Forearm fracture dislocations

Ankit Desai
Mohammed Amer
Lisa Tourret
Joideep Phadnis

Abstract

Foerearm stability is provided by a complex interplay of the bony and osseo-ligamentous structures which constitute the forearm unit. Consequently, fractures of the radius and/or ulna with concurrent injuries to the stabilizing ligamentous structures can lead to chronic instability and dysfunction if treated incorrectly. Seen in both the adult and paediatric populations, correct diagnosis and management are essential to prevent long-term forearm pain and instability. This article covers the three main instability pattern injuries of the forearm with a focus on anatomy, biomechanics and surgical principles of acute and chronic reconstruction.

Keywords Essex-Lopresti; forearm instability; Galeazzi; Monteggia

Introduction

Forearm instability injuries occur after a trauma to the arm, usually high energy, causing damage to the primary and secondary stabilizers of the forearm.

The function of the forearm is (1) to provide stability and maintain the anatomical relationship of the radius and ulna thus allowing pronosupination, (2) to provide load transfer between the radius and ulna and from the wrist to the elbow, (3) to serve locally as a site for forearm muscle attachment.[1]

Anatomy

The forearm is best considered as a single functional unit comprising the radius and ulna connected proximally by the proximal radial ulnar joint (PRUJ), centrally by intraosseous membrane (IOM) and distally at the distal radioulnar joint (DRUJ).

Ankit Desai *MBBS BSc FRCS (Tr&Orth), Specialist Registrar, Trauma and Orthopaedics Department, Brighton and Sussex University Hospital, Brighton, UK. Conflicts of interest: none declared.*

Mohammed Amer *MBBCH MSc MRCS, Specialist Registrar, Brighton and Sussex University Hospitals, Brighton, UK and Assistant Lecturer of Orthopaedics and Traumatology, Cairo University, Egypt. Conflicts of interest: none declared.*

Lisa Tourret *MB ChB MSc FRCS (Lon) FRCS (Tr&Orth), Consultant Hand Surgeon, Brighton and Sussex University Hospitals, Brighton, UK. Conflicts of interest: none declared.*

Joideep Phadnis *FRCS (Tr&Orth) Dip Sports Med MRCS MBChB, Consultant Shoulder and Elbow Surgeon, Brighton and Sussex University Hospitals and Brighton Medical School, Brighton, UK. Conflicts of interest: none declared.*

The radial head is the primary stabilizer for longitudinal stability of the forearm as it articulates with the capitellum to prevent proximal migration of the radius. The radial head articulates with the lesser sigmoid notch of the ulna which forms the PRUJ and is stabilized by the annular ligament which arises from the supinator crest as part of the lateral collateral ligament and inserts onto the anterior edge of the lesser sigmoid notch. The annular ligament is further supported by the radial collateral ligament and accessory radial collateral ligament.

The quadrate ligament provides further support to the PRUJ stabilizing the radial neck to the ulnar. It arises from the lateral surface of the ulnar just proximal to the PRUJ and attaches to the neck of the radius just distal to the articular margin. As well as reinforcing the distal joint capsule, it provides further joint stability by restriction excessive forearm supination and pronation.

The IOM and the triangular fibrocartilage complex (TFCC) are secondary stabilizers of the forearm unit.

The IOM functions to provide longitudinal stability to the forearm and offers further stability to the DRUJ. It has been shown to provide 71% of the total stiffness of the forearm unit.[2] Noda et al. described five key components to the IOM (Figure 1).[3] Proximally, it is made up of the proximal and dorsal oblique accessory cords which travel in a proximal to distal direction. The middle ligamentous section is the stiffest and compromises a central band flanked by accessory bands. The central band is the most important structure running at an angle of 21° in a proximal–radial to distal–ulna direction. Distally, a distal oblique band runs from the dorsal ulna at the level of the pronator quadratus to the inferior rim of the wrist sigmoid notch and the DRUJ capsule. This band provides stability to the DRUJ and is isometric in all rotational positions.

The DRUJ is stabilized by both intrinsic and extrinsic stabilisers. The TFCC is the primary intrinsic stabilizer of the DRUJ. It has a dorsal radioulnar ligament (DRUL) and palmer radioulnar ligament (PRUL) which have longitudinal orientated fibres towards its ulnar insertion.[4] Each ligament passes ulnarly and divides into two limbs, the superficial and deep limb attaching to the base of the ulnar styloid and fovea respectively. Soft tissue extrinsic stabilizers to the DRUJ include the distal aspects of the IOM, the pronator quadratus muscle and the extensor carpi ulnaris (ECU) tendon which acts as a dynamic stabilizer by elevating the ulnar carpus dorsally while depressing the ulnar head palmarly during forearm pronation.[4] Despite its importance to the DRUJ, the TFCC confers only 8% of the total stiffness to the forearm unit.[2] Both the sigmoid notch cross-section and the longitudinal shape varies but there is not yet any evidence to support the assertion that any one morphology is more stable than another, although the more congruent is likely to be more stable. The shape of sigmoid notch is not uniform and has been classified into: 1) flat face, 2) ski slope, 3) C type, and 4) S type while the longitudinal shape is three main types according to Tolat: 1) vertical 2) oblique and 3) reverse oblique.[5]

The forearm should be considered as a unit. Stability of this unit is essential to providing normal wrist, elbow and rotatory function. Key to understanding the interactions of the unit is that the ulna is the fixed bone with full prono-supination only possible with normal alignment and stability of the radius relative to the ulna as it rotates around the ulna. The axis of forearm rotation runs from the radial neck to the ulna styloid. Even small

