EAS Journal of Orthopaedic and Physiotherapy
Abbreviated Key Title: EAS J Orthop Physiother
ISSN 2663-0974 (Print) | ISSN 2663-8320 (Online)
Published By East African Scholars Publisher, Kenya

OPEN ACCESS

Volume-5 | Issue-1 | Jan-Feb, 2023 | DOI: 10.36349/easjop.2023.v05i01.001

Original Research Article

Medial Displacement of the Radial Shaft with Fracture of the Radial Neck and Proximal Ulna

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Article History
Received: 18.12.2022
Accepted: 25.01.2023
Published: 04.02.2023

Journal homepage:
https://www.easpublisher.com

Quick Response Code

Abstract: ***Introduction:*** Fractures of the neck and head of the radius in children are relatively uncommon, constituting 4% to 7% of elbow fractures and dislocations. A child with a fracture of the radial neck and proximal ulna with complete medial displacement of the radial shaft is presented and the classification of the injury is discussed. ***Objective:*** To assess the medial displacement of the radial shaft with fracture of the radial neck and proximal ulna. ***Materials & Methods:*** This was a retrospective study conducted at Dept. of Ortho-Surgery, Patuakhali Medical College Hospital, Patuakhali, Bangladesh from January 2018 to December 2021. Twelve patients who had displaced radial neck fractures (Judet type III and type IV) treated. Patients were assessed for functional outcome by Mayo elbow performance score (MEPS), the Tibone and Stoltz functional criteria, and for complications with the average follow-up of four years (range: six months to seven years). Inclusion criteria were Judet type III and type IV radial neck fractures, open physis of radial neck at the time of fracture, minimum follow up time of six months. Exclusion criteria were open fractures and Judet type I and type II radial neck fractures. ***Results:*** The mean age of the patients was 9.12±2.2 years (range: 4 to 14 years). Nine (75%) patients were males and three (25%) patients were females. The right side was the most commonly injured side (right at 68% and left at 32%). 60% cases were of Judet type III and IV 40% cases were of Judet type IV. The mean fracture angulation of the series was 56.5 degrees (range 33.2 degrees to 79.2 degrees). Five patients had isolated radial neck fractures and five patients had associated proximal ulna fractures and two patients had associated posterolateral elbow dislocation. Six cases required open reduction and K-wire fixation as closed and percutaneous pin leverage techniques did not achieve acceptable reduction. The mean follow-up of all patients was four years (range: six months to seven years and five months). Four cases treated with closed reduction and intramedullary nailing by the Metaizeau technique had excellent functional results. Among two patients treated with percutaneous pin leverage and intramedullary nailing by the Metaizeau technique, one patient had an excellent outcome and the other a good outcome. Among four cases treated with open reduction and K-wire fixation, two patients had good outcomes, one patient had fair outcomes, and one patient had a poor outcome. ***Conclusion:*** In conclusion, majority of moderately to severely displaced pediatric radial neck fractures which need intervention can be managed by the closed reduction technique of Metaizeau with or without pin leverage with excellent to good functional outcomes at short-term follow-up.

Keywords: Medial Displacement, Radial Shaft, Fracture, Proximal Ulna.

INTRODUCTION

Fractures of the neck and head of the radius in children are relatively uncommon, constituting 4% to 7% of elbow fractures and dislocations [1-4]. A review of the early literature reveals considerable controversy on the significance, treatment, and late results of this injury [5-8]. However, as is explained in the body of this chapter, since the last edition of this text there has been a growing body of evidence indicating that open reduction and internal fixation should be avoided whenever possible, and that percutaneous reduction (and fixation if necessary) is much more likely to result in a favorable outcome. Sex frequency varies from series to series, but overall, there seems to be a slight female preponderance. The typical patient age range for radial neck fractures is between 4 and 14 years, with a mean age between 10 and 12 years. Approximately 30% to 50% of patients have associated injuries to the elbow region [9, 10]. The radial head is relatively stable and locked by the annular ligament. The immature radial head that is primarily cartilaginous absorbs the

