Chinese Journal of Traumatology 23 (2020) 233–237

Contents lists available at ScienceDirect

Chinese Journal of Traumatology

journal homepage: http://www.elsevier.com/locate/CJTEE

Original Article

Clinical effect of manual reduction of humeroradial joint in the treatment of type I–III fresh Monteggia fracture in children

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ARTICLE INFO

Article history:
Received 16 February 2020
Received in revised form
6 May 2020
Accepted 12 May 2020
Available online 22 May 2020

Keywords:
Children
Monteggia fracture
Manual reduction

ABSTRACT

Purpose: To evaluate the efficacy of closed reduction on the humeroradial joint in the treatment of Bado type I, II and III fresh Monteggia fractures in children and investigate the effect of clinical factors, including Bado classification, age and time of treatment on the success rate of closed reduction.

Methods: We retrospectively studied the data of children ≤10 years old with fresh Monteggia fractures (injury within two weeks) treated by manual reduction with plaster immobilization from January 2014 to April 2019. All patients were followed up in the outpatient department every two weeks for 4–6 weeks until plaster removal and then 3, 6 and 12 months. Online or telephone interview was provided for some inconvenient patients after 6 months. Mackay criteria were used to evaluate the clinical effect. Radiographic data were collected and reviewed to assess the reduction of the humeroradial joint. Function of the elbow joint and forearm was evaluated and risk factors related to the failure of reduction were assessed. The successful manual reduction was analyzed from three aspects, respectively Bado fracture type (I, II, III), patient age (<3 year, 3–6 years, >6 years) and time interval from injury to treatment (group A, <1 day; group B, 1–3 days; group C, >3 days).

Results: Altogether 88 patients were employed in this study, including 58 males (65.9%) and 30 females (34.1%) aged from 1 to 10 years. There were 29 cases (33.0%) of Bado type I Monteggia fractures, 16 (18.2%) type II and 43 (48.7%) type III. Successful manual reduction was achieved in 79 children (89.8%) at the last follow-up. The failed 9 patients received open surgery. Mackay criteria showed 100% good-excellent rate for all the patients. The success rate of manual reduction was 89.7%, 87.5% and 90.7% in Bado type I, II and III cases, respectively, revealing no significant differences among different Bado types ($\chi^2 = 0.131$, $p = 0.937$). Successful closed reduction was achieved in 13 toddlers (13/13, 100%), 38 preschool children (28/42, 90.5%) and 28 school-age children (28/33, 84.8%), suggesting no significant difference either ($\chi^2 = 2.375$, $p = 0.305$). However time interval from injury to treatment showed that patients treated within 3 days had a much higher rate of successful manual reduction: 67 cases (67/71, 94.4%) in group A, 10 cases (10/11, 90.9%) in group B, and 2 cases (2/6, 33.3%) in group C ($\chi^2 = 22.464$, $p < 0.001$). Fisher's test further showed significant differences between groups A and C ($p = 0.001$) and groups B and C ($p = 0.028$).

Conclusion: Closed reduction is a safe and effective method for treating fresh Monteggia fractures in children. The reduction should be conducted as soon as possible once the diagnosis has been made.

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Introduction

Monteggia fracture[1–3] is defined as a fracture of the ulna with dislocation of the humeroradial joint, which commonly occurs in children and adolescents. It accounts for approximately 0.8% of all pediatric fractures, 12% of elbow injuries and 1%–5% of forearm

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Peer review under responsibility of Chinese Medical Association.

https://doi.org/10.1016/j.cjtee.2020.05.004
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fractures in children.[4,5] Missed diagnosis is common in regard to Monteggia fractures[6,7] and the rate is reported to be 16%–33% in some studies.[8–10] Missed diagnosis usually leads to serious complications and deformities and complicates its treatment. According to the injury mechanism and direction of the dislocated radial head, Bado classified Monteggia fractures into four types: Bado I–IV. Letts further divided the Bado type I Monteggia fractures into three subtypes according to different fracture sites of the ulnar, respectively IA, IB and IC.[11] Also according to the location of the ulnar fracture, Jupiter divided Bado II fractures into four subtypes: IIA, IIB, IIC and IID.[12]

Closed manual reduction is the first choice for fresh Monteggia fractures, but the principle of manual reduction has not reached a consensus, and it is still a debated point whether the deformity at the ulnar fracture site should be specially treated. The injury mechanism of a Bado IV fracture is complicated, as there are concomitant fractures in the radius and ulna. Therefore, manual reduction would not be suitable for Bado IV fractures because there would be no bone to firmly support the forearm. Furthermore, Chen et al.[13] found that the success rate of manual reduction on Bado IV fractures was relatively low; therefore, surgical method was preferred for such injuries.

