Management of Radial Neck Fractures

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Abstract:

Radial neck fractures account for up to 10% of all pediatric elbow fractures, usually occurring as a result of valgus stress onto an outstretched arm. Most radial neck fractures occur through the periphyseal metaphyseal bone, with a smaller subset occurring through the physis. Treatment can depend on the fracture morphology, degree of displacement and/or angulation, age of the patient, and associated injuries. Stiffness following these injuries is common, but a number of other complications have also been described. This paper provides a brief review of radial neck fractures and offers guidance on their management and especially highlights less invasive methods to manage these fractures.

Key Concepts:

- Radial neck fractures comprise up to 10% of all pediatric elbow fractures and usually occur as a result of a valgus force on an outstretched arm.

- A number of concomitant elbow injuries are associated with radial neck fractures, necessitating careful radiologic and clinical scrutiny by treating providers.

- Displacement greater than 2 mm and/or angulation greater than 30 degrees generally requires closed versus open reduction, and a stepwise approach from least to most invasive is recommended when treating these injuries.

- Several key tools and techniques can be utilized to assist in reduction of pediatric radial neck fractures and are described within this article.

Introduction

Radial neck fractures comprise roughly 5% to 10% of pediatric elbow fractures, with a peak incidence between ages 5 and 8 years.[1,2] These injuries usually are sustained from a fall onto the outstretched arm with a valgus load at the elbow. Fractures typically extend through the metaphyseal bone, with a smaller number of these injuries occurring through the physis.

CLASSIFICATION

Most classifications rely heavily on the maximum degree of displacement which can be difficult to measure on static images. An accurate assessment of displacement requires rotating the arm so that the maximum degree of angulation is maximized. It can then be measured relative to the long axis of the radius (Figure 1).

Judet

Originally described by Judet in 1962 and modified by Metaizeau, the Judet classification uses radial neck angulation to classify radial neck fractures.[3,4]

- Grade 1: nondisplaced or horizontal shift
- Grade 2: <30 degrees angulation
- Grade 3: angulation between 30 and 60 degrees

- Grade 4: >60 degrees of angulation, with two groups
  - 4a: angulation up to 80 degrees
  - 4b: angulation >80 degrees
- Grade 5: epiphyseal separation

O'Brien

In 1965, O'Brien also classified radial neck fractures based on angulation.[5] They further suggested treatment based on the degree of angulation.

- Type I: <30 degrees angulation–immobilization
- Type II: 30–60 degrees angulation–closed reduction
- Type III: >60 degrees angulation–open reduction

Chambers

Chambers et al. described an expanded classification system for radial neck fractures.[6] This took into account injury mechanism as well as injury pattern.

- Group I: Radial head primarily displaced
  - A. Valgus fractures
- Type A: SH I or II injury
- Type B: SH IV pattern
- Type C: Fracture line remains metaphyseal
  - B. Fractures associated with dislocation
- Type D: Reduction injuries
- Type E: Dislocation injuries
- Group II: Radial neck primarily displaced
  - A. Angular injuries (Monteggia Type III variant)
  - B. Torsional injuries
- Group III: Stress injuries
  - A. Osteochondritis dissecans of the radial head
  - B. Physeal injuries with neck angulation

The degree of radial neck angulation and/or displacement which is acceptable for children who sustain radial neck fractures varies within the literature.[7] Most authors agree that less than 30 degree angulation should be treated with casting. There are diverging opinions as to how best to treat fractures angulated beyond 30 degrees. Many authors recommend attempting closed reduction for fractures angulated beyond 30 degrees. Regarding acceptable reduction following closed reduction, there is also a wide variance of reported outcomes. Salter and
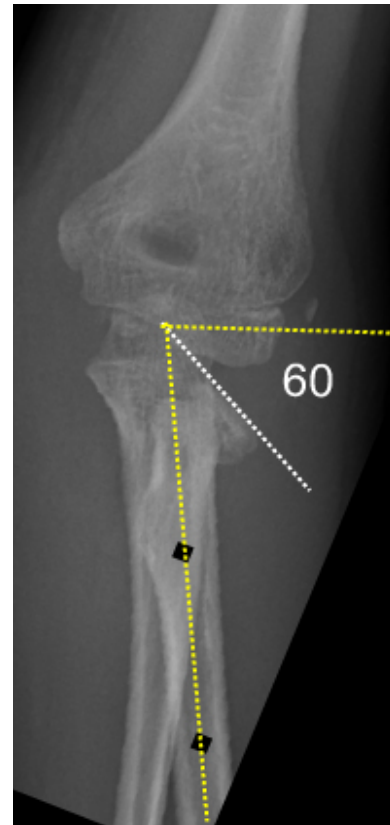

Figure 1. This image demonstrates 60 degrees of angulation on the AP radiograph. The maximum degree of angulation is at least 60 degrees and could be even greater if there is any angulation on an orthogonal radiograph.

