Assessment of The Functional results of the Metaizeau technique Used for Treatment of Displaced Fracture Neck of Radius in Pediatrics

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ABSTRACT

Background: Fractures of the radial neck accounts for 1% of all childhood fractures and 5% to 10% of childhood traumatic lesions involving the elbow. Intramedullary percutaneous nail reduction (Metaizeau technique) is considered the most effective surgical technique.
Objective: The purpose of this study was to identify the main clinical features of radial neck fracture in children and to evaluate the functional results of the Metaizeau technique.
Conclusion: The elastic stable intramedullary pinning according to the Metaizeau technique is the treatment of choice for displaced radial neck fractures in children.
Keywords: Metaizeau, radial Neck, fracture, child.

Introduction

Proximal radius fractures are the third most common elbow fracture in children, representing 5% to 10% of elbow fractures after supracondylar and lateral condyle fractures. The literature often does not differentiate between radial neck and radial head fractures, but they are distinct entities [1].

Radial neck fractures are far more common in children and are fractures typically occur after the proximal radial physis has closed, and outcomes from these intra-articular injuries are particularly poor. The most common radial neck fractures are extraphyseal fractures of the metaphysis or Salter-Harris I or II fractures of the proximal radial physis. Treatment of radial neck fractures is aimed at restoring the anatomy of the proximal radius to preserve elbow range of motion, particularly forearm rotation, some of which is usually lost [2,3].

There is little difference in the occurrence rates between males and females however, this injury seems to occur on an average approximately 2 years earlier in girls than in boys [4].

Etiology

Radial neck fractures most commonly occur after a fall on an outstretched upper hand with the elbow in extension and a valgus force across the elbow. The capitellum compresses the lateral most aspect of the radial head, which changes according to the rotation of the forearm at the time of the fall [5].

Mechanism of injury

- Fall on outestretched hand
- Posteroior dislocation of elbow
- Relocation of elbow dislocation
- Stress fracture with athletic (longitudinal and rotational force) [6].

A final mechanism of injury is chronic repetitive stress, both longitudinal and rotational, on either the head or the proximal radial physis. These injuries are usually the result of athletic activity in which the upper extremity is required to perform repetitive motions. Repetitive stresses disrupt growth of either the neck or the head with eventual deformity. A true stress fracture is not present [7].

Direction of angulations

In neutral, the force is directed laterally; in supination, the force is directed anteriorly; and in pronation, the force is directed posteriorly. A second mechanism of injury may occur after elbow dislocation. During the dislocation, the capitellum may compress the radial head in an anterior direction, while during reduction, the radial head may be compressed in a posterior direction [8].

Importantly, a proximal radius fracture should be considered a sentinel injury because concomitant injuries occur in 30% to 50% of patients. When a proximal radius fracture is identified, one must immediately look for another fracture! Elbow dislocations, medial epicondyle fractures, and olecranon fractures are the most commonly reported concomitant injuries, although ulnar shaft, radial shaft, supracondylar, lateral epicondyle, and capitellum fractures have all been reported as well. Associated injuries have been associated with poorer outcomes [9].

Injuries Associated With Fractures of the Proximal Radius

Proximal radius fractures can occur concomitantly with distal humerus, ulna, radial shaft, or distal radius fractures. Fractures in combination with ulnar fractures often are part of the Monteggia fracture pattern . Presence of associated fractures portends a poor prognosis for patients with proximal radius fractures with higher rates of persistent stiffness and pain compared to those with isolated proximal radius fractures. proximal radius fractures can also occur during traumatic elbow dislocations. The posterior interosseous nerve (PIN) wraps around the proximal radius and occasionally can be injured in association with proximal radius fractures. More typically, however, the nerve is at risk during percutaneous manipulation or open reduction of proximal radius fractures [(10)].

Clinical picture

There is usually pain, tenderness, and swelling over the lateral aspect of the elbow and decreased forearm rotation (pronation/supination). Deformity is not typically a feature unless there are associated injuries (e.g. elbow joint dislocation, ulna shaft fracture) [(10)].