In the present study, children with fresh Monteggia fractures treated by manual reduction with plaster immobilization in our hospital were reviewed. The curative effect was observed and analyzed to evaluate the efficacy of this treatment strategy and investigate the influencing clinical factors on the success rate of closed reduction.

Methods

Inclusion and exclusion

This retrospective study was conducted at Children's Hospital of Chongqing Medical University, China from January 2014 to April 2019 and has been approved by the institutional review board of the hospital (Approval No. 241/2019). The inclusion criteria were: (1) children between 0 and 10 years of age; (2) children diagnosed with fresh Monteggia fracture in our hospital or other hospitals within 2 weeks after injury; and (3) treated by manual reduction with plaster immobilization in our hospital. The patients' clinical and radiographic data were analyzed. Exclusion criteria were: (1) children with multiple fractures in other parts of the limb and functional deficit; (2) interval from injury to treatment of more than 2 weeks; (3) fracture with concurrent vascular or nerve injury; (4) open fractures; (5) pathological fractures; (6) Bado type IV Monteggia fractures; and (7) congenital radial head dislocation.

Grouping

Analysis of the success of manual reduction was conducted based on Bado fracture types (I, II, III), patient age (toddler period, <3 years; preschool period, 3–6 years; school period, >6 years) and time interval from injury to treatment (group A, <1 day; group B, 1–3 days; group C, >3 days).

Treatment

The injury history was carefully collected in the outpatient department. All patients underwent anteroposterior and lateral plain films of the affected forearm and elbow joint. The way to treat Monteggia fractures is by simple manual reduction of the humeroradial joint and plaster external fixation. The displacement and angulation of the residual ulnar fracture is no greater than that with any other treatments.

The manipulation of reduction and immobilization varied based on different Bado classification types: patients with Bado I and Bado III fractures were immobilized in supine position. The assistant stood on the same side as the affected limb and held the upper arm, and then performed shoulder joint abduction and elbow joint flexion of the affected limb. The operator held the wrist and pulled the forearm, and when the muscle was relaxed (approximately 5 min), a force was applied with the thumb, of which the direction was opposite to the dislocation of the radial head. After reduction, the forearm was immobilized in supine position using a plaster, and the elbow joint was fixed at >90°.

On the contrary, for the treatment of Bado II fractures, during the process of limb extension, reduction, and forearm pronation, the operator pushed the radial head forward with the thumb from the back and outside, and the elbow joint was fixed in the extended position after reduction. One week later, the elbow joint was fixed at 90°.

After manipulation, all patients underwent an X-ray examination. A computed tomography or magnetic resonance imaging was necessary only when it was difficult to accurately evaluate the relationship of the humeroradial joint on X-ray films.[14]

The key points[9,15,16] of the successful cases of manual reduction can be concluded as follows: (1) the resistance of humeroradial joint movement was reduced; (2) the movement range of the elbow was restored; (3) the reduction of the humeroradial joint could be maintained; and (4) the reduction of the humeroradial joint was showed in the anatomical position on radiological images. If the first manual reduction failed and swelling of the forearm was not obvious, reduction could be tried again under local anesthesia. However, if the swelling of the forearm was obvious, mannitol and other treatment could be given. After the swelling of the forearm subsided, manual reduction could be done under local anesthesia as soon as possible. If reduction of the humeroradial joint failed or cannot be maintained, surgical treatment should be chosen.[15] In principle, manual reduction should not be performed more than three times.[16]

Follow-up and outcome assessment

All patients were followed-up at the outpatient department of Children's Hospital of Chongqing Medical University regularly: every two weeks for 4–6 weeks to check and change the plaster and then the plaster was removed and patients were encouraged to do exercises. Thereafter patients were followed up at 3 months, 6 months and 1 year. For patients inconvenient to go the outpatient department, online or telephone follow-up was provided 6 months after manual reduction. During the follow-up visits, external fixation was changed when the swelling of the forearm decreased or the external fixation became loose. The relationship of the humeroradial joint was closely monitored using imaging examinations. The Mackay evaluation standard of elbow joint function was used to evaluate the functional status at the last follow-up visit.[17]

Statistical analysis

SPSS 20.0 (version 17.0, SPSS Inc, Chicago, IL) software was used to perform all the statistical analyses. Correlations between the success rate of closed reduction and the Bado classification, age and time interval from injury to treatment was tested individually using the Chi-square test. Fisher's test was adopted between each two groups at the test level of $\alpha = 0.05$ when the difference was statistically significant. The results of the Mackay criteria used to evaluate the efficacy of manual reduction in children at the last follow-up were expressed as excellent and good rates.

