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Dislocations of the elbow – An instructional review

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ABSTRACT

Dislocations of the elbow require recognition of the injury pattern followed by adequate treatment to allow early mobilisation. Not every injury requires surgery but if surgery is undertaken all structures providing stability should be addressed, including fractures, medial and lateral ligament insertion and the radial head. The current concepts of biomechanical modelling are addressed and surgical implications discussed.

1. Introduction

Elbow dislocations present with a variety of injury patterns which require expert recognition to define the best treatment pathway. These injuries are not uncommon and in children the elbow joint is the most frequently dislocated joint. In adults only the shoulder joint is more frequently dislocated.

Notably, the incidence of all elbow dislocations has been recorded at 5.21 per 100,000 person-years, with greater incidence in males (53% in males, with a 1.02 male – female incidence ratio, $p < 0.001$).[1] Of all elbow dislocations 18–45% are likely to be terrible triad injuries,[2] constituting a combination of elbow dislocation, radial head fracture and coronoid process fracture. These are more common in adults as children have flexible and strong ligaments whilst the bones are still immature. Consequently, children are more likely to incur a fracture of the distal humerus or an avulsion fracture at the ligament attachment but not commonly a dislocation.[3,4]

The mechanism of injury may vary, ranging from falling onto an outstretched hand or direct high energy impact. The combination of direction of the injury forces, energy of injury and patient characteristics, particularly bone age, will determine the injury pattern.

Elbow dislocations can be classified as simple, *i.e.*, a stand-alone dislocation, mostly posterior, at the joint with peri-articular avulsions less than 2 mm,[5] or complex, in combination with an associated fracture of the radius, humerus or ulna at the ipsilateral elbow joint.[6] Multiple complex dislocation patterns can be identified, ranging from a posterior dislocation with a fracture of the radial head (Posterior radial head fracture dislocation, PRHFD), and the terrible triad injury (TTI),[2] to the Varus posteromedial rotational instability injury (VPMRI), the latter potentially leading to chronic subluxation. Fractures of the proximal ulna not involving the trochlear notch are often associated with a dislocation of the proximal radio-ulnar joint and are known as Monteggia fracture dislocations. Olecranon fractures may be associated with anterior olecranon fracture dislocation (AOFD) or posterior olecranon fracture dislocation (POFD).

Treatment of simple and complex fracture dislocations of the elbow follows the principles of achieving a stable reduction with the aim to commence mobilisation as soon as possible. Stiffness is the most common untoward outcome rather than instability. Surgical intervention must be judiciously considered for the restoration of joint congruity and stabilisation of ligament injuries and avulsion fractures. Traditional treatment was mainly nonoperative[7] but even with prolonged immobilisation ligament stability could not be guaranteed.[8] Modern treatment advocates re-establishing

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the congruency and stability of the joint to allow early mobilisation, by surgical repair if necessary, as this would prevent joint stiffness, instability and arthrosis of the elbow.[9,10]

This review will address the anatomical background of simple and complex dislocations, including the role of stabilisers, present an overview of classification systems and provide a review of treatment principles as discussed in the literature.

1.1. Stabilisers of the elbow

The elbow joint is a tricompartmental hinge joint. Bony and soft tissue components contribute to the stability of the elbow (Fig. 1). They can be broadly classified into:

Bony components
Ligaments
Muscles

1.1.1. Bony components

The ulno-humeral joint, by virtue of its shape, is the primary stabiliser of the elbow joint. The radial head is an important secondary stabiliser to resist valgus stress; and will become the main stabiliser against valgus forces if the medical collateral ligament (MCL) is incompetent. An intact coronoid process[11] is necessary to counter posteriorly directed forces and plays an important role in stabilising the elbow.[12,13] B Morrey has aptly described the coronoid process as the *'most important piece of real estate in the elbow'* (personal communication).

