Fractures of the proximal radius and ulna

Adhish Avasthi
Chris Peach

Abstract

Acute injuries of the proximal radius and ulna can be challenging to manage. This review article summarizes the classification, injury patterns, treatment and outcome of fractures of the olecranon, coronoid process, adult Monteggia fracture dislocations and radial head fractures. Undisplaced fractures and stable injuries can be treated conservatively and displaced and complex injuries should be treated surgically to permit early range of motion with a functional rehabilitation programme.

Keywords coronoid; fracture; Monteggia; olecranon; proximal ulna; radial head

Introduction

Injuries to the proximal ulna and radius can represent a wide range of injury patterns. Fractures can range from simple undisplaced radial head fractures to complex fracture dislocations of the elbow. One key feature of these intra-articular fractures is that there are frequently significant soft tissue injuries associated. Therefore the treating clinician should always proceed with a high index of suspicion for occult ligamentous pathology, which if left untreated or managed inappropriately, will negatively affect the outcome for the patient. This review focuses on fractures involving the olecranon and coronoid processes of the ulna; adult Monteggia fracture dislocations and radial head fractures.

Olecranon fractures

Olecranon fractures are common injuries around the elbow. They may be caused by a fall directly on to the elbow or indirect forces applied by forcible contraction of the triceps mechanism. The morphology of the fracture is often dictated by the injury mechanism. Transverse or oblique fractures are caused by indirect trauma and direct impact causes more comminuted patterns. The subcutaneous location of the elbow makes them prone to open fractures. The incidence of olecranon fractures is 12 per 100,000 population with a mean age of 57 years.[1]

Adhish Avasthi *MBBS MS (Orth) FRCS (Tr & Orth), Senior Clinical Shoulder and Elbow Fellow, Manchester Shoulder and Elbow Unit, Manchester University NHS Foundation Trust, UK. Conflict of interests: none declared.*

Chris Peach *MD FRCS (Tr & Orth), Consultant Shoulder and Elbow Surgeon, Manchester Shoulder and Elbow Unit, Manchester University NHS Foundation Trust, UK. Conflict of interests: none declared.*

They may be classified by the Mayo classification, which is based on comminution, displacement, fracture-dislocation. Type I fractures are undisplaced, Type II are displaced and Type III are associated with elbow joint instability. Each type is subdivided into A and B depending on the absence or presence of comminution.

Schatzker's classification (see Figure 1) attempted to guide the method of internal fixation by subdividing fractures into six groups including transverse (with and without comminution), oblique types and those with associated dislocation.[2] Associated elbow instability and more complex fracture morphology are prognostic factors for subsequent elbow function and the development of arthritis after the operative treatment of olecranon fractures.[3]

Treatment

The aim of treatment should be to restore function by achieving anatomical reconstruction of the articular surface combined with early mobilization. Most olecranon fractures are treated operatively; however, there is a role for non-operative management in select cases.

Non-operative treatment

Undisplaced fractures can be effectively treated without operative intervention with good outcomes. The elbow should be subjected to a short period of immobilization (2 weeks) in mid-flexion followed by a graduated rehabilitation programme.[4] Non-operative management can also be considered in some patients presenting with displaced fractures. We would recommend this when associated with medical co-morbidities or frailty. In a cohort of elderly low-demand patients, there was a satisfactory short-term and long-term outcome following the non-operative management of isolated displaced olecranon fractures.[5]

Operative treatment

Decision-making in the management of olecranon fractures is largely governed by morphology of the fracture and therefore the Schatzker classification system can aid this.

