Cast index in predicting outcome of proximal pediatric forearm fractures

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Abstract

Background: Many pediatric forearm fractures can be treated in plaster following closed reduction. The cast index (CI, a ratio of anteroposterior to lateral internal diameters of the cast at the fracture site) is a simple, reliable marker of quality of molding and a CI of >0.8 correlates with increased risk of redisplacement. Previously, CI has been applied to all forearm fractures. We hypothesize that an acceptable CI is more difficult to achieve and does not predict outcome in fractures of the proximal forearm.
Materials and Methods: Seventynine cases of pediatric forearm fractures initially treated by manipulation alone over a year were included in this retrospective radiographic analysis. The CI was calculated from the post manipulation radiographs. All fractures were divided as either proximal or distal half forearm based on the location of the radius fracture. Subsequent radiographs were reviewed to assess redisplacement and reoperation.
Results: The mean CI was 0.77. Remanipulation was required in five cases (6%), all distal half fractures – mean CI 0.79. CI was higher in proximal half forearm fractures (0.83 vs. 0.76, *P* = 0.006), nonetheless these fractures did not re-displace more than distal fractures.
Conclusion: Cast index is useful in predicting redisplacement of manipulated distal forearm fractures. We found that in proximal half forearm fractures it is difficult to achieve a CI of <0.8, but increased CI does not predict loss of position in these fractures. We therefore discourage the use of CI in proximal half forearm fractures.

Key words: *Cast index, closed reduction, forearm fracture, paediatric, redisplacement*
MeSH terms: *Forearm injuries, plaster casts, fractures, pediatrics*

Introduction

Forearm fractures are among the most common childhood fractures after clavicular fractures. Distal radius fractures are the most common limb fractures in childhood, accounting for 20–30% of all limb fractures.[1] Proximal forearm fractures account for 16–24% of all pediatric forearm fractures.[2] The majority of these fractures occur in children aged over 5 years, usually sustained by direct trauma to the upper limb. The incidence of fractures peaks in girls aged 9–12 years and boys aged 12–15 years at the time of the pubertal growth spurt.[3,4]

Closed fractures of the forearm in children are often treated with closed reduction and immobilization in a well fitting plaster cast and achieve a satisfactory outcome in a majority of patients. Fixation is generally reserved for unstable fractures, failed reduction and complications such as open fractures or those associated with compartment syndrome. Distal radius fractures in children heal quickly and mild to moderate degrees of displacement can be accepted as bone remodeling during early childhood has the potential to correct deformities.[4] However, in children aged over 9 years a reduced potential for remodeling means that lesser degrees of deformity are acceptable.[4] Redisplacement of these fractures remains a complication. The rates of redisplacement as high as 25% have been quoted and several authors advocate surgical fixing of high risk forearm fractures.[3,5]

Previous studies have consistently shown that the most important risk factor for redisplacement of a forearm fracture is the initial displacement of the fracture.[3,6,7] Other factors that are important in redisplacement include distance of the fracture from the physis, obliquity of the fracture,

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inadequate initial closed reduction, poor cast molding and resolution of edema whilst in the cast.[8]

An important modifiable risk factor for fracture redisplacement is the quality of casting, which can be measured objectively by the use of casting indices. The first and simplest index to be described is the cast index (CI), described by Chess *et al.*[9] It is calculated by measuring the internal anteroposterior (AP) diameter of the cast (excluding padding) at the level of the fracture and dividing it by the internal lateral diameter of the cast (excluding padding). Both measurements are made using the first proper radiograph taken after closed reduction and the calculation results in a numerical ratio. Chess *et al.* initially described an ideal CI to be 0.7 at the distal radius based on anthropomorphic studies, but more recent studies have shown a CI of over 0.8–0.84 carries a significant risk of redisplacement that is, a poorly molded cast (as seen on the lateral radiograph view) is more likely to allow the fracture to displace.[10,11] Both of these studies included patients with radius with or without ulnar fractures. Debnath *et al.*[11] included patients with proximal and distal forearm fractures, whereas Bhatia and Housden[10] focused on distal forearm fractures.

Due to the greater amount of soft tissue present in the proximal forearm as compared to the distal forearm, an ideal CI of <0.8 is more difficult to achieve for proximal forearm fractures following closed reduction. In other words, as the proximal forearm is more circular than elliptical in axial section than the distal forearm, it is more difficult to mold an elliptical cast at the proximal forearm, although this may not necessarily result in a loss of reduction. Traditionally, CI has been used for distal forearm fractures but there is little evidence to determine how effective CI is at judging the quality of cast molding in proximal forearm fractures. We hypothesize that an ideal CI of <0.8 is more difficult to achieve in the proximal forearm but that this does not necessarily adversely affect the risk of fracture redisplacement.