1.1.2. Ligaments

The medio-lateral and rotatory stability to the elbow is provided by the medial and lateral ligament complex. The anterior band of the MCL[14] and lateral ulnar collateral ligaments (LUCL) are the most important ligaments[15] that provide postero-medial and postero-lateral rotatory stability to the elbow.[16,17]

1.1.3. Muscles

All muscles crossing the elbow and the anterior capsule contribute to the stability of elbow.[18,19]

Of all the structures, the following are the main primary stabiliser of the elbow:

Ulno-humeral joint
Anterior band of MCL
Lateral ulnar collateral ligament (LUCL)

1.2. Mechanism of injury and injury pattern

The two main rotatory mechanisms of injury are posterolateral and posteromedial. During a posterolateral rotatory force, the elbow dislocates posteriorly, radial head and coronoid process impact and may fracture, followed by the rupture of the anterior band of the MCL. This might occur falling onto an outstretched hand with the elbow in extension and forearm in supination[20,21] thus the valgus force resulting in a terrible triad injury[22,23](Fig. 2).

The posterior radial head fracture dislocation involves falling onto the extended arm where there is hyperextension and posterolateral rotation, causing a radial head fracture.[24,25]

Conversely, a varus posteromedial rotatory load combined with an axial force will first lead to a fracture of the anteromedial facet followed by a fracture of the olecranon possibly with an additional fragment at the base of the coronoid and/or a lateral collateral ligament (LCL) injury.[26] Both, the LCL and MCL usually avulse from the origin of their epicondyles.

The anterior olecranon fracture dislocation is thought to be caused by a direct high energy blow to the dorsal aspect of the forearm with the elbow in mid-flexion[27] however the mechanism is not as well described.

1.3. Pathoanatomy and classification: dislocation, radial head fracture and coronoid fracture

There is no unifying classification for fracture dislocation of the elbow and authors have addressed separate elements to guide management. Specifically, the coronoid, radial head/neck and olecranon fractures are assessed for classification of the pathology.[21] More recently recognition and description of instability as a

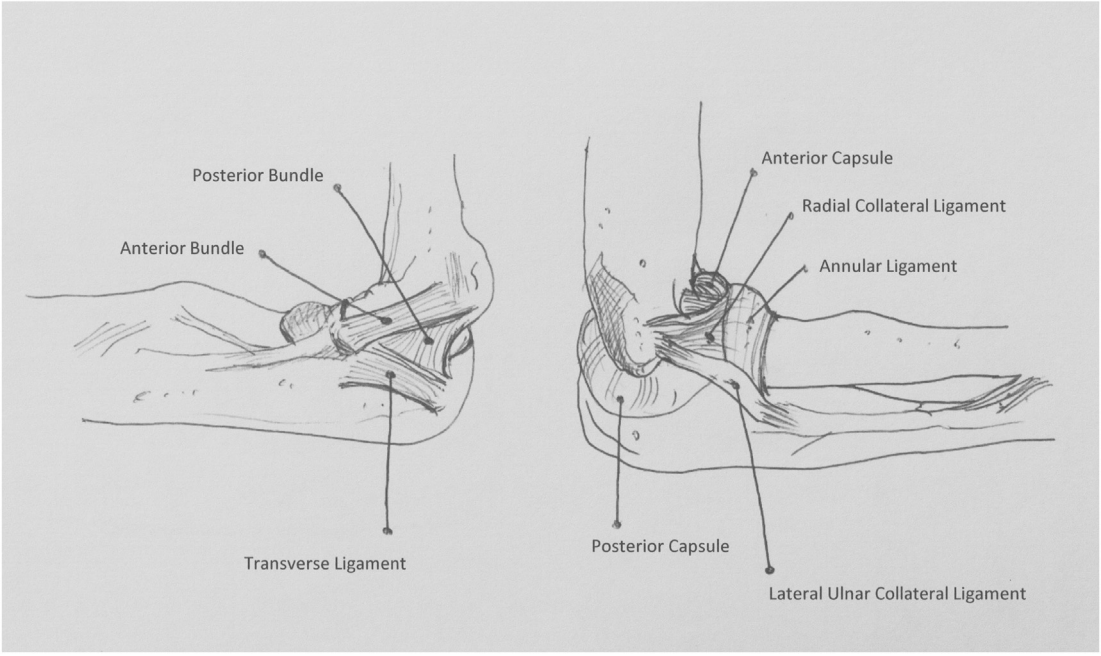


Fig. 1. Anatomy of elbow stabilisers (after Karbach and Elfar[65]).