Transverse fractures: 74% of olecranon fractures fall into this category and tension band techniques are frequently and successfully used. The tension band technique converts tension forces to compressive forces and it works well in transverse fracture patterns. Less soft tissue dissection is necessary compared with plating, however removal of metalwork is commonly needed. Tension band wiring should be avoided with severely comminuted and fractures distal to the coronoid process. Congruity of the trochlear notch is the important factor when surgery is undertaken for these fractures, particularly in the face of a minor degree of comminution. The K-wires can be passed along the intramedullary canal of the ulna, taking care to bury the bent tips of the wires under the triceps tendon to decrease the chance of them backing out. Other techniques have been described to reduce the risk of K-wires backing out by securing the wires into the anterior cortex of the ulna. However, care should be taken to avoid penetrating the anterior ulnar cortex by more than 10 mm, as perforation of the anterior cortex has been shown to be associated with an increased risk of anterior interosseous nerve injury and reduced forearm rotation

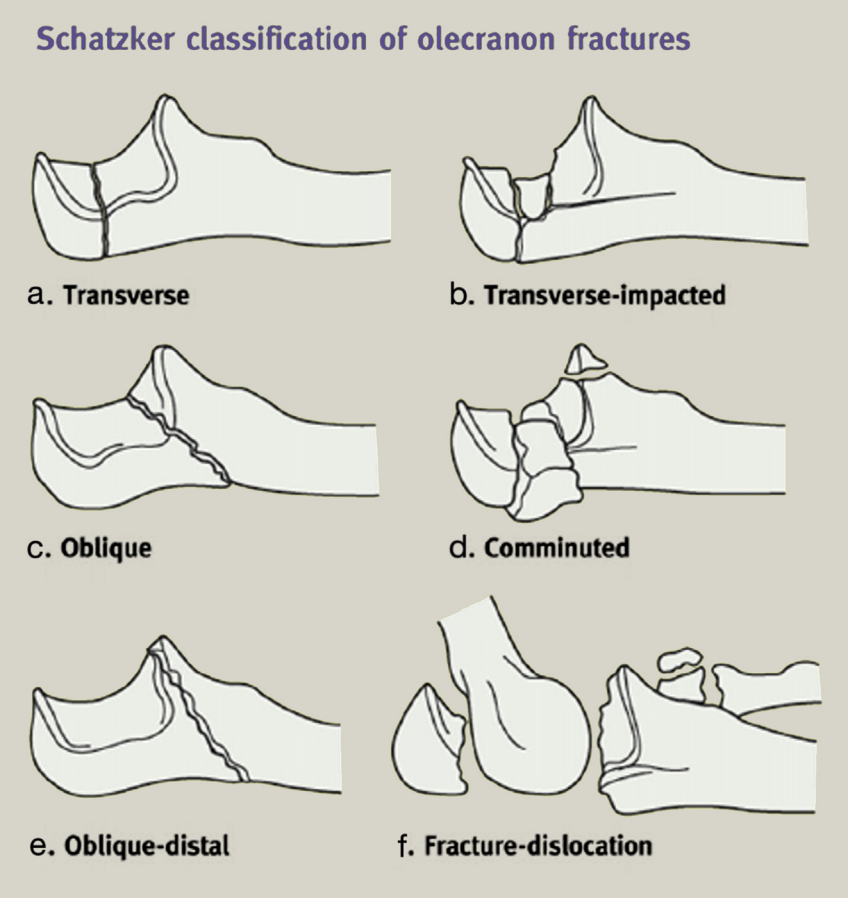

Figure 1 Schatzker's classification of olecranon fractures which addresses the mechanical considerations of fracture with reference to internal fixation methods. The original report notes that relative instability of oblique fractures to tension band wiring.[2] Reproduced from reference 4 with permission from Elsevier.

(see Figure 2). An MRI study has identified the median nerve and ulnar artery most at risk if wires penetrate more than 10 mm.[6]

Huang et al. reviewed 78 displaced olecranon fractures treated with tension band wiring fixation with three different K-wire placement techniques: proximal ulnar canal, anterior ulnar cortex, and distal ulnar canal. They found proximal pin migration and elbow irritation when the wires were placed in the proximal ulnar canal and advocated placement in the distal canal to obtain adequate purchase and avoid the risk associated with anterior cortical penetration.[7]

Ravenscoft et al. first described the use of sutures as a tension band instead of K-wires and metal wire which aimed to reduce the rate of metalwork removal.[8] Although their results have been replicated in other small series, there are currently no large randomized controlled studies to recommend their use.