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force and transmits it to the weaker physis or metaphysis of the neck [1-3]. In children and adolescents the intraarticular radial head fractures have a significantly lower incidence, compared with the extraarticular ones, but they are associated with a much higher rate of complications [4].Chambers classification of the proximal radial fractures into three major groups is based on the mechanism of injury and the displacement of the radial head. In group I, which is the most common type of injury, the radial head is primarily displaced. In group II the distal radial fragment is primarily displaced. Finally, in group III chronic repetitive stress injuries, due to both longitudinal and rotational forces on either the head or the proximal radial physis are included. Group I fractures are divided in two subclasses including the valgus injuries or those associated with elbow dislocations. Valgus injuries are subdivided into three types based on the location of the fracture line. Type A includes Salter-Harris type I or II injuries, type B includes Salter-Harris type IV injuries and type C includes metaphyseal fractures with no involvement of the physis. Fractures associated with an elbow dislocation are subdivided into two types. The former occur during spontaneous reduction, while the latter occur during the process of dislocation of the elbow [5]. The most common mechanism of radial neck fractures involves a fall on the outstretched hand with the elbow extended. An associated valgus force to the forearm compresses the capitulum against the radial head. The cartilaginous head absorbs the force and transmits it to the weaker physis or metaphysis. This may produce an angular displacement of the neck. Further valgus forces may produce other concomitant injuries in the elbow region, such as a posterior dislocation of the elbow, an avulsion of the ulnar (medial) epicondyle, a rupture of the ulnar collateral ligament or capsule, and a fracture of the olecranon or of the proximal shaft of the ulna [6-8]. Most of the valgus force is usually concentrated in the distal portion of the olecranon. The prognosis after this fracture seems to depend more on the severity of the injury, the associated injuries about the elbow, and the type of treatment than on the accuracy of the reduction [10-12]. Although emphasis has been placed on the angulation of the radial head, it is actually the displacement of the fracture that is the more important component of the deformity. The classic discussion on this subject was published by Jeffery [10], whose observations in 1950 clarified the nature of the fracture, the mechanism of injury, the radiologic assessment, the method of reduction, and the prognosis. Complete remodeling of a fracture was demonstrated with perfect function after a residual angulation of 50 degrees. Closed reduction consistently produces better results than open reduction, even taking into account that more severe injuries are more likely to require operation [13, 14]. Recently, significant technical advances have been made, making possible the percutaneous reduction of even severely displaced or angulated fractures [1, 8, 9, 15]. In addition, the fracture line may occasionally extend distally to the coronoid process or to the proximal ulnar shaft region, due to the distal localization of the fulcrum of the bending force [9, 10, 16-20]. The radial neck displaces laterally, leaving the radial head and proximal neck fragment in anatomic position under the annular ligament. Placing the forearm in supination results in the apex being anterior; therefore, anterior pressure on the proximal radial shaft with the arm in supination reduces the shaft to the radial head [21-23]. The first description of a fracture of the radial neck that was associated with medial displacement of the shaft of the radius was made by Manoli [24] and was followed by Fogarty [25]. In both cases the radial shaft was displaced medially to the coronoid process and was locked in that position. A diagnosis of anterior dislocation of the proximal fragment was also made intraoperatively. Both authors have used the term dislocation to describe the severe tilting or rotation, as well as the translocation or complete separation of the proximal radial fragment [26]. The radial diaphysis was then manipulated with the retractors laterally and reduced. The fracture was fixed with a transcapitellar K-wire. Uneventful healing of the fractures was recorded 6 months later.

MATERIALS & METHODS

This was a retrospective study conducted at Dept. of Ortho-Surgery, Patuakhali Medical College Hospital, Patuakhali, Bangladesh from January 2018 to December 2021. Medical records of nine patients who had displaced radial neck fractures treated at our Hospital. Twelve patients who had displaced radial neck fractures (Judet type III and type IV) treated. Patients were assessed for functional outcome by Mayo elbow performance score (MEPS), the Tibone and Stoltz functional criteria, and for complications with the average follow-up of four years (range: six months to seven years).

Judet type I is a non-displaced fracture, Judet type II involves angulation of less than 30°, and Judet type III involves angulation of between 30° and 60°. Type-IVa fractures are those with more than 60° of angulation of the radial head and type-IVb fractures are those with more than 80° of angulation of the radial head. Inclusion criteria were Judet type III and type IV radial neck fractures, open physis of radial neck at the time of fracture, minimum follow up time of six months. Exclusion criteria were open fractures and Judet type I and type II radial neck fractures.