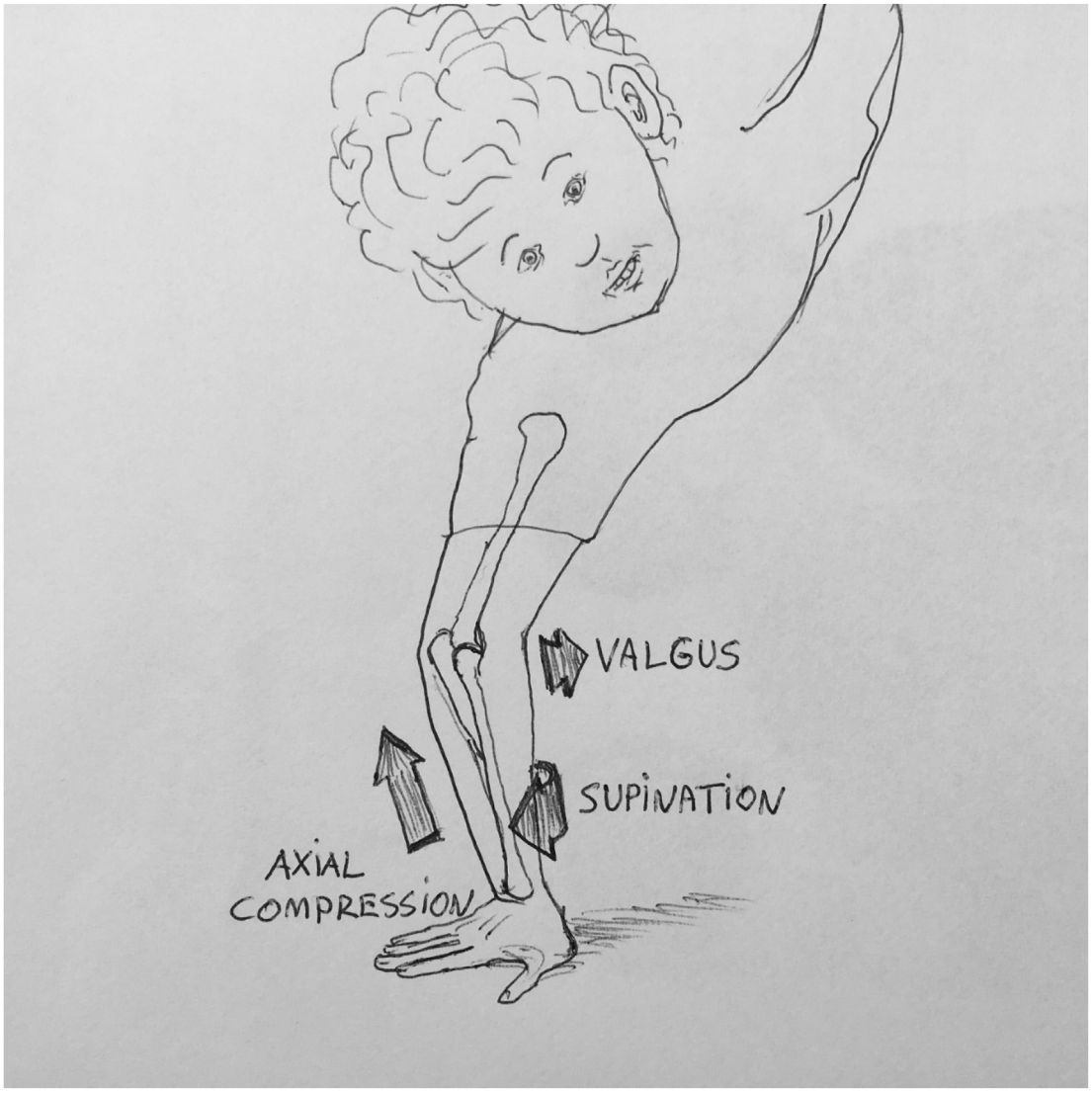


Fig. 2. Illustration of mechanism resulting in a terrible triad injury.

continuum has come into the foreground.