Most studies have failed to show one method being associated with less metalwork irritation and need for removal than the other and therefore the authors recommend the use of intramedullary K-wire positioning to avoid iatrogenic injury to forearm neurovascular structures.

Oblique fractures: Care should be taken with this fracture pattern to avoid shortening of the ulna disrupting the anatomy of the greater sigmoid notch and leading to rapid onset of arthrosis. These fractures can be fixed primarily with a lag screw and a dorsal contoured plate.

Comminuted fractures: The key to treating these fractures is to maintain the shape of the olecranon and the coronoid articulations without altering the contour of the greater sigmoid notch. The trochlea and/or the dorsal cortex can be used to template

Figure 2 Anchoring of K-wires into anterior cortex to prevent migration. Perforation of anterior cortex is associated with anterior interosseous nerve palsy and reduced forearm rotation.

reconstruction. We recommend using a pre-contoured plate dorsally. The plate is temporarily applied distally on the shaft of the ulna, and then the most proximal screw is directed towards the coronoid fragment, compressing the fracture. Care must be taken at this point not to over compress the fracture particularly with extensive comminution, to avoid articular incongruency.

The pre-contoured implants with variable angle locking screws allow the surgeon to reduce the fragments against the implant and to securely buttress the articular surface. However, the dorsal plates can cause soft tissue irritation and patients should be warned about the need for metalwork removal.

Resection

Resection of the proximal olecranon fragment and direct repair of the triceps mechanism to the ulna can be a good option in patients with small fracture fragments, osteoporotic bone, extensive comminution or as a salvage procedure in the event of non-union. This should be performed in patients with intact medial collateral ligament, distal radioulnar joint, and interosseous membrane. The indications, technique for triceps attachment, and amount of olecranon that can be excised remain controversial. An et al. evaluated elbow stability and found a linear decrease in elbow constraint with increasing amounts of resection. They concluded that with resection of more than 50%, instability may occur.[9]

Comparison of tension band wiring versus dorsal plate

Overall the results of treatment are very good. Duckworth et al. found that among active patients with a simple displaced fracture of the olecranon, no difference was found between tension band wiring and plate fixation in the patient-reported outcome at 1 year following surgery. The complication rate was higher following tension band wiring fixation and was due to a higher rate of implant removal in symptomatic patients. However, the more serious complications of infection and the need for revision surgery occurred exclusively following plate fixation in this trial.[10]

Coronoid fractures

The coronoid along with the radial head provides resistance to posterior displacement of the ulna on the distal humerus and adds to elbow stability. The anteromedial facet of coronoid provides stability against varus force. The coronoid also serves to indirectly provide dynamic stability to the elbow joint through its insertion of the brachialis muscle, the anterior joint capsule, and the medial ulnar collateral ligament. It is important to recognise the fracture and appreciate elbow injuries which commonly produce distinct coronoid fracture patterns. The goal of coronoid fracture treatment should be to restore both the bony and often under-recognized soft tissue constraints for elbow stability.

Classification

Coronoid fractures have typically been classified based on size using the Regan and Morrey classification.[11] Type 1: avulsion from the tip; Type 2: single or comminuted fragment involving 50% of the process or less; and Type 3: a single or comminuted fragment involving more than 50% of the process. This is suffixed with either an A or a B respectively with regard to absence or presence of an associated elbow dislocation.

O'Driscoll proposed a more clinically relevant system based on the anatomical location of the fracture and the overall pattern of injury, is more helpful to guide treatment. (Figure 3).[12] Three fracture types are described. Tip type fractures that do not extend medially past the sublime tubercle or into the body; Fractures involving the anteromedial facet; and basal fractures (at least 50% of the height). The three groups are further sub-classified based on severity of coronoid involvement and termed subtype 1, 2 or, for the anteromedial type, 3.