Surgical Technique:

All the patients with elbow injuries were initially evaluated with anteroposterior, lateral, and oblique views and once the diagnosis of radial neck fracture was confirmed, limb was supported with an above-elbow posterior slab and were planned for surgery as early as possible. Under general anesthesia, the patient was kept in supine position and the involved upper limb was prepared and placed on a hand table.

Initially, closed reduction was tried by Patterson's method i.e., pulling the extended elbow in a varus direction and applying pressure on the radial head to reduce it. If reduction was not achieved, percutaneous K-wire joystick technique was used by checking under live fluoroscopic control in anteroposterior, lateral and oblique views to find the position of maximum displacement and angulation. If the satisfactory reduction was achieved with joystick, then the fracture was fixed with K-wire by passing K-wire from proximal radial epiphysis to metaphysis. In case of incomplete reduction, further reduction and maintenance of reduction was done with the Metaizeau technique. Only in one of our earlier cases (case 3) we resorted to transcapitellar K wire, which is highly discouraged by many authors in the literature. After Judet type IV was converted to Judet type III fracture with joystick technique, further reduction was obtained by Metaizeau technique of retrograde intramedullary nailing (Fig-1).

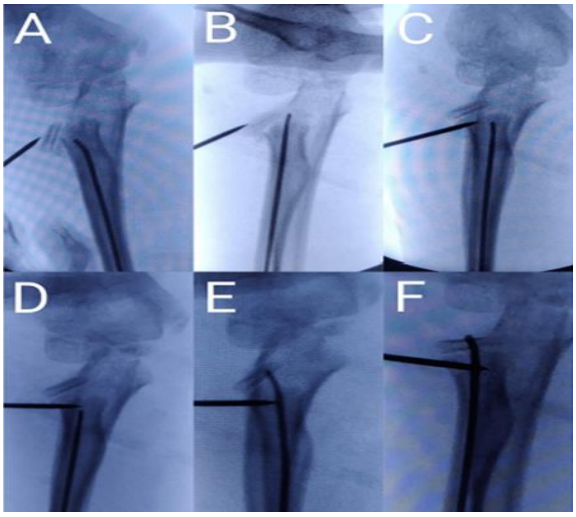

Fig-1: Picture A to F show percutaneous joystick reduction of fracture followed intramedullary nailing by metaizeau technique.

The nail not only helps in getting the reduction but also maintaining it. If reduction was not obtained with either of the techniques mentioned above, then open reduction was done by Kocher approach and K-wire fixation was done with forearm in pronation to prevent posterior interosseous nerve injury. Also, care was taken to preserve the periosteal hinge to decrease the chances of avascular necrosis of radial head. The K-wire removal was done at three to four weeks following which the gradual mobilization of the elbow started. Patients were assessed for functional outcomes by the Mayo elbow performance score (MEPS), the Tibone and Stoltz functional criteria, and for complications at one year [15, 16]. The MEP is based on four variables: pain, range of motion, stability and daily function [17]. Each of these variables was given certain points and all variables put together give a sum of 100 points (Table-1).

Table-1: The Mayo elbow performance score (MEPS).

Variable	Definition	Points
Pain (maximum 45 points)	None	45
	Mild	30
	Moderate	15
	Severe	0
Range of motion, degrees (Maximum 20 points)	Arc > 100	20
	Arc 50-100	15
	Arc < 50	5
Stability (Maximum 10 points)	Stable	10
	Moderately unstable	5
	Grossly unstable	0
Function (Maximum 25 points)	Comb hair	5
	Feed oneself	5
	Personal hygiene	5
	Put on shirt	5
	Put on shoe	5

The results were categorized into four groups based on total points obtained: excellent >90 points; good 75 to 89 points; fair 60 to 74 points; poor <60 points. The Tibone and Stoltz classification for functional results is based on pain, deformity, and range of motion and is shown in Table-2.

Table-2: Tibone and Stoltz classification for functional results of radial neck fractures
ROM: Range of motion.

