

Satisfactory mid- to long-term clinical and radiographic outcomes after surgical treatment of radial neck fracture in 10 children

Shinsuke Takeda¹, Hidemasa Yoneda², Masahiro Tatebe²,
Toshikazu Kurahashi³, So Mitsuya¹ and Hitoshi Hirata²

¹Trauma and Microsurgery Center, Toyohashi Municipal Hospital, Toyohashi, Japan
²Department of Hand Surgery, Nagoya University Graduate School of Medicine, Nagoya, Japan
³Hand and Microsurgery Center, Anjo Kosei Hospital, Anjo, Japan

ABSTRACT

Complications after surgical treatment of pediatric radial neck fractures are common. The purpose of this study was to evaluate the mid- to long-term clinical and radiographic outcomes after surgical treatment of pediatric radial neck fractures. We assessed 10 children who had been surgically treated for radial neck fractures. We mainly performed percutaneous intrafocal pinning to reduce the fracture; where this was inappropriate, we performed open reduction. Mid- to long-term clinical and radiographic outcomes were assessed, as well as whether these affected patient-related outcomes (Hand 20 questionnaire) at the final follow-up. Of the 10 patients (seven boys; mean age, 9 years; age range, 5–14 years; four fractures on the right-hand side, six on the left), four each were grades II and III, and two were grade IV, according to the Judet classification. The mean follow-up time was 6.7 (range, 3.6–11.2) years. Eight patients had restricted forearm pronation. The mean radial neck angulation on the fractured side was 36° (range, 5°–96°), preoperatively, and 2° (range, 0°–11°) at the final follow-up. There were eight cases of radial head overgrowth, three of premature physal closure, two of notching of the radial neck, and one of heterotopic ossification. According to the Leung/Peterson Classification, four patients had “excellent,” three had “good,” and three had “fair” functionality. Eight patients had a perfect score upon completing the Hand 20 questionnaire. In conclusion, postsurgical patient-related outcomes for the 10 cases were satisfactory despite slightly restricted forearm range of motion and complications detected using radiography.

Keywords: radius fracture, fracture fixation, open fracture reduction, pediatrics, treatment outcome

This is an Open Access article distributed under the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License. To view the details of this license, please visit (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

INTRODUCTION

Radial neck fractures account for 5–10% of pediatric elbow injuries and 1% of overall childhood fractures, and complications are not rare.^{1,2} Since most pediatric radial neck fractures

Received: January 15, 2021; accepted: October 7, 2021

Corresponding Author: Shinsuke Takeda, MD, PhD

Trauma and Microsurgery Center, Toyohashi Municipal Hospital, 50 Aza Hachiken Nishi, Aotake-cho, Toyohashi 441-8570, Japan

Tel: +81-532-33-6111, Fax: +81-532-33-6177, E-mail: s7.takeda.jpn@gmail.com

are nondisplaced or minimally displaced, casting without closed reduction is the most common treatment.^{2,3} Cases with severe displacement or angulation are indications for surgical treatment.^{4,5} Inappropriate fracture reduction can decrease the postoperative range of motion and result in a valgus deformity of the elbow. Even when appropriate reduction and fixation of the fracture is performed, several complications have been reported, such as avascular necrosis, nonunion, proximal radioulnar synostosis, heterotopic ossification, notching of the radial neck, and radial head overgrowth.⁵⁻⁷

To date, only a few reports have described the long-term surgical outcomes after surgical treatment for pediatric radial neck fractures,⁶⁻⁸ and the occurrence of complications during long-term follow-up has not been described. Therefore, the purpose of this study was to evaluate the mid- to long-term clinical and radiographic outcomes after surgical treatment for radial neck fractures in children.

METHODS

Patient backgrounds

This retrospective study was approved by our institutional ethics committee (Anjo Kosei Hospital) and performed in accordance with the ethical standards stated in the 1964 Declaration of Helsinki and its later amendments. The first author obtained written informed consent in which all patients' parents agreed with the publication of this study.

We assessed 15 children who had been surgically treated for radial neck fracture at Anjo Kosei Hospital from April 2005 to March 2013. Inclusion criteria for the study were as follows: patient age <15 years and follow-up duration ≥ 3 years. Prior to the analysis, we defined exclusion criteria as cases where we could not obtain radiographic and/or treatment-related information. Ultimately, after the exclusion of 5 patients whose medical and radiographic records were unavailable (three did not come to our hospital for over 3 years and two moved), 10 patients were included in the study (seven boys and three girls; four fractures on the right-hand side and six on the left).