This classification system has shifted clinical importance of the coronoid fracture towards by recognizing that the anteromedial facet can affect stability of the elbow when fractured. This type of fracture has a reliable injury pattern caused by varus posteromedial rotational forces rather than by posterolateral rotational force. They are also associated with a lateral collateral ligament injury rather than a medial collateral ligament injury and radial head fracture.

Small fractures of the anteromedial facet can cause varus posteromedial instability because of the lateral collateral ligament injury and then secondary incongruency of the medial ulnahumeral articulation under varus stress can lead of rapid onset of posttraumatic osteoarthritis.

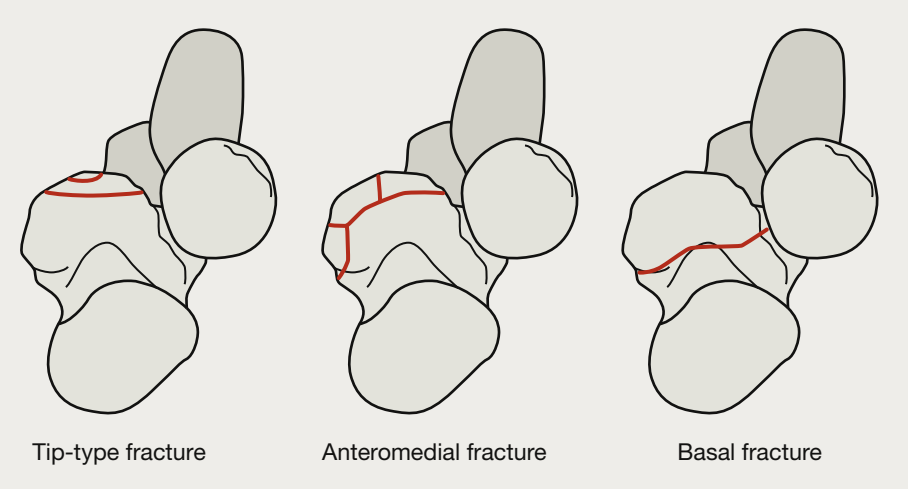

Figure 3 Classification of coronoid process fractures.

Doornberg et al. showed a strong association between O'Driscoll fracture type and mechanism of injury. The pattern of injury was classified as an olecranon fracture dislocation (anterior or posterior), terrible triad, or varus posteromedial rotational instability pattern. They showed that olecranon fracture-dislocations were associated with large (>50%) coronoid fractures in 22 of 24 patients, whereas 31 of 32 terrible triad patterns had associated small (<50%) coronoid fractures. Of the 11 patients in the varus posteromedial instability group, all had fractures of the anteromedial facet.[13]

Imaging

Coronoid fractures have been traditionally assessed on antero-posterior and lateral radiographs of the elbow but because the fracture often is small and can be difficult to adequately evaluate when there are concomitant fractures, CT scanning will delineate the size and anatomy of the coronoid fracture. Lindenhovius et al. examined the intra-observer and inter-observer reliability of two-dimensional (2D) versus three-dimensional (3D) CT scanning in assessing fracture characteristics and classifying coronoid fractures. The investigators found better inter-observer reliability with both the Regan and Morrey and the O'Driscoll classifications using 3D CT scans.[14]

Treatment

Operative treatment and the surgical approach used will often depend on the fracture type as well as the associated injuries.

O'Driscoll tip type fracture: these injuries are often underestimated on plain radiographs in terms of size. Operative treatment is reserved for associated elbow instability. In case of doubt an examination of the elbow under anaesthesia can be done to guide the decision-making process. Small fragments with no instability can be treated with early mobilization as long as other associated injuries are managed.

