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ORIGINAL STUDY

Radiological and functional outcomes of modified Metaizeau technique in displaced radial neck fractures

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The management of displaced radial neck fractures in children is still a controversial topic. The objective of this study is to examine the outcomes of modified Metaizeau technique in the children with displaced radius neck fractures.

The retrospective study included 15 children with displaced radial neck fracture with an angulation of more than 30° who were managed with the use of leverage technique by mosquito clamps and internal fixation with elastic stable intramedullary nailing (ESIN). Radiological and functional assessments were performed during follow-up. Additionally, the patients were evaluated using Mayo Elbow Performance Score (MEPS).

All the children could be managed with clamp-assisted closed reduction. The average duration of follow up was 25.5 ± 6.1 months (15-36 months). An excellent elbow function was achieved in all but one patient. Based on Metaizeau classification, excellent, good, fair, and poor outcomes were achieved in 11, 1, 2, and 1 patients, respectively. The average postoperative MEPS score was 98.7 ± 5.1 (80-100).

Clamp-assisted closed reduction and fixation with ESIN is a good choice in the children with displaced radial neck fractures. This technique is associated with good functional and radiologic outcomes in the medium-term. Further studies are warranted with larger sample sizes.

Keywords : Radius neck fracture ; children ; closed reduction ; displaced fracture ; intramedullary nailing.

INTRODUCTION

Radial neck fractures comprise 5-10% of all the paediatric elbow injuries and 1% of all paediatric fractures *(1,2)*. These fractures mostly occur upon a fall on the palm of the hand with an extended elbow. Fracture in the proximal radius and dislocation of the radial head may occur because of the force exerted by the capitellum on the radial head *(3,4)*. The reported co-occurrence rate of other associated fractures in the radial neck fractures varies between 15% and 60% *(5)*.

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The management of displaced radial neck fractures in children remains a controversial topic. Factors that should be considered while making therapeutic decisions in these patients include the degree of displacement and angulation as well as the level of skeletal maturity. However, decision making is complicated by several issues such as the controversy surrounding the acceptable fracture alignment, the wide spectrum of available reduction techniques, unpredictable and/or unsatisfactory outcomes, concerns regarding the vascularity of the developing proximal epiphysis, growth disturbance risks, and the possibility of proximal radioulnar and radiocapitellar joint malalignment resulting in impaired elbow function *(2,6)*. Most fractures are not displaced or minimally displaced and can be treated with closed reduction and casting with a good outcome *(7)*. In contrast, displaced radial neck fractures require management with closed reduction, percutaneous pin reduction and/or fixation, open reduction with or without internal fixation, and transcapitellar pinning. A higher degree of displacement or angulation has been associated with poorer outcomes, even after open reduction *(1,2,6)*.

The open reduction of these fractures is associated with a higher risk of complications *(4)*. Although open reduction and internal fixation allows the surgeon to perform an anatomical reduction, avascular necrosis, an early physeal closure, abnormal enlargement of the radial head, and radioulnar synostosis pose higher risks. In contrast the closed reduction percutaneous fixation technique is associated with good results, but it has several drawbacks such as the difficulty of the intraoperative forearm rotation test and posterior interosseous nerve injury risk *(4,6)*.

The elastic stable intramedullary nailing (ESIN) technique originally proposed by Metaizeau et al. *(2)* consists of introducing a pin into the medullary canal of the radius and its proximal advancement until it reaches the inferior part of the epiphysis, thus lifting the epiphysis. This technique allows extracapsular intramedullary reduction and fixation, thus enabling closed reduction and minimal invasive internal fixation while protecting soft tissue attachments *(8)*. The technique has shown excellent results, but can be associated with several complications including injury to proximal epiphysis, extensor pollicis longus, and superficial radial nerve at the pin insertion site *(4)*. In our technique we use mosquito clamps for leverage, which is different from the original technique.

The objective of this study is to examine the functional and radiological outcomes of children with displaced radius neck fractures who underwent closed reduction using an (ESIN) technique with the addition of clamp assistance.