Physical Examination

Examination of a proximal radius fracture will reveal tenderness to palpation at the proximal radius and pain with elbow motion, particularly with attempted supination and pronation, which the patient will avoid. Very subtle metaphyseal buckle fractures on a radiograph may be confirmed as true fractures with boney tenderness over the proximal radius and pain with pronation or supination. Forearm rotation is usually notably diminished, particularly in the setting of angulated radial neck fracture, and should be documented before initiating treatment. Discussion with family should emphasize future loss of pronation and supination regardless of treatment so as to appropriately guide expectations [(11)].

At the time of evaluation, a thorough neurovascular examination is warranted. Attention should be paid to soft tissue swelling because compartment syndrome may occur after minimally displaced fractures of the radial neck. Examination of nerve function is important, particularly the posterior interosseous nerve (PIN) because it courses directly over the radial neck before providing motor innervation to the digital extensors. A reliable indicator of PIN function is resisted extension of the thumb when the hand is placed on a flat surface. In the search for concomitant injuries, adjacent joints should be examined. Of particular note, wrist pain referred from the elbow may be the only presenting symptom in a young patient with a radial neck fracture and an otherwise normal examination [(12)].

Radiological Diagnosis:-

Displaced proximal radius fractures are usually easy to identify on standard anteroposterior (AP) and lateral radiographs. Some variants in the ossification process can resemble a fracture. Most of these involve the radial head, although a step-off can also develop as a normal variant of the metaphysis. There may be a persistence of the secondary ossification centers of the epiphysis. Comparison views of the contralateral elbow are useful for evaluation of unusual ossification centers after an acute elbow injury [(12)].

Anterior fat pad

An anterior fat pad can be a normal variant when it appears as a narrow radiolucent strip superior to the radial head and anterior to the distal humerus. A wide anterior fat pad, however, is known as a "sail" sign and may be indicative of an occult fracture [13].

In one study of 197 children (25 percent with fractures) undergoing elbow radiographs in a pediatric emergency department, an abnormal anterior fat pad, as interpreted by a pediatric radiologist, had a sensitivity of 96 percent and a positive predictive value of 64 percent for an occult elbow fracture [14].

Posterior fat pad

The posterior fat pad is not visible in normal children but usually appears as a radiolucency posterior to the distal humerus and adjacent to the olecranon fossa in children with a distal humeral fracture.The presence of a posterior fat pad on radiograph indicates an effusion of the elbow joint caused by significant trauma[13].

There are many studies that have evaluated this finding and have described that the posterior fat pad sign could be predictive of an occult fracture of the elbow following trauma. **Skaggs and Mirzayan** described this fat pad sign in a prospective series of 45 children with a traumatic history about the elbow who had an elevated posterior fat pad and had no other radiographic evidence of fracture. The authors reimaged the elbows in these children and noted that periosteal reaction from an occult fracture was present in 76% of patients [14].

Imaging

Views:-

- Anterior posterior AP (lateral angulation)
- Lateral view (fat bad sing)
- Radiocapitellar view (better evaluated radiocapitellar joint)
- Oblique view (oblique angulation**)**

Proximal radius fractures are evaluated with AP and lateral radiographs. Before ossification of the radial head, an arthrogram is useful in patients with a suspected proximal radius fracture. Oblique views may aid in determining maximal angulation, although no single projection will reliably demonstrate maximal angulation because the direction of displacement varies by patient and is determined by the forearm position at the time of injury. Contralateral elbow views may be useful for determining anatomic radial neck valgus or clarification of ossification centers in the uninjured elbow. A radiocapitellar view, taken 45^o obliquely from a true lateral to remove the superimposed coronoid process, is helpful for unobstructed view of the proximal radius .Maximal angulation is best determined with an examination under fluoroscopy, although without fluoroscopy, fracture angulation should be measured on whichever view demonstrates the greatest abnormality [(15)].