MATERIALS AND METHODS

All consecutive patients under the age of 16 years that underwent closed reduction of radius (with or without ulna) fractures under general anesthetic over a 1-year period (August 2010 to July 2011) were identified retrospectively. All fractures were manipulated to anatomical position under X-ray image intensification before the application of an above elbow plaster cast using plaster of Paris. The elbow was flexed to 90° and the forearm kept in a neutral position. A uniform layer of padding was applied throughout with a 50% overlap between successive wraps.

In all cases, the manipulation and casting was done by orthopedic consultants and registrars. All of these cases were treated and followed up at out institute.

All patients were initially followed up in clinic 1-week after manipulation and then followed up every 1–2 weeks until fracture union. Functional outcomes such as final range of movements were not studied. Fractures that redisplaced significantly were remanipulated or fixed internally.

Data were collected from the hospital's online radiograph database and the initial, intra operative and all followup radiographs were reviewed. All images were reviewed by an orthopedic trainee and the CI was calculated using the PACS software (Agfa, Mortsel, Belgium) to obtain internal cast measurements. Proximal and distal fracture fragment lengths were also calculated using the same software. The first ten images were also reviewed by another orthopedic trainee and the same measurements were made and compared with those made by observer one to calculate interobserver error [Table 1]. The initial observer repeated the measurements of CI 12 months after the initial measurements to calculate intraobserver error. Other data collected included hospital number, gender, age, date of procedure and fracture angulation in all radiographs. Exclusion criteria included cases where radiograph series were incomplete, e.g. patients followed up elsewhere.

Cast index was calculated and expressed as a ratio of the internal cast AP and lateral diameters (excluding padding, as described by Chess *et al.*) in the first postreduction radiograph [Figure 1]. Both measurements were made at the level of the radius fracture site. This is a validated index and an ideal CI was taken to be 0.8 or less as evidenced in previous studies.[10,11] All fractures were then

Table 1: Inter and intra observer errors

Initial CI measurement (observer 1)	Intra observer measurements (observer 2)	Interobserver measurements 12 months later (observer 1)
0.62	0.63	0.63
0.69	0.69	0.67
0.78	0.77	0.81
1.00	1.00	0.98
0.89	0.85	0.84
0.83	0.78	0.79
0.83	0.8	0.83
0.58	0.57	0.59
0.66	0.71	0.69
0.78	0.77	0.75
Mean error % (SD %)	2.76 (2.44)	3.09 (1.75)
Correlation value*	0.978	0.979

*Pearson's product-moment correlation coefficient. SD=Standard deviation, CI=Cast index
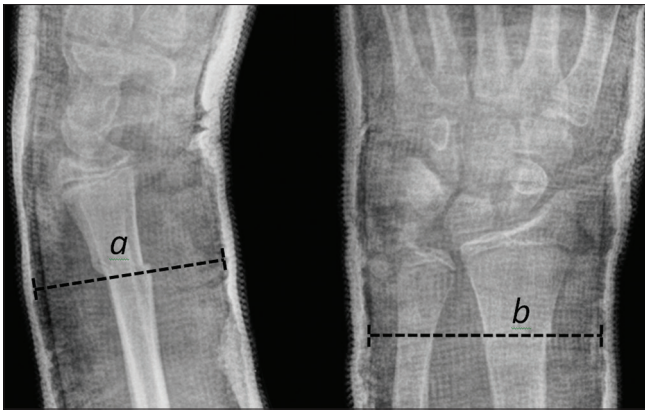
Figure 1: X-ray of forearm with wrist joint lateral and anteroposterior views showing calculation of cast index (CI). CI = *a/b*, *a* = Internal anteroposterior diameter of cast excluding padding, *b* = Internal mediolateral diameter of cast excluding padding

Figure 2: X-ray of forearm with wrist and elbow joint lateral view showing calculation of fracture position. Fracture position = $x/(x + y)$, x = Length of distal fragment, y = Length of proximal fragment

categorized as either proximal or distal by dividing the length of the distal radius fragment by the total length of both fragments (i.e., the length of the entire radius). The resultant ratio gave a numerical value ranging from 0 (distal) to 1 (proximal) [Figure 2]. Fractures with a ratio of <0.5 were grouped as distal and fractures with a ratio of >0.5 were grouped as proximal. These measurements were made from the proximal radioulnar joint proximally to the wrist joint distally.

