Distance of translation as a predictor of failure of fixation in paediatric supracondylar fractures

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ABSTRACT

INTRODUCTION This study investigates the influence of incomplete reduction of supracondylar fractures on the incidence of loss of reduction requiring reoperation

MATERIALS AND METHODS A review of 107 consecutive patients presenting with supracondylar fractures treated with closed reduction and Kirschner wire stabilisation, between January 2011 and March 2013, was conducted. The mean age was 5 years (range 10 months to 12 years). Pre-, intra- and postoperative radiographs were reviewed. All patients who had failure of fixation requiring revision surgery were identified.

RESULTS Ninety-nine patients had an initial adequate radiographic reduction. Of these, one (1%) required revision surgery. Eight patients had an initial incomplete radiographic reduction and, of these, six (75%) required revision surgery ($P < 0.0001$).

DISCUSSION Supracondylar fractures treated with closed reduction and K wire stabilisation require adequate intraoperative reduction. Incomplete reduction should not be accepted, as despite the bones potential to remodel, the risk of further loss of reduction is high, requiring reoperation.

KEYWORDS

Supracondylar – Fracture – Paediatric – Reoperation – Complications

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Supracondylar fractures of the humerus are common. They account for up to 17% of all paediatric fractures and approximately 70% of paediatric elbow fractures.^{1,2} Displaced supracondylar fractures are notoriously difficult to treat. Indeed, Gartland commented in 1959 about, 'the trepidation with which men, otherwise versed in the management of trauma, approach a fresh supracondylar fracture'.³ Together with the technical challenges posed by these fractures, a further reason for trepidation is the high incidence of complications.

Loss of reduction is one of the most common complications. Following manipulation and Kirschner wire (K-wire) stabilisation of Gartland II and Gartland III supracondylar fractures, the incidence of loss of reduction is reported to be up to 18%.⁴ Reoperation to manage loss of reduction can result in poorer elbow function, damage to the physis and significant negative psychological consequences to the patient and family.⁵ Risk factors for reoperation that have been investigated include K-wire configuration and fracture configuration.^{6,7} To date, no single factor has been found to be a reliable predictor of failure of fixation.^{7–15}

In our experience, when the initial reduction is inadequate there is a high incidence of further loss of reduction

requiring reoperation. The difficulty arises in objectively quantifying 'adequate' reduction. Certainly, inadequate reduction results in only small areas of the bone ends being opposed, so the construct is inherently unstable and further loss of reduction is likely. We hypothesise that inadequate reduction, rather than K-wire configuration or fracture pattern, is the overwhelming factor that results in a loss of reduction requiring reoperation.

The supracondylar region in the adult humerus, measures just 12mm in the AP diameter. A displacement of just 6 mm causes a marked reduction in the contact area of the bone ends (Fig 1). The typical age of a child with a supracondylar fracture is approximately 6 years.¹⁶ Although no studies have described how the anatomy of the supracondylar region changes with age, this region is proportionally narrow in the AP diameter in the paediatric population. Any displacement is likely to lead to proportionally less bone contact at the fracture site compared with an adult skeleton.

Paediatric supracondylar fractures do have a thick periosteum that is often intact and can be relied upon to reduce the fracture and maintain the fracture reduction. The periosteum can only be taut when the fracture is completely reduced. When a fracture is inadequately reduced, parts of

Figure 1

the periosteum will not be under tension. This further increases the inherent instability of the inadequately reduced fracture.

Malreduction in the coronal plane does not remodel, even with long-term follow up.^{17–19} Malreduction in the sagittal plane has good potential to remodel.^{17–19} The capacity to remodel, however, is unimportant if the position that is accepted intraoperatively cannot be maintained. This study investigates whether initial inadequate reduction of supracondylar fractures is a risk factor for loss of reduction requiring reoperation.

Materials and Methods

All patients with extension type supracondylar fractures who underwent manipulation under anaesthesia and K-wire stabilisation between January 2011 and March 2013 were identified. A consecutive series of patients was used to minimise the risk of selection bias. There were 107 fractures in 107 patients. The mean age was 5 years (range 10 months to 12 years); 58 patients were male and 49 patients were female.

Fractures were stabilised with either two lateral K-wires, two crossed K-wires or three K-wires. The wire configuration was at the treating surgeon's discretion. The lead surgeon was a consultant or specialty registrar (ST3 or above) in all cases. All the K-wires were 2mm in diameter and were left percutaneous. K-wires were all removed without anaesthesia in the outpatient clinic three weeks postoperatively. The patient was then placed into an above-elbow plaster until four weeks postoperatively when the plaster was removed.