Angulation is measured by comparing a line drawn perpendicular to the articular surface of the radial head with a line drawn down the radial shaft. Whether the second line is drawn down the shaft of the radius or the neck is variably reported, but considering that thenormal radial neck is in up to 15^o of valgus relative to the radial shaft, the authors find that a long line down the shaft is more reproducible. Because the direction of displacement varies, this measurement should be made on whichever view demonstrates the greatest angulation. The classic teaching that the radiocapitellar line must intersect the capitellum in all views has drawn interest because it misses the capitellum in 16% of normal pediatric elbow radiographs, particularly in the AP projection in children younger than 5 years of age(ossification center >5yeras) [(16,17)].

Souder et al proposed a new radiographic parameter, the lateral humeral line, which is helpful for evaluating radiocapitellar dislocation in monteggia fracture dislocations and may be applied to the evaluation of radial neck fractures, where angulation leads to radiocapitellar incongruity. The lateral humeral line is drawn parallel to the long axis of the humerus at the lateral-most extent of the ossified distal humerus and should lie lateral to the radial neck when extended distally on the AP projection [(18)].

The lateral radiograph is helpful for the identification of fracture as well as a posterior fat pad, which may represent a fracture that is otherwise difficult to identify. Because many radial neck fractures are extracapsular, however, the fat pad sign is not a reliable indicator of radial neck fracture [(19)].

Advanced imaging is not commonly indicated when evaluating pediatric proximal radius fractures. In the absence of readily available arthrography, MRI will adequately visualize the pre-ossified elbow, but its use should be weighed against its high cost. Furthermore, in older children with comminuted radial head fractures, CT may help delineate fracture fragments if operative fixation is planned. Finally, a compression fracture of the anterior radial head, which has been associated with radiocapitellar instability, may benefit from MRI to evaluate for concurrent ligamentous injury [(20)].

Classification

Judet Classification of Radial Neck Fractures:

Table (2): Judet Classification of Radial Neck Fractures [21].

TABLE 1. Judet Classification of Radial Neck Fractures

Type	Description
I	Undisplaced
II	Angulation < 30 degree Translation $< 50\%$
III	Angulation 30 to 60 degrees Translation $< 100\%$
IV	Angulation > 60 degree Translation $> 100\%$

Most radial neck fractures occur through the proximal radial metaphysis, whereas others occur through the proximal radial physis as Salter- Harris I or II fractures Intra-articular extension in children is rare and is not covered in classification schemes for radial neck fractures. The Jeffery, O'Brien, and Judet classifications are most commonly referenced in the literature and differentiate injuries by mechanism of injury and degree of angulation [22].

According to **Jeffery,** group I is the most common injury type, resulting from impaction of the capitellum against the radial head during a fall on an outstretched hand with valgus displacement of the radial neck. Group II fractures occur from an elbow dislocation or subluxation with up to 90^{o} angulation of the radial neck in the direction of dislocation [23].

In the O'Brien classification, type I fractures are angulated less than 30o, type II fractures 30^{o} to 60^{o}, and type III fractures greater than 60^{o}. The Judet classification is perhaps the most widely used. Grade I fractures involve translation of the proximal radial epiphysis with no angulation. Grade II fractures are angulated ,30^{o}, grade III 30^{o} to 60^{o}, grade IVa 60^{o} to 80^{o}, and grade IVb 80^{o} to 90^{o}[24].

Management

Nonsurgical Management

It is accepted that fractures with,30^{o} angulation (Judet type I and II) and ,3 mm of displacement do well without manipulation, whereas those with .60^{o} angulation or 3 mm of displacement require intervention [25].

Treatment recommendations vary for fractures with 30^{o} to 60^{o} angulation, but most authors use 30^{o} as a threshold for intervention. Furthermore, the recommendation for intervention may vary by patient age, although no high-quality studies have established specific age criteria for intervention. For example, according to **Radomisli and Rosen,** fractures with angulation greater than 15º in children older than 10 years and greater than 30º in children younger than 10 years do not remodel, and closed reduction should be attempted in these cases [(26)].

On the other end of the spectrum, Vocke and Von Laer reported good results with short-term casting and early motion in patients younger than 10 years with up to 50º angulation [(27)].