Planning and treatment

We determined the appropriate treatment for each fracture according to the Judet classification,^{9,10} which is composed of the angulation of the radial neck in the sagittal plane, and the degree of translation of the proximal fracture fragment. Radial neck angulation was defined as the angle between the line perpendicular to the axis of the displaced radial epiphysis and the axis of the radial neck shaft. Grade-III and grade-II fractures were treated surgically. Treatment of grade-II fractures with either angulation $<30^\circ$ or translation $<50\%$ was determined by each surgeon. Although there is general agreement that angulation $\geq 30^\circ$ should be treated surgically,³ it is difficult to determine the boundary of the radial neck used to calculate angulation on a plain, two-dimensional roentgenogram. Therefore, the policy at our hospital is to treat grade-II fractures with angulation between 20° and 30° operatively.

In most cases, we performed percutaneous, intrafocal pinning to reduce the fracture; however, we performed open reduction in cases where such treatment would be inadequate.

Clinical and radiographic evaluation

Our primary focus was to examine the mid- to long-term clinical and radiographic outcomes after surgical treatment. Our secondary focus was to investigate whether the clinical and radiographic outcomes affected patient-related outcomes at the final follow-up. All clinical and radiographic investigations were performed by a surgeon (S.T.) and an occupational therapist in

our hospital. We measured the range of motion of the elbow and forearm joints. Bilateral carrying angles of the elbows in full extension were measured with a goniometer. We asked patients to report pain levels and the disturbance of their daily and sporting activities. Functional results were assessed using the Leung/Peterson Classification (Table 1).^{2,11} In terms of patient-related outcomes, we used Hand 20, a self-administered questionnaire for upper-extremity disorders composed of 20 illustrated questions. Scoring ranges from 0 to 10 per item, with 10 indicating the greatest disability. The final score is obtained by dividing the sum of all questions by half (range, 0 to 100).^{12,13} We performed radiographic evaluations with standard anteroposterior and lateral radiographs of both elbows.

Table 1 Leung/Peterson Classification of ROM outcomes

Rating	Pain	Loss of extension	Flexion	Supination	Pronation
Excellent	None	None	> 145	> 85	> 70
Good	None	0 – 15	140–145	70 – 85	60 – 70
Fair	Mild	15 – 30	130–140	50 – 70	50 – 60
Poor	Moderate/severe	> 30	< 130	< 50	< 50

ROM: range of motion

All values are expressed in degrees.

This table was adapted from Leung and Peterson.¹¹

RESULTS

All 10 patients' fractures were falling injuries, most commonly caused by falling on an outstretched hand. Angulation of the radial head is indicated in Table 2. According to the Judet classification, four patients were grade II, four were grade III, and two were grade IV.

All patients had injuries around the unilateral elbow joint. Five patients had associated fractures: olecranon fractures (n=4) and an avulsion fracture of the medial collateral ligament attachment (n=1). The mean time between injury and surgery was 3 days (range 0–7). Eight patients were treated via percutaneous reduction using intrafocal pinning, and two underwent open reduction internal fixation using Kirschner wires or cortical screws. After an average of 4 weeks' (range, 3–8 weeks) immobilization with a long-arm cast, the Kirchner wires were removed.

Table 2 Case details

Patient no.	Sex	Age (years) ^a	Injured side	Angle (degrees) ^b	Judet class	Concomitant injuries	Days to surgery	Surgical technique	Long-arm cast (weeks)	Follow up (years)
1	M	7	L	22	II		1	Intrafocal	3	6.4
2	M	7	R	22	II	Olecranon fracture	1	Intrafocal	4	6.4
3	F	12	L	25	II		5	Intrafocal	4	4.8
4	F	10	R	20	II	Olecranon fracture	1	Intrafocal	4	3.6
5	M	10	R	5	III		6	ORIF	8	11.2
6	M	14	L	32	III	Avulsion fracture of the MCL attachment	7	Intrafocal	5	7.1
7	M	9	R	33	III		1	Intrafocal	4	6.4
8	M	5	L	45	III	Olecranon fracture	1	Intrafocal	4	4.1
9	F	6	L	62	IV	Olecranon fracture	0	Intrafocal	4	6.6
10	M	7	L	96	IV		3	ORIF	4	10.4