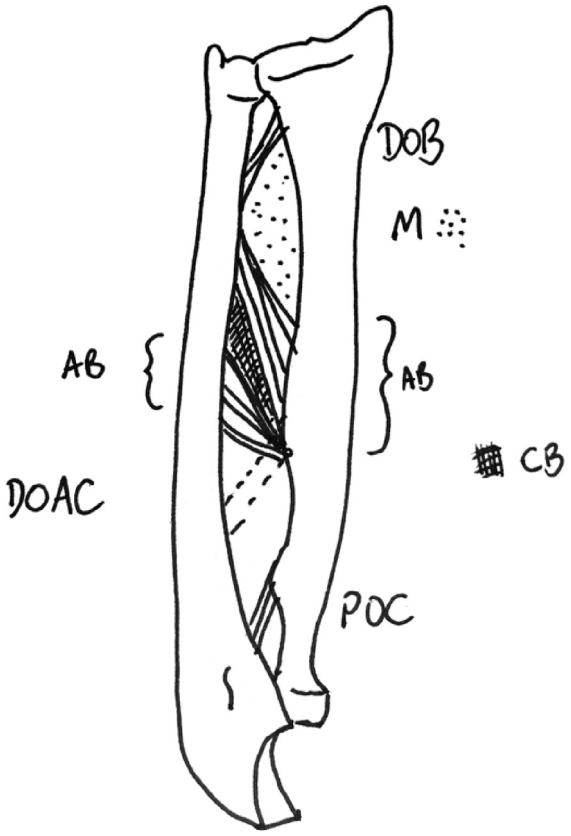

Figure 1 Intraosseous membrane components of the forearm. DOB, distal oblique band; AB, accessory bands; CB, central band; DOAC, dorsal oblique accessory cord; POC, proximal oblique cord; M, membrane.

anatomic disruptions of any component of the forearm unit thus affects the rotational axis which may limit motion, load transfer and function. The deleterious effects of injury to the forearm unit means the forearm should be considered with the same principles as a joint, where the aim is to prevent and restore anatomic integrity and stability to prevent dysfunction and development of secondary arthritis at the wrist and elbow. Similar to the ring concept of the pelvis, a disruption of one part of the unit will be accompanied by a soft tissue or bony disruption elsewhere.

Pathologic conditions causing instability of the forearm unit

Galeazzi fractures

A Galeazzi fracture involves a fracture of the radius with concurrent disruption of the DRUJ. This injury pattern was first described by Cooper in 1822 but it was the Italian orthopaedic surgeon, Professor Riccardo Galeazzi, who's name became synonymous with the injury after his documentation in 1934.[6] Galeazzi believed that the fracture component occurred first followed by the DRUJ injury.[7]

Galeazzi fractures have a reported incidence of less than 7% of all adult forearm fractures and less than 3% in children.[8] Galaezzi fractures are caused by axial load on the forearm with the arm in either pronation or supination. Attempts to confirm these observations and recreate the forces required to reproduce a Galeazzi in a research setting have proven difficult. The main classification system used was described by Walsh et al., where the fractures where divided into two main types[9] (Table 1).

Distal third fractures of the radius have a higher propensity to have involvement of the DRUJ compared to proximal or middle third fractures (Figure 2). Schiederman et al. reported the association between soft tissue injury and radial shortening following fracture. They found that radial shortening of more than 5 mm may indicate injury to either the TFCC or IOM and shortening of more than 10 mm predicted damage to both the TFCC and IOM.[10]

Retting et al. reported the incidence of DRUJ instability in Galeazzi fractures according to the level of the distal radius fracture.[11] They found that only 1 out of 18 (6%) patients with a radial fracture more than 7.5 cm from the articular surface of the distal radius had residual DRUJ instability after the radius was fixed. In contrast, 12 of the 22 (55%) patients with a fracture less than 7.5 cm from the articular surface had evidence of DRUJ instability following radial fixation. However, a more recent study looking at the predictive value of radiographic measurements to determine DRUJ instability found these to measurements to be only moderately accurate.[12]

Skeletally immature patients have an inherent area of weakness at the growth plate. A Galeazzi-equivalent type injury can occur where a fractured radius is associated with a Salter–Harris type 4 fracture of the ulna physis. In this injury, the relatively stronger ligamentous attachments around the DRUJ are preserved and therefore reduction of the physeal injury and the radius should normally return stability to the forearm unit.

Management: clinical evaluation of patients with any forearm fracture should include examination and imaging of the whole forearm including the wrist and elbow.

DRUJ injury can be difficult to appreciate with clinical examination alone, however, prominence of the of ulna head may be visible when compared to the non-injured arm. Severely angulated, shortened or displaced radius fractures with or without ulnar styloid fractures should alert clinicians to the risk of forearm instability and further focused imaging should be performed.

The aim of surgical management in both adult and paediatric population is to re-establish a functional forearm unit by achieving anatomic alignment and stabilization of the radius fracture and congruent reduction of the DRUJ.

Paediatric patients have greater tolerance for slight deformities and therefore there is a role for non-surgical management with closed reduction and casting which is usually

Walsh classification of Galaezzi fractures[9]

Type	Displacement of distal fragment	Description
1	Dorsal	Apex volar fracture typically caused with axial force with forearm in supination
2	Volar	Apex dorsal fracture typically caused with axial force with forearm in pronation

Table 1

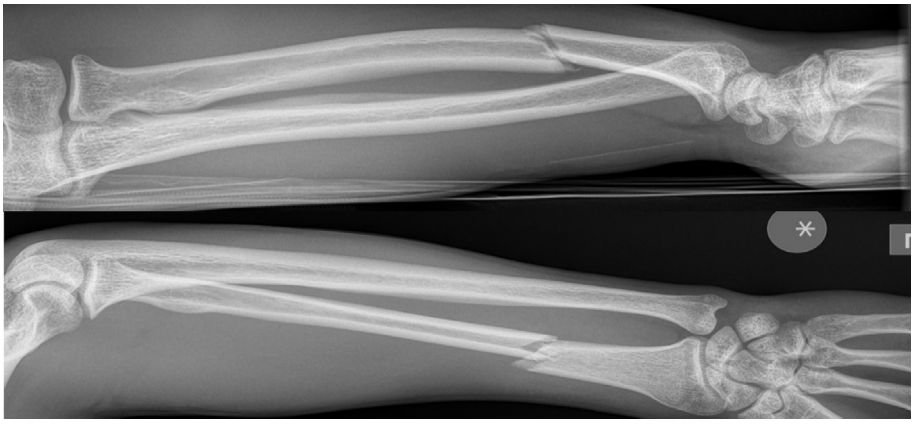

Figure 2 Galeazzi fracture. Lateral and anterior posterior radiographs of a distal third radius fracture associated with dislocation of the distal radioulnar joint.

performed in a supinated position to maintain DRUJ reduction. It is essential that a congruent reduction of the DRUJ is achieved and maintained with this technique which requires correct alignment and length of the radius. Close follow-up is required as subluxation of the DRUJ may not remodel with time. Any doubt regarding DRUJ stability should trigger a change in management plan towards surgical stabilisation. This may be more appropriate from the outset for significantly displaced or shortened fractures with disruption of the periosteal hinge. Fixation using length stable implants such as intramedullary nails or plates is preferred in these unstable injuries. If intramedullary nailing is used to achieve relative stability, supplementary casting in supination is recommended. One study reported that only 2 out of 41 patients required open reduction, internal fixation with fair to excellent outcomes. Similar good outcomes were reported for the remaining patients who underwent closed reduction and immobilisation in plaster.[9] Poor results were only found in 3 of the 16 patients treated in a below elbow cast.