1.3.1. Coronoid fractures

1.3.1.1. Regan-Morrey Classification. The size of the coronoid fragment has been recognised as important fracture to predict instability and been utilised in the Regan-Morrey Classification.[28,29]

Type 1: Avulsion fracture of the coronoid process tip
Type 2: fracture fragment is less than 50% of the coronoid process
Type 3: fracture fragment is more than 50% of the coronoid process

Also:

A: No associated elbow dislocation
B: Associated Elbow dislocation

1.3.2. O'Driscoll Stages of Instability

This classification originates from an understanding of the stages of instability and involves the anatomical location and fracture size, thus helping to derive further details entailing the mechanism of injury.[30–32] This classification is based on anatomical location of the fracture: tip, anteromedial facet and base (which are subdivided further).[32]

1.3.2.1. Type 1 - tip fracture. Involves the coronoid tip with fragments smaller then 2 mm, most commonly seen in terrible triad injuries[33] and also in isolation with subluxations.[34] It is important to note the tip fractures does not extend past the sublime tubercle, hence the MCLC insertion to the sublime tubercle tends to remain intact with these injuries.[35,36]

1.3.2.2. Type 2 - anteromedial facet fracture. Sub-type 1: No coronoid tip involvement, fracture extends medially to the tip and anterior to the sublime tubercle.

Sub-type 2: Subtype 1 with the involvement of the tip.

Sub-type 3: Anteromedial rim of the coronoid process and the sublime tubercle ± tip involvement.

The type 2 injury is usually associated with varus posteromedial

rotatory fracture subluxations,[21] and anteromedial fractures are less common with triad injuries[23] (Fig. 3a, b, 3c).

1.3.2.3. Type 3 - basal coronoid (large fractures). Fracture through the body and basal part of the coronoid process with a minimum of 50% of the coronoid process height.

Sub-type 1: Involving only the coronoid process.

Sub-type 2: Involving both a coronoid body fracture and fracture of the olecranon.

Fig. 3. 3a, 3b, 3c: Coronoid fracture Type 2 (anteromedial facet) treated with open reduction and internal fixation.

1.4. Radial head fracture

The radial head fracture configuration may help to determine stability of the elbow and can also be classified into specific types to determine an effective treatment plan. The Mason classification was initially devised[37] and succeeded by Johnson modifications, which has also been updated by Morrey and later Hotchkiss.[38]

1.4.1. Mason-Johnson classification

Type 1: Non-displaced fracture at head, neck, intra articular, or marginal lip (or those displaced up to less than 2 mm with no mechanical block).

Type 2: Displaced partial articular fracture with or without comminution (displacement more than 2 mm and considered repairable, possible mechanical block to motion and loss of congruency of joint surface therefore needing surgical intervention).

Type 3: Comminuted fracture of the radial head or neck involving the entire radial head (considered not repairable when radiographically/intraoperatively analysed, requiring excision or replacement).

Type 4: Radial head fracture with dislocation of the elbow joint.

Note: Type 4 might apply to all configurations of radial head fractures.

1.5. Olecranon fractures

Olecranon fractures are present in AOFD and POFD and have implication on the stability of the elbow. They can be classified by multiple methods including the Colton,[39] Mayo[40] and AO (Arbeitsgemeinschaft Osteosynthese)[41] classifications.