MATERIALS AND METHODS

This retrospective study included 15 children (aged more than 16 years) who underwent intramedullary nailing with titanium elastic nail (TEN) for the management of radial neck fracture at the Department of Orthopedics and Traumatology, Kahramanmaras Sutcu Imam University Medical Faculty between July 2012 and September 2014. All the patients had displaced radial neck fracture with an angulation of more than 30°. The study protocol was approved by the Scientific Research Ethics Committee of Kahramanmaras Sutcu Imam University Medical Faculty on 12 January 2015 (session, 01 ; no, 03) and the study was conducted in accordance with the Declaration of Helsinki.

In addition to the routine clinical assessments, angulation was measured on anteroposterior X-ray images. Each fracture was graded according to the Judet classification modified by Metaizeau et al. *(2,9)* as follows : grade 1, undisplaced fracture or horizontal epiphyseal shift ; grade 2, angulation less than 30° ; grade 3, angulation between 30° and 60° ; grade 4a, angulation mor than 60° and less than 80° ; and grade 4b, angulation more than 80°.

All the patients underwent intramedullary nailing with intramedullary TEN using a modified Metaizeau method *(2)*. A 1 cm longitudinal skin incision was made approximately 1 to 1.5 cm proximal to the physis line, and at the lateral distal radius under fluoroscopic control. The bone was exposed with a blunt dissection of soft tissues. A hole in the cortex was made with an awl in the direction of the longitudinal axis of the radius, approximately 2 cm proximal to the distal radial physis line. The intramedullary canal was accessed using a TEN

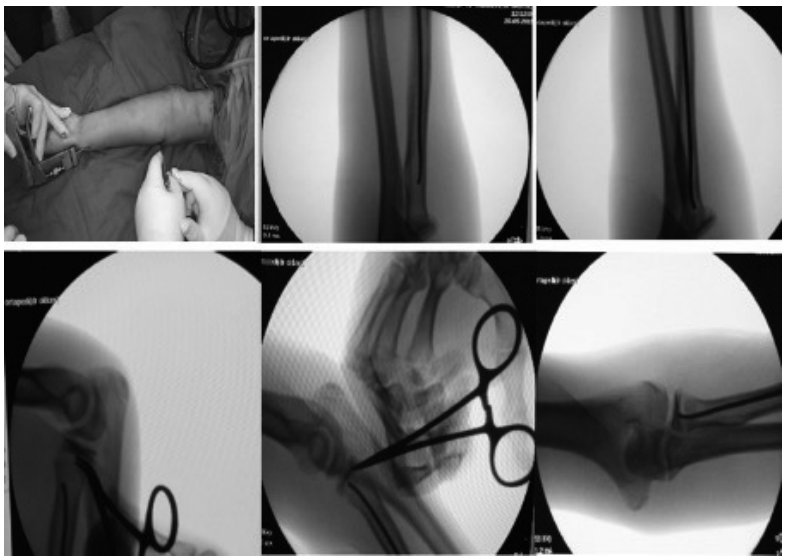

Figure 1. — Surgical technique.

with a blunt and rounded tip with a diameter of 2 to 2.5 mm. The fracture line was accessed with gentle oscillation-like movements or using the assistance of a hammer in the proximal direction within the intramedullary canal. A 2-mm skin incision lateral to the radial head was made with a No. 11 scalpel and fluoroscopy-assisted reduction was performed using mosquito clamps. Then the tip of the TEN was gently nailed under fluoroscopy control (Figure 1). A long arm cast was applied postoperatively. The cast was removed at postoperative week 3 and the patients started elbow movements. TEN was removed at week 8.