Results

Eighty-eight patients were enrolled in this study. There were 58 males (65.9%) and 30 females (34.1%), from 1 to 10 years of age, mean 4.8 years. The follow-up period in the clinic ranged from 6 to 15 months, mean 8.6 months. The longest follow-up online by WeChat or QQ or telephone was 60 months. Bony union was obtained in all the cases, and no one suffered from re-dislocation of the humeroradial joint during the follow-up period.

Among the 88 patients, 79 (89.8%) were successfully treated by manual reduction. The failed 9 cases finally underwent open reduction and achieve satisfactory closed reduction. Table 1 shows the general information of the two groups. The Mackay evaluation standard of elbow joint function showed 100% good-excellent rate for both manual reduction patients and surgery patients. None of them had poor results (Table 1).

Manual reduction based on Bado classification

Fracture type distribution showed that 29 cases (33.0%) were of Bado type I, 16 (18.2%) type II and 43 (48.7%) type III. Successful manual reduction was achieved in 26 cases of type I, 14 type II and 39 type III. Bado type III Monteggia fracture had the best success rate of manual reduction, but no statistically significant result was revealed among different Bado types ($\chi^2 = 0.131$, $p = 0.937$), as shown in Table 2.

Manual reduction based on age

There were 13 cases (14.8%) in toddler period, 42 (47.7%) in preschool period and 33 (37.5%) in school period. Toddler period patients had the best success rate of manual reduction (13/13, 100%). But no statistically significant result was revealed among different age groups either ($\chi^2 = 2.375$, $p = 0.305$), as shown in Table 3.

Manual reduction based on time interval from injury to treatment

Seventy-one patients (80.7%) were treated within one day after injury (group A), 11 (12.5%) within 3 days (group B) and 6 (6.8%) within 14 days (group C). Group A had the best rate of manual reduction (94.4%), followed by group B (90.9%) and group C (33.3%). The difference was statistically significant ($\chi^2 = 22.464$, $p < 0.001$) among different time intervals from injury to treatment, as shown in Table 4.

We also tested the difference in the success rate of manual reduction between any two groups using Fisher's test. There was no significant difference between groups A and B, but there were significant differences between groups A and C ($p = 0.001$) and groups B and C ($p = 0.028$) (Table 4).

A typical case

A typical case of Bado III Monteggia fracture in a six-year-old girl is shown in Fig. 1. The patient fell down over an outstretched arm and was sent to out hospital 3 h after the injury. Bado III Monteggia

Table 1
General information of the 88 patients based on manual reduction result.

Manual reduction	Location		Gender		Mean age (years)	Mean injury to treatment (days)	Mean follow-up (months)	Elbow joint function[a]	
	Left	Right	Male	Female				Excellent	Good
Success ($n = 79$)	39 (49.4)	40 (50.6)	53 (67.1)	26 (32.9)	4.7	1.2	8.1	73 (92.4)	6 (7.6)
Failure ($n = 9$)	5 (55.6)	4 (44.4)	5 (55.6)	4 (44.4)	5.9	4.3	12.7	7 (77.8)	2 (22.2)

Data are expressed as *n* (%) except for mean age, injury to treatment and follow-up.
[a] The elbow joint function was assessed by the Mackay evaluation standard.

Table 2
Success rate among different Bado classification types ($n = 88$).

Bado type	Total cases	Success, *n* (%)	Failure, *n* (%)	Rate of success (%)	χ^2 value	*p* value
I	29	26 (89.7)	3 (10.3)	89.7	0.131	0.937
II	16	14 (87.5)	2 (12.5)	87.5		
III	43	39 (90.3)	4 (9.7)	90.7		

Table 3
Success rate among different age groups ($n = 88$).

Age (years)	Total	Success, *n* (%)	Failure, *n* (%)	Rate of success (%)	χ^2 value	*p* value
<3	13	13 (100.0)	0 (0)	100	2.375	0.305
3–6	42	38 (90.5)	4 (9.5)	90.5		
>6[a]	33	28 (84.8)	5 (15.2)	84.8		

[a] All the included patients were ≤10 years old.

Table 4
Success rate among time intervals from injury to diagnosis.

