Risk factors for unsuccessful reduction of chronic Monteggia fractures in children treated surgically

a review of 209 cases

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Aims

To investigate the risk factors for unsuccessful radial head reduction (RHR) in children with chronic Monteggia fractures (CMFs) treated surgically.

Methods

A total of 209 children (mean age 6.84 years (SD 2.87)), who underwent surgical treatment for CMFs between March 2015 and March 2023 at six institutions, were retrospectively reviewed. Assessed risk factors included age, sex, laterality, dislocation direction and distance, preoperative proximal radial metaphysis width, time from injury to surgery, reduction method, annular ligament reconstruction, radiocapitellar joint fixation, ulnar osteotomy, site of ulnar osteotomy, preoperative and postoperative ulnar angulation, ulnar fixation method, progressive ulnar distraction, and postoperative cast immobilization. Independent-samples *t*-test, chi-squared test, and logistic regression analysis were used to identify the risk factors associated with unsuccessful RHR.

Results

Redislocation occurred during surgery in 48 patients (23%), and during follow-up in 44 (21.1%). The mean follow-up of patients with successful RHR was 13.25 months (6 to 78). According to the univariable analysis, time from injury to surgery (p = 0.002) and preoperative dislocation distance (p = 0.042) were identified as potential risk factors for unsuccessful RHR. However, only time from injury to surgery (p = 0.007) was confirmed as a risk factor by logistic regression analysis. Receiver operating characteristic curve analysis and chi-squared test confirmed that a

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time from injury to surgery greater than 1.75 months increased the rate of unsuccessful RHR above the cutoff (p = 0.002).

Conclusion

Time from injury to surgery is the primary independent risk factor for unsuccessful RHR in surgically treated children with CMFs, particularly in those with a time from injury to surgery of more than 1.75 months. No other factors were found to influence the incidence of unsuccessful RHR. Surgical reduction of paediatric CMFs should be performed within the first two months of injury whenever possible.

Take home message

- Time from injury to surgery is the primary independent risk factor for unsuccessful radial head reduction (RHR) in surgically treated children with chronic Monteggia fractures (CMFs), particularly in those with a time from injury to surgery of more than 1.75 months.
- No other factors influence the incidence of unsuccessful RHR; surgical reduction of CMFs should be performed within the first two months of injury whenever possible.

Introduction

Monteggia fractures are rare in children, accounting for less than 1% of all paediatric fractures.[1,2] The primary diagnosis is missed in up to 50% of cases,[3] leading to chronic Monteggia fractures (CMFs) when the interval from injury to diagnosis exceeds four weeks.[3-5] A chronically dislocated radial head can lead to severe complications such as pain, limited range of motion, and deformity.[1,2] Stable anatomical reduction of the radial head remains difficult to achieve despite multiple treatments, and is considered a challenging objective in patients with CMFs.[6-14]

Previous studies have identified several risk factors related to unsuccessful radial head reduction (RHR) in patients with CMFs. The inconsistent findings and the limited risk factors analyzed, such as age and time from injury to surgery, may be attributed to inadequate statistical power resulting from small sample sizes in studies with fewer than 70 patients.[6-14] Other potential factors that could contribute to unsuccessful RHR, including the distance between the chronically dislocated radial head and its anatomical position, as well as the level of ulnar osteotomy, were not adequately examined. Additionally, the use of single-factor analysis rather than multiple risk factor analysis diminished the accuracy of conclusions. Furthermore, previous reports have primarily concentrated on identifying risk factors linked with unsuccessful RHR for different treatment techniques, potentially introducing sample selection bias. Thus, the most effective technique and the applicability of the conclusions to patients who have undergone these treatments are unclear.[6-14] Although meta-analysis can enhance the sample size and offer a more comprehensive data analysis, it is crucial to be aware that the heterogeneity of previous reports can potentially undermine the conclusions.[15]

The purpose of this multicentre retrospective study was to evaluate the radiological outcomes of surgically treated CMFs in children and to identify risk factors for unsuccessful RHR using single-factor and multiple regression analyses. Our hypothesis was that multiple risk factors, including time from injury to surgical reduction, could be identified as risk factors for unsuccessful RHR.

Methods

After obtaining Institutional Review Board approval (no. 2023132), we performed a retrospective analysis of the medical records of 312 consecutive patients who underwent surgical treatment for paediatric Monteggia fracture dislocation with an interval from injury to diagnosis of more than two weeks between March 2015 and March 2023 at six institutions.

The study included participants who met the following criteria: 1) more than four weeks from injury to diagnosis of unilateral CMF;[3-5] 2) age at the time of reduction being less than 17 years; 3) complete clinical and radiological data, including full-length anteroposterior (AP) and lateral radiographs of the forearm; and 4) follow-up more than six months in those with a successful RHR.