Closed Reduction

Attempt at closed reduction for Judet type III and IV fractures or patients with ,70º of passive pronation or supination is recommended. In a tolerant patient with a borderline degree of angulation or displacement, a closed reduction under sedation in the emergency department may be attempted. With higher degrees of angulation or displacement, one should consider a closed reduction under general anesthesia in the operating room where conversion to percutaneous or open procedures may be attempted with ease [(13)].

Several methods of closed reduction have been published. The Patterson technique involves traction and a varus force applied to the forearm, while direct pressure is applied over the radial head. The Israeli technique uses supination of the maximally flexed elbow to relieve capsular tension while direct pressure is applied over the radial head from the lateral side. The forearm is then gently pronated to rotate the radial head under the applied pressure and reduce it [(28)].

Neher and Torch described a technique that begins by rotating the forearm under fluoroscopy until the AP view with maximal angulation is obtained with the elbow in extension [(29)].An assistant then applies a laterally directed force over the anterior proximal radial shaft to serve as counter-traction while the surgeon applies a direct force over the radial head with one hand and a varus stress with the other [(30)].

Percutaneous Reduction

When a closed reduction does not achieve acceptable clinical or radiographic parameters, most authors recommend proceeding to a percutaneous manipulation [(31)].

The most common method uses a rigid Kirschner wire or Steinman pin to manipulate the radial head into place. The forearm is maximally pronated by an assistant to direct the PIN away from the entry point. Fluoroscopy is used to identify the plane of maximal displacement and this position is maintained. The wire then pierces the skin almost one third of the length of the ulna distal to the fracture along the lateral aspect of radius. The sharp end of the Kirschner wire is used to pierce the skin, whereas the blunt or sharp end is used to push the radial head into position. The force is first directed proximally to free the proximal fragment and then medially to translate the fragment into a reduced position. Closed reduction techniques are applied in conjunction with percutaneous manipulation: pushing on the radial head with the surgeon's thumbs, rotating the forearm, and applying a varus stress may facilitate the reduction [(11)].

If reduction using a Kirschner wire is unsuccessful, we recommend a second percutaneous attempt using. A small incision is made at the level of the fracture posterolaterally to avoid the PIN, and a freer elevator is inserted into the fracture site. The radial head is guided into place using the smooth freer elevator as a skid. When the freer elevator is removed, usually enough bony interdigitation to hold the fracture reduced. Alternatively, the Wallace technique uses the freer elevator to pull the distal fragment laterally while the surgeon's thumb guides the radial head back into place [(17)].

The Metaizeau technique

The Metaizeau technique is an alternative percutaneous reduction technique that uses a Kirschner wire or intramedullary nail passed from distal to proximal. An incision is made over the radial styloid and a drill is used to open the near cortex. A long 1.4 to 1.8 mm wire or nail with the last 1 cm bent 30^o is inserted and passed from distal to proximal to the level of the radial neck. The wire is then rotated so the tip can be passed into the displaced radial head and held in subchondral bone. The wire is then rotated until the radial head is reduced [(32)].

Once percutaneous manipulation is completed, the reduction is verified fluoroscopically. In the pre-ossified elbow, intra-operative arthrography is useful to confirm the quality of reduction. Forearm rotation is also evaluated intra-operatively to confirm restoration of pronosupination and to assess stability of the reduced fracture [(13)].

Fixation

A stable reduction is typically obtained after closed or percutaneous reduction because of interdigitation of fracture ends. Many authors recommend an assessment of fracture stability under fluoroscopy after reduction and to proceed with fixation only if the fracture remains unstable. A Kirschner wire is inserted from the lateral aspect of the proximal fragment obliquely across the fracture site and through the ulnar metaphyseal cortex of the distal fragment. If necessary, two Kirschner wires may be placed in this manner. Fixation within the 90o "safe zone" between the radial styloid and lister tubercle in the axial plane is recommended [(33)].

Metaizeau technique is, intramedullary stabilization of the fracture may be achieved using a Kirschner wire or a flexible nail as described by **Metaizeau** [(34)].