Time interval from injury to treatment (day)	Total	Success	Failure	Rate of success (%)	χ^2 value	*p* value
<1 (group A)	71	67 (94.4)	4 (5.6)	94.4	22.464	<0.001
1-3 (group B)	11	10 (90.9)	1 (9.1)	90.9		
>3 (group C)[a]	6	2 (33.3)	4 (66.7)	33.3		

Note: Fisher's test showed significant differences between groups A and C ($p = 0.001$) and groups B and C ($p = 0.028$).
[a] Only patients treated within 14 days were included in this study.

fracture was diagnosed. She underwent manual reduction of the humeroradial joint successfully. At 6 months after injury, the radial head was stable in all positions on plain radiography, and the patient had no pain and a full range of motion.

Discussion

There are two procedures for the treatment of Monteggia fractures: closed reduction and surgical treatment. Manual reduction is the top choice for the treatment of fresh Monteggia fractures in children because it is simple, effective, non-invasive, economical and thus easily accepted by parents and patients. Regarding the principle of manual reduction, three different views are currently debated. (1) The first view is that the ulnar fracture should be reduced by manipulation first, and then the humeroradial joint can be spontaneously reduced.[18] Some doctors think that the ulna is the rotating axis of the forearm, and that reduction of the ulna could make it easier to reduce the humeroradial joint. (2) The second view is that the humeroradial joint should be reduced first, and then the ulnar deformity is treated.[14] Doctors believe in this view think that the ulnar fracture might spontaneously reduce in part with the reduction of the humeroradial joint. (3) The last view is that the type of ulnar fracture decides which method should be used. If the ulnar fracture is a greenstick fracture with an angulation deformity, the ulnar deformity should be corrected first, and then the humeroradial joint can be spontaneously reduced; if the ulnar fracture is a displaced fracture, the humeroradial joint should be reduced first, and the force line of the ulna can be largely corrected after the reduction of the humeroradial joint. Surgical treatment should be introduced to patients as soon as manual reduction fails or in cases of chronic Monteggia fracture.

It is widely believed that ulnar fracture should obtain anatomical restoration in order to maintain the stability of the humeroradial joint by the way of K-wire, Orthofix, steel plate or elastic nail to fix the ulna.[5,19,20] In this study, 79 of the 88 children were successfully treated with manual reduction of the humeroradial joint, and the residual deformity of the ulnar fracture was not specially corrected. The overall success rate was 89.8% and no redislocation was found during follow-up. The success rate was reported to be 95.4% (61/65) in Yuan et al's study,[21] 96.2% (50/52) in Zhao et al's study[22] and 87.7% (57/65) in Liu and Guo's study[23]; in all of these studies, the ulnar fracture was specially corrected. No great difference was revealed among these success rates.

The good-excellent rate of the elbow joint at the last follow-up was 100%. The key points of this study can be concluded as follows: (1) The radius maintained the length of the forearm after reduction of the humeroradial joint. With the traction of the soft tissue between the radius and ulna, the ulnar deformity spontaneously reduced in part. (2) The younger the children, the stronger the ability of bone remodeling. The strong bone healing and remodeling ability in children could correct the remaining displacement and angulation of the ulnar fracture. (3) In order to accurately evaluate the relationship of the humeroradial joint, all patients underwent an X-ray examination and/or computed tomography or magnetic resonance imaging after manipulation. And (4) for all the patients, it took 4–6 weeks for the ulnar fracture to heal before the external fixation was removed and elbow flexion and extension was performed. Compared to other treatment methods, this simple method was not only easy to perform, but could also reduce the pain during reduction of the ulnar fracture and the possibility of a secondary injury. Moreover manual reduction could reduce the economic burden of the family, without a surgical incision or hospitalization.

The results of this study suggested that there is no significant correlation between the success rate of manual reduction and Bado classification. As we all know, Bado classification is based on the direction of the dislocated radial head, instead of the severity of actual injury, so it cannot judge the prognosis.[17] We believe that this is why manual reduction will not be affected by Bado types.