Larger fragments can be fixed using either screws if the fragment is big enough or with sutures passing around the fragment and anterior soft tissues, pulled through onto the subcutaneous border of the ulna for tying. The surgical approach depends on the associated injuries to be treated. In the event of an associated radial head fracture needing a replacement, the coronoid can be approached through the radial head fracture laterally. In this approach it is advisable to insert the sutures around the coronoid and through the ulna but not secure them until the radial head replacement has been trialled and inserted. This prevents pull out of the sutures whilst attempting to replace the radial head. In isolated coronoid fractures, a medial approach is preferred. The coronoid is approached through the bed of the ulnar nerve and by splitting the flexor carpi ulnaris and elevating the anterior portion of the muscle.

Jeon et al. demonstrated in a cadaver study that Regan and Morrey types I and II coronoid fractures did not affect elbow stability with an intact radial head and lateral ligament complex.[15] Papatheodorou et al. reviewed the outcomes of 14 consecutive patients with Regan and Morrey type I (2 patients) or type II (12 patients) fractures treated non-operatively. All patients had radial head repair or reconstruction and repair of the lateral ulnar collateral ligament (LUCL). They suggested that non-operative treatment of coronoid fractures is appropriate in carefully selected patients with close follow-up.[16]

O'Driscoll anteromedial fracture type: Anteromedial facet fractures are important and if not appreciated and addressed, they render the ulno-humeral joint incongruent and can lead to rapid onset of post-traumatic osteoarthritis. These injuries need to be approached from the medial side but also have an associated lateral collateral ligament injury and a separate lateral incision will also need to be used. The method of fixation depends on the size of the fragments, using sutures or a buttress plate as necessary (see Figure 4).

Although the general recommendation has been to fix all anteromedial facet fractures, Chan et al. reported non-operative treatment of nine type II fractures and one type III fracture. They recommended consideration of non-operative treatment for fractures that are small and minimally displaced with no evidence of elbow subluxation.[17] Park et al. described their protocol involving repair of the lateral ulnar collateral ligament (LUCL) only in type I fractures and buttress plating and LUCL repair in types II and III. Their results were encouraging, with an average range of motion of 128° and average Mayo Elbow Performance Index (MEPI) of 89.[18] This approach highlights the need to consider the whole injury pattern of the soft tissue elements as well as the bony injury.

O'Driscoll basal type fracture: these injuries often associated with a fracture dislocation and have large coronoid fractures that are amenable to fixation, often in association with the olecranon

Figure 4 Anteromedial fracture type fracture fixed using buttress plate via medial approach to elbow.

fracture, using a dorsal contoured plate. The coronoid can be visualized either through the olecranon fracture or through a separate medial approach. Osteoporotic fracture dislocations are often associated with considerable comminution and can be difficult to address. More elderly patients can be treated with a total elbow arthroplasty.

Adult Monteggia fracture dislocations

Monteggia injuries, Monteggia-like lesions and trans-olecranon fracture dislocations are frequently confused, and it can prove very difficult to classify some lesions.

Monteggia described a fracture of the proximal third of the ulna with anterior dislocation of the radial head from both the proximal radioulnar and radio-capitellar joints. Bado classified them according to direction (anterior, lateral or posterior): type 1, anterior; type 2, posterior; type 3, lateral; and type 4 with a concomitant radial diaphyseal fracture.

Jupiter classified Bado's type II fracture in order to guide necessary treatment strategies based on the location and type of ulna fracture as well as the pattern of radial head injury. Jupiter defined four subtypes: type IIA fractures involve the most proximal aspect of the ulna (olecranon) and the coronoid process; type IIB fractures occur at the ulnar metaphyseal–diaphyseal junction, distal to the coronoid process; type IIC fractures occur at the diaphyseal level; and type IID fractures are comminuted, extending from the olecranon to the ulnar diaphysis.[19]

The commonest pattern in adults is the posterior Monteggia fracture, which has been associated with osteoporosis. Anterolateral diaphyseal proximal radioulnar joint fracture-dislocations are uncommon in adults.