1.6. Dislocations

1.6.1. Simple dislocations of the elbow

Simple dislocations of the elbow constitute injuries without major fracture component (Fig. 4) and most of them are stable after manipulation and reduction (98%). In a small percentage of injuries there may be a persistent subtle subluxation due to associated

Fig. 4. Simple posterior dislocation of the elbow without fracture.

ligamentous injury. Further imaging utilising magnetic resonance imaging (MRI) may be useful.[42] The threshold to perform a formal EUA under general anaesthesia should be low and these injuries may require surgical fixation.[43,44]

1.6.1.1. Valgus hyper extension. Valgus hyper extension causes a posterolateral dislocation, which is considered the most frequent direction for dislocation.[12] There is circular disruption of soft tissue structures, first being the LCLC, then the anterior and posterior capsule then MCLC, followed by the common flexor origin.[5]

1.6.1.2. Varus internal rotation. Posteromedial dislocations are 10% of all dislocations caused by varus and posteromedial rotation, leading to significant damage of the medial structures in the first instance (Fig. 5).

1.6.1.3. Stages of simple elbow dislocation[10]

Stage 1

Disruption of LUCL with partial or complete disruption of remainder of LCLC, resulting in posterolateral subluxation.

Stage 2

Additional disruption of the anterior capsule, resulting in yet incomplete posterolateral elbow dislocation.

Stage 3

a) Disruption of all soft tissues lateral to medial except the anterior bundle of the MCL, which forms a pivot around which the elbow dislocates in posterolateral rotational direction.
b) Complete disruption of all medial collateral ligament structures.

The staging is based on the concept by O'Driscoll[10] that the same mechanism of injury may lead with a different magnitude of force to an increasing circumferential rupture of soft tissues. Injuries at Stage 2 and 3 usually require surgical repair even in the absence of any bony injury (Fig. 6a and b) and can be diagnosed on careful analysis of the radiographs. It is important to understand that all simple elbow dislocations are not the same. The more energy is imparted during the injury, the more 'aggressive' the management

Fig. 5. Simple medial dislocation of elbow with high risk of persistent instability.