Clinical condition of the patient	Result
Pain-Absent Deformity-Absent ROM-Complete	Excellent
Pain-Occasional Deformity- Carrying angle increase < 20 degrees	Good
Pain-Occasional Deformity- Carrying angle increase >10 degrees ROM-Limited >20 degrees	Fair
Radial head removal required to treat pain or ROM limitation	Poor

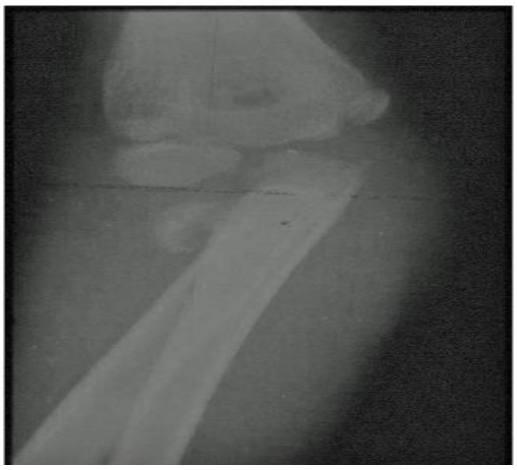

Fig-2: Radiographs of the left elbow showed a displaced fracture of the radial neck and an undisplaced fracture of the olecranon. The distal radial fragment was completely displaced medially.

RESULTS

The mean age of the patients was 9.12±2.2 years (range: 4 to 14 years). Nine (75%) patients were males and three (25%) patients were females. The right side was the most commonly injured side (right at 68% and left at 32%). 60% cases were of Judet type III and IV 40% cases were of Judet type IV. The mean fracture angulation of the series was 56.5 degrees (range 33.2 degrees to 79.2 degrees). Five patients had isolated radial neck fractures and five patients had associated proximal ulna fractures and two patients had associated posterolateral elbow dislocation. Closed reduction and intramedullary nailing by Metaizeau technique were done in four cases and percutaneous joystick reduction and intramedullary nailing by Metaizeau were done in two cases (Fig-3).

Fig-3: Radiographs of a nine year old male patient.

A and B: Preoperative radiograph of nine-year-old male showing Judet type III radial neck fracture and proximal ulna fracture; C and D: Immediate postoperative radiograph showing intramedullary nailing of radial neck fracture and K-wire fixation of ulna; E and F: Radiograph at the two-year follow-up showing fracture union.

Fig-4: Pictures A to D show excellent function after closed reduction and intramedullary nailing by the Metaizeau technique of the male patient.

Fig-5: Radiographs of a nine-year-old female patient

A and B: Preoperative radiograph of a nine-year-old female patient showing Judet type IV radial neck fracture; C and D: Immediate postoperative radiograph after percutaneous K-wire assisted joystick reduction followed by intramedullary nailing by the Metaizeau technique; E and F: Radiograph at the two-year follow-up showing fracture union.

Six cases required open reduction and K-wire fixation as closed and percutaneous pin leverage techniques did not achieve acceptable reduction. The mean follow-up of all patients was four years (range: six months to seven years and five months). Four cases treated with closed reduction and intramedullary nailing by the Metaizeau technique had excellent functional results. Among two patients treated with percutaneous pin leverage and intramedullary nailing by the Metaizeau technique, one patient had an excellent outcome and the other a good outcome (Table-3).

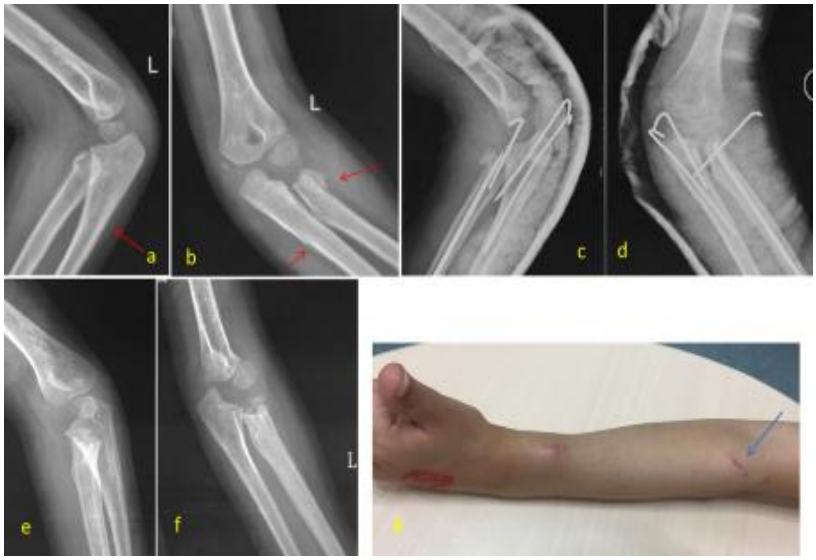

Fig-6: Pictures A to G show excellent function after percutaneous K-wire assisted joystick reduction followed by intramedullary nailing by the Metaizeau technique of the female patient.