In contrast, non-surgical management of adult Galleazi fractures has been shown to result in poor outcomes in the majority of patients because of the unstable nature of these fractures in adults and their low tolerance to deformity.[13] Hence for adults, internal fixation with anatomic reduction and absolute stability where possible is preferred. This respects the notion that a forearm fracture should be treated like an intra-articular fracture. For simple fractures compression plating is preferred (Figure 3). In multi-fragmentary fractures, bridge plating with care to restore length, alignment and rotation is required to prevent persistent DRUJ instability.

Intraoperative determination of DRUJ stability requires both radiological and clinical assessment. Static assessment with anteroposterior (AP) and true lateral fluoroscopic imaging should be used. Lateral views with the wrist flexed, extended and pronated are recommended to provide a dynamic assessment. Variation in the sigmoid notch morphology and distal ulnar shape between individuals may be misleading and if uncertainty arises, comparative views of the uninjured forearm should be obtained. In the vast majority of cases, restoration of radial

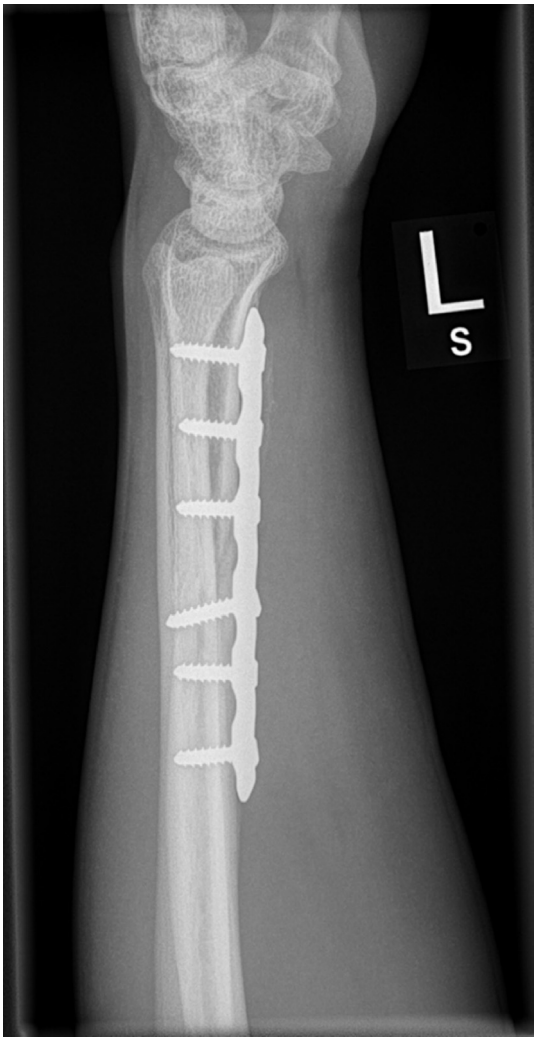

Figure 3 Post-fixation of Galeazzi fracture. Compression plating of distal third radius fracture with dynamic compression plate. Note reduction of ulna once radius has been anatomically fixed recreating the forearm unit.

alignment results in a stable congruent DRUJ and further immobilization is unnecessary. In the rare circumstance that the DRUJ remains unstable, the first step should be to re-check the radial fixation and alignment. Following this the surgeon should note whether the joint is reducible in any position. If the DRUJ remains unstable or irreducible despite anatomical reduction of the radius fracture, then the DRUJ should be inspected. After reduction, the joint should be tested over the full range of forearm rotation to determine the stable arc. Typically, a dorsal dislocation is most stable in supination, and a palmar dislocation is most stable in pronation. If the joint is stable only in extreme pronation or supination, additional treatment should be considered.

Direct reduction, soft tissue repair and casting in neutral is preferable to indirect reduction and temporary fixation with wires in a non-anatomical position.

The approach to the ulnocarpal joint and DRUJ is in the floor of the fifth compartment. The sixth compartment is left intact as the subsheath should be undisturbed. The capsule of the DRUJ is opened using a ligament-sparing L-shaped incision along the dorsal aspect of the sigmoid notch proximal to the dorsal radioulnar ligament. A cuff of capsule is left for later repair. The DRUJ is inspected to ensure relocation and the TFCC assessed for repairability. Exposure can be improved by flexing the wrist and retracting the ECU sheath. If the foveal attachment is avulsed (the most common injury), it is advised that it is repaired to the bone either using an anchor or sutures through tunnels drilled with a 0.45 mm K-wire. Provided stability has been restored, this can then be protected in neutral casting for 6 weeks and protective splints during activity for a further month during rehabilitation.

Alternatively, the DRUJ may be reduced in supination and the reduction maintained using two transfixing wires between the radius and ulna. These should be at least 1.6 mm in diameter to minimise the risk of breakage and should cross all four cortices to aid retrieval if breakage occurs. The wires are cut beneath the skin and removed after 4–6 weeks. In general, this technique is not recommended as late displacement can occur once the wires are removed and the patient is at risk of stiffness and complex regional pain syndrome by extensive mobilization. If the surgeon performing radial fixation is not familiar with TFCC repair, it may be more prudent and better for the patient to splint the arm in plaster following radius open reduction internal fixation (ORIF) and arrange expedient referral to a hand specialist for TFCC repair.