M: male

F: female

L: left

R: right

MCL: medial collateral ligament

ORIF: open reduction internal fixation

^a Age at surgery^b Angulation of radial neck at surgery

The mean follow-up time was 6.7 years (range, 3.6–11.2 years). All clinical measurements at the final follow-up are indicated in Table 3. The mean forearm pronation was 72° (range, 60°–90°) on the fractured side; 8/10 patients had restricted forearm pronation. All patients had full elbow extension and forearm supination. The carrying angles of three patients were $\geq 10^\circ$ more on the fractured than on the normal side, indicating that these patients had a valgus deformity. Radiographic evaluation of the fractured radius revealed a mean radial neck angulation of 36° (range, 5°–96°), preoperatively, and 2° (range, 0°–11°) at the final follow-up.

Table 3 Clinical measurements and the Leung/Peterson rating of range of motion

Patient no.	Pron -F	Pron -N	Sup -F	Sup -N	Flex -F	Flex -N	Ext -F	Ext -N	Carry -F	Carry -N	Leung/Peterson Classification
1	90	90	90	90	155	155	0	0	17	11	Excellent
2	65	70	100	100	150	150	10	10	15	12	Good
3	60	80	90	90	130	150	5	5	28	15	Fair
4	80	85	90	90	145	145	10	10	20	15	Excellent
5	60	85	90	90	145	145	0	0	20	20	Fair
6	80	90	95	95	150	150	0	0	12	10	Excellent
7	70	85	90	90	140	140	5	5	20	20	Good
8	85	85	90	90	145	145	0	5	10	6	Excellent
9	70	85	85	85	140	140	0	0	25	15	Good
10	60	75	85	95	140	145	15	10	25	15	Fair

Pron: pronation

Sup: supination

Flex: flexion

Ext: extension

Carry: carrying angle

F: fractured side

N: normal side

All values are expressed in degrees.

In our series, there were no patients with avascular necrosis, nonunion, or proximal radioulnar synostosis. Three patients (nos. 1, 2, and 9) had premature physal closure. Patient no. 3 exhibited heterotopic ossification above the proximal part of the ulna at the site of insertion of the supinator muscle (Fig. 1). Two patients (nos. 5 and 10) exhibited notching of the radial neck (Fig. 2). The findings of heterotopic ossification or notching of the radial neck were confirmed 6 months postoperatively on standard anteroposterior or lateral radiographs. Radial head overgrowth was observed in 8/10 patients. As evaluated by standard anteroposterior or lateral radiographs, the average difference in radial head diameter between patients' two elbows was 1.8 mm (range, 1.4–2.3 mm).

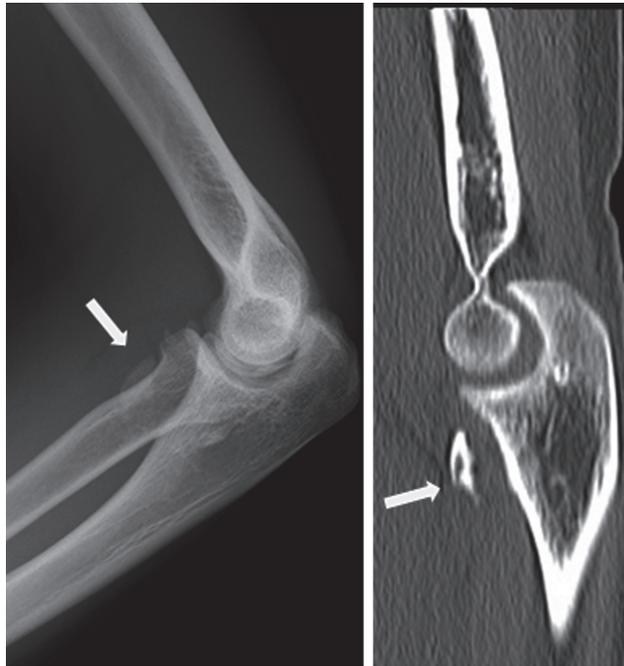


Fig. 1 Heterotopic ossification

Patient no. 3 exhibits heterotopic ossification (arrows) above the proximal part of the ulna on standard lateral radiograph and sagittal computed tomography.