Table-3: Summary of the cases (N=12)

S. NO	Age (years)	Sex	Judet type	Side of injury	Associated injuries	Treatment	Follow up	MEPS	Tibone and Stoltz classification	Complication
1	9	M	3	Right	Ulna Fracture	CR+ Metaizeau	4 years 5 months	Excellent	Excellent	Posterior interosseous nerve palsy
2	14	M	3	Left	Ulna fracture	OR+ K wire	7 years 5 months	Good	Good	None
3	4	F	4	Left	None	Or+transcapitellar wire	6 years 4months	Fair	Fair	Stiffness
4	9	M	3	Right	Ulna fracture	CR+ Metaizeau	4 years 11 months	Excellent	Excellent	None
5	9	F	4	Left	None	Percutaneous Pin Leverage + Metaizeau	3 years 9 months	Excellent	Excellent	None
6	12	M	4	Right	Ulna fracture	Percutaneous Pin Leverage + Metaizeau	3 years 9 months	Good	Good	Posterior interosseous nerve palsy
7	11	M	4	Right	None	OR and K wire fixation	4 years 1 months	Good	Good	None
8	11	M	3	Right	Posterolateral elbow dislocation	CR of dislocation	6 months	Poor	Poor	Stiffness
9	11	M	3	Right	Posterolateral elbow dislocation	OR and k-wire fixation	6 months	Poor	Poor	Stiffness
10	8	M	3	Right	None	CR+ Metaizeau	13 months	Excellent	Excellent	None
11	9	M	3	Right	Posterolateral elbow dislocation	CR of dislocation	6 months	Poor	Poor	Stiffness
12	9	M	3	Right	Posterolateral elbow dislocation	OR and k-wire fixation	6 months	Poor	Poor	Stiffness