Chronic DRUJ subluxation following Galeazzi fracture: management of chronic DRUJ instability is beyond the scope of this article, however, the principles of management are to first consider the skeletal and soft tissue deficiencies as well as the presence of post-traumatic arthritis. Depending on the situation, soft tissue reconstructive procedures alone or combined with bony osteotomies are first-line measures. Salvage procedures such as the Sauvé–Kapandji technique or various arthroplasty options are considered when other measures are exhausted as they create irreversible biomechanical changes that carry a more complex spectrum of complications.

Monteggia fractures

Classification: Monteggia fracture dislocations were first described by the surgical pathologist, Giovanni Battista Monteggia in 1814[14] however, it was Jose Luis Bado who created a classification system to aid understanding of the condition in 1967.[15]

This classification divides the injury into four distinct types according to the level and angulation of ulna fracture and the direction of dislocation of the radial head (Table 2). In addition to these four types Bado added six Monteggia equivalents to type 1 and one equivalent to type 2 (Table 3).[15,16]

Letts proposed a classification which includes the plastic deformation rather than fracture sometimes seen in paediatric patients[17] (Table 4). Adult type 2 (posterior) Monteggia fractures are frequently caused by high-energy mechanisms such as falls from height or motor vehicle collisions. These injuries carry the worst prognosis and are the most complex to treat surgically because they often include separate fractures of the coronoid and radial head as well as collateral ligament injuries of the elbow.

Diagnosis: Monteggia fractures dislocations can present in both adults and children. They usually present acutely but can present as a chronic neglected injury especially in children. Chronic injuries pose a surgical challenge therefore emphasis should be placed on timely diagnosis and treatment of these injuries. Unfortunately, because the radiographic signs, particularly in

Bado classification

Type	% of cases	Mechanism	Description
1	55–78	Forced pronation	Anterior dislocation of the radial head with concomitant fracture of the ulnar diaphysis with anterior angulation
2	10–15	Axial load with forearm flexed	Posterior dislocation of the radial head with concomitant fracture of the ulnar with posterior angulation • Rare in children • Poor outcome compared to others
3	6.7–20	Forced abduction of the elbow	Lateral or anterolateral dislocation of the radial head associated with a fracture in the ulnar metaphysis and this type occurs primarily in children.
4	5	Forced pronation	Anterior dislocation of the radial head with fractures of both the radius and ulna within the proximal third at the same level.

Table 2

Bado equivalent injuries

Equivalent type	Description
1	Anterior dislocation in radial head in child or adult (pulled elbow in child) Fracture ulna diaphysis and fracture neck of radius Fracture of the neck of radius Fracture of the ulna diaphysis with fracture of the proximal third of radius. Fracture of ulna diaphysis with anterior dislocation of radial head and olecranon fracture Posterior dislocation of the elbow and fracture ulna diaphysis, with or without fracture of the proximal radius
2	Epiphyseal fractures of the dislocated radial head of fractures of neck of the radius.

Table 3

Letts classification

Letts type	Bado equivalent	Description
I	1	Radial head dislocation with plastic deformation of the ulnar diaphysis
II	1	Radial head anterior dislocation with greenstick fracture of ulnar diaphysis
III	1	Complete fracture of the ulnar diaphysis and anterior dislocation of the radial head
IV	2	Posterior dislocation of the radial head with concomitant fracture of the ulnar diaphysis with posterior angulation
V	3	Lateral or anterolateral dislocation of the radial head associated with a fracture in the ulnar metaphysis

Table 4

paediatric patients can be subtle and because the patients may do reasonably well despite radial head dislocation the presentation can be delayed for months or even years.[18] This is more common in areas of the world with large rural communities and poor healthcare infrastructure.

Acute presentation – the mechanism of injury correlates with the pattern of dislocation (Table 1).[18] Pain and deformity may be present at both the elbow and at the ulna fracture site. Careful neurovascular examination should be performed to rule out neurological injury or compartment syndrome. The posterior interosseous nerve is particularly susceptible in type 1 injuries due to its course anterior to the radial head.

Chronic presentation – these are cases presenting at least 1 month after trauma in which the radial head remains dislocated with a malunion of the ulna fracture. The clinical picture differs according to time of presentation and many patients may have relatively few symptoms for several years before presentation. Most patients complain of aching in the anterior elbow or pain/crepitus if degenerative changes start to develop. They often report loss of flexion because of radial head impingent against the anterior humerus and/or restricted prono-supination.[18] There are also several reports of tardy posterior interosseous nerve palsy being the presenting complaint with a neglected Monteggia injury.[19,20]

Radiographic evaluation: careful scrutiny of the elbow radiographs in all acute cases of ulnar diaphyseal and proximal metaphyseal fractures for a Monteggia injury is essential. Several radiographic signs and lines have been described to determine congruent radio-capitellar alignment (Figures 4 and 5). Surgeons should have an awareness of the normal variation in proximal ulna anatomy between individuals and that the mean varus bow and apex posterior angulation are 12.1° and 4.3° respectively.[21]

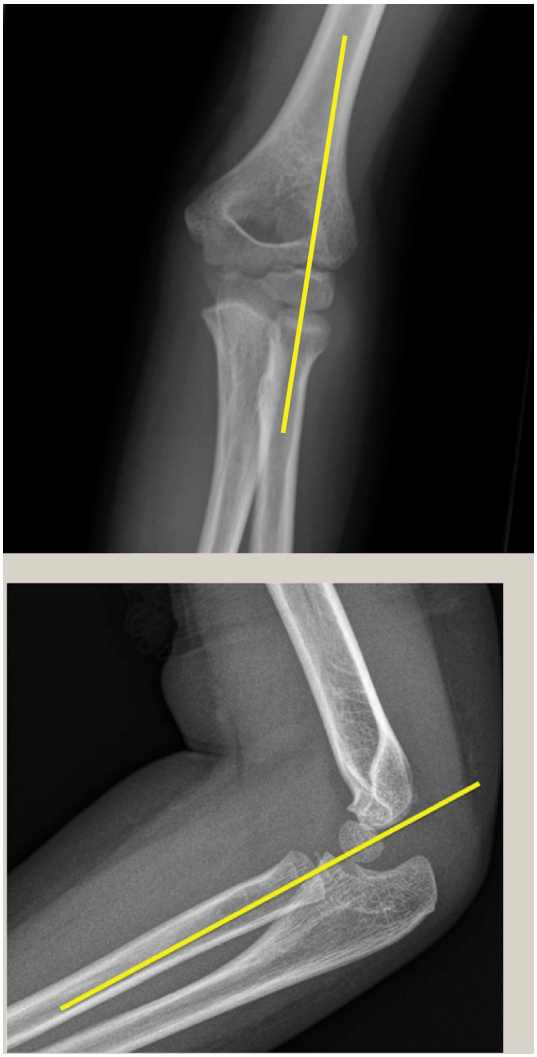

Figure 4 Radiographic assessment of radiocapitellar congruency. Lateral humeral line which is the tangent line to lateral humeral ossification and parallel to the axis of the distal humeral shaft centre drawn in the anteroposterior (AP) view the radial head should lie medial to it.[31] Radiocapitellar line drawn along the anatomical axis of the radius normally intersects the centre of the capitellum in both AP and lateral view.[32]