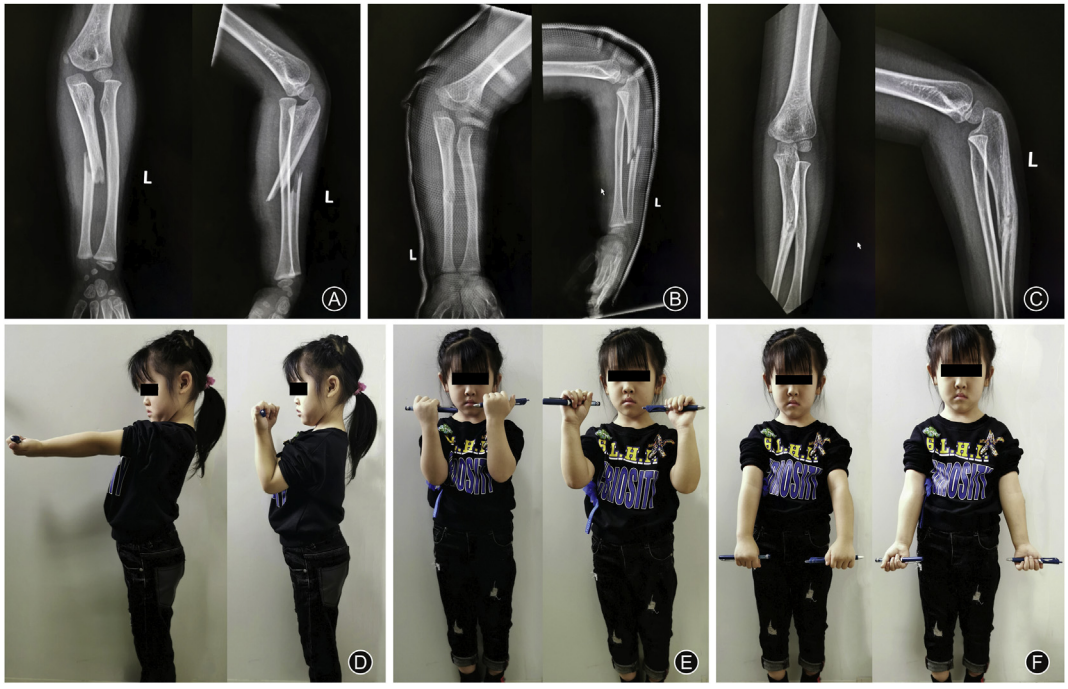

Fig. 1. (A–C) Anteroposterior and lateral plain films including the elbow joint. (A) Before manual reduction, the fracture occurred at the left proximal ulna, and the radial head was anterolaterally dislocated. (B) After manual reduction, the dislocated humeroradial joint was partly reduced and the deformity at the fracture site of the proximal ulna had been corrected. (C) The humeroradial joint was stable in any position at 6 months after manual reduction. (D–F) Six-month follow-up images. (D) The elbow range of motion was extension to 0°, flexion to 130°. (E and F): The forearm range of motion was supination to 90°, and forearm pronation to 90°.

Analysis of success rate of manual reduction based on age also revealed no significant difference. This may be because that the children in this study were all pre-pubescent (≤10 years old), and the strong bone healing and remolding ability could correct the residual ulnar deformity. By further increasing the number of adolescent cases, further studies can be conducted to observe the correlation between the success rate of manual reduction and age.

The relationship between the success rate of reduction and the time interval from injury to conservative treatment has rarely been reported. In this study, the success rate of closed reduction was 94.4% in group A (<1 day), 90.9% in group B (1–3 days), and 33.3% in group C (3–14 days). The results suggested that the success rate of manual reduction treatment is much higher within 3 days after injury (group A *vs*. group C, p=0.001, group B *vs*. group C, p=0.028). The most obvious swelling of soft tissue is seen on the third day after injury.[24,25] The swelling of soft tissue would hinder the reduction of the humeroradial joint. At the same time, the repair of the joint capsule, ligaments and other soft tissues around the elbow joint would increase the amount of fibrous connective tissue and further hinder the reduction. Therefore, once a fresh Monteggia fracture is diagnosed, manual reduction should be introduced as soon as possible.

Above all, manual reduction of the humeroradial joint for the treatment of type I–III fresh Monteggia fractures in children is safe and effective. We should note that manual reduction needs to be introduced as soon as diagnosis has been made. The disadvantage of this study is that the sample size is small. More high-quality, multi-center, large-sample trials are required.

Funding

This study was supported by the Key Project of Chongqing Health Planning Commission of Research Fund (No. 2019ZDXM047), Chongqing science and technology commission basic and frontier exploration general project (No. cstc2018jcyjAX0259) and Yuzhong science and technology commission basic and frontier exploration general project (No. 20180115).

Ethical Statement

The current research protocol was approved by the Institutional Review Board of Children's Hospital of Chongqing Medical University (Approval No. 241/2019). And the requirement for informed consent was waived given the retrospective design of the study.

Acknowledgements

We thank Dr. Hai Zhou for providing some cases. We thank Dr. Jun Wu for providing insightful discussions about the manuscript.

Declaration of Competing Interest

The authors declared no competing interest.

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