Harris found less than 15 degrees to be the optimal residual angle, whereas Metaizeau et al. suggested less than 20 degrees and Herring and Ho proposed less than 30 degrees to be acceptable limits.[4,8,9] On the other hand, D'Souza et al. found excellent remodeling in fractures angulated up to 45 degrees.[1] Regardless of classification scheme or proposed acceptable alignment, additional factors should be considered when choosing management of radial neck fractures, including amount of translation/displacement, age of the patient, and time elapsed since injury.[9]

Associated Injuries

Radial neck fractures occur with associated injuries in 30-50% of patients.[10] Fractures of the proximal ulna, olecranon, medial and/or lateral epicondyles, or shear-type injuries to the articular cartilage may occur concomitantly with radial neck fractures. Soft tissue injuries such as medial collateral ligament rupture may also be seen. A careful examination for concomitant injuries is therefore warranted in patients presenting with a pediatric elbow fracture. Orthogonal radiographs should be

scrutinized and, when in doubt, advanced imaging such as MRI may be warranted.

NONOPERATIVE MANAGEMENT

Angulated radial neck fractures often are treated with closed reduction, with younger children faring better.[2] Angulation up to 30 degrees can be tolerated in any patient less than 10 years old, with patients younger than 6 years old having been shown to remodel up to 60 degrees of angulation.[11] Zimmerman et al. retrospectively analyzed 151 radial neck fractures and found age greater than 10 years, time to surgery greater than 2 days, and increasing displacement as independent risk factors for failed nonoperative management.[12] Using their model, they predicted that closed manipulation will fail for half of all radial neck fractures angled more than 36 degrees and for half of fractures displaced more than 65%.

It's further important to be aware of the radial head being flipped 180 degrees either with injury or after reduction. It is very important to scrutinize reduced fractures to ensure the concave radial articular surface is pointing towards the capitellum and if there is a question, an arthrogram is necessary to confirm.

A number of closed reduction maneuvers have been described for radial head and neck fractures. Primary among these are the Israeli (Kaufman) method, the Columbus (Neher-Torch) method, the Monson method, and the Esmarch bandage method.

- Israeli (Kaufman): With the elbow flexed to 90 degrees and the forearm supinated, the forearm is then pronated while direct pressure is applied to the radial head.[13]
- Columbus (Neher-Torch): With the elbow extended and the forearm supinated, two thumbs are used to apply a lateral force to the radial shaft while varus elbow stress and a lateral-to-medial pressure to the radial head are applied.[14]
- Monson: With the elbow flexed to 90 degrees and the forearm supinated, anterior-to-posterior pressure is applied to the radial shaft.[15]

- Esmarch bandage: While holding a varus stress to the elbow, an Esmarch bandage is applied distal-to-proximal over the forearm. This technique may be enough to reduce the radial neck alone or may be combined with other described maneuvers. At the very minimum, one should always check images of the fracture after use of the Esmarch bandage and prior to open reduction.

OPERATIVE MANAGEMENT

When closed reduction fails to obtain acceptable alignment and/or concomitant injuries necessitate surgical intervention, operative management of pediatric radial neck fractures may be utilized. Percutaneous methods remain the workhorse of management of operatively treated radial neck fractures, with a number of described techniques including the Metaizeau technique, the Kapandji (leveraging) technique, and the Wallace technique.

