Surgical Techniques for Displaced Radial Neck Fractures: Predictive Factors of Functional Results

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Background: Fractures of the radial neck represent about 1% of all childhood fractures and 5% to 10% of childhood traumatic lesions involving the elbow. Management of these fractures in children is still controversial. Intramedullary percutaneous nail reduction (Métaizeau technique) is considered the most effective surgical technique because of its excellent results and easy learning curve. Complications may arise, however, especially in Böhler technique, in which a percutaneous pin is placed over the radial head. When this technique does not provide correct reduction, open reduction must be performed. Because open reduction is traditionally associated with a high risk of complications, however, its use is restricted to severely displaced fractures and only when the percutaneous techniques have failed or their application contraindicated because of associated injuries to the distal radius.

Methods: In this retrospective study, we evaluated 51 children between the ages of 6 and 15 years who presented to our institution from 1996 to 2012 with Métaizeau-modified Judet grades 3, 4a, and 4b radial head fractures. The surgical techniques used were closed reduction and casting under general anesthesia (n = 7), closed reduction and intramedullary nailing using Métaizeau technique (n = 27), and Métaizeau technique and open reduction with intramedullary nailing (n = 17). Functional results of the 3 surgical techniques were evaluated using the Mayo Elbow Performance Score (MEPS) and compared by modified Judet classification using χ^2 analysis.

Results: No statistic significant association was found between type of surgery and final MEPS was observed ($P = 0.110$). However, a significant association was found between initial modified Judet grade and final MEPS.

Conclusions: In the present study, final functional outcome seems to be not affected by open reduction but was significantly associated with initial modified Judet grade.

Level of Evidence: Level III—retrospective study comparing closed and open reduction techniques, performed at the same institution.

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Radial neck fractures account for 1% to 2% of all childhood fractures and 5% to 10% of childhood fractures involving the elbow.[1–4] The treatment of displaced fractures varies greatly depending on the degree of displacement and ranges from orthopaedic treatment to open reduction and internal fixation for severe displacement. Initial displacement has been shown to be the most important predictor of long-term functional outcomes.[5–7]

The most widely used technique in the treatment of displaced fractures is percutaneous nail osteosynthesis using Métaizeau technique,[8–10] a surgical method that provides excellent results.[3,8,11–15] In some cases, however, a second nail may be necessary to manipulate the displaced radial head (Böhler technique),[1,16] a procedure that entails some risk of iatrogenic injuries such as interosseus posterior nerve injury and head necrosis due to repeated trauma over the radial epiphysis. To avoid stiffness and other complications such as pseudarthrosis and osteonecrosis, percutaneous techniques are now favored over open techniques.[2,4,5,7,13,17,18] However, although percutaneous techniques are the first choice in difficult reductions, the Böhler technique can also lead to complications and in some cases does not provide acceptable anatomic reduction of the radial head.

The purpose of this study was to compare the functional results of percutaneous surgery to those of open surgery in the treatment of displaced radial neck fractures in children; and to determine whether open surgery is in fact associated with an increased risk of complications[7,11,19] and whether open surgery may be an appropriate initial treatment for severely displaced fractures, thus avoiding the overuse of percutaneous techniques.

METHODS

This retrospective study investigated functional outcomes in 51 patients (age, 3 to 16 y) treated for displaced radial neck fractures at Sant Joan de Déu Children's Hospital, University of Barcelona, from 1995 to 2014. Inclusion criteria were (a) > 30 degrees of angulation[19,20] requiring manipulation under general anesthesia, with or

without associated injuries; (b) open growth plates of the elbow at the time of injury; and (c) minimum follow-up of 6 months. Exclusion criteria were (a) open fracture; (b) incomplete medical or radiographic records; and (c) associated elbow fractures requiring surgical fixation.

Fractures were classified according to Judet classification as modified by Métaizeau (Table 1).[5,12] Fractures included in the present study were those with displacement >30 degrees (modified Judet grades 3, 4a, and 4b).[19,20]

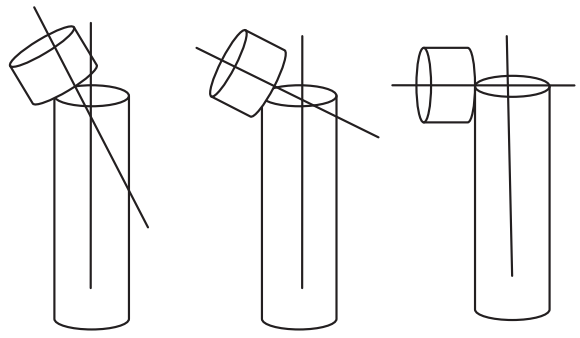
Six surgeons performed all patients' surgical procedures based on the following therapeutic approach: initially, closed reduction with Israeli or Patterson maneuvers and brachial casting were performed in the operating room (n = 7 patients, 14%). When those techniques did not provide satisfactory reduction (residual displacement >30 degrees or 30% translation),[7,15,20–22] percutaneous techniques were attempted: Métaizeau technique in 27 patients (53%), of whom 5 (9%) underwent a Böhler reduction in association with Métaizeau technique[1,3,13,15,21,23] (Figs. 1–4).