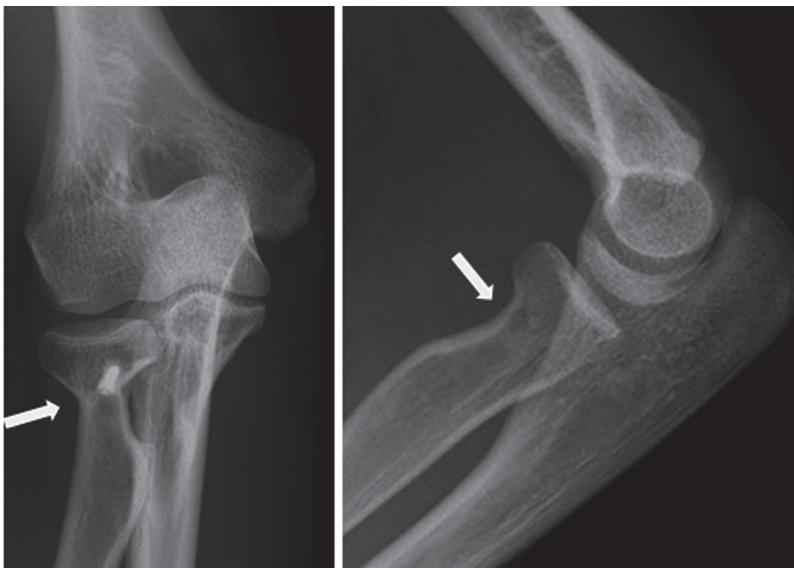


Fig. 2 Notching of the radial neck

Two patients (left: no. 5, right: no. 10) exhibit notching of the radial neck (arrows) on standard anteroposterior or lateral radiographs.

Although only one patient (no. 3) experienced elbow pain when partaking in Kendo (traditional Japanese fencing), others experienced no pain during daily or sporting activities. Functionality, according to the Leung/Peterson Classification, was “excellent” for four patients, “good” for three, and “fair” for three. Upon completing the Hand 20 questionnaire, eight patients achieved a score of 0, a perfect score. Only one patient (no. 3) had a non-perfect Hand 20 score (3/100). One patient (no. 5) did not partake in the questionnaire because of autism.

DISCUSSION

The purpose of this study was to evaluate the mid- to long-term clinical and radiographic outcomes after surgical treatment of pediatric radial neck fractures. In our series, no patients had a “poor” Leung/Peterson rating. The three cases with a “fair” rating were affected by a restriction in forearm pronation of 30°. We demonstrated that patient-related outcomes (Hand 20 questionnaire) at the final follow-up were not associated with these limitations.

In our study, most cases exhibited restricted pronation at the mid- to long-term follow-up, similar to what was previously reported.¹⁴ This limitation is typically secondary to postoperative radiohumeral joint incongruity and fibrous adhesion,¹⁵ and it more frequently occurs after open than after closed reduction.¹⁻⁷ Eight of 10 patients in our series exhibited radial head overgrowth, none of which resulted in functional disorder in the mid- to long-term. This was expected, as radial head overgrowth is a known common sequela of radial neck fracture and is not correlated with functional disorder.⁷ Increased vascularity following injury may stimulate epiphyseal growth; however, the mechanisms of overgrowth following fractures are poorly understood.¹⁴ Notching of the radial neck was observed in two patients, both of whom underwent open reduction and experienced slight pronation restriction. D’souza et al¹⁴ stated that this notching is a common radiologic finding after open reduction and that it causes no functional deficit. O’Brien¹⁶ stated that notching of the radial neck resulted from scar tissue forming around the neck from the orbicular ligament. Heterotopic ossification was observed in one case, accompanied by restrictions of forearm pronation and elbow flexion. Vahvanen et al⁸ also reported that, after long-term follow-up, heterotopic ossification was relatively common, and where it remained, the motion was slightly limited.

Two limitations of this study are its small sample size and no control group was included; therefore, the effect of the surgical intervention could not be determined. We also did not include data showing the differences between the short-term and mid- to long term outcomes because the data for the short-term outcomes were measured by several doctors, inconsistent, and some data were missing.

However, our report has value because, to date, there are few reports describing the mid- to long-term surgical outcomes and patient-related outcomes after surgical treatment for pediatric radial neck fractures.