The mechanism of injury is thought to involve falling onto an outstretched hand with an extended elbow and the forearm in hyperpronation. An alternative theory suggests that a hyperextended elbow causes an anterior dislocation of the radial head, the subsequent axial force applied solely to the ulna aided by forces through the brachialis and interosseous membrane then causes the angulated proximal ulna fracture. These injuries are frequently associated with a radial head fracture, with the 15° head neck offset and offset concavity in the head contributing to the fracture involving the anterolateral head segment, seen in the majority of cases. Radial head fractures are seen in 70% of Type III injuries, as the head shears against the capitellum. In another series of patients, 16% had associated coronoid fractures all of which were seen in the Type II group.

Investigations

Plain radiographs of the elbow, forearm and wrist can reduce the risk of mistakenly diagnosing an isolated ulna fracture. CT scans can further delineate the fracture pattern, especially using 3D reconstructions.

Operative treatment

The key treatment principle in Monteggia fractures is stable anatomic alignment of the ulna. If the lateral collateral ligament or coronoid are injured, repair them and also reconstruct or replace the fracture of the radial head.

The patient is positioned supine with the arm draped over the chest or in the lateral position. In the majority of patients, the radiocapitellar alignment will be restored once the ulna alignment is restored. Failure is usually due to soft tissue interposition (capsule, radial nerve, biceps tendon) and requires further exploration. In Monteggia-like lesions the radial head fracture as well as the coronoid fracture can be fixed through the ulnar fracture via the dorsal approach. In Monteggia-like lesions the reconstruction starts with the radial head which is also possible using the Boyd's approach.[20] Radial head fractures can also be fixed or replaced using a separate lateral Kaplan approach. The operative algorithm should then address the coronoid process, followed by the ulnar shaft. For a better visualization of the coronoid it might be necessary in some cases to use an additional medial approach in order to anatomically reduce the fracture. Ligament reconstructions should be performed last.[21] Postoperatively the limb is rested in 90° flexion and mid-supination for 1 week to rest the soft tissues. Active range of movement is commenced thereafter (see Figure 5).

Outcomes

For Monteggia fractures, complications can range from ulna malunions or non-unions, nerve irritations (ulnar and radial nerve), elbow stiffness, heterotopic ossification (HO), radioulnar synostosis and persistent radial head subluxations or dislocations depending on the injury severity. Bado type-II fractures in particular were found to be associated with poorer outcomes and, the involvement of the radial head and/or the coronoid process was a negative prognostic factor for long-term outcome.

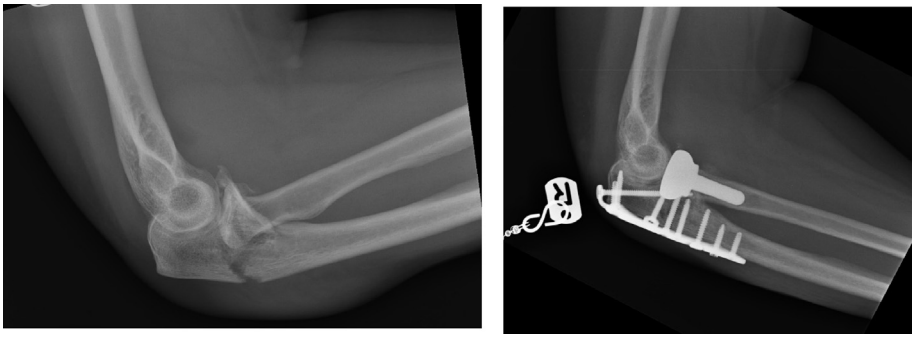

Figure 5 Adult Monteggia fracture dislocation. CT scan was carried out prior to surgery and delineated large coronoid fracture fragment. Failure to restore the alignment of the ulna will not reduce the radial head which is seen to be misaligned posteriorly in the preoperative X-rays. Normal anatomy is restored after fixation and immediate range of motion postoperatively.