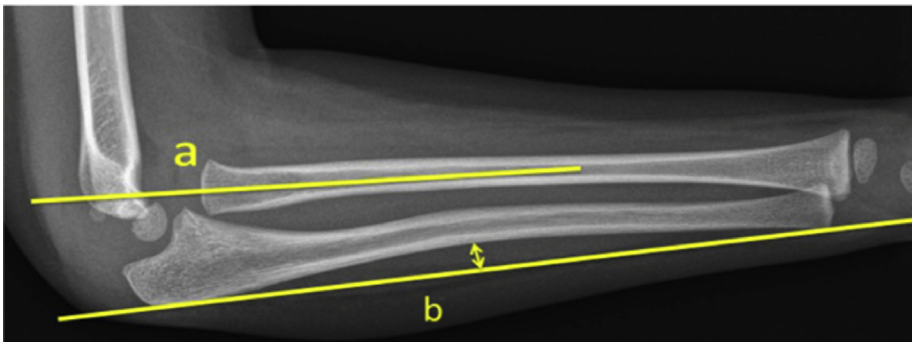

Figure 5 Lateral radiograph of a Monteggia fracture. Radiocapitellar line **(a)** passing above the radial head on this lateral view. Ulnar bow **(b)** which is normally rectilinear and apex posterior, is now shown reversed indicating plastic deformation and should raise the possibility of this injury to be more complex than it seems.[33] Reproduced from reference 18 with permission from Elsevier.

In chronic cases, radiographic findings include evidence of ulna malunion, capitellar hypoplasia and radial head hypertrophy. An important distinction is that the radial head may look relatively normal following a neglected Monteggia injury as compared to the typical abnormalities seen with congenital dislocation of the radial head.

If there is any doubt regarding the morphology of the ulna, comparative radiographs of the contralateral forearm are recommended. CT scanning is also useful to quantify deformities and plan osteotomies.

Management: surgical management is recommended for all acute cases. The goals of surgery are to re-store anatomic alignment of the ulna and achieve a congruent reduction of the PRUJ and radio-capitellar joints. Correct alignment and reduction of the ulna invariably achieves reduction of the radial head and hence attention to achieving correct ulna length, alignment and rotation should be paramount. Stable internal fixation with plates is recommended for all adult injuries although in paediatric patients, intramedullary implants may be sufficient.

Bado type 1 (anterior) (Figure 6) – following ulna fixation, careful examination of the radiocapitellar congruency must be assessed. Fluoroscopy should be performed in all positions of flexion-extension with supination and pronation in both the AP and lateral planes. It is recommended that this is done before all screws are placed through the plate. Dorsal pre-contoured plates with sufficient stiffness are recommended for fractures in the proximal half of the ulna. For more distal fractures, straight compression plates are suitable and for segmental fractures spanning the whole ulna overlapping plates may be required.

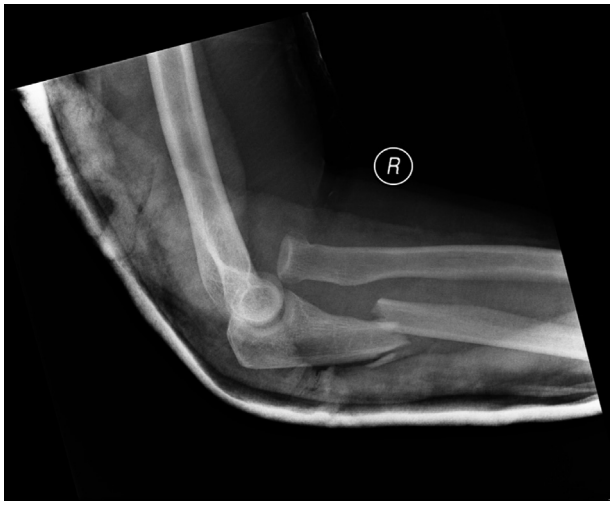

Figure 6 Monteggia fracture: Bado type 1 (anterior). Lateral radiograph of elbow showing proximal ulna shaft fracture with anterior dislocation of radial head.

In the event that the radial head does not relocate after ulnar fixation, ulnar alignment and length should be re-checked and revision of the fixation should be considered. The direction of radial head instability (usually anterior) should be assessed and the ulna angulation should be increased in the opposite direction. Very small degrees of correction may be enough to correct the radio-capitellar alignment. Pre-bending a plate at the fracture level and using cortical screws to align the ulna to the plate is a useful technique. In the rare scenario, if the radial head is irreducible following these measures, co-existing disruption of the lateral collateral ligament (LCL) (radial head posterior in forearm supination) or soft tissue interposition should be considered. An extensor digitorum splitting lateral approach to the elbow allows the joint space and LCL to be inspected and addressed. It is important to emphasize that this situation is rare and ulna alignment is usually the problem. Hamaker et al.[22] reported the need for removal of an incarcerated annular ligament in 13% (16/119 patients) of all Monteggia fractures treated in their series. In this situation the radial head is unlikely to be reducible in any position of forearm rotation which may guide surgeons to assess the radio-capitellar joint open.