Following the removal of TEN, the follow-up visits were scheduled at postoperative months 3, 6, and 12, and yearly thereafter. At each visit, radiological and functional assessments were performed and radiographs were examined for the presence of translation, periarticular ossification, avascular necrosis of radius head, radius head enlargement, or premature physeal closure, in addition to the angulation measurements. Translation, periarticular ossification, avascular necrosis of radius head, radius head enlargement, and premature physeal closure were reported as 'present' or 'absent' with the consensus of two radiologists. Angulation measurements were conducted as described by Metaizeau *(2)*. The radiological results were graded as excellent if the reduction was anatomic, good if a simple shift or inclination not exceeding 20° was present, fair if the tilt was between 20° and 40°, and poor if it was more than 40° *(2)*. The function was graded as excellent (normal and complete range of motion), good (less than 20° restriction), acceptable (restriction between 20° and 40°), and poor (more than 40° restriction) *(2,10)*. Additionally, each patient was evaluated using Mayo Elbow Performance Score (MEPS) that has four domains (pain, range of motion, stability and daily function) and a total score ranging between 0 (worse) and 100 (best) *(11)*.

RESULTS

Table 1 shows the demographical and clinical characteristic of individual patients along with radiological and functional outcomes as assessed during the last follow-up visit. The mean age of the patients was 121.3±32.6 months (77-189 months). There were nine boys (60%), and six girls (40%) in the study group. All patients had right sided dominance of the upper extremity. The injury had occurred in the right and left elbows in seven (46.7%) and eight (53.3%) of the individuals, respectively. All fractures occured due to a fall. According to the Judet classification (as modified by Metaizeau) there were 12 type 3 (80%) and 3 type 4 (20%) fractures.

Table 1. — Patient characteristics and radiological/functional outcomes

		Preoperative evaluation							Follow-up evaluation*			
Pt. Number	Age†/Sex	Side	Additional pathology	Modified Judet Class	Angulation	Time to operation (h)	Complications	Follow-up (mo)	Angulation‡	Radiological rating	Functional rating	MEPS
1.	77/F	R	-	4A	64°	48	-	30	Anatomic	Excellent	Excellent	100
2	115/M	R	-	3	33°	240	-	36	Anatomic	Excellent	Excellent	100
3	156/M	L	-	3	35°	48	-	34	Anatomic	Excellent	Excellent	100
4	96/M	L	-	3	46°	48	-	30	20°	Good	Excellent	100
5.	101/F	L	Olecranon Fx.	3	54°	12	-	30	Anatomic	Excellent	Excellent	100
6.	162/M	L	-	3	35°	24	-	28	Anatomic	Excellent	Excellent	100
7.	142/M	L		3	52°	24	-	24	Anatomic	Excellent	Excellent	100
8	83/M	R	Olecranon Fx.	4B	80°	120	Radial neuropraxia, physeal arrest, loss of fixation	26	60°	Poor	Poor	80
9.	131/M	L	-	3	48°	36	-	24	Anatomic	Excellent	Excellent	100
10.	100/F	R		4A	62°	12	Heterotropic ossification	26	24°	Fair	Excellent	100
11.	114/F	R	-	3	53°	156	-	24	Anatomic	Excellent	Excellent	100
12.	100/M	L	-	3	41°	24	-	21	Anatomic	Excellent	Excellent	100
13.	153/M	R	Medial and lateral epicondyle Fx.	3	56°	24	-	17	Anatomic	Excellent	Excellent	100
14	100/F	L	-	3	37°	96	-	18	Anatomic	Excellent	Excellent	100
15	189/F	R	-	3	43°	36	-	15	21°	Fair	Excellent	100

Abbreviations: Fx, fracture; F, female; M, male; R, right; L, left; MEPS, Mayo Elbow Performance Score

Preoperative average angulation was 49.3 ± 13.0° (range : 33-80). All the children could be managed without a need for an open reduction.

The average time from injury to surgery was 63.2 ± 64.2 hours (12-240 h). Surgery was postponed in a single patient by the anesthesiology team because of an active severe upper respiratory tract infection resulting in 240-hour delay between the time of injury and surgery (Pt. no 2). Importantly, general anaesthesia was administered in 14 patients, and axillary anaesthesia was administered in 1 patient.