In conclusion, several clinical and radiographic complications occurred, similar to those of previous reports, and postsurgical patient-related outcomes of the 10 cases were satisfactory, despite slightly restricted forearm range of motion and complications upon radiography.

ACKNOWLEDGEMENTS

We are grateful to all the subjects who participated in this study. ST would also like to take this opportunity to thank Ichiro Takeda for advice.

DISCLOSURE STATEMENT

None.

REFERENCES

- 1 Zimmerman RM, Kalish LA, Hresko MT, Waters PM, Bae DS. Surgical management of pediatric radial neck fractures. *J Bone Joint Surg Am.* 2013;95(20):1825–1832. doi:10.2106/JBJS.L.01130.
- 2 De Mattos CB, Ramski DE, Kushare IV, Angsanuntsukh C, Flynn JM. Radial neck fractures in children and adolescents: an examination of operative and nonoperative treatment and outcomes. *J Pediatr Orthop.* 2016;36(1):6–12. doi:10.1097/BPO.0000000000000387.
- 3 Tarallo L, Mugnai R, Fiacchi F, Capra F, Catani F. Management of displaced radial neck fractures in children: percutaneous pinning vs. elastic stable intramedullary nailing. *J Orthop Traumatol.* 2013;14(4):291–297. doi:10.1007/s10195-013-0252-0.
- 4 Tan BH, Mahadev A. Radial neck fractures in children. *J Orthop Surg (Hong Kong).* 2011;19(2):209–212. doi:10.1177/230949901101900216.
- 5 Badoi A, Frech-Dörfler M, Häcker FM, Mayr J. Influence of immobilization time on functional outcome in radial neck fractures in children. *Eur J Pediatr Surg.* 2016;26(6):514–518. doi:10.1055/s-0035-1566108.
- 6 Falciglia F, Giordano M, Aulisa AG, Di Lazzaro A, Guzzanti V. Radial neck fractures in children: results when open reduction is indicated. *J Pediatr Orthop.* 2014;34(8):756–762. doi:10.1097/BPO.0000000000000299.
- 7 Vocke AK, Von Laer L. Displaced fractures of the radial neck in children: long-term results and prognosis of conservative treatment. *J Pediatr Orthop B.* 1998;7(3):217–222. doi:10.1097/01202412-199807000-00007.
- 8 Vahvanen V, Gripenberg L. Fracture of the radial neck in children: a long-term follow-up study of 43 cases. *Acta Orthop Scand.* 1978;49(1):32–38. doi:10.3109/17453677809005720.
- 9 Judet J, Judet R, Lefranc J. Fracture of the radial head in the child [in French]. *Ann Chir.* 1962;16:1377–1385.
- 10 Stiefel D, Meuli M, Altermatt S. Fractures of the neck of the radius in children. Early experience with intramedullary pinning. *J Bone Joint Surg Br.* 2001;83(4):536–541. doi:10.1302/0301-620x.83b4.0830536.
- 11 Leung AG, Peterson HA. Fractures of the proximal radial head and neck in children with emphasis on those that involve the articular cartilage. *J Pediatr Orthop.* 2000;20(1):7–14.
- 12 Kurimoto S, Yamamoto M, Shinohara T, Tatebe M, Iwatsuki K, Hirata H. Favorable effects of explanatory illustrations attached to a self-administered questionnaire for upper extremity disorders. *Qual Life Res.* 2013;22(5):1145–1149. doi:10.1007/s11136-012-0233-4.
- 13 Nakagawa Y, Kurimoto S, Maheu E, et al. Cross-cultural translation, adaptation and validation of a Japanese version of the functional index for hand osteoarthritis (J-FIHOA). *BMC Musculoskelet Disord.* 2020;21(1):173. doi:10.1186/s12891-020-03193-6.
- 14 D'souza S, Vaishya R, Klenerman L. Management of radial neck fractures in children: a retrospective analysis of one hundred patients. *J Pediatr Orthop.* 1993;13(2):232–238.
- 15 Key JA. Survival of the head of the radius in a child after removal and replacement. *J Bone Joint Surg Am.* 1946;28(1):148–149.
- 16 O'Brien PI. Injuries involving the proximal radial epiphysis. *Clin Orthop Relat Res.* 1965;41:51–58.