- Metaizeau: A flexible intramedullary nail is introduced retrograde from the distal aspect of the radius (with care to avoid damaging the perichondral ring and physis). The curved tip of the nail is used to capture the radial head, reduce it via rotation, and hold the alignment until healing can occur.[16]
- Kapandji: With the forearm held in pronation to protect the posterior interosseous nerve, a K-wire is percutaneously introduced from the posterior and distal aspect of the forearm. The radial head is then directly leveraged into place.[17]
- Wallace: A blunt-tipped instrument such as a Joker or a hemostat is inserted on the dorsal subcutaneous border of the ulna at the level of the bicipital tuberosity. This is then used to push and reduce the radial shaft back toward the radial head.[18]

More invasive techniques such as open reduction and/or transcapitellar pinning have been associated with a number of complications and should be reserved as a last resort when percutaneous techniques fail.[1,12,19–21]

COMPLICATIONS

Stiffness

Loss of forearm rotation remains the most common complication following radial neck fractures.[22,23] D'Souza et al. found a high rate of motion loss in their review of 100 patients with radial neck fractures, with open reduction resulting in greater loss.[1] However, most patients did not have functional impairment. Because stiffness is so common with elbow immobilization, it is important to begin motion as early as the injury will tolerate. Typically, stable radial head/neck fractures are casted without motion for 5 to 7 days. At this time, the patient can be given a removable splint to start protected motion. Extremely unstable elbow dislocations may require up to 3 weeks of strict immobilization prior to starting motion.

Malunion/nonunion

Deformity and/or nonunion may occur following radial neck fractures. Angulation tends to be better tolerated than displacement because of the resultant "cam-like effect" that displacement can create on the radius.[24] Physeal injury may result in growth arrest, affecting the length of the radius and/or the angulation of the radial head. The most common deformity following pediatric radial neck fractures is cubitus valgus.[24] In one single-center retrospective study of 100 patients with radial neck fractures, cubitus valgus was found in 3% of patients who had nonoperative treatment and 10% of patients with open reduction.[1] Waters and Stewart evaluated nine patients who developed nonunions after radial neck fractures.[25] Average displacement was 83%, with average angulation of 83 degrees. Unfortunately, subsequent union was not shown to improve clinical symptoms. Other authors have investigated methods of repair of radial neck malunion/nonunion with uniformly poor results independent of surgical technique. Kruppa et al. showed a roughly 36% complication rate with elastomeric intramedullary nailing.[26] Open reduction has been associated with worse outcomes, with Falciglia et al. reporting fair or poor results in 45% of patients treated with open surgery.[27]

Radial head overgrowth

Radial head overgrowth also is a documented complication of radial neck fractures. In a retrospective review of 38 cases, Vock and Von Laer demonstrated radial head deformity in 83% but functional disturbance in only 11%.[28] D'Souza et al. found a rate of 18% of patients developing radial head deformity and associated crepitus and clicking.[1]

Osteonecrosis

Osteonecrosis has been associated with pediatric radial neck fractures and may occur as a result of the initial injury and/or attempted fracture reduction.[10] D'Souza et al. reported a 10% rate of osteonecrosis in patients with radial neck fractures.[1] Radial head deformity caused by growth plate disturbance and osteonecrosis can have significant effects on outcome, with roughly half of patients having poor to fair results.[27] Additionally, radial head osteonecrosis has been associated with a number of other pediatric elbow fractures and in severe cases may require radial head resection.[29]

Radioulnar synostosis

Crossunion, or radioulnar synostosis, is a rare but morbid complication of radial neck fractures.[26] Operatively treated radial neck fractures may be at increased risk, although it is difficult to discern whether this is due to the more severe nature of operatively treated injuries or the surgery itself. Some evidence suggests that increased radial head angulation and/or displacement, as well as associated elbow injuries, may increase the risk of radioulnar synostosis.[30]

Compartment syndrome

Although rarely noted, compartment syndrome may occur in children with radial neck fractures.[31] This has been shown to occur in children treated without reduction, with closed reduction, and with open reduction. While radial head fractures often are viewed as relatively benign injuries, care should be taken to detect the potentially devastating complication of compartment syndrome when treating elbow and forearm injuries.

Author's Preferred Method

The approach to radial neck fractures in children begins with a careful assessment for any associated injuries. On physical exam, one must assess whether the elbow is located and the presence of any neurovascular injuries. Recent literature suggests that patients with Monteggia equivalent injuries are at a higher risk for developing subsequent compartment syndrome in comparison to supracondylar humerus fractures (Figure 2).[32]

One must obtain orthogonal radiographs of the elbow and forearm and these must be carefully examined to rule out other injuries. As many of these patients have a fracture as a result of excessive valgus force, the treating provider needs to pay particular attention to the presence of associated elbow dislocation, radial head dislocation, medial epicondyle fractures, proximal olecranon fractures, and forearm injuries (Figure 3).