The pre-, intra- and postoperative radiographs were interpreted by two independent observers. Preoperative radiographs were interpreted to classify fractures according to Garland's classification. The modified Gartland classification was not used because we considered the inter- and intraobserver variability to be too large.²

The AP and lateral intra- and postoperative radiographs were interpreted to measure completeness of reduction. On the lateral radiographs, the measurement used was the distance from the anterior humeral line to the centre of the capitellum (LATtrans; Figure 2). On the AP radiographs, the

measurement used was the distance from the lateral cortex of the proximal fragment to the lateral cortex of the distal fragment (APtrans; Figure 3). These measurements were calibrated using the K-wires. The sum of these two measurements was used to represent total amount of displacement and is referred to as the distance of translation (DOT):

$$(\text{DOT}) (\text{DOT}(\text{mm}) = \text{APtrans}(\text{mm}) + \text{LATtrans}(\text{mm})).$$

DOT increases with translation or malrotation in the coronal, sagittal or axial planes. This makes it a more complete measurement tool for assessing total displacement compared with other commonly used measurements such as Baumann's angle or the anterior humeral line, as these measurements only assess displacement in a single plane on a single radiograph. Baumann's angle varies between patients and with the angle that a radiograph is taken. It is impractical to reliably measure postoperatively in an above-elbow plaster and has a large inter- and intraobserver error.¹⁸ When used accurately, Baumann's angle can allow

Figure 2

Figure 3

an objective measurement of coronal angulation when a comparative radiograph is taken of the contralateral side. It has not been used for this study because of its impracticality, and it is not the standard practice in our institution to take intraoperative radiographs of the contralateral uninjured limb for comparative views.

An absolute numerical DOT was measured in preference to the proportion or fraction of translation to provide a practical simple measurement that can easily be reproduced in the operating theatre. This method of measurement is similar to the tip apex distance that is commonly used to assist in hip fracture fixation. The absolute DOT can be easily estimated as three times that diameter of the 2-mm K-wire used intraoperatively.

The initial reduction was considered adequate when the DOT was less than 6 mm and inadequate when the DOT was 6mm or greater. The DOT and wire configuration was recorded for all patients.

Patients that required revision surgery for loss of reduction within two weeks of the index operation were identified. The difference between the intraoperative DOT and the postoperative DOT was recorded.

Statistical analysis

Descriptive statistics using means and ranges were calculated for patient age, gender, fracture type, wire configuration and intraoperative DOT. Outcomes for loss of reduction requiring reoperation was examined with respect to fracture pattern, wire configuration and intraoperative DOT, using multivariate frequency distribution analysis.

The relationships were analysed using a Fischer’s exact test to allow for the small number of incomplete reductions and reoperations. The level of statistical significance used was $P < 0.05$.

Results

One hundred and seven patients underwent manipulation under anaesthesia and K-wire stabilisation of a supracondylar humeral fracture: 45 fractures were right sided and 62 fractures were left sided. Gartland II fractures occurred in 51 patients and Gartland III fractures occurred in 56 patients. There were no Gartland I fractures. Seven (6.5%) patients underwent a reoperation: there were no reoperations for Gartland II fractures and seven (12.5%) for Gartland III fractures.

Ninety-nine cases were found to have intraoperative adequate reduction, with a DOT less than 6 mm. One patient (1%) required a reoperation in this group. Eight fractures had an initial inadequate reduction and six (75%) had a loss of reduction requiring reoperation in this group ($P < 0.001$).

The mean intraoperative DOT of Gartland II fractures post-reduction was 1.4 mm (range 0–8.3 mm). One of the Gartland II fractures had an initial incomplete reduction with a DOT of 8.3mm. Postoperatively, the mean DOT was 1.3mm (range 0-8mm). The mean DOT of Gartland III fracture post-reduction was 3mm (range 0–18.3mm). Of the patients with Gartland III fractures that required a reoperation, the mean DOT intraoperatively was 10.9 mm (range 1.7–18.3mm). Postoperatively this increased to a mean DOT of 16 mm (range 8–20.1mm).

Table 1 shows the number of operations for each wire configuration. There was no statistically significant association between in K-wire configuration and reoperation ($P = 0.463$). The mean age of patients who had a loss of reduction was 4.3 years and of those who had no loss of reduction was 5.2 years.