Only when closed reduction techniques failed (residual displacement >30 degrees or 30% translation) was open reduction undertaken in 17 fractures (33%) (Table 2).[19,24] A radiocapitellar arthrotomy (Kocher approach) was developed, ensuring an accurate periarticular dissection, and making a radial head fixation using intramedullary or neck pinning (Figs. 5–9). Author's surgical recommendations when open reduction is required are: an incision no wider than 2 or 3 cm, annular ligament preservation and to avoid tools which could damage the head of the radius during reduction.

All patients were evaluated for radiologic alignment 7 to 10 days after surgery, followed by assessment of radiologic and functional outcomes every month for at least 3 months, then at 6 months and 1 year. We considered normal range of motion (ROM) 0 to 145 degrees of extension and flexion, and 0 to 70 degrees of pronosupination.

Two functional assessment scales were used to evaluate function: the Mayo Elbow Performance Score (MEPS),[5,12] which was designed for the assessment of the adult elbow; and the Métaizeau functional scale.[8] MEPS results were categorized as follows: >90 points, excellent; >80 points, good; >60 points, fair; and <60 points, poor. Functional outcome was also determined to be excellent, good, fair, or poor according to Métaizeau classification (Tables 3 and 4).

TABLE 1. Classification of Radial Neck Fractures of Judet Modified by Métaizeau



Judet grade 3	Judet grade 4a	Judet grade 4b
30-60 degrees	60-80 degrees	> 80 degrees
N = 21	N = 17	N = 13

FIGURE 1. Radial neck fracture Judet grade 3.

RESULTS

Fifty-one patients (30 males, 21 females) were included. The left elbow was the most often affected (32 of 51 fractures, or 62%). Mean age at the time of fracture was 8 years (range, 3 to 15 y). Mean follow-up was 14 months (range, 8 to 39 mo). Only 5 patients had <1 year of follow-up. Patients were discharged when they demonstrated full elbow ROM. Complications were decreased ROM, radial head overgrowth, early closure of the physis, radial neck pseudarthrosis, radial head avascular necrosis, change in ulnar carrying angle, vascular lesions, neurological lesions, radioulnar synostosis, ossifying myositis, osteomyelitis, and malunion. There were no cases of pseudarthrosis or necrosis of the radial head; however, other complications were overgrowth of the

FIGURE 2. Judet grade 3 fracture after closed reduction and cast.

FIGURE 3. Judet grade 4a radial neck fracture.

radial head to >25% of the size of the contralateral side in 16 cases (31.4%), 7 cases in percutaneous surgery group and 9 cases in open surgery group; malunion, which ranged from 10 to 30 degrees of angulation in 10 cases (19.6%), 2 cases in closed reduction group, 5 cases in percutaneous surgery group, and 2 cases in open surgery group; radial nerve neurapraxia with spontaneous resolution 6 months postoperatively in 1 case (2.0%); and proximal radioulnar posttraumatic synostosis in a modified Judet grade 3 fracture requiring casting, in 1 case (2.0%).

In cases in which excellent Métaizeau and MEPS functional outcomes were not achieved, the alterations were due to varying degrees of supination deficit. There was only 1 poor outcome according to Métaizeau classification, in which the patient experienced posttraumatic synostosis with a marked lack of supination and distal radioulnar joint pain. This was treated with resection of the area of synostosis and interposition of a fascia-fat flap, with complete resolution. Excellent results were observed in all but 1 case (n = 6) of closed reduction and casting in the operating room (Table 4). Results of percutaneous surgery group (n = 27) were excellent in 85% of patients and good in the remaining 15%. In the open surgery group (n = 17) the results were excellent in 60% and good in 40%.

Pearson χ^2 analysis revealed that a greater degree of displacement was associated with significantly greater functional loss, as measured by both the MEPS ($P = 0.005$) and Métaizeau functional scales ($P = 0.007$) (Table 3). No significant differences, however, were observed between surgical technique and surgical outcome as measured by the MEPS ($P = 0.110$) and Métaizeau scale ($P = 0.151$) (Table 4).

DISCUSSION

A detailed literature review revealed the present study to be the second largest on displaced radial neck fractures after the work by Zimmerman et al,[7] Basmajian et al,[6] and Sun et al[25] pointed out a correlation between open reduction and poor functional outcomes, and studies by Zimmerman et al,[7] Klitscher et al,[13] and Falciglia et al,[26] with similar numbers of patients, had already come to the same conclusions. According to Zimmerman et al,[7] not only initial displacement, but also age above 10 years, is predictive of poor results. Previous studies have reported that arthrotomy was associated with more complications and greater impairment of mobility, and that open reduction should therefore be reserved for very severely displaced fractures, and usually when percutaneous surgery attempts had failed.[7,11,12,22,25,27] Although

FIGURE 4. Judet grade 4a fracture after percutaneous reduction by Métaizeau technique using intramedullary K-wire fixation.