The study's exclusion criteria included patients with concomitant metabolic bone disease, osteoporosis, or a pathological fracture, as well as those with congenital dislocation of the radial head. Additionally, patients who had incomplete clinical or radiological data or non-standard radiographs, and those with a follow-up period < six months, were excluded from the study.

A total of 209/312 patients (139 males and 70 females) with CMFs (67%) were included in the study (124 right and 85 left). Overall, 103/312 of elbows (33%) were excluded from the analysis due to pathological fracture diagnosis (n = 1; 0.3%), congenital dislocation of the radial head (n = 1; 0.3%), surgical reduction less than four weeks (n = 28; 9%), follow-up period of < six months (n = 55; 17.6%), and incomplete clinical and radiological data and non-standard radiographs (n = 18; 5.8%).

Surgical treatment

Surgical treatment decisions were based primarily on surgeon experience and preference, and intraoperative stability of the radial head. A total of 174 patients (83.3%) underwent open reduction (OR) of the radial head through an anterolateral approach, while the remaining 35 (16.7%) underwent closed reduction (CR) of the radial head. Among the patients treated with OR, dislocated radial heads were reduced without attempting CR in 78 cases (44.8%), while in the remaining 96 cases (55.2%), OR was performed after unsuccessful CR of the radial head. All patients (16.7%) who underwent radial head CR also underwent ulnar osteotomy (UO), and UO was also performed in 157/174 patients (75.1%) who underwent radial head OR.

UO was performed through a posterior ulnar approach or Boyd posterolateral elbow approach.[6] Plate and screws were used to fix the osteotomy site in 74 patients (35.4%), monolateral external fixator (Libeier, China) was used in 77 (36.8%), and Kirschner (K-)wires were used in the remaining 41 (19.6%). The monolateral external fixator was removed once the ulnar osteotomy site achieved radiological union. Additional

Fig. 1
Direction of radial head dislocation according to anteroposterior and lateral radiographs: a) anterolateral, b) anterior, c) lateral, d) anteromedial, and e) posterolateral.

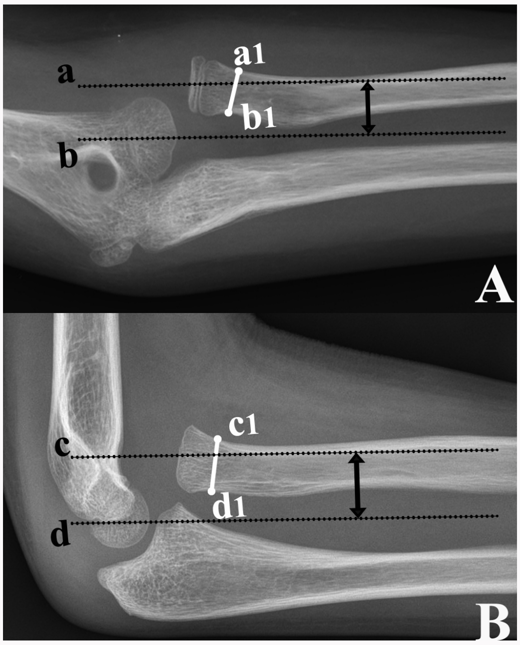

Fig. 2
Radial head elevation, measured on anteroposterior (A) and lateral (B) radiographs, is expressed as the ratio of the distance between the lines passing through the centre of the proximal radial metaphysis (a and c) and the centre of the humeral capitellum (b and d) to that of the narrowest width of the radial neck (a1 to b1 and c1 to d1).

procedures included annular ligament reconstruction (ALR), radiocapitellar joint fixation (RCJF), and cast immobilization.

Annular ligament reconstruction
ALR was performed on 146/174 patients (69.9%) who underwent OR of the radial head with either forearm fascia or triceps fascia circumferentially around the radial neck.

Radiocapitellar joint fixation
In addition to surgeon preference and experience, RCJF was also performed when the radial head did not achieve adequate stability during surgery. RCJF was achieved by passing a K-wire through the capitellum to the proximal part of the radius via the posterior elbow. Of the 108 elbows (51.7%) with RCJF, five (2.4%) underwent radial head CR, and 103/174 (49.3%) underwent radial head OR; the K-wire was removed four to five weeks after the index procedure.

Cast immobilization
In addition to surgeon preference and experience, cast immobilization was used to improve joint stability. Following the RHR, 168 elbows (80.4%) were immobilized using a long arm cast (4 to 6 weeks), while the remaining 41 elbows (19.6%) were treated without cast immobilization. Cast immobilization was performed in 12/35 patients treated by CR of the radial head (5.7%) and in 156/174 patients treated by OR of the radial head (74.6%).