Intramedullary reduction and fixation of proximal radius fractures was described by Metaizeau in 1980[(120)]. After selection of an appropriate-sized implant (K-wire or titanium flexible nail), the distal 3 to 4 mm of the implant should be bent sharply about 40 degrees. Either a dorsal or radial approach can be utilized at the entry site of the distal radius. The wire is advanced through the radial canal to the fracture site. If necessary, closed maneuvers should be used to improve alignment at the fracture site to allow for successful passage of the distal tip of the implant into the proximal fragment. The implant should be impacted into the epiphysis to achieve maximal fixation prior to reduction attempts with the implant. Once advanced appropriately, the nail should be rotated 90 to 180 degrees as needed to reduce the proximal fragment. The forearm should be held by the assistant to prevent the radial shaft from rotating with the implant .Stability at the elbow joint and range of motion are assessed. The implant should be cut distally, balancing need for ease of recovery during implant removal with soft tissue irritation from implant prominence at the distal radius. Rigid immobilization is not necessary with use of an intramedullary implant; however, most surgeons will immobilize the extremity in a long-arm splint or cast for 7 to 10 days for pain relief and to allow for soft tissue healing. Early range of motion is encouraged to minimize postoperative stiffness [(35)].

Transcapitellar fixation has resulted in unacceptable rates of hardware failure and should be avoided. In more mature patients, one may consider mini-fragment screws or plates, provided all hardware remains in the “safe zone.” [(36)].

Open Reduction

An open reduction is indicated if closed and percutaneous methods fail to achieve an acceptable reduction. Most authors agree that the posterolateral (Kocher) approach is the optimal approach for reduction. With the forearm maximally pronated to move the PIN anteriorly, the interval between anconeus and extensor carpi ulnaris is used to expose the proximal radius. The annular ligament may be incised if necessary for reduction but should be repaired afterwards for additional stability. Periosteum, capsule, or annular ligament may be interposed at the fracture site and necessitate removal. Soft tissue stripping should be avoided to reduce the risk of osteonecrosis and heterotopic ossification [(37)].

Immobilization

Most authors agree that a 2- to 3- week period of above-elbow immobilization in a long arm cast with the forearm in neutral rotation is indicated regardless of reduction method or the presence of internal fixation [(38)].

Outcomes

Good or excellent outcomes have been reported in 64% to 86% of pediatric radial neck fractures, including 90% to 95% of patients that require casting with no reduction. Factors associated with worse outcome include greater initial angulation and displacement, associated injury, age more than 10 years, articular involvement, the need for open reduction, and inadequate fixation [(13)].

- **Angulation and Displacement**

Greater initial angulation and displacement have been correlated with worse outcome by many authors independent of treatment method. It was noted a good or excellent result in 94% of patients presenting with angulation of the radial head less than 30^{o} versus 64% presenting with angulation more than 30^{o}. Similarly, the same authors report 90% good or excellent result in patients presenting with less than 3 mm of displacement versus 70% presenting with more than 3 mm of displacement [(39)].

Cornwall, demonstrated worse outcomes in patients presenting with worse initial angulation despite achieving acceptable postreduction angulation, supporting the concept that outcome is correlated with overall degree of injury rather than just the final alignment [(15)].

On the contrary, among patients with greater initial angulation and displacement, **Falciglia et al** noted an improvement in outcome when an anatomic reduction is achieved and advocate for open reduction to achieve this goal in worse (Judet type IV) fractures [(39)]. Similarly, it was noted a 57% rate of unsuccessful outcome in fractures with residual displacement compared with 37% of those without residual displacement. In another large series of patients with Judet type IV fractures, **Kaiser et al** differentiate between fractures with and without bony contact between the radial head and neck. Those without bony contact have a higher rate of associated injuries, a higher need for open reduction, and were more likely to have a poor outcome [(40)].

- **Associated Injuries**

Thirty to fifty percent of radial neck fractures are associated with additional injuries, including olecranon fractures, ulnar shaft fractures, elbow dislocations, epicondyle fractures, and collateral ligament ruptures [(38)].