Radial head and neck fractures

Fractures of the radial head are the most common fractures around the elbow. Radial head fractures were found to be almost twice as common as radial neck fractures.[22]

The peak incidence in men is between the age of 30 and 40 years and in women it is between 50 and 60 years. Once the age rises above 50 years, the number of female patients with a radial head fracture is significantly larger than the number of male patients.[23]

Biomechanics

The radial head is an important secondary stabilizer in valgus and external rotation. In a cadaveric study, a significant decrease in elbow stability was noted if the radial head was excised in elbows with an associated disruption of the lateral collateral ligament. Elbow laxity was improved following radial head arthroplasty; however, these elbows were still unstable relative to those with intact ligaments. These findings demonstrate how important it is to repair the disrupted lateral collateral ligament complex in order to restore elbow stability following open reduction and internal fixation of the radial head or radial head arthroplasty.[24] In the same study, laxity of the elbow increased after radial head excision in elbows with disruption of the medial collateral ligament (MCL). In the same study, radial head arthroplasty restored valgus stability in elbows with disruption of the MCL to a state similar to that seen in elbows with a native radial head.

Classification

The Mason classification is the most commonly used classification system for radial head fractures.[25] Type I fractures are undisplaced, Type II fractures are displaced partial head fractures, and Type III fractures are displaced fractures that involve the entire radial head. Johnston added a fourth type to the Mason classification as a fracture of the radial head with associated elbow dislocation.[26]

Hotchkiss modified the Mason classification with respect to mechanical block to motion and helps to guide treatment. Type I fractures are defined as non-displaced fractures or minimally displaced marginal lip fractures (<2 mm displacement) that do not block motion and can be treated non-operatively. Type II fractures are displaced fractures (usually >2 mm) that may have a mechanical block to motion or are incongruous but do not have severe comminution. Type II fractures are often amenable to open reduction and internal fixation. Type III fractures are comminuted fractures that are unable to be repaired and should be considered for either excision or radial head arthroplasty.[27]

Ring showed that the presence of more than three fragments has a higher correlation with poor results following open reduction and internal fixation. Absolute stability of the radial head is essential to allow early range of motion of the elbow, not only to prevent stiffness, but also to activate the dynamic stabilizers of the elbow joint. Radial head fractures with elbow dislocations are complex injuries and associated fractures and ligamentous injuries that may also result in a less optimal outcome.[28]

Associated injuries

Radial head fractures maybe associated with other injuries. MRI scan may show ligamentous injuries with lateral collateral ligament and/or MCL injuries, bone bruising of the capitellum, injuries of the interosseous membrane.

The combination of an elbow dislocation, radial head fracture and a coronoid fracture is called 'the terrible triad of the elbow'. Severe elbow instability and post-traumatic complications are associated with the terrible triad.

Ulna fractures can occur with a radial head fractures and Monteggia lesions (described earlier). Osteochondral fractures of the capitellum may also be associated with the radial head fractures. A rare but severe associated injury of radial head fractures with a rupture of the interosseous membrane between radius and ulna is known as an Essex-Lopresti injury.

Treatment

Management of undisplaced fractures: Mason type 1 fractures are managed non-operatively with a sling for support and early active mobilization.[29]

Management of stable partial articular displaced fractures: There is currently no consensus on the treatment of patients with isolated, displaced, stable, partial articular fractures of the radial head. Khalfayan et al. found significantly greater functional scores in patients treated with open reduction internal fixation (ORIF) versus non-operative treatment.[30] Yoon et al. found in favour of non-operative treatment versus ORIF after an average of 3 and 4.5 years and, no significant differences were seen on the scores. Complications occurred in 33% in patients treated with ORIF compared with 7% in the non-operative group.[31]

The Rambo trial, which is a multi-centre randomized controlled trial, has been initiated to compare if stable partial articular displaced fractures of the radial head are best treated by ORIF or non-operative management, the results of which are awaited.[32]

Treatment goals should aim to restore functional anatomy of the patient with rigid fixation of the intra-articular radial head fracture with repair of the lateral ulnar collateral ligament to allow early range of motion (see Figure 6).