Data were analyzed using Microsoft Excel 2010 software (Redmond, WA 98052-7329, USA). The primary variable of interest was the fracture position and the main outcomes were CI and remanipulation due to redisplacement. Paired, two-tailed Student's *t*-tests were performed to analyze statistical differences between means in the groups of continuous data. For categorical data, the Chi-square or Fisher Exact tests were used.

RESULTS

Seventy-nine cases (47 males and 32 females) between ages 2 and 15 years (mean age 8.6 years) were included in the study after exclusions. Thirteen children had incomplete image series (either of the initial reduction or subsequent X-rays) and two children were followed up elsewhere and were therefore excluded.

The mean CI was 0.77 (range 0.56–1.00). The mean fracture position was 0.26 (range 0.03–0.71) that is, the distal radius fragment was just over a quarter of the total bone length. Five out of the 79 cases were subsequently remanipulated and/or fixed percutaneously due to redisplacement.

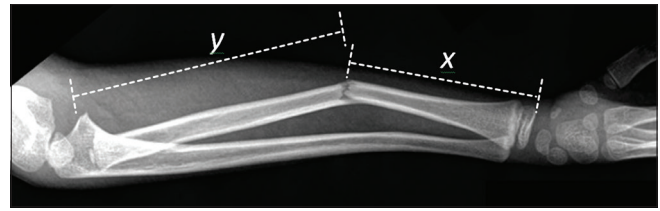All patients were followed up a week after manipulation and then every 1–2 weeks until union. Median followup time was 2 weeks and maximum time to union was 11 weeks after manipulation.

The Pearson's product-moment correlation coefficient was used to assess correlation between the repeat measurements and the original measurements. Both analyses showed that inter and intraobserver agreements were very high and that CI could be reproduced reliably [Table 1].

Of the five patients that required reoperation, the average redisplacement was 18.4° (range 7–26°), whereas in the non reoperated group, the average final angulation was 4.7° (range 0–18°). Displacement occurred after 2–3 weeks in all five cases. All of the reoperated fractures were distal half (position 0.09–0.40) and there were no data to suggest any causal link between fracture position and CI and remanipulation risk. Between the two groups there were not any significant differences between the gender, age and incidence of ulna fracture. The initial displacement of the fractures was also not significantly different [Table 2].

Table 3 analyses CI and fracture position when patients are grouped by their age (1–5 years, 6–10 years and 10–15 years). The only significant difference is that older children (10–15 years) are more likely to have more distal fractures forearm fractures compared to younger age groups. There are no significant differences in CI when grouped by age.

Table 4 summarizes the results when fractures are grouped as either proximal or distal half of the forearm. There is a significant difference in the two sets of CI between proximal half and distal half forearm fractures. Patients with proximal half forearm fractures were older than those with distal half fractures and were more likely to have a concurrent ulna fracture. However, the fact that proximal half forearm fractures are more likely to have a concurrent ulna fracture did not result in more redisplacement in this group. In the same two groups, there is no significant difference between reangulation of fractures, other fracture characteristics or patient demographics.

Table 2: Comparison between reoperated and non reoperated fractures

	Non reoperated	Reoperated	P
Number	74	5	
Males/females	44/30	3/2	NS
Mean age (in years)	8.6	7.8	NS
Mean fracture position (0-distal, 1-proximal)	0.27	0.20	NS
Initial mean displacement (in degrees)	20.6	26.8	NS
Manipulation angle (in degrees)	1.5	0.0	NS
Mean redisplacement (in degrees)	4.7	18.4	<0.001
Concurrent ulna fracture	34	3	NS
Mean CI	0.77	0.79	NS

NS=Not significant, CI=Cast index

Table 3: Analysis of CI and fracture position limited by age

	1-5 years	6-10 years	11-15 years
Number	22	31	26
Males/females	10/12 (NS)	18/13 (NS)	19/7 (NS)
Mean fracture (0-distal, 1-proximal)	0.37 (NS)	0.31 (NS)	0.12 ($P<0.05$)
Mean CI	0.79 (NS)	0.76 (NS)	0.77 (NS)