The influence of concomitant injury on outcome is uncertain. The presence of associated injury has been correlated with worse outcomes by many authors who demonstrated decreased forearm rotation when a radial neck fracture occurs in association with an ipsilateral elbow injury. This is in contrast to other authors, including **Zimmerman et al** who found no association between concomitant injury and outcome in a logistic regression analysis [(3)].

- **Age**

Older children with radial neck fractures demonstrate worse outcomes than younger children. **Basmajian et al** report 74% excellent and good outcomes in patients younger than 10 years compared with 54% of patients equal to or older than 10 years [(9)]. Similarly, **Zimmerman et al** report 32% unsuccessful outcome rates in children less than age 10 and unsuccessful outcome rates more than 50% in patients older than 10 years [(3)].

- **Open Reduction**

Fractures requiring open reduction have been shown to result in worse outcomes; whereas it is unknown how much of the poor outcome is attributable to the open reduction rather than the worse nature of the injury, open reduction is typically recommended as a last step in the management cascade [17].

In a large series of surgically treated radial neck fractures, **Basmajian et al** reported a 35% rate of good or excellent outcome with open reduction compared with a 73% rate of good or excellent outcome with percutaneous reduction [9].

In a series of 24 fractures treated with open reduction after failed closed reduction, **Falciglia et al** report 25% fair and 20% poor outcomes; fair and poor outcomes were associated with a loss of forearm rotation, loss of flexion-extension, increased valgus carrying angle, osteonecrosis of the radial head, premature physeal closure, and associated injuries [39].

24% of patients requiring an open reduction did not have any surgical attempts at reduction before open treatment, highlighting the wide variability in practice patterns and the need for a progressively invasive approach to management [13].

- **Inadequate Fixation**

Although most fractures are stable after reduction, internal fixation is indicated for fractures that remain unstable. In a series of nine patients with radial neck nonunion, eight of whom required open reduction, **Waters and Stewart** concluded that inadequate stability played a role in the development of nonunion and advocate for fixation whenever an open reduction is needed [41].

De Mattos et al identified cases of osteonecrosis and radioulnar synostosis when open reduction was not accompanied by internal fixation and similarly concluded that an open reduction automatically warrants internal fixation [12].

Importantly, transcapitellar pin fixation is associated with a high complication rate and is not to be used [42].

- **Articular Involvement**

Articular involvement of proximal radius fractures denotes a separate entity from the more common radial neck fracture and is rare in children with open physes. In a review of 116 patients with a proximal radius fracture, 6 of 83 patients (7%) with open physes had intra-articular involvement, whereas 17 of 33 teenagers (52%) with closed physes had intraarticular involvement [43].

In another series of 311 children with proximal radius fracture, 12 (3.9%) were intra-articular and 299 (96.1%) were extra-articular. The incidence of complications was 50% in the intra-articular group and 1.3% in the extra-articular group (P, 0.0001), whereas revision surgery was also markedly higher in the intra-articular group (25%) versus the extra-articular group (0%) [(44)].

Progressive radial head subluxation with development of rapid radiocapitellar degeneration has been described in skeletally immature patients with intra-articular radial head fractures, and early surgical intervention is recommended to restore radiocapitellar stability [(45)].

- **Other Complications**

The most common complication following radial neck fracture is stiffness, which occurs in 10% to 31% of cases and has been shown to correlate with a poor functional outcome. Injury severity, associated fracture, and multiple attempts at closed reduction and open reduction have been correlated with stiffness [(37)].

Zimmerman et al reported mean follow-up flexion, extension, pronation, and supination of 129^o, 3^o, 76^o, 74^o, respectively. Radial head overgrowth is a common radiographic finding in 18% to 37% of patients after treatment and is often asymptomatic [(3)].

Osteonecrosis may present in up to 10% of all patients and up to 25% of patients requiring an open reduction. Premature physeal closure is often reported but rarely affects function because radial growth occurs predominantly at the distal physis [(39)].

Additional reported complications include heterotopic ossification, radioulnar synostosis, and neurovascular injury [(41)].

Conclusion

The elastic stable intramedullary pinning according to the Metaizeau technique is the treatment of choice for displaced radial neck fractures in children.

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