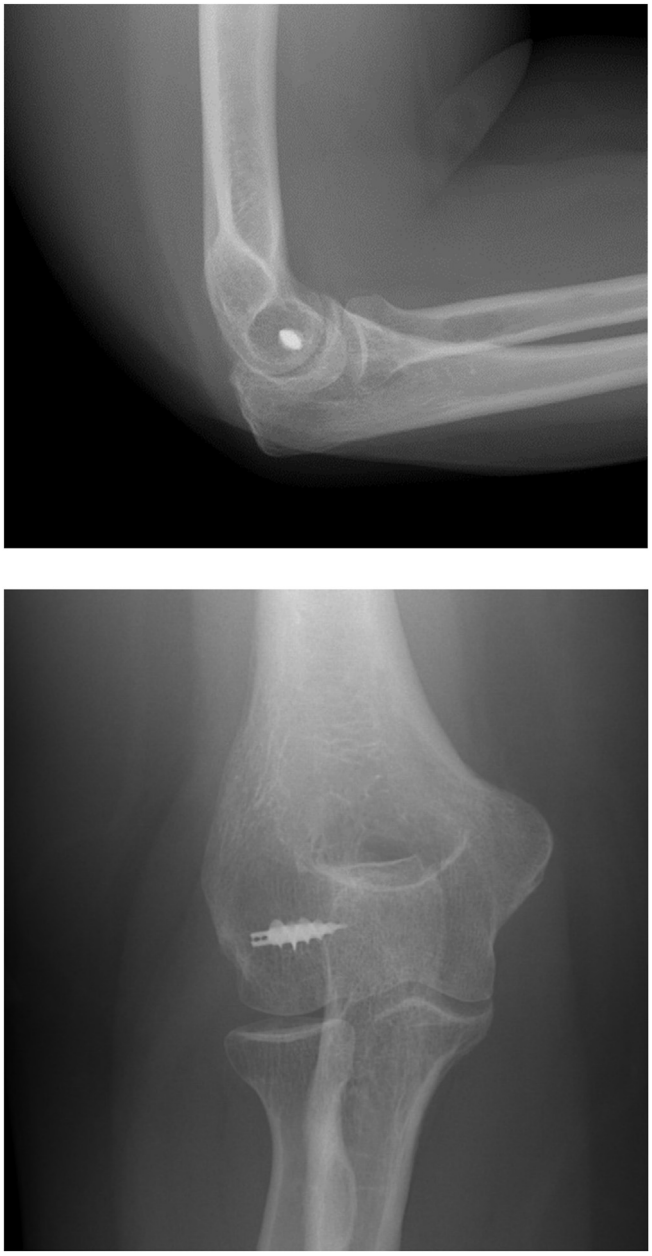


Fig. 6. 6 a, 6b: Ligament reconstruction following simple dislocation with complete ligament disruption (Stage 3).

may need to be, and the more guarded is the prognosis.

1.6.2. Complex fracture-dislocations

Complex dislocations involve dislocations with one or more associated fractures. Treatment usually requires surgical reconstruction of bony and ligamentous stability. Recognition of the injury pattern is critical to diagnose and manage this injury.

1.7. Stability model and relevance for treatment

The conventional patterns of instability and fracture dislocation may fall under the following groups: Terrible triad,[20,21] Posterior radial head fracture dislocation, Monteggia fracture-dislocation[45] (Fig. 7a and b), Anteromedial coronoid fracture and *Trans*-olecranon fracture-dislocations.

These groups are useful for identifying the mechanism of injury and possible treatment plans of the individual pathologies, furthermore the concept is important to make valid assumptions regarding the stability status of the joint.

Recently the three-column model has been proposed by Watts *et al.* from Wrightington,[5] which differs from the previously discussed ring concept.[46] The model consists of a lateral, middle and medial column with the structures involved listed below:

Lateral Column: Radial head + Capitellum + LCLC

Middle Column: Anterolateral facet of coronoid process + lateral trochlea

Medial Column: Anteromedial facet + medial trochlea + MCLC

In this model varus and valgus stability is balanced around an axis between the medial and middle columns, with the lateral column being the primary resisting osseous structure against valgus stress. Varus forces are thought to be resisted primarily by the medial column.

As long as the lateral column is intact the middle column may be neglected in its contribution to valgus stability, however following disruption of the lateral column, the middle column (being a secondary valgus stabiliser) becomes important as a valgus restraint[47,48] (Fig. 8).

Fig. 7. 7a, 7b: Monteggia fracture-dislocation treated with open reduction and internal fixation.

1.8. Clinical assessments

1.8.1. Presentation

Clinical presentation of a dislocated elbow is usually unmistakable with pain, swelling, deformity and inability to flex or extend the elbow.[49] However, a subluxed or unstable elbow following injury may present with subtle symptoms. Patients will complain of pain, clicking of the joint and inability to move through a full range of motion. Specifically, the patient may experience locking on extension.[20]

Overall, it is vital to derive a full history of the injury to develop an understanding of the mechanism of injury and if possible, to visualise the position of the elbow, along with the forces involved in the scenario of the accident. Evaluation and recording of the neurovascular status, the condition of surrounding skin and the involvement of other joints (shoulder and wrist) are also important.[50]

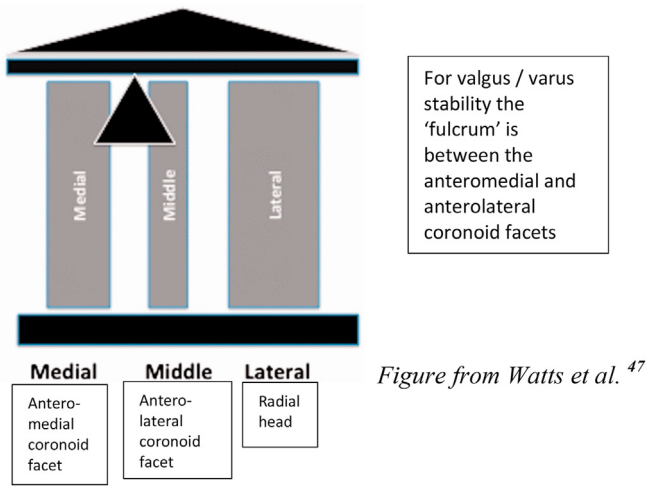


Fig. 8. Illustration of 'column theory' – from Watts et al.[47]