High index of suspicion is required for children who are 4-6 years of age as small flecks of bone on x-ray may represent large displacements of unossified articular surface.

The goal of treatment is to reduce the radial head to less than 30 degrees of angulation, assess its stability, provide stability if needed, and treat other elbow injuries as required. The literature suggests that poor outcomes are more likely in patients who have an open reduction to effectuate these goals. It is unclear if increased risks of elbow stiffness, AVN, nonunion, synostosis, and other problems are the result of the operative approach or is in fact a result of higher initial trauma that resulted in an injury pattern which required an open approach. Yet it stands to remember that the retrograde blood flow to the radial head is tenuous and would be further jeopardized by an open approach that also leads to joint capsule scarring. As such, we advocate for a strategy of a surgical stepwise approach that begins with attempted closed reduction, indirect reduction, percutaneous reduction, and finally open reduction if adequate alignment cannot be achieved with the less invasive measures.
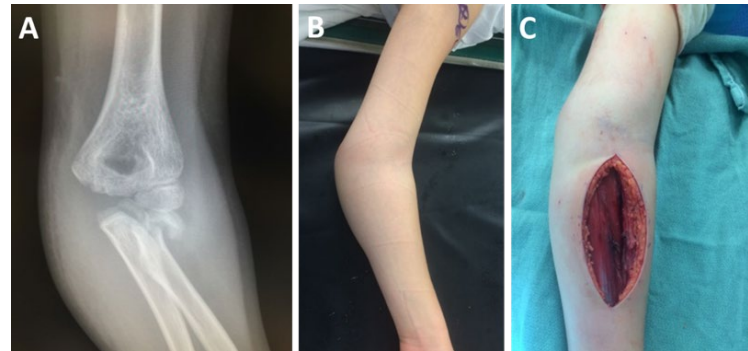

Figure 2. *This 6-year-old girl with a displaced Monteggia Equivalent (A) presented with significant swelling and signs consistent with acute compartment syndrome (B). Following fixation, she underwent a volar fasciotomy (C).*

Figure 3. *As a result of extreme valgus force, this child sustained an avulsion fracture to his medial epicondyle and transverse fractures to both his proximal ulna and radial neck.*

Operative Strategy

The success of the different approaches is dependent on the degree of elbow swelling, the age and size of the patient, the direction and degree of radial head displacement and the presence of associated elbow injuries. In general, fractures that are angulated without a lot of translation are more likely to be closed reduced than in those fractures with significant translation. In addition, most closed reduction strategies require some degree of varus positioning of the elbow while the radial head is pushed into place. It can be difficult to perform this maneuver in a patient with global elbow instability as a result of a concurrent olecranon fracture or elbow dislocation.

Closed Reduction. In order to perform a closed reduction, we believe that two surgeons are required—one pre-positions the arm and applies the varus force to the extended elbow while the other attempts to translate and to reduce the radial head. Prior to reduction it is beneficial

to utilize fluoroscopy to localize the radial head so that precise pressure can be applied. After marking the location on the skin, we rotate the forearm until the maximum amount of displacement of the radial head is visualized. In this position we apply a varus force and push the radial head back onto the radial shaft along a plane that is orthogonal to the fluoroscopic beam. Once reduced we can apply direct pressure to the radial head while the arm is pronated and supinated. In young children we consider an arthrogram to assess reduction in those whose proximal radius is mostly cartilage (Figure 4).

In order to provide a more direct source of pressure on the radial head, one can make a small incision over the radial head and use a hemostat or an awl to directly apply pressure percutaneously (Figure 5A, 5B, and 5C).

Indirect Reduction–Metaizeau Method. In 1993, Metaizeau et al. presented their method of radial head reduction and stabilization with the use of an intramedullary rod that is passed retrograde.[16] From a distal incision on the radius a titanium nail is passed retrograde up to the fracture site. The rod is directed into the proximal fragment and the fracture is disimpacted. Under image intensification the rod is rotated in a manner that will translate the radial head back onto the shaft of the radius. If the reduction is incomplete, then one can withdraw the nail and re-engage the radius neck and head and then re-rotate (Figure 6a and 6b). Once the fracture is fully reduced the rod is cut off distally and left in place; this device stabilizes the fracture and usually allows for earlier range of motion.