Discussion

The reoperation rate in our series was 0% for Gartland II fractures, 12.5% for Gartland III fractures and 6.5% overall. This is comparable with other studies.^{12,14,18} Nevertheless, this reoperation rate is high and identifying the risk factors for reoperation is an important step in working to reduce the risk of reoperation.

Preoperative fracture classification used the Gartland classification. The modified Gartland classification was not used, as it has been shown to have a large inter- and intraobserver error.²⁰ The present study uses a pragmatic approach by which we mean that the treating surgeon decided upon

Table 1 Number of operations for each wire configuration						
	Wire configuration					
	Two crossed		Two lateral		Three	
	(n)	(%)	(n)	(%)	(n)	(%)
Operation	34	32	53	50	18	19
Reoperation	3	8.3	2	3.6	2	9.5

which fractures required surgery, the wire configuration and the number of wires used. An orthopaedic consultant specialising in paediatric surgery made all of these decisions.

There were no cases of loss of reduction requiring revision surgery in patients with Gartland II fractures despite one of them being incompletely reduced.

Complete reduction is obtained more commonly for Gartland II than for Gartland III fractures. The more commonly achieved complete reduction may provide better bony stability and may explain why loss of reduction is uncommon for these fractures. Another possibility may be that reoperation is rare because Gartland II fractures have an intact posterior bone hinge that provides inherent stability. This may be true regardless of whether or not an anatomical reduction is achieved. This may explain why the one patient in our study with an incomplete reduction did not displace further on close postoperative follow-up. We have demonstrated that Gartland II fractures treated with manipulation under anaesthesia and K-wire fixation have a low reoperation rate.

Our study shows that an incomplete reduction is a statistically significant risk factor for failure of fixation of Gartland III supracondylar fractures. The reoperation rate was 86% in this group of patients ($P < 0.0001$). This is much higher than the reoperation rates reported in existing studies.⁴ The reoperation rate for Gartland III fractures that are completely reduced in our study was 2%. This is lower than the reoperation rate reported by most studies.^{21,22}

Degree of displacement was recorded to ensure that reoperations were necessary owing to a loss of reduction and not because a fracture position that was previously considered acceptable was subsequently considered unacceptable. DOT was used to record degree of displacement and appears to be a reliable measure of loss of reduction as it was strongly associated with reoperation.

The focus of much of the literature on supracondylar fractures has been investigating wire configuration and fracture pattern. No consistent wire pattern producing the most stable fracture configuration has been found in studies investigating wiring technique and we believe this is because accuracy of reduction is the most important overriding factor.

Interestingly, given the wide variation in size of the paediatric population, a DOT of 6 mm remained a significant 'cut-off' in identifying stability of the supracondylar fracture. We speculate that this may be a consequence of the increased periosteal layer and shortened healing time in the younger patient group, thereby tolerating a proportionally greater DOT.

This study has limitations, as it is a single centre study. We look forward to other centres publishing their results, which should include DOT measurements and the incidence of reoperation. This study is prone to type-one error as the number of incompletely reduced Gartland III fractures was small. This is, however, unavoidable, as it is rare that an incomplete reduction is accepted intraoperatively. We have used statistical analysis tools (Fischer's exact test) to minimise this potential error.

The present study used a pragmatic approach and did not prescribe how fractures were treated. This is a potential source of error, as variables such as wire configuration and number of wires were not controlled. It would be impractical to control these factors without compromising the operating surgeon's judgment. The present study did not consider surgeon grade, complexity of surgery, duration of surgery or other factors separately for analysis, as this would produce a large number of small groups for statistical analysis which would increase the risk of type two error.

Studies should consider Gartland II and III fractures separately. Gartland II fractures are more likely to be reduced fully and have more inherent stability than Gartland III fractures. The necessity for K-wires to maintain the reduction is controversial for Gartland II fractures and is beyond the scope of this study.

Conclusion

Incomplete reduction of supracondylar fractures appears to be the largest single risk factor for reoperation. Incomplete reduction should not be accepted based upon the bones potential to remodel but complete anatomical reduction should be aimed for to prevent loss of reduction requiring reoperation.

The use of DOT is a simple, quick tool that can be used easily intraoperatively. It strongly predicts subsequent failure were it is greater than 6 mm. It allows the surgeon to confidently predict stability, regardless of wire configuration, and if adhered to should reduce the risk of loss of reduction requiring reoperation in supracondylar fractures.

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