Outcome of surgery
Immediate RHR was attempted in 191/209 patients (91.4%). Specifically, it was obtained in 20/35 patients (9.6%) treated by CR of the radial head, and in 171/174 patients (81.8%) treated by OR of the radial head.

In the remaining 18 patients (8.6%), monolateral external fixation was used to achieve gradual RHR at a rate of 1 mm/day of ulnar distraction. RHR was achieved in all

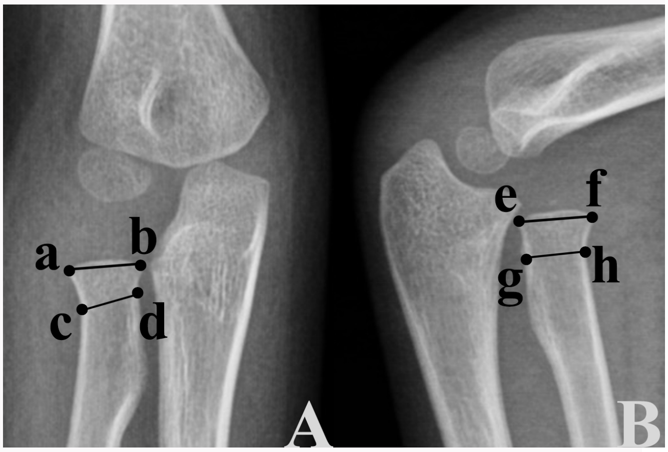

Fig. 3

The width of the proximal radial metaphysis measured on anteroposterior (A) and lateral (B) radiographs, is the ratio of the width (a to b, and e to f) of the proximal radial metaphysis to the width (c to d, and g to h) of the narrowest part of the radial neck.

these patients treated with gradual ulnar distraction, with 3/18 (1.4%) requiring another ALR, 2/18 (1.0%) undergoing another RCJF, and 3/18 (1.4%) requiring another cast immobilization. Monolateral external fixator removal was performed when RHR was achieved.

Radiological evaluation

Pre-surgery radiographs of the forearm were used to assess the direction of radial head dislocation, the elevation of the dislocated radial head (ELEV-RH), the width of the proximal radial metaphysis (WPRM), and the angulation of the ulnar (AU) before surgery. Postoperative AU, the site of UO (S-UO), and the quality of RHR were determined using radiographs taken on the first or second day following the procedure. All measurements were conducted via the Picture Archiving and Communication Systems (PACS; GE Healthcare, USA).

Two paediatric orthopedists (WT, YL) independently measured these parameters. Radiological measurements were repeated at two-week intervals and mean values were used for statistical analysis.

Direction of radial head dislocation

Due to the inapplicability of the Bado classification in paediatric CMFs,[16] the direction of radial head dislocation was determined by analyzing preoperative AP and lateral forearm radiographs. The observed directions of radial head dislocation were anterior (44.5%; 93 elbows), anterolateral (32.5%; 68 elbows), anteromedial (13.9%; 29 elbows), lateral (6.2%; 13 elbows), and posterolateral (2.9%; six elbows) (Figure 1).

Elevation of the dislocated radial head

Preoperative AP and lateral radiographs were used to quantify the ELEV-RH by measuring the distance between the centre of the dislocated radial head and the centre of the humeral capitellum. To reduce individual differences, the ELEV-RH was expressed as the ratio of the distance between the line passing through the centre of the humeral capitellum and that of the proximal radial metaphysis to the narrowest width of the radial neck, which was commonly used as the reference in

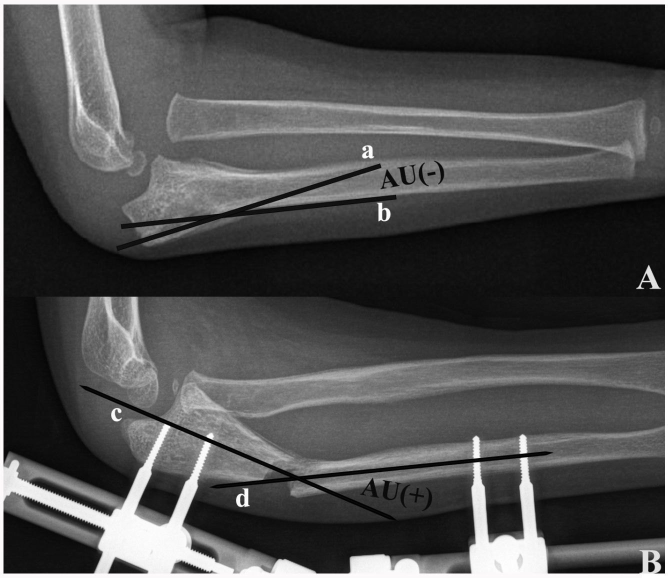

Fig. 4

Preoperative (A) and postoperative (B) angulation of the ulnar (AU) measured on lateral radiographs. AU is the angle between the axis of the proximal (lines a and c) and distal portions of the ulna (lines b and d). It is expressed as zero when the two axes are parallel, negative when the apex of the intersecting axes is inferior (forming an inverted V-shape), and positive when superior (forming a V-shape).

the previous report.[17] The same measurement was performed on the AP and lateral views, and the mean value was used for statistical analysis (Figure 2). The larger ELEV-RH shows the dislocated radial head further distant from the anatomical position.