Bado type 2 (posterior) – these injuries are related to axial instability of the ulnohumeral joint rather than a primary forearm instability and have a notoriously poor prognosis. They comprise a spectrum of severity with the worst scenarios including multi-fragmentary ulna fractures with separate coronoid and radial head fractures as well as lateral collateral ligament tears. Careful planning and surgical management is required to achieve ulno humeral and forearm stability by addressing the ulna fracture, radial head and coronoid to optimise outcome. The primary issue in this fracture type is ulnohumeral rather than radio-capitellar stability and hence a detailed description is beyond the scope of this article.[23]

Chronic neglected Monteggia fracture-dislocations: soft tissue contracture and symptomatic post-traumatic arthritis of the

radial head and/or ulnohumeral joint should be assessed in the chronic setting. Reconstructive options are more limited in the presence of these changes and radial head excision and or total elbow arthroplasty may be considered. Nevertheless, in most cases these secondary changes are not so pronounced that reconstructive options cannot be used.

A variety of escalating treatment strategies may be employed. Foremost is corrective osteotomy of the ulna plus minus bone grafting. Excision of fibrous scar adjacent to the capitellum may be required to allow reduction following osteotomy. The direction of correction is opposite to the direction of dislocation meaning that for a Bado type 1 injury the apex posterior angulation is increased following osteotomy (Figures 7 and 8). Some authors recommend annular ligament reconstruction although other authors describe increased stiffness or radio-ulnar synostosis following this procedure. Our experience has been that annular ligament reconstruction is not usually required. Chronic soft tissue contracture may be a factor in the residual instability which can be addressed by gradual lengthening and angular correction of the ulna using an external fixator. An alternative unpublished technique describes radial shortening which shows promising results and may lower the concerns of union seen in ulna lengthening.

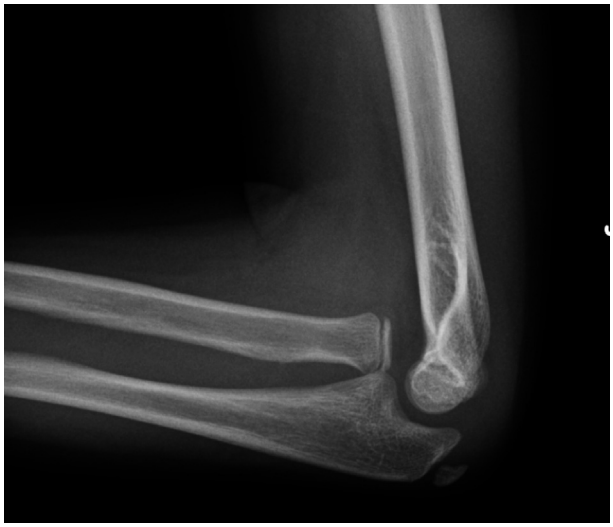

Figure 7 Lateral radiograph of skeletally immature elbow with plastic deformation of ulna along with anterior radial head dislocation. Loss of normal ulna bow can be seen.

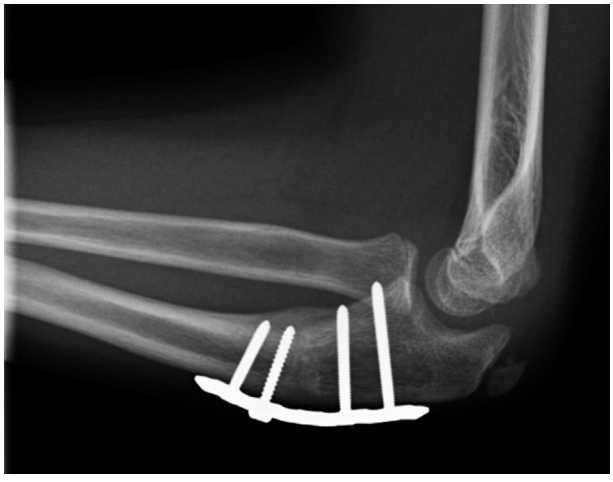

Figure 8 Lateral post-surgical radiograph of skeletally immature elbow. Corrective osteotomy of ulna to correct plastic deformation. Angulation of osteotomy opposite to direction of radial head dislocation.

Essex-Lopresti injury

Longitudinal instability of the forearm results from high-energy traumatic axial loading of the wrist that results in abnormal longitudinal translation of the radius relative to the ulna. It typically results from injury to the three constraints of this anatomical unit: the radial head, the IOM and DRUJ and may be acute or chronic in nature. The consequence of persistent, longitudinal instability is pain and disability caused by progressive proximal migration of the radius and abnormal load transfer that leads to radiocapitellar erosion and DRUJ instability.

The injury derived its common name in 1951 when Peter Essex-Lopresti, an English surgeon, reported two cases with longitudinal migration of the radius following radial head excision. His original description described longitudinal instability of the radius following an axial load on the forearm affecting the three main constraints of the forearm unit: the DRUJ, IOM and radial head[24]

The importance of recognition of this injury as early as possible is highlighted by the difference in functional outcomes, rate of complications and secondary procedures in favour of acute cases compared to chronic ones.[25] Trousdale et al. reported in his review of 20 cases that only 25% of patients with Essex-Lopresti injury (ELI) were diagnosed at presentation, and of those with a delayed diagnosis and subsequent treatment, only 20% had positive outcomes.[26] The diagnosis of ELI is challenging as longitudinal instability is rare, with an estimated occurrence of 1 % of all radial head fractures and may not be obviously detected on routine evaluation. A high index of suspicion is therefore required for all radial head fractures.

Acute diagnosis:

Clinical features – the patient may report an axial load mechanism of injury although this is sometimes difficult in a high energy trauma setting. A complete upper limb examination includes the elbow, forearm and wrist. Swelling and bruising of the forearm, tenderness around the wrist and association with a radial head fracture should arise suspicion that there is an ELI. Physical examination of the entire forearm unit may reveal several positive signs. Grip strength may be reduced, along with forearm rotation, especially pronation which may be restricted or provoke pain.

Forearm pain may be elicited by squeezing the interosseous space in varying degrees of supination and pronation, although this is unreliable in the chronic setting. The wrist examination often yields ulnar-sided wrist tenderness with increasing pain as the forearm is rotated. DRUJ stability is evaluated by assessing translation of the radius relative to the ulna in pronation, neutral and supination and its mobility compared to the contralateral wrist. Typically, translation is reduced in supination and radial

deviation. Persistent translation compared to the normal side in these positions is indicative of pathologic instability.