FIGURE 5. Girl 8 years old, displaced radial neck fracture Judet grade 4b of the right side, x-ray showing fracture.

we agree with the majority of authors, who recommend surgical treatment for fractures with >30 degrees of angulation or 30% displacement,[3,4,7,13,14,28] our analysis demonstrated that only initial fracture displacement had a significant influence on functional outcome. No study, including that of Zimmerman and colleagues, has reported open reduction to be a negative predictive factor.[29]

Métaizeau technique is a reproducible surgical method for reduction and stabilization of displaced radial neck fractures in children that provides very good results.[8,9,12,23,30] Similar to revised authors, we consider Métaizeau technique as the most recommended surgery for treating radial neck fractures in children, making percutaneous surgery our recommendation in the majority of radial neck fractures. However, we believe open reduction is a useful resource for anatomic reduction of the radial head, which has been shown to be a predictive factor of functional outcome[26] and that it can produce good functional outcomes with the same incidence of complications as other surgical techniques and less functional impairment than previously thought.

Open reduction technique was necessary in 30% fractures. Although this rate is similar to other published series,[6] we may consider that, as pediatric traumatology reference center, we may receive the most complex fractures in our area.

Only Basmajian et al[6] have reported statistical results about open reduction as a negative predictive factor. Comparing our study to the mentioned before, the reviewed cohorts are similar but we observe various restrictive limitations to Basmajian work: a short follow-up, an isolated scoring system[20] and a no pre-established treatment protocol. Moreover, 70% of open surgery were grade IV in Basmajan work (they do not differentiate subgrades A and B). Therefore, their poor outcomes

TABLE 2. Correlation Type of Fracture/Surgical Technique Used

Type of Fracture Classified Judet Modified by Métaizeau	Closed Reduction and Cast Immobilization	Percutaneous Reduction With Métaizeau ± Böhler	Open Reduction and Percutaneous or Internal Fixation
Grade 3 (21)	6	14	1
Grade 4a (17)	1	10	6
Grade 4b (13)	0	2	11

FIGURE 6. Reconstruction with 3D scan showing displacement.

might be associated with the fracture severity rather than with the selected surgical technique applied.

Zimmerman et al[7] reported that initial displacement of the fracture and the age of the patient were the only independent predictors of final functional results. However, in that study, patients were treated by 21 different surgeons, whereas our patients were treated by 6 surgeons using the standardized algorithm detailed in the Methods section of the present report.

We agree with Cornwall that "We are all afraid of radial neck fractures that need surgery," especially when considering open surgery. Open reduction has long been thought, even in the absence of supporting statistical evidence, to produce a poor functional outcome. The present study challenges the conventional wisdom by presenting a therapeutic approach comparable to those presented in other studies, avoiding the limitations of previous studies, and providing evidence that open reduction may not be associated with poorer outcomes.

A limitation of our study is its retrospective nature; in addition, a more detailed functional scale could be used

FIGURE 7. Image during surgery showing the approach and radial head dislocated.

FIGURE 8. X-ray after open surgery and K-wire fixation.

in future studies. For example, the modified Disabilities of the Arm, Shoulder and Hand questionnaire, which correlates with final elbow functional results, could be used.[29] We believe the Métaizeau scale is more appropriate for evaluating functional outcomes in the pediatric population because it emphasizes the evaluation of ROM, especially in forearm supination, in which we observed more changes when evaluating final ROM. Losses of

FIGURE 9. Outcome at 6 months of follow-up, with complete flexion-extension and pronation-supination of the elbow.

TABLE 3. Functional Scale of Métaizeau

Functional Results According to Métaizeau	Grade 3	Grade 4a	Grade 4b
Excellent (no loss of motion)	20	13	5
Good (< 20% loss of motion/any direction)	0	2	5
Fair (20%-40% loss of motion)	0	2	3
Poor (> 40% loss of motion)	1 (synostosis)	0	0

TABLE 4. Correlation Type of Surgical Treatment and Functional Outcome (MEPS and Métaizeau Scale)

	MEPS		Métaizeau		
Surgical Treatment	Excellent	Good	Excellent	Good	Fair
Closed reduction and cast	6	1 (poor)	6	0	1 (poor)
Métaizeau technique	23	4	23	2	2
Open reduction	10	7	9	5	3

MEPS indicates Mayo Elbow Performance Score.

forearm pronation-supination and elbow flexion-extension have recently been demonstrated to be associated with poor final functional results.[26]

CONCLUSIONS

We observed no significant differences in complications or in final functional results, as assessed using the MEPS and Métaizeau scales, between closed and open reduction. We therefore advocate for open reduction, in severely displaced radial neck fractures, avoiding excessive percutaneous attempts (especially in conjunction with Böhler technique, in which an external pin is used to lift the radial head). Our results suggest that traditional guidelines and protocols for the surgical treatment of radial neck fractures in children should be reconsidered and that open reduction and stabilization with intramedullary pinning could play significant roles in the treatment of these fractures, particularly when closed reduction is difficult or contraindicated.

Our analysis revealed only initial fracture displacement to be an independent predictor of functional outcome. We also found that open surgical reduction was not associated with poorer functional results, Falciglia et al[26] seem to be close to this statement in his article. Nevertheless, future prospective studies should be conducted to evaluate the treatment of radial neck fractures in children.[14,19,20]

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