One patient had concurrent olecranon fracture and underwent open reduction with internal fixation using a cannulated compression screw (Pt. no 8), in whom the preoperative angulation of 80° was almost completely corrected postoperatively ; however, an angulation up to 60° occurred during the follow up due to physeal arrest. Another patient (Pt. no 5) also had additional olecranon fracture, for which internal fixation with a cannulated compression screw was performed after open reduction. One patient with medial and lateral epicondyle fracture (Pt. no 13) underwent K-wire fixation after open reduction. These open reductions were performed because of the additional fractures, not for the radial neck fracture per se.

The average duration of follow up was 25.5 ± 6.1 months (15-36 months). An excellent elbow function was attained in all but one patient (Pt. no 8) who had 80° flexion, with 20° extension limitation, 45° supination limitation and with nearly completed pronation. The outcome in this patient was categorized as "poor". The average postoperative MEPS score was 98.7 ± 5.1 (80-100).

Except for four patients, radiological anatomic reduction could be accomplished in all the patients in the long term. In four patients, radiological anatomical reduction could not be achieved during follow-up ; however, no intervention was necessary as the function was excellent. Based on the radiological Metaizeau classification, excellent, good, fair, and poor outcomes were achieved in 11, 1, 2, and 1 patients, respectively.

One patient developed heterotrophic ossification postoperatively (Pt. no 10). In this patient's most recent follow up examination, the functional outcome was excellent with a MEPS score of 100. One patient (Pt. no 8) had an injury to the

dorsal interosseous branch of the radial nerve postoperatively, and recovered during follow up.

DISCUSSION

Favourable outcomes were achieved in this study that examined the medium-term clinical and radiological outcomes of modified Metaizeau procedure in the children with displaced radial neck fractures. Our modified technique differs from the standard technique because it involves fluoroscopy-assisted reduction through a small incision lateral to the radial head using mosquito clamps. The ideal management strategy in the radial neck fractures in children remains a matter of debate and gold standards have not been defined yet.

Patterson *(12)* originally proposed the most frequently utilised method for closed manipulation, which involves the application of varus stress on the forearm while extending the elbow. An attempt is made to push the radial head directly with the thumb to achieve reduction. However, this manoeuvre is challenging in the patients with oedema of the elbow. When this approach fails, the flexion-pronation technique proposed by Kaufman may be used *(13)* where pushing the forearm to pronation while the elbow is in flexion and exerting pressure on the radial head are recommended. If adequate reduction could still not be obtained, then assistive methods should be used to facilitate a closed reduction. Some researchers have advocated the use of open reduction in the fractures involving an angulation exceeding 60° *(5,7,11)*.

Zimmerman and co-workers recommended open reduction in open fractures or in the presence of neurovascular injury or a displacement of more than 100% *(1)*. These authors have emphasised the importance of attempting a closed reduction initially using all the available closed reduction methods in other groups of patients, before resorting to open reduction. Accordingly, in our study closed reduction could be accomplished successfully with clamp-assisted reduction in all the cases, with no patients requiring an open reduction. However, open reduction may still be required in the patients with excessive angulation and tilt *(1)*.

In the study by Bither et al. involving 14 patients with Judet type 4 radial neck fractures who were treated with percutaneous-assisted Metaizeau technique, the use of joystick has been reported to achieve a better reduction *(7)*. We use a mosquito clamp instead of K-wire because mosquito clamp is harder than K-wire and more resistant to bending ; moreover, its use as a joystick allows a more precise reduction. The achievement of reduction via rotation in the Metaizeau technique has been found to be adequate, whereas the authors pointed out to the shortcomings of this approach in achieving reduction in type 4 fractures. The authors also advocated the notion that the use of small calibre K-wires in the Metaizeau technique may help prevent the crush injury that may occur at the radial head. However, our experience suggests that the movement of the K-wire through the bone medulla during the fixation performed by a tilted tip of the K-wire may be more challenging than TEN and is more likely to result in injury to the surrounding tissues, prolonged surgery, and more fluoroscopic imaging than TEN. Therefore, the higher cost of TEN may be offset by such advantages.