Width of the proximal radial metaphysis

According to the previous study reported by Kim et al,[17] measurements of the width of the proximal radial metaphysis on preoperative AP and lateral radiographs were used to calculate the mean WPRM; in particular, WPRM is expressed as the ratio between the width of the proximal radial metaphysis and the width of the narrowest part of the radial neck (Figure 3). The larger WPRM reflects the excessive enlargement of radial head in relation to the radial neck.

Ulnar angulation

Furthermore, lateral radiographs were used to measure the angle between the axis of the proximal and distal parts of the ulna (AU). It is expressed as zero (anatomical) when the two axes are parallel, negative when the apex of the intersecting axes is inferior (forming an inverted V-shape), and positive when superior (forming a V-shape) (Figure 4). The larger absolute AU exhibits the more severe deformity of ulnar.

Site of ulnar osteotomy

The ratio of the length of the proximal ulna to the total length of the ulnar bone was used to express the S-UO (Figure 5). The larger S-UO reflects the osteotomy site more distal to the elbow.

Quality of reduction

The radiocapitellar joint congruity was used to assess the quality of RHR based on AP and lateral forearm radiographs.

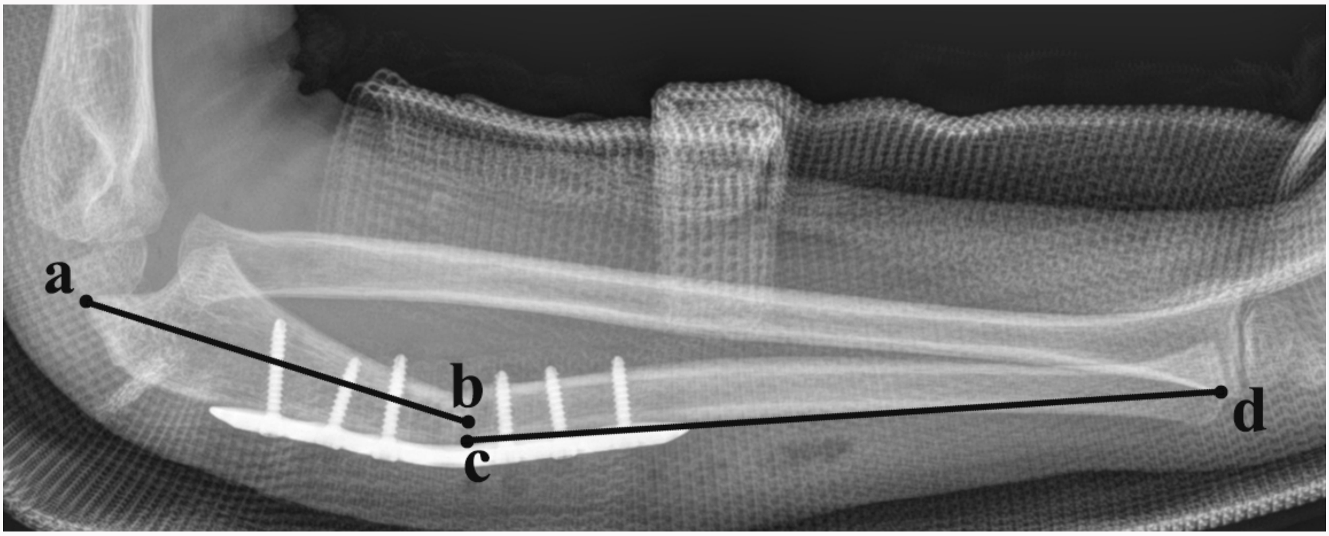

Fig. 5
The ratio of proximal ulna length (a to b) to total ulnar length (a to b, plus c to d) is used as the ulna osteotomy site.

An anatomical RHR is achieved when the axis of the radial neck passes through the middle third of the capitellum in both AP and lateral views. In contrast, unsuccessful RHR is defined as: 1) inability to achieve anatomical reduction during surgery or radial head dislocation visible on radiographs taken on the first or second postoperative day, except for patients treated with gradual reduction with external fixation; 2) redislocation of the radial head during the postoperative follow-up with an interval of two weeks; or 3) redislocation of the radial head after removal of external fixation in patients treated with gradual reduction with a monolateral external fixator or after removal of the K-wire in patients treated with RCJF.