1.9. Clinical examination

In simple dislocations, loss of relationship of the normal bony landmarks will be evident.[5] Bruising on the medial or lateral side would indicate possible ligamentous injury.[12] Any associated neurovascular deficit and open injuries should be noted.

Posterolateral instability associated with a terrible triad injury might lead to a positive drawer sign and positive pivot test, this should only be assessed under general anaesthesia.

1.10. Imaging

Plain radiographs of the elbow in anteroposterior and lateral position, are usually diagnostic and would show any additional fractures (Fig. 10a and b). Post-manipulation radiographs are mandatory to demonstrate satisfactory relocation and full congruency of the joint.[5,21] The drop sign, if persistent, may alert to ongoing instability (Fig. 9).

As a simple guidance, a line drawn through the radial head and neck should always pass through the centre of the capitellum in a normally aligned elbow in any view seen on x-ray.[20] Suspected injury anywhere else in the ipsilateral upper limb (10–20%)[21] should be excluded by appropriate radiographs.

CT scan, especially 3D views (Fig. 10), is extremely helpful to evaluate any associated fracture.[51]

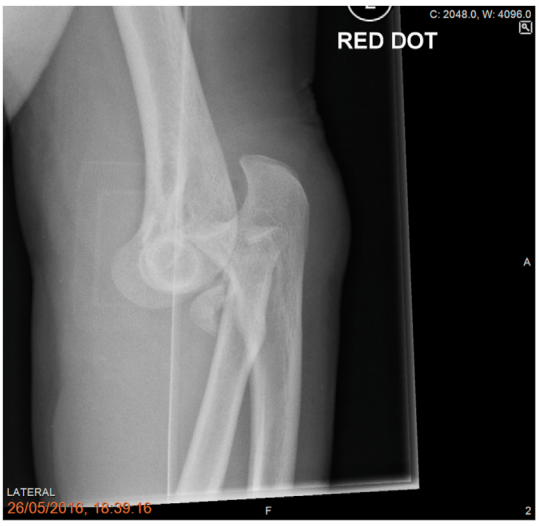
In an acute setting an MRI[23] scan may be of limited use, unless required for further evaluation of a 'simple dislocation' with persistent instability (Fig. 11). In the case of longstanding symptoms an MRI may be invaluable to understand the structural status of the tendons and ligaments.[12] To further investigate the soft tissue structures, ultrasound imaging can provide a dynamic examination of these structures but is of limited role in the acute setting.[52]

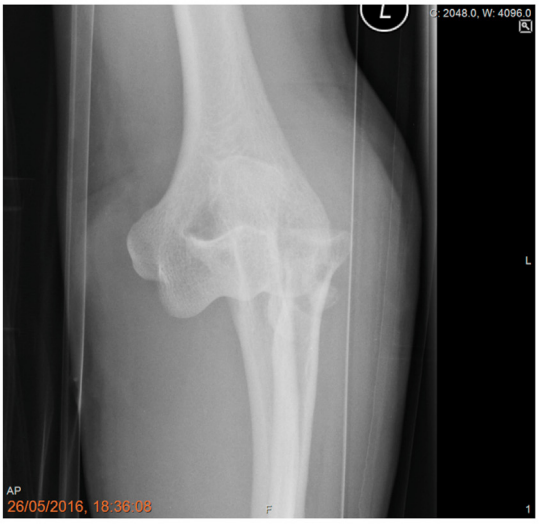
1.11. Treatment

1.11.1. Non-surgical

Reduction of the dislocated elbow is usually performed with pain relief and under conscious sedation. Manipulation involves inline traction with leverage of the olecranon over the distal humerus. Stability is checked by supervised active range of motion by the patient. A posterior splint in 90° of flexion in a neutral position, or if unstable in protonation, for one to two weeks, will help the tissues to settle before commencing range of movement exercises.