Management of comminuted fractures: In cases of isolated comminuted radial head fractures, without associated ligamentous injury of the elbow, resection of the radial head can be performed. Radial head excision may have complications such as elbow pain, limited range of motion, cubitus valgus, and elbow instability, and these patients may be at an increased risk of long-term joint degeneration. Operative fixation produces superior outcomes than excision for these fractures. Despite one study suggesting satisfactory outcomes,[33] excision should be reserved in the rare patient with an unreconstructable fracture in the absence of instability.

Open reduction and internal fixation of comminuted fractures has become more feasible with the availability of radial head plates and headless screws. Good results have been reported after fixation of stable radial head fractures. However, Ring et al. showed that fixation for Mason type III fractures with more than three articular fragments was more likely to result in unsatisfactory outcomes compared to fractures with only two or three simple fragments.[34]

In comminuted fractures that are unreconstructable, radial head replacement produces good outcomes. Chen et al., compared

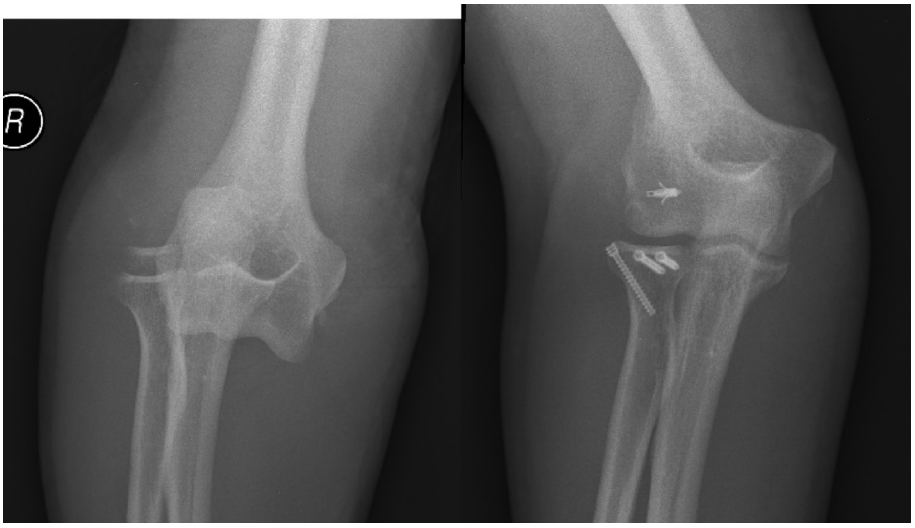

Figure 6 Radial head fracture with dislocation of the elbow. Late postoperative X-rays showing radial head screws in situ with metal anchor used to secure lateral collateral ligament repair.

fixation versus arthroplasty for comminuted unstable Mason type 3 radial head fractures. After an average of 2 years of follow-up, patients in the replacement group had significantly better outcome. More complications (limitation in motion, non-union, malunion, HO, infection) were seen following fixation (11/23) compared to arthroplasty (3/22). The authors concluded that replacement is more effective than internal fixation in clinical practice.[35]

Liu et al. published results of 72 patients with Mason type III fractures, monitored for an average of 14 months for radial head arthroplasty and 15 months after fixation, also showing a more favourable functional result with arthroplasty.[36] However only short- to mid-term results are known for most studies reporting on radial head arthroplasty. In addition, the complexity surrounding the differences in design philosophy and clinical performance in beyond the scope of this review.

Conclusion

Fractures of the proximal ulna and radius can be challenging, as their injury is frequently associated with dislocations or other ligamentous injuries around the elbow joint. Careful assessment of the injuries needs to be undertaken prior to treatment in order to recognize injury patterns not only to the bony elements but also to the ligamentous constraints. These soft tissue injuries, which may not show up on imaging, need to be identified and treated in order to maximize patient outcomes. Operative treatment should be undertaken to achieve rigid anatomical reduction with a stable elbow in order to enable an early functional rehabilitation programme. ◆

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