CR: Closed reduction, OR: Open reduction

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DISCUSSION

Radial neck fractures are relatively rare fractures in the pediatric age group and management of displaced radial neck fractures is challenging. The Judet type I and type II fractures are managed non-operatively and they heal with acceptable functional results [8]. The Judet type III and type IV radial neck fractures are managed surgically and various surgical options like percutaneous pin leverage method, elastic stable intramedullary nailing, and open reduction with or without internal fixation are available [8-11]. The mean age in the present study was 9.2 years. This is closer to the operative group of a study by De Mattos *et al.,* [18]. The mean fracture angulation in this series was 56.5 degrees (range 33.2 degrees to 79.2 degrees) and was comparable to the study by Klitscher D *et al.,* (62 degrees) [19]. Approximately 30% to 50% of patients with radial neck fractures have associated injuries like fractures of the proximal ulna, medial and lateral epicondyle, ruptures of the medial collateral ligament, elbow dislocation, etc. [16, 20]. In this series, four patients had associated proximal ulna fractures and one patient had associated poster lateral dislocation of the elbow. The proximal ulna was treated with closed reduction and intramedullary K-wire fixation in all cases and elbow dislocation was reduced by closed manipulation under general anesthesia. It is reported that associated fractures negatively influence the functional outcome of radial neck fractures [15, 21]. In our series, among five patients with associated fractures, two patients had excellent results, two patients had good results, and one patient had poor results. Closed reduction and intramedullary nailing by the Metaizeau technique were done in three cases. All these cases were Judet type III fractures and had excellent functional results as per the MEPS and the Tibone and Stoltz classification. Our results were in agreement with a study done by Metaizeau *et al.,* and Klitscher D *et al.,* in which they report excellent results in 100% of Judet type III fractures treated using closed intramedullary nailing [8, 19]. This can be attributed to the ease of reduction of Judet type III fractures as they rarely require percutaneous methods of reduction or open reduction. Two cases were treated by percutaneous joystick reduction with K-wire followed by intramedullary nailing. The reduction was assessed by looking for radiocapitellar alignment in lateral view under C-arm and by doing intraoperative pronation and supination. If these movements were satisfactory, then the reduction was considered adequate. Among these, one case was Judet type III and the other one was Judet type IV fracture. One case had an excellent functional result and the other had good functional results according to MEPS, and Tibone and Stoltz classification. Brandão *et al.,* and D'Souza *et al.,* concluded that the percutaneous reduction with K-wire followed by intramedullary fixation with the Metaizeau technique gives better functional results compared to open reduction in displaced radial neck fractures [22, 23]. Similarly, Klitscher *et al.,* reported excellent results in all patients who underwent percutaneous K-wire reduction and intramedullary nailing [19]. Despite all techniques of closed and percutaneous reduction, at times acceptable reduction may not be achieved where open reduction becomes the only option. Six cases required open reduction and K-wire fixation as closed and percutaneous pin leverage techniques did not achieve acceptable reduction. The mean follow-up of all patients was four years (range: six months to seven years and five months). Four cases treated with closed reduction and intramedullary nailing by the Metaizeau technique had excellent functional results. Among two patients treated with percutaneous pin leverage and intramedullary nailing by the Metaizeau technique, one patient had an excellent outcome and the other a good outcome.Several studies have reported that open reduction will give poor functional outcomes despite the anatomical reduction of the fracture [24-26]. These poor results may be due to the associated complications with an open reduction such as avascular necrosis, proximal synostosis, heterotopic ossification, infection, premature physeal closure, and loss of range of motion due to fibrous adhesions. Kaiser *et al.,* studied 19 severely displaced radial neck fractures (Judet IV) comparing those with and without bony contact and concluded that the unfavorable results are because of the nature of the initial injury and not because of open reduction [27]. However, the authors in the present study cannot make such inferences as this is a small case series. Shah *et al.,* described a new technique of closed reduction to obtain an anatomical and stable reduction in Judet type III and IV fractures [28]. This technique involves the application of varus stress at the elbow with thumb pressure applied at the radial head at the poster lateral aspect like in Patterson's technique, after which the elbow is hyper flexed and hyper pronated simultaneously with continuous pressure over the radial head. The arm is immobilized in an above-elbow cast in 90-degree flexion and mid-prone position, with no K-wire or nail fixation after achieving complete reduction. The authors achieved excellent results without complications in all patients in their series. Elbow stiffness, radio-ulnar synostosis, avascular necrosis, posterior interosseous nerve injury, heterotopic ossification, non-union, and malunion are some of the known complications of radial neck fractures with open or closed methods of treatment [13]. Elbow stiffness and posterior interosseous nerve palsy were the complications encountered in our series. All the reported cases here were from a single institute and were operated by the experienced senior author SKC.

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Our study is not without limitations. The authors are of the opinion that the small sample size is justified owing to the rarity or lesser incidence of this fracture. The authors would like to try the recently published Shah *et al.,*'s technique of closed reduction in severely displaced fractures without the need for internal fixation in their future cases and compare the results with the present patient database [28]. However, an association with a proximal fracture of the ulna has only been presented in two reports thereafter. Strong *et al.,* [29] reported two children with fractures of the radial neck and medial displacement of the radial shaft. In both cases a long oblique greenstick fracture of the proximal ulna was also diagnosed. The radial head was dislocated anteriorly as well. The most recent case was reported by Dillon and King [30] who indicated that their case was irreducible by closed means, requiring open reduction and internal fixation.

CONCLUSION

In conclusion, majority of moderately to severely displaced pediatric radial neck fractures which need intervention can be managed by the closed reduction technique of Metaizeau with or without pin leverage with excellent to good functional outcomes at short-term follow-up. Some cases need open reduction which also has good to fair outcomes. Initial trauma and associated injuries seem to play a role in the outcome rather than the treatment method per se. However, a larger sample size and longer follow-up are needed for comparisons and for arriving at better and definitive conclusions.

Conflict of Interest: None.

Source of Fund: Nil.

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Citation: Md. Salim Matber, M. Muniruzzaman, Mohammad Golam Sagir, AKM Fakhrul Alam (2023). Medial Displacement of the Radial Shaft with Fracture of the Radial Neck and Proximal Ulna. *EAS J Orthop Physiother*, *5*(1): 1-9.