital when initially reduced in the ED, without fluoroscopy. A simple method of improving this and avoiding unnecessary GA might be the introduction of fluoroscopy to the ED to evaluate and alter the reduction in real-time, especially in patients with suspected non-distal fractures (proximal or mid-shaft) of the radius and/or ulna.

COMPETING INTERESTS

Nil.

AUTHOR INFORMATION

Shaye Seefried BSc: Medicine, The University of Auckland Faculty of Medical and Health Sciences, New Zealand.

Kim Chin-Goh MBChB: Orthopaedics, Starship Children's Health, New Zealand.

Vahe Sahakian MBChB: Orthopaedic Department, Counties Manukau DHB, New Zealand.

Nicholas Lightfoot MBChB, FANZCA: Anaesthesia, Middlemore Hospital, New Zealand.

Matthew Boyle MBChB, FRACS: Paediatric Orthopaedics, Starship Children's Health, New Zealand.

CORRESPONDING AUTHOR

Shaye Seefried: Medicine, The University of Auckland Faculty of Medical and Health Sciences, 1404/363 Queen Street, Auckland Central, Auckland 1010 New Zealand. Ph: (+64) 021 198 6757. E: shaye.seefried@gmail.com

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