Static radiographs – AP and lateral radiographs of the elbow will identify radial head fractures and their configurations. Additional CT with three-dimensional reconstruction may be needed for preoperative planning. A loss of 'empty space' in which the radial head could be reconstructed, as seen on the lateral elbow radiograph, is suggestive of proximal radial migration.

AP and lateral radiographs of the wrist are needed to detect proximal migration of the radius which is evident on the wrist AP radiograph where the lowest point of the distal radius articular surface is compared to the ulnar head. Radiographs of the contralateral wrist should be obtained to determine normal ulnar variance for each patient if subtle change is concerned (Figure 9). The lateral radiograph may reveal distal radioulnar subluxation (Figure 10).

Advanced imaging – the change in ulnar variance on stressing the DRUJ whether by axial loading or performing a power grip in pronation can also aid in diagnosis, however these signs are not reliable nor convenient to perform in a high-energy trauma setting. Their use in theatres under anaesthesia and fluoroscopic guidance is a more realistic option.

Ultrasound and MRI scans are very helpful in detecting IOM tears, especially in cases where clinical examination is suspicious, but radiographs are normal. There is no difference between the two modalities in term of specificity or sensitivity.[27] The MRI has the added benefit of detecting TFCC tears and DRUJ congruence if the wrist is included. However, over diagnosis is an issue with MRI is a problem as even simple radial head fractures have been shown to have some degree of IOM injury on MRI with no clinical consequence. Ultrasound can clearly visualize the central band (CB) as a hyper echoic line between the radius and ulna. Any tear in the CB resulting in a change in its signal can be identified with 96% accuracy. Using dynamic USS, Soubeyrand et al. described the 'muscular hernia sign' where the volar forearm muscles can be seen to herniate through the CB defect when a dorsally directed pressure is applied to the volar compartment.[28] However, ultrasound is user dependent and the expertise required may not be available in all centres.

Intraoperative tests – intraoperative assessment of the longitudinal stability of forearm is performed before the radial head is fixed or replaced with the remnants removed.

The pull test which was based on cadaveric studies, is performed with the elbow flexed to 90° and application of longitudinal pressure to assess dynamic proximal radial migration. A positive test is when there is more than 3 mm change in variance which indicates IOM insufficiency. The radial 'joystick test'[28] is also performed pulling the radius laterally using a bone clamp. Divergence of the radius and ulna signifies a positive test and indicates disruption of the IOM.

Chronic diagnosis: many patients with longitudinal instability present late because of the rarity of the condition and difficulty making an acute diagnosis. Furthermore, it is not known how many longitudinal instabilities are treated satisfactorily by acute radial head fixation/replacement and which cases may benefit from DRUJ stabilization or IOM reconstruction acutely. Suspicion should be heightened if any of the previously described acute clinical or radiographic features are present or if a patient is not progressing in the normal manner despite satisfactory treatment. Patients who have undergone non-standard treatment such as radial head resection or where DRUJ instability has been overlooked are at high risk of developing symptomatic longitudinal instability if a significant IOM injury has occurred.

Presentation – the patient may provide a previous history of an axial loading injury mechanism together with a radial head fracture treated conservatively or surgically. Persistent postoperative stiffness, wrist, elbow or forearm pain different to the normal recovery after a radial head fracture is likely to be present, and many patients may have undergone various treatments to address these prior to recognition of longitudinal instability.

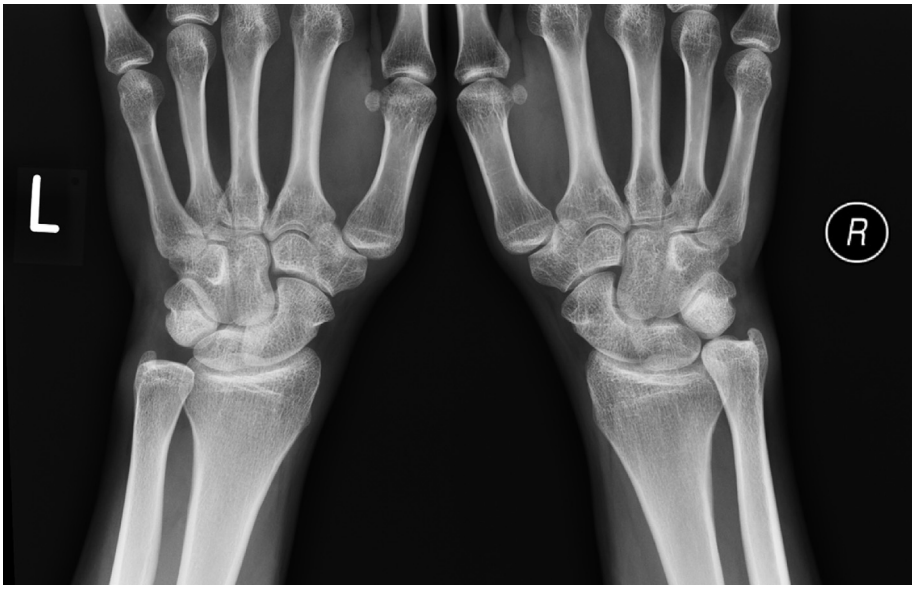

Figure 9 Comparative wrist radiographs. Right side shows evidence of radial shortening secondary to an Essex-Lopreseti injury.

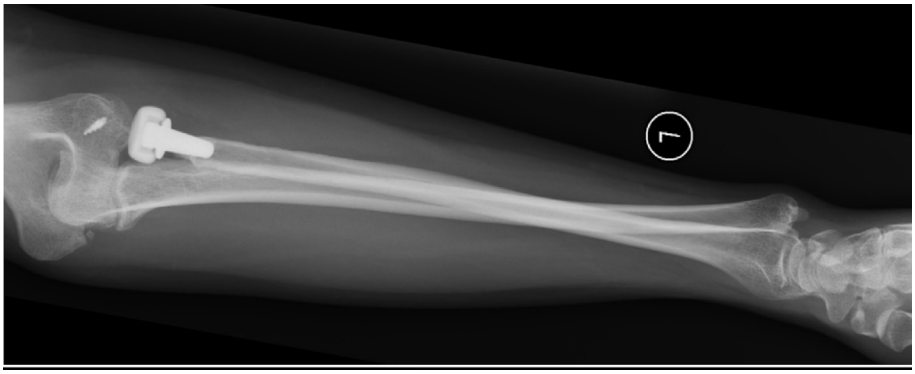

Figure 10 Lateral radiograph of left forearm. Patient presented with ongoing wrist pain after a radial head replacement for an acute fracture. Radiograph shows evidence of chronic distal radioulnar joint subluxation in keeping with an Essex-Lopresti injury.