Cossio et al. utilised the closed reduction external fixation in nine patients with radial neck fractures, and reported that this technique has very limited indications in addition to the scarcity of data on the complication rate *(4)*. Additionally, they emphasised the importance of dorsal and ventral branches of the radial recurrent artery in supplying the radial head, requiring care not to cause injury. In our technique, the tip of the clamp was not sharp allowing blunt dissection to be performed, potentially limiting the risk of injury. Although Cossio et al. reported excellent results with the Metaizeau technique, they also pointed out to a need for secondary surgery and the risk of iatrogenic complications *(4)*. In our study no complications requiring re-operation occurred and the rate of complications was acceptable.

Basmajian et al., reported a complication rate of 36% in a 78-patient series, which is the largest till now. However, these authors utilised a number of different approaches such as non-operative treatment, open reduction internal fixation, and closed reduction and internal fixation, rather than a single treatment strategy. *(14)*. They reported

that the age, severity of the fracture, and treatment method had an impact on the outcome, whereas co-existent injury did not appear to affect the results. In the study by Falciglia et al. involving a total of 24 open reductions for radial neck fractures with an average follow up of 7.1 years, additional elbow injuries were found to be associated with a poorer prognosis in the patients with radial neck fractures *(5)*. In our study the complication rate was low and it does not appear to be associated with the severity of the fracture. However, the patients with a negative outcome in our study had concurrent injuries ; hence, larger samples and longer follow-up periods are required for a better delineation of the association between concurrent injuries and the outcomes.

Novoth et al. used the Metaizeau technique in seven patients with isolated radial neck fractures and accomplished reduction with K-wire assistance upon the failure of closed reduction *(15)*. One of the patients who required K-wire assistance developed periarticular ossification, although with no effect on the functional outcome. In our series, clamp-assisted reduction was utilised and only two patients had complications (one had neuropraxia, heterotopic ossification and loss of fixation ; and the other one had heterotrophic ossification).

Endele et al. used internal fixation with intra-medullary approach in 56 open or closed reductions, and found nerve irritation in eight patients, in whom Metaizeau technique was used *(10)*, corresponding to a complication rate of 15%. This complication only occurred in one patient of our study. One patient who required open reduction in that study was a delayed case (13 days after trauma) *(10)*. On the contrary, in a single patient in our study the clamp-assisted closed reduction and intramedullary elastic nail technique were successfully utilised ten days after trauma. As recommended by Endele and co-workers *(10)*, we also believe that every attempt should be initially made to accomplish a closed reduction.

Klitscher et al. used the Metaizeau method in 28 patients and reported that this approach is a minimally invasive technique that allows an early mobilisation by providing a stable fixation and that anatomic reduction may be achieved in many cases with low complication rates and excellent results, as indicated by an MEPS score of 97 (range : 85-100) *(16)*. This figure is similar to our observations, that is a MEPS score of 98.6.

Pring et al. pointed out to a potential risk of elbow limitation or avascular necrosis of the radial head in closed or percutaneous reductions, and recommended a transition to open reduction whenever this is a failure in closed reduction *(17)*. In contrast, no patients required open reduction in our study, and we believe that before deciding or planning for open reduction, closed reduction should certainly be tried, with assisted reduction when necessary, based on the higher rates of complications in open reduction.

The limitations of our study include a small sample size and the absence of comparison with other treatment modalities. We believe that further comparative studies with a much larger sample size are required for establishing the treatment algorithms for paediatric radial neck fractures.

CONCLUSIONS

Our results suggest that clamp-assisted closed reduction using an (ESIN) in the children with displaced radial neck fractures is associated with good functional and radiologic outcomes in the medium-term. In children with modified Judet type 3-4 radial neck fractures, this technique has the potential to prevent many complications arising from the use of open reduction. Further studies are warranted with larger samples.

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