Statistical analysis

Statistical analysis was conducted using SPSS v. 23.0 (IBM, USA). Data were presented as numerical variables, frequencies, and percentages with means and SDs. Independent-samples *t*-tests, chi-squared tests, and logistic regression analysis were used to identify risk factors for unsuccessful RHR. Independent-samples *t*-tests and chi-squared tests were first performed to screen for positive risk factors, and then logistic regression analysis was performed to exclude false-positive factors. The current statistical method was similar to the Bonferroni method, which was not used in the current study.

If a numerical variable was identified as a risk factor, we used receiver operating characteristic (ROC) analysis and the chi-squared test to determine the cutoff value for an increased rate of reduction failure. Two-way random intraclass correlation coefficient (ICC) models were performed to evaluate the agreement of the measurements for all the radiological parameters including preoperative WPRM, ELEV-RH, S-UO, and preoperative and postoperative AU. Agreement was defined as follows: 0 to 0.4, fair agreement; 0.41 to 0.60, moderate agreement; 0.61 to 0.80, substantial agreement; and 0.81 to 1.00, excellent agreement. The significance level was set at $p < 0.05$.

Results

A total of 209 patients were included in the study, with a mean age of 6.84 years (SD 2.87 (1 to 17)). The mean interval between injury and surgery was 14.08 months (1 to 132). The mean follow-up for those without an unsuccessful RHR was 13.25 months (6 to 78). Table I shows the demographic information (Table I).

Evaluation of preoperative WPRM, ELEV-RH, S-UO, and preoperative and postoperative AU, showed substantial to excellent agreement, with the mean ICCs of 0.869, 0.905, 0.891, 0.953, and 0.949, respectively. The mean preoperative WPRM, ELEV-RH, S-UO, and preoperative and postoperative AU, were 1.52 (SD 0.2; 1.08 to 2.33), 1.35 (SD 0.42; 0.11 to 2.7), 0.26 (SD 0.11; 0 to 0.59), -2.59 (SD 6.86; -29.80 to 28), and 11.09 (SD 9.58; -17.40 to 50), respectively.

The unsuccessful RHR rate was 44%; it occurred during surgery in 48 patients (23%) and during follow-up in 44 (21.1%) who had successful intraoperative RHR according to intraoperative reports and radiographs taken on the first or second postoperative day. Of the 48 patients (23%) with unsuccessful intraoperative RHR, six (2.9%) were identified by intraoperative reports and the remaining 42 (20.1%) were detected on the radiographs taken on the first or second postoperative day.

Results of single factor analysis

According to the results of the independent-samples *t*-test, patients with unsuccessful RHR had a significantly longer mean time from injury to surgery than those without ($t = 3.088$; $p = 0.002$). Additionally, there was a notable difference in preoperative ELEV-RH, with patients who experienced unsuccessful RHR having higher measurement values in comparison to those who did not ($t = 2.016$; $p = 0.045$). Chi-squared test results indicated that patients treated with UO and external fixation had a significantly higher rate of unsuccessful RHR compared to those without UO or with K-wire or screws and plate fixation following UO ($\chi^2 = 7.659$; $p = 0.053$). In addition, among 174 patients (83.3%) treated with OR, the rate of unsuccessful RHR (42.7%) in patients

Table I. Analysis of unsuccessful radial head reduction based on patient demographics.