The original implant used was called a "Nancy nail" as the technique of flexible intramedullary fixation (FIN), also known as elastic stable intramedullary nailing (ESIN), was popularized by Professor Pierre Lascombes at the Nancy University Orthopedic Facility in northeastern France. The original nail was distributed in the U.S. by DePuy and has a much sharper tip then the Synthes flexible nails (which are more popular in the United States) and the original tip allows the surgeon to more effectively impale the radial neck fragment. The Nancy
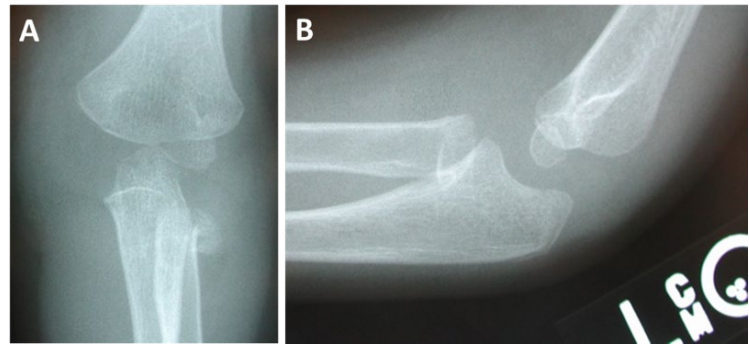
Figures 4A and 4B. This 3-year-old girl has a displaced injury to her proximal radius. There are no other apparent injuries on these radiographs.
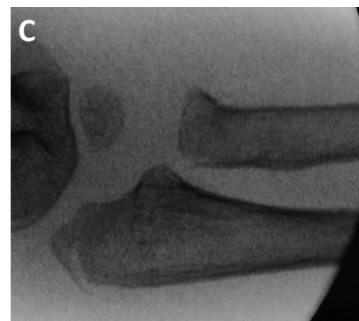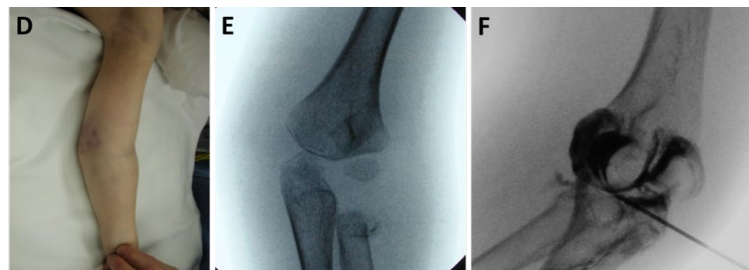

Figure 4C. Fluoroscopic evaluation prior to reduction reveals a minimally displaced olecranon injury.

Figures 4D, 4E, 4F. In order to reduce the radial head, the arm is rotated (D) until the radial head is maximally displaced on the AP fluoroscopic image (E). Direct lateral pressure in the plane of maximal displacement is applied in order to effectuate reduction. In this case an arthrogram was performed to better visualize the radial head (F).
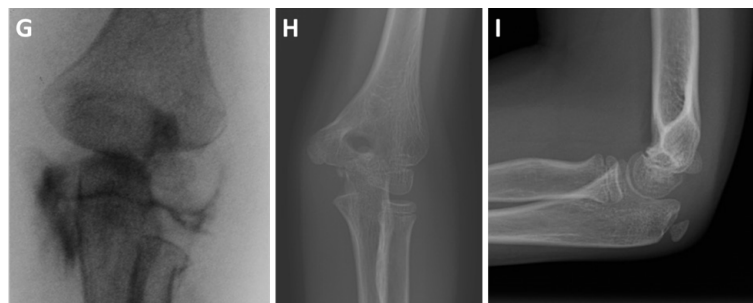
Figures 4G, 4H and 4I. The radial head is now reduced and is well visualized (G). Four years after injury she has full elbow function and normal appearing radiographs (H, I).

nail tip has greater offset at the tip which could make it slightly more difficult to pass than the more commonly used Synthes nails. Yet once the Nancy nail makes it to the fracture site, the combination of a sharp tip and greater offset of the Nancy nail may allow more translation with rod rotation.