NS=Not significant, CI=Cast index

Table 4: Summary of results

	Fracture position <0.5 (distal forearm)	Fracture position >0.5 (proximal forearm)	P
Number	66	13	
Males/females	41/25	6/7	NS
Mean age (in years)	6.54 (2-10)	9.00 (2-15)	0.032
Initial mean displacement (in degrees)	20.4	24.2	NS
Mean CI	0.76	0.83	0.006
Mean redisplacement (in degrees)	6.0	3.46	NS
Ulna fracture	25	12	<0.001
Reoperated fractures	5	0	

NS=Not significant, CI=Cast index

DISCUSSION

A risk of closed reduction of forearm fractures is fracture redisplacement. Closed reduction and further stabilization of forearm fractures with percutaneous K-wires or elastic nails are acceptable methods for fixation of fractures at high risk of displacement.[5] In our hospital, K-wire fixation/elastic nail fixation is reserved for fractures that are unstable after manipulation.

The position of the elbow during casting was previously thought to be important in maintaining immobilization of the fracture site. However, more recent research has shown that it does not affect the final outcome. The same has been shown for positioning the wrist in pronation/neutral/ supination.[12,13] Despite this, uniform cast molding and positioning techniques were used throughout this study.

Significant risk factors for loss of reduction following manipulation of forearm fractures can be divided into fracture related, surgeon related and patient related.[8] The most important of these factors are the initial displacement of the fracture, near anatomical reduction and a close fitting cast. Previous studies have also correlated an increased risk of redisplacement in combined radius and ulna fractures; however, our results did not show this.[13]

The most important factors for adequate application of a plaster cast are thin and uniform padding and good molding that achieves adequate three-point fixation.[14] Numerous previous studies have validated the use of cast indices as predictors of redisplacement, both in distal radius fractures and both bone fractures.[8] A previous study also found that teaching the use of CI and padding index to orthopedic surgeons significantly improved their accuracy of assessing the risk of redisplacement of forearm (radius fracture with or without ulna fracture, proximal and distal) fractures in children.[15] Clearly, these indices need to be used in association with patient and fracture characteristics in clinical assessment.

Previous studies have used CI for proximal and distal forearm fractures, not just limited to distal forearm fractures.[10] However, previous authors have not studied whether it is easier or more difficult to achieve an ideal CI in more proximal forearm fractures as compared to distal fractures. We therefore analyzed our data to examine the difference in cast indices and displacement as forearm fractures become more proximal.

Our data suggest that for proximal forearm fractures, it is more difficult to achieve a CI of <0.8. Nevertheless, this did not cause significant loss of reduction and thus these fractures did not have to be re-manipulated [Table 4]. This correlates with our hypothesis that an acceptable CI is more difficult to achieve in proximal half forearm fractures. There is more soft tissue present in the proximal forearm compared with the distal forearm and therefore a cast that is more elliptical in cross section is less likely. However, a "less elliptical" proximal forearm cast (i.e., one with a higher CI) may still provide adequate three point fixation.

An assumption that has been made in this study is that a higher CI in the proximal forearm is due to increased soft tissue mass and not due to other factors such as inadequate molding in the proximal forearm. The mean cast indices of the two groups of patients (proximal half and distal half

forearm fractures) are significantly different. However, none of the proximal fractures were reoperated on. Furthermore, Table 4 demonstrates that the two sets of fractures are not significantly different demographically or in the type of fracture. It may be argued that the difference in cast indices between the two groups is due to inadequate molding of the proximal forearm casts, however, as these fractures did not significantly displace we feel that proper molding techniques were applied throughout. It is therefore the shape of the proximal forearm that affects the CI.

Inter and intra observer errors were low suggesting that calculation of the CI from radiographs can be reproduced reliably by different observers or after an amount of time has elapsed. We also realize that our number of reoperated fractures is small (5/79 fractures) and that gives a statistically weaker calculation. However, it still stands that a low CI is difficult to achieve in the proximal forearm and that none of the proximal fractures had to be re-operated despite a higher CI.

Cast index remains a useful clinical tool to rapidly assess cast molding following closed reduction of distal forearm fractures and to predict redisplacement of distal forearm fractures as highlighted in multiple previous studies.[9-11,15] Its use in proximal half forearm fractures should be discouraged, however, as the shape of the proximal forearm makes it difficult to achieve an acceptable CI of <0.8 despite adequate molding and a higher CI in the proximal forearm does not predict the risk of redisplacement or re-manipulation.

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