Variable	No	Yes	t-value/χ^2	p-value
Total, n (%)	117 (56)	92 (44)	-	-
Mean age, yrs (SD)	6.58 (2.68)	7.18 (3.08)	1.494	0.137*
Sex, n (%)				
Male	74 (53.2)	65 (46.8)		
Female	43 (61.4)	27 (38.6)	1.268	0.302†
Laterality, n (%)				
Right	72 (58.1)	52 (41.9)		
Left	45 (52.9)	40 (47.1)	0.537	0.481†
Direction of dislocation, n (%)				
Anterolateral	35 (51.5)	33 (48.5)		
Anterior	53 (57.0)	40 (43.0)		
Lateral	9 (69.2)	4 (30.8)		
Anteromedial	15 (51.7)	14 (48.3)		
Posterolateral	5 (83.3)	1 (16.7)	3.561	0.476†
Mean ELEV-RH (SD)	1.30 (0.45)	1.41 (0.38)	2.045	0.042*
Mean WPRM (SD)	1.51 (0.20)	1.53 (0.21)	0.918	0.360*
Mean time from injury to surgery, mnths (SD)	9.70 (16.42)	19.65 (27.25)	3.088	0.002*
Reduction method, n (%)				
Closed reduction	18 (51.4)	17 (48.6)		
Open reduction	99 (56.9)	75 (43.1)	0.354	0.580†
ALR, n (%)				
No	32 (50.8)	31 (49.2)		
Yes	85 (58.2)	61 (41.8)	0.985	0.363†
No	54 (53.5)	47 (46.5)		
Yes	63 (58.3)	45 (41.7)	0.502	0.489†
Ulnar osteotomy, n (%)				
No	9 (52.9)	8 (47.1)		
Yes	108 (56.3)	84 (43.8)	0.069	0.804†
Mean site of ulnar osteotomy (SD)	0.26 (0.11)	0.26 (0.11)	0.251	0.802*
Mean preoperative AU, degrees (SD)	-2.33 (7.74)	-2.91 (5.58)	0.604	0.547*
Mean postoperative AU, degrees (SD)	11.28 (9.76)	10.85 (9.39)	0.319	0.750*
Fixation method of ulnar, n (%)				
Without fixation	9 (52.9)	8 (47.1)		
Screws and plate fixation	42 (56.8)	32 (43.2)		
External fixation	36 (46.8)	41 (53.2)		
Kirschner wire fixation	30 (73.2)	11 (26.8)	7.659	0.053†
Progressive ulnar distraction, n (%)				
No	108 (56.5)	83 (43.5)		
Yes	9 (50.0)	9 (50.0)	0.286	0.626†
Postoperative cast immobilization, n (%)				
No	20 (48.8)	21 (51.2)		
Yes	97; 57.7%	71 (42.3)	1.073	0.381†

*Independent-samples *t*-test.
†Chi-squared test.
ALR, annular ligament reconstruction; AU, angulation of ulnar; ELEV-RH, elevation of the dislocated radial head; RCJF, radiocapitellar joint fixation; RHR, radial head reduction; WPRM, width of the proximal radial metaphysis.

Table II. Results of logistic regression analysis.

Variable	Coefficient	SE	Wald	p-value	RR	95% CI
ELEV-RH	0.389	0.356	1.193	0.275	1.476	0.734 to 2.966
Time from injury to surgery	0.021	0.008	7.290	0.007	1.021	1.006 to 1.037
Fixation method of ulnar	-0.233	0.166	1.962	0.161	0.792	0.572 to 1.097

ELEV-RH, elevation of the dislocated radial head; RR, relative risk; Wald, chi-squared test.

Table III. Analysis of unsuccessful radial head reduction according to the time from injury to surgery.

Time from injury to surgery	No	Yes	χ^2	p-value
< 1.75 months, n (%)	46 (71.9)	18 (28.1)	9.457	0.002
≥ 1.75 months, n (%)	71 (49.0)	74 (51.0)		

RHR, radial head reduction.

undergoing UO was similar to that (47.1%) in those treated without UO (χ^2 = 0.12; p = 0.799).

Other factors, such as age (p = 0.137), sex (p = 0.302), laterality (p = 0.481), direction of dislocation (p = 0.476), reduction method (p = 0.58), ALR (p = 0.363), UO (p = 0.804), RCJF (p = 0.489), progressive ulnar distraction (p = 0.626), and postoperative cast immobilization (p = 0.381), were not associated with unsuccessful RHR. Similarly, the WPRM (p = 0.360), preoperative (p = 0.547) and postoperative (p = 0.750) AU, and S-UO (p = 0.802) demonstrated no significant difference between patients with anatomical and unsuccessful RHR.

Table I exhibits detailed results of the single-factor analysis findings.

Results of logistic regression analysis

Based on the aforementioned results, further logistic regression analysis incorporated time from injury to surgery, preoperative ELEV-RH, and ulnar fixation method. However, only time from injury to surgery (p = 0.007) was identified as a risk factor for unsuccessful RHR by the logistic regression analysis, whereas preoperative ELEV-RH (p = 0.275) and fixation method of the ulna were not (p = 0.161) (Table II) (Figures 6 to 10).

Results of ROC and chi-squared analysis

The results of the ROC curve analysis show that surgery more than 1.75 months after initial injury led to an increased incidence of unsuccessful RHR (Figures 6 to 10). Conversely, patients receiving surgery within 1.75 months had lower failure rates, with only 28.1% (18/64) compared to 51% (74/145) for those who had surgery after 1.75 months (χ^2 = 9.457; p = 0.002), as demonstrated by the chi-squared test (Table III).

Fig. 6
a) Anteroposterior and lateral radiographs of an eight-year-old female with a chronic Monteggia fracture with a three-year interval between injury and surgery. b) Anteroposterior and lateral radiographs after open reduction, external fixation of the ulna, radiocapitellar joint fixation with Kirschner wire and postoperative cast immobilization. c) Anteroposterior and lateral radiographs performed at the nine-month follow-up showing redislocation of the radial head.