While one can attempt the Metaizeau method with a flexible titanium implant or a K-wire, it cannot be used exclusively for severe or completely displaced fractures. It is our further experience that some form of indirect translation with a finger or direct translation with a percutaneous awl or hemostat is needed to get the bulk of the reduction with some fine tuning via rod rotation from an intramedullary device (Figures 7).

Some important tips on the Metaizeau method:

1. It may be difficult to impossible to use the radial rod to reduce the fracture especially if widely displaced. Other methods may be required to improve the radial head position before using the IM rod to fully reduce and stabilize the fracture.
2. It is challenging to impact and rotate the radial head in the setting of an elbow fracture dislocation. In order to effectively impact the rod into the radial fragment it has to be stabilized by an intact elbow joint otherwise one merely distracts the radial fracture as the disrupted elbow joint cannot prevent the distraction.

Cantilever Reduction Via Kapandji Maneuver. Adalbert Kapandji was a Turkish-French orthopaedic surgeon who pioneered several treatments in hand surgery and who developed a method of reducing and stabilizing distal radius fractures with an intra-focal pin which levers and stabilizes the distal radius into place.[33] Pediatric orthopaedic surgeons have applied the Kapandji principle of a precisely placed "lever" [K-wire or other surgical instrument such as a hemostat] which can per cutaneously leverage a fracture into a reduced position. This technique was first described in radial neck fractures by Feray in 1969 and further developed by Angelov in 1981 and Pesudo in 1982.[34–36] We have found this method to be an effective adjunct to reducing a displaced radial
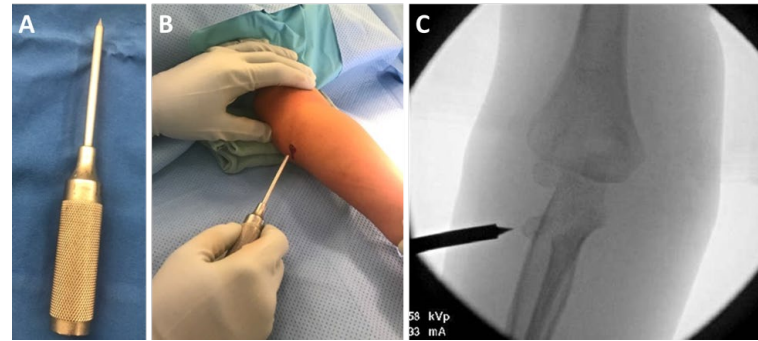

Figure 5. *A Zuelzer Awl (A) can be used to directly translate the radial head back onto the radial shaft (B, C).*
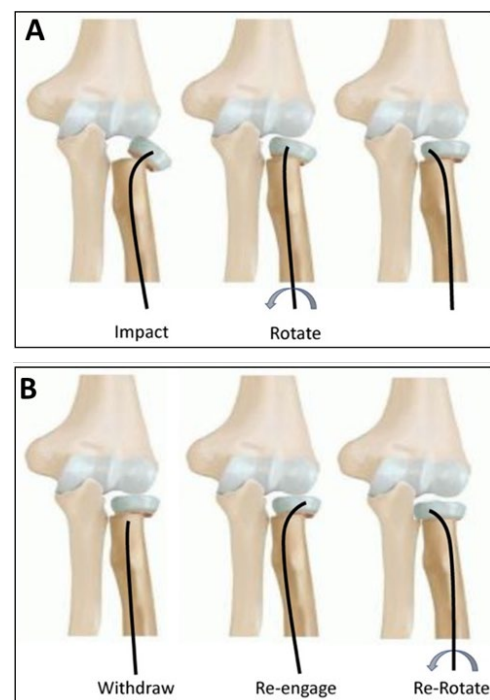

Figure 6. *The Metaizeau indirect method of radial head reduction with the use of an intramedullary nail or K-wire. The radial head can be initially reduced via this technique (A). The nail can then be withdrawn and the technique repeated to effect further reduction (B).*
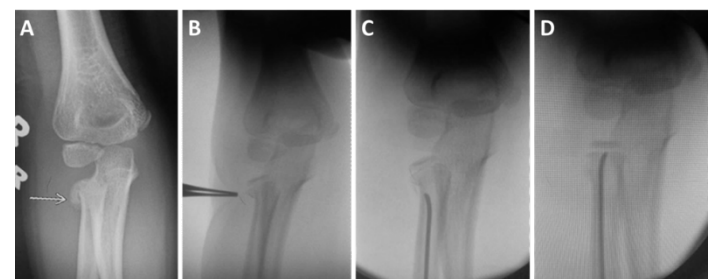

Figure 7. *This 4-year-old girl has a significantly displaced radial neck fracture (A, white arrow) which is partially reduced with percutaneous reduction (B). The subsequent reduction (C) is improved with rod rotation (D) as described by Metaizeau.*

head. Several factors need to be considered in order to effectively reduce the radial neck fracture with the Kapandji maneuver.