Radiographs of the elbow may show changes at the radiocapitellar joint, malunion of the radial head or previous surgery to the radial head. Signs of early failure of radial head ORIF, early loosening of radial head replacement or capitellar erosion with proximal migration of the radius should alert the clinician to the possibility of longitudinal instability. Positive ulnar variance can be seen in comparative wrist radiographs and may be static in the chronic setting.

Advanced imaging including CT scans are useful to assess for skeletal deformities, joint subluxation and secondary arthrosis at the wrist or radio-capitellar joint. MRI is likely to be difficult to interpret in the chronic setting unless there is persistent high signal in the interosseous space.

Management of longitudinal forearm instability

Whether acute or chronic, the management goals are to re-establish load transfer and pain free rotation by addressing the three main constraints to forearm stability (radial head, DRUJ and IOM).

The radial head

A true ELI is unlikely to be present in conjunction with a simple minimally displaced radial head fracture. Hence, in the acute setting when longitudinal instability is suspected, retention of the radial head either through fixation or replacement should be performed. Because of the difficulty in making an acute diagnosis of longitudinal instability, radial head excision is not advised unless there are truly no intraoperative features of forearm or elbow instability. A technical issue with radial head replacement in longitudinal instability is that the radial head is often very comminuted together with the absence of longitudinal stabilizers which makes head sizing and length assessment more challenging. The tendency may be to overstuff the joint to improve stability which can increases radio-capitellar contact pressures and accelerates capitellar erosion. The most reliable intraoperative landmark is the lesser sigmoid notch. The prosthesis should not be more proximal than the most proximal aspect of the lesser sigmoid notch in forearm pronation.

In the chronic longitudinal instability, if there is absence of the radial head, radial head replacement should be considered to restore the lateral column of the forearm. In the presence of malalignment of the radial neck with the capitellum a bipolar implant may be preferred. If there is capitellar erosion or radioulnar impingement then a radiocapitellar interposition with allograft or anconeus may be considered. Alternatively, in the presence of erosion without malalignment, radiocapitellar arthroplasty is an option, although the longevity of this may yet be compromised with continued IOM insufficiency.

The interosseous membrane

Acute reconstruction of the IOM is controversial. Traditional thinking has advocated restoration of the radiocapitellar joint and DRUJ stabilization to allow the IOM to heal or scar at its normal resting length. However, despite this protocol, some patients still develop late signs of persistent longitudinal instability including DRUG subluxation, wrist pain and capitellar erosion. Schnetzke et al.[25] reported that 7 out of 16 patients treated in this manner had proximal migration over 2 mm during their follow-up and that those patients had inferior functional outcomes than those with migration below 2 mm. Consequently, it is felt that in severe disruptions of the IOM, healing sufficient healing/scar formation may not occur to stabilize the forearm fully. Hence, if longitudinal instability is established in the acute setting, acute IOM reconstruction may be considered.

In the chronic setting, IOM reconstruction is an integral part of the management plan. This is done using autografts, allografts or synthetic grafts. The aim of the procedure is to reconstruct the central band of the IOM with a graft stiff enough to resist the longitudinal forces and resist creep over time. The procedure is usually preformed through a dorsal approach to the radius and a direct approach to the ulna, the graft is passed from the point of maximum bow of the radius to a point 6 cm below ulnar styloid underneath the extensors to replicate the 21° angle of the native central band (Figure 11).[29]

The wrist

Acutely, if the DRUJ is found to be unstable in the presence of a radial head fracture it should be stabilized with a soft tissue repair as described earlier in this article or by DRUJ pinning.

In the chronic setting gross DRUJ instability may require soft tissue reconstruction. More commonly a joint levelling procedure to restore normal ulnar variance such as ulnar shortening osteotomy or a wafer procedure can be used in conjunction with treatment of the IOM and radial head to correct marked proximal migration.[29]

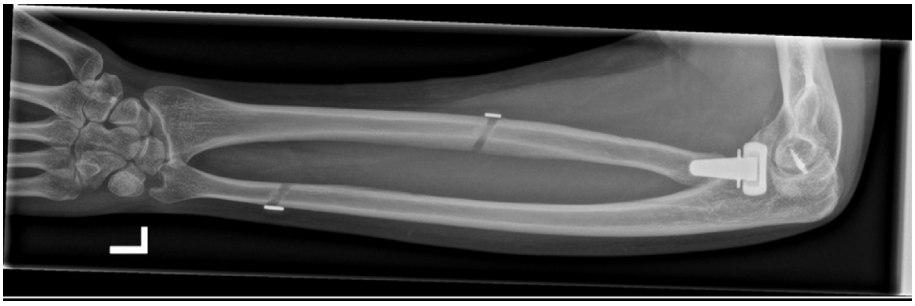

Figure 11 Postoperative lateral radiograph of left forearm showing evidence of intraosseous membrane reconstruction and radial head replacement.

Salvage procedures such as DRUJ arthroplasty or the Sauvé–Kapandji procedure may help pain at the wrist but are unpredictable because of altered radiocapitellar loading and higher risk of failure. Ultimately, in the most severe cases for patients with continuous pain and disability creation of a single bone forearm by inducing radioulnar synostosis may be a salvage option. This subjects all the load from the hand to be transferred through the fusion mass and through the ulnohumeral joint but is unpredictable with a high complication rate.[30]

Summary

Forearm fracture dislocations are complicated injuries which require an understanding of the forces and anatomy involved. Careful assessment and evaluation of the injury are required to ensure injuries are not missed and when detected are managed appropriately. The aim of management is to restore anatomical alignment and recreate the functional forearm unit. Correct early diagnosis and appropriate management can lead to good outcomes in both adults and children; however, missed diagnosis or incorrect treatment can lead to significant morbidity for the patient. ◆

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