Table IV showed the risk factors for unsuccessful RHR in surgically treated paediatric CMFs according to previous reports [6-14] and current study.

Discussion

Our results suggest that the time from injury to surgery is the only independent risk factor for unsuccessful RHR, especially in cases where the time from injury to surgery is longer than 1.75 months. Restoring anatomy within this time frame, whenever possible, may reduce the rate of unsuccessful RHR in children with surgically treated CMFs, partially confirming our hypothesis.

The overall reduction failure rate was 44%, which differed slightly from the range of 0% to 60% reported in previous studies.[6-1418-21] Previous reports mostly focused on patients treated with specific methods and defined unsuccessful RHR as redislocation of the radial head at final follow-up, rather than failure during the surgery. In addition, the lack of an adequate sample size (e.g. fewer than 70 cases) in previous studies would also decrease the accuracy of the rate of unsuccessful RHR.[6-14] However, our study defined unsuccessful RHR as the inability to achieve anatomical reduction during surgery and during follow-up, providing more accurate results. Additionally, our study

Fig. 7

a) Anteroposterior and lateral radiographs of a six-year-old female with a chronic Monteggia fracture with an interval of 1.5 months between injury and surgery. b) Anteroposterior and lateral radiographs after open reduction and fixation of the ulna osteotomy with plate and screws. c) Anteroposterior and lateral radiographs performed at 17-month follow-up showing the reduced radial head.

Fig. 8

a) Anteroposterior and lateral radiographs of an eight-year-old male with a chronic Monteggia fracture with a six-month interval between injury and surgery. b) Anteroposterior and lateral radiographs after open reduction, fixation of the ulna osteotomy with plate and screws, radiocapitellar joint fixation with Kirschner wire and postoperative cast immobilization. c) Anteroposterior and lateral radiographs performed at the three-month follow-up showing redislocation of the radial head.

reports the largest number of cases compared to previous studies, to our knowledge.[22,23]

Our analysis identified time from injury to surgery as a risk factor for unsuccessful RHR. Our findings correspond with those of Dai et al,[6] who reported an increase in the unsuccessful reduction rate with delayed time from injury to surgery in 62 patients with paediatric CMFs undergoing UO and OR of the radial head, and the monthly rate of unsuccessful RHR increased by 1.37-fold. During the period between injury and surgery, the ulna undergoes gradual remodeling and reduction in length, which can lead to a narrowing of the joint space between the humerus and radius. Moreover, due to the absence of mechanical stimulation from the humeral capitellum, the dislocated radial head may enlarge and shift from concave to convex, adding further obstacles to successful reduction.[3,24,25] However, Eamsobhana et al[10] reported conflicting results, as their study did not find any association between time from injury to surgery and poor outcomes as a risk factor. This discrepancy can be explained by the small sample size and sample selection bias in their study, which only examined 30 cases of missed paediatric CMFs treated with OR of the radial head.[10]

Interestingly, changes at the site of injury commonly occur within the initial seven weeks (1.75 months) following the injury and may become harder to rectify if surgical intervention is postponed. The proximal radial growth plate plays a significant role in the development of the radial head, and the radiocapitellar joint can inhibit excessive overgrowth of the radial head.[26] Kim et al[17] found evidence of both radial head enlargement and a slender radial neck within three months of radial head dislocation. In our analysis, the results indicated that surgery performed after 1.75 months led to a higher rate of unsuccessful RHR. This contrasted with findings from Cao et al,[14] Nakamura et al,[7] and Eamsobhana et al,[10] where cutoff values of six months, 24 months, and 36 months, respectively, were associated with an increased rate of unsuccessful RHR. This disparity may be a result of inconsistent grouping and insufficient statistical analysis in their studies. Cao et al[14] divided the patients into two categories based on their personal experience: those who underwent surgery less than six months from injury versus those who underwent surgery more than six months from injury. The cutoff value was established if there was a substantial discrepancy in the rate of reduction failure between the two groups solely based on the results of univariate analysis.[14] Nakamura et al[7] and Eamsobhana et al[10] used comparable techniques for identifying the cutoff value. However, the group division based on surgeons' experience was subjective, and the absence of

Fig. 9

a) Anteroposterior and lateral radiographs of a two-year-old female with a chronic Monteggia fracture with a one-month interval between injury and surgery. b) Anteroposterior and lateral radiographs after open reduction and fixation of the ulna osteotomy with plate and screws. c) Anteroposterior and lateral radiographs performed at the nine-month follow-up showing the reduced radial head.