1. It is important that the small incision through which the "lever" is placed is directly over the proximal radius and thus fluoroscopic imaging is critical to plan your incision. Most of the time, these fractures are displaced laterally. If the incision is anterior or posterior to the axis of the radial shaft, it will be more difficult to reduce the fracture. The incision should not be more than 1.5 centimeters distal to the facture as a far distal to proximal placement of a lever could endanger the radial nerve within the supinator.

2. Several different devices can be considered and used as a "lever." A simple straight K-wire is the most common method that has been previously published. Our team has modified this by bending the tip of a 2.0 or a 2.4 mm K-wire which may enhance translation (Figure 8).
   Finally, a curved hemostat can be an equally effective lever; slightly spreading the tips increases the surface area of the lever after it is placed into the fracture site (Figure 9).

3. Similar to a closed reduction, the effective use of this maneuver requires accurate positioning of the arm under image guidance so that one rotates the forearm until the proximal radius is maximally displaced and the lever is used to translate the proximal radius in the plane of maximal displacement which is orthogonal to the fluoroscopic beam. Slight varus loading can open up the elbow and assist with translation.

4. One should leverage the radius under image guidance as it is possible to over-reduce the fragment especially in very unstable injury patterns (Figure 10).

5. In our experience, we have tended to stabilize the reduced proximal radius with an intramedullary device especially if the fracture was severely displaced or if there were associated fractures. On occasion, if a patient has an isolated radial neck fracture that is stable, a long arm cast for 3 weeks will suffice. *Key Point:* Always check radiographs of the elbow in the
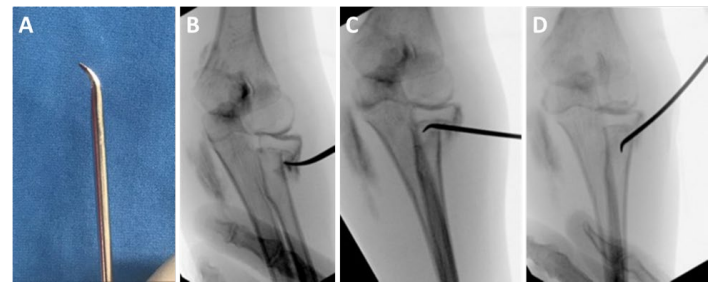

Figure 8. A 2.0 K-wire tip is bent (A) in order to improve its ability to reduce the radial head via the Kapandji maneuver. The wire is introduced percutaneously into the fracture (B) and is rotated to hook the radial shaft (C). With the K-wire fully engaged in the shaft it is leveraged proximally to reduce the radial head (D). Note In this young 4-year-old an arthrogram was performed to better visualize the cartilaginous radial head.

Figure 9. This 5-year-old with a completely displaced radial neck fracture (A) undergoes percutaneous reduction of the fracture with a hemostat (B). Intramedullary stabilization was required and further facilitated with an awl (C) while the nail is passed into the proximal fragment (D). Follow-up x-rays (E, F) correlate with his full motion on clinical examination.

cast prior to leaving the OR suite to ensure that the fracture has not displaced.

Open Reduction and Internal Fixation. When closed and percutaneous methods are unable to adequately reduce the radial head, the surgical team must proceed

with an open reduction. A lateral Kocher approach to the elbow is utilized and the interval between the anconeus and extensor carpi ulnaris is developed. The capsule is then incised and permits access to the proximal radius. Care should be taken to preserve any soft tissue attachments to the proximal radius in order to avoid osteonecrosis and to facilitate healing. A variety of different implants can be used to stabilize the fragment and include suture, pin fixation, plate and screw fixation as well as retrograde intramedullary fixation. In our experience, there is not one method or implant which appears superior to others (Figure 11). The following case highlights the difficulty encountered when open reduction is required.