Fig. 10

a) Anteroposterior and lateral radiographs of a six-year-old female with a chronic Monteggia fracture with a ten-month interval between injury and surgery. b) Anteroposterior and lateral radiographs after open reduction and fixation of the ulna osteotomy with monolateral external fixator. c) Anteroposterior and lateral radiographs performed at the six-month follow-up showing the reduced radial head.

multiple regression analysis could weaken the accuracy of the statistical results.

Notably, this study did not find age at the time of surgery to be a risk factor for unsuccessful RHR. Our results agree with those of most previous studies. However, several previous studies reported a significant correlation between age at the time of surgery and reduction failure rates based on single factor analysis results.[6-8,13] The controversy may stem from the limited sample size (e.g. fewer than 28 cases) reported in their studies and the lack of multiple regression analysis.[7,8,13] The results of the multiple regression analysis might refute the results of the univariate analysis. In the study conducted by Dai et al,[6] age at the time of surgery was identified as a potential risk factor for unsuccessful RHR based on univariate analysis, but the conclusions were refuted by multiple regression analysis. However, our study found that both single- and multiple-factor analyses failed to identify age at the time of surgery as a risk factor for reduction failure.

There are limitations to our study that should be acknowledged. First, our study was retrospective and power analysis was not performed. However, despite this limitation, our study used the single- and multiple-factor analysis to identify the risk factor for unsuccessful RHR. Second, we did not consider the functional outcome of patients with surgically treated paediatric CMFs and other risk factors, including the follow-up period. Third, we did not record the follow-up of patients with unsuccessful RHR after the index procedure and the outcome of those patients with unsuccessful RHR. However, regardless of how the choice of treatment method was made, we only recorded the type of treatment method because the primary aim of the study is to identify risk factors for unsuccessful RHR. Fourth, the minimum follow-up period for those with successful RHR in our study was six months, which is similar to previous reports.[4,19] Fifth, the centre of the radial head was replaced with the centre of the proximal radial metaphysis for ELEV-RH measurement in patients with nonossified radial head, but this occurred in only six patients (2.9%). Despite these limitations, this is the first study to systematically investigate the risk factors for unsuccessful RHR in patients with paediatric CMFs treated with different methods in the largest sample of such patients thus far. Additional prospective and randomized studies with longer follow-up are required.

In conclusion, the study revealed that the time interval between injury and surgery constitutes an independent risk factor for unsuccessful RHR in children with CMFs who undergo surgical treatment. The study also established that the cutoff value for time from injury to surgery is 1.75 months (seven weeks), which is shorter than that previously reported. This suggests that anatomical changes that make RHR challenging in patients with CMFs may occur quicker than previously thought.

Table IV. Risk factors for unsuccessful radial head reduction in surgically treated paediatric chronic Monteggia fractures (yes/no).

				Risk factors									
Study	Patients, n	Rate of unsuccessful RHR, %	Treatment methods	Age	Sex	Laterality	Fracture type	Time from injury to surgery	Reduction methods	ALR	RCJF	S-UO	Postoperative AU
Dai et al[6]	62	16.1	OR and UO with or without ALR	No	N/A	No	No	Yes	N/A	No	No	N/A	N/A
Nakamura et al[7]	22	22.7	OR and UO and ALR	Yes	N/A	N/A	N/A	Yes	N/A	N/A	N/A	N/A	N/A
Stragier et al[8]	14	35.7	OR and UO	Yes	N/A	N/A	N/A	Yes	N/A	N/A	N/A	N/A	N/A
Rahbek et al[9]	16 Bado type I	37.5	OR and UO	N/A	N/A	N/A	N/A	Yes	N/A	No	No	N/A	N/A
Eamsobhana et al[10]	30	20.0	OR	No	No	N/A	No	No	N/A	No	N/A	N/A	N/A
Gallone et al[11]	20	60.0	UO and progressive distraction	N/A	N/A	N/A	N/A	N/A	No	N/A	N/A	Yes	Yes
Musikachat et al[12]	21 (Bado type I)	28.6	UO	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Yes
Ko et al[13]	28	32.1	OR and UO and ALR	Yes	N/A	N/A	N/A	Yes	N/A	N/A	N/A	N/A	N/A
Cao et al[14]	29	34.5	OR and UO with or without HR	No	No	N/A	N/A	Yes	N/A	No	No	N/A	N/A
Current study	198	44.0	Multiple methods	No	No	No	No	Yes	No	No	No	No	No

ALR, annular ligament reconstruction; AU, angulation of ulnar; N/A, not available; OR, open reduction; RCJF, radiocapitellar joint fixation; RHR, radial head reduction; S-UO, the site of ulnar osteotomy; UO, ulnar osteotomy.

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Data sharing

The datasets generated and analyzed in the current study are not publicly available due to data protection regulations. Access to data is limited to the researchers who have obtained permission for data processing. Further inquiries can be made to the corresponding author.

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