Discussion/Conclusion

Pediatric radial neck fractures, while less common than other pediatric elbow fractures, are a persistent and challenging injury. Recent investigations have suggested complication rates as high as 36%.[12,37] They are often associated with other injuries, including additional fractures, cartilage damage, and ligamentous disruption. Providers should therefore carefully examine the patient and scrutinize the radiographs for additional concomitant pathology. Arthrography and/or MRI can be useful adjuncts in evaluation, especially in younger patients whose proximal radius is less ossified. A number of treatment strategies exist for pediatric radial neck fractures, ranging from closed to percutaneous to open procedures. Several authors have advocated for careful, stepwise progression of treatment, with a focus on least invasive methods first.[10,12,19] As such, it is important for clinicians and surgeons to compile a variety of techniques which can assist in acceptable fracture reduction.

Regardless of which treatment they receive, these patients should be followed closely for maintenance of reduction as well as the development of any late sequelae such as stiffness, osteonecrosis, radial head overgrowth, or crossunion.
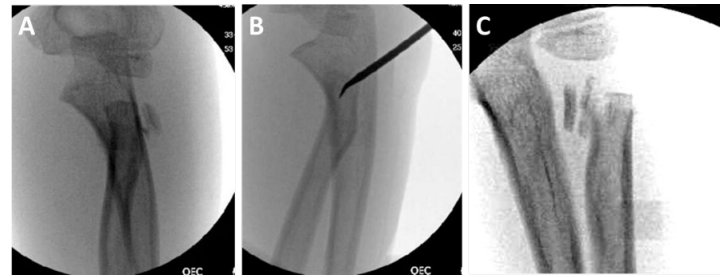

Figure 10. *This 6-year-old with a laterally dislocated radial neck fracture (A) underwent attempted reduction with a K-wire (B). Overzealous leveraging pushed the fragment medially (C). The child required open reduction.*
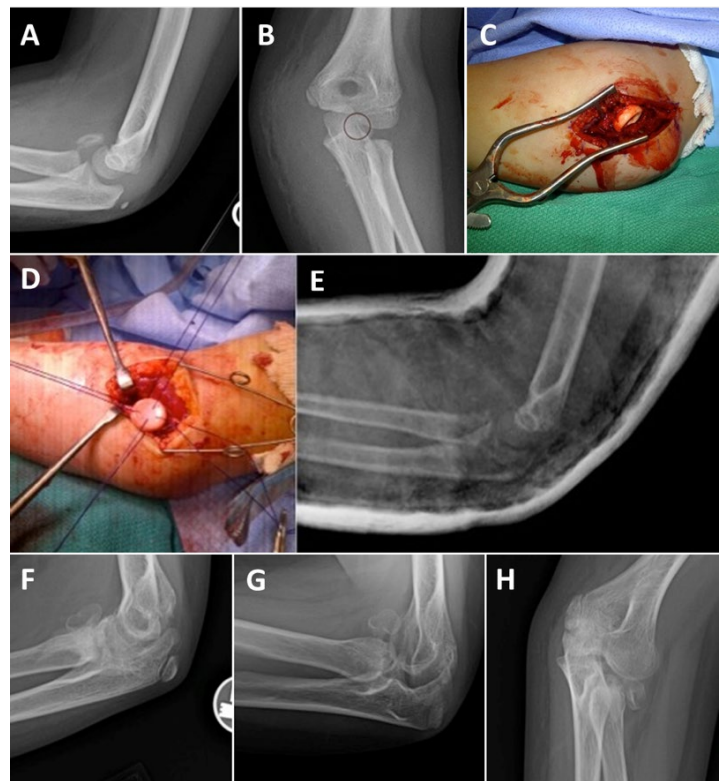

Figure 11. *This 9-year-old girl presented to the emergency department where radiographs revealed a completely displaced radial neck fracture (A, B). During the surgical approach, the detached radial head (C) was encountered in the soft tissues. She subsequently underwent open approach and reduction with suture stabilization (D). Postoperative radiographs (E) revealed good alignment. Two years later, her follow-up radiographs (F-H) demonstrate a poor radiographic outcome. Despite having no pain, her valgus deformity eventually required ulnar nerve transposition for tardy ulnar nerve palsy.*

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