Fig. 9. The 'drop sign' after closed reduction indicating instability.[66]





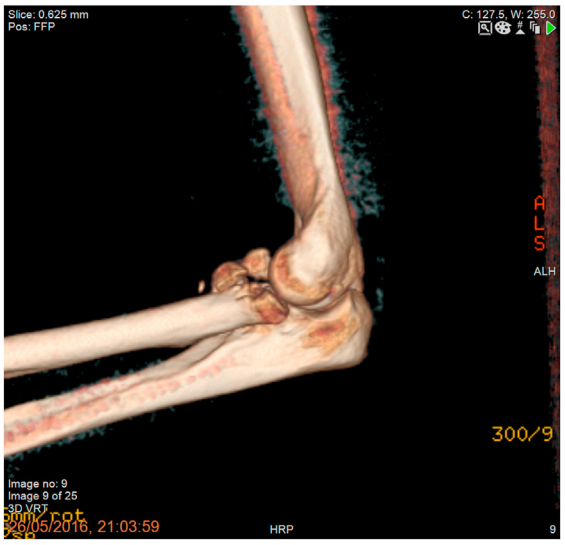


Fig. 10. 10a, 10b, 10c: Radiographic assessment (10a, b) of terrible triad injury followed by CT (10c).

Fig. 11. MRI following postero-lateral elbow dislocation with disruption of the LCLC.

Should there be an unstable dislocation which cannot be held reduced concentrically, further assessment and surgical intervention must be considered.

A nonoperative approach would be appropriate in following circumstances.[20,53]:

- Small radial head fracture with no rotation block (pronation and supination being 60° block free), minimal radial fracture fragment displacement
- Stable after reduction; on ROM from 45° flexion and beyond
- Joint congruency
- Small coronoid fracture that is reduced
- Small fractures but no intra-articular fragments

The failure to recognise subtle instability may lead to persistent pain, stiffness and post-traumatic arthritis.[53] Undisplaced or minimally displaced (<5 mm) fractures of the anteromedial facet (AMF) of the coronoid can be treated nonoperatively, provided the joint is concentric and stable to at least 30° of extension.[51] In these patients, initial weekly radiograph is mandatory to exclude any re-displacement of joint or fracture fragments.

1.11.2. Surgical treatment

Surgical repair is required for the majority of terrible triad injuries[15]: the radial head by open reduction and internal fixation (ORIF) (Fig. 12) or replacement if irreparable (Fig. 13), the LCLC by reattaching to the lateral epicondyle by anchors or bony tunnel and secure fixation of the coronoid fracture by any of several different techniques. If there is stability throughout the range of motion after lateral (radial head and LCLC) column repair, ORIF may not be required for Regan-Morrey 1 and 2 coronoid fractures.[54] The MCLC may need repair if there is persisting instability shown by a posterior sag test after lateral column and capsule/coronoid repair.

The surgical approach would depend on the type of proposed procedure. The single universal posterior approach allows lateral and medial access, for fixation or replacement of the radial head as well as repair of the coronoid process.[55] Separate approaches might carry less risk regarding haematoma formation and potential healing problems of the long posterior skin flaps[15] but there is an increased chance of cutaneous nerve injury.

A trans-olecranon fracture dislocation will require surgical fixation of the olecranon by either tension-band wiring (for simple, non-comminuted transverse or short oblique fractures) or contoured plate (for comminuted or unstable fractures)[51,56](Fig. 14).

Anteromedial facet (AMF) fractures would normally require internal fixation (cannulated screws, tension band or buttress plate)[57] as chronic instability, if developed, may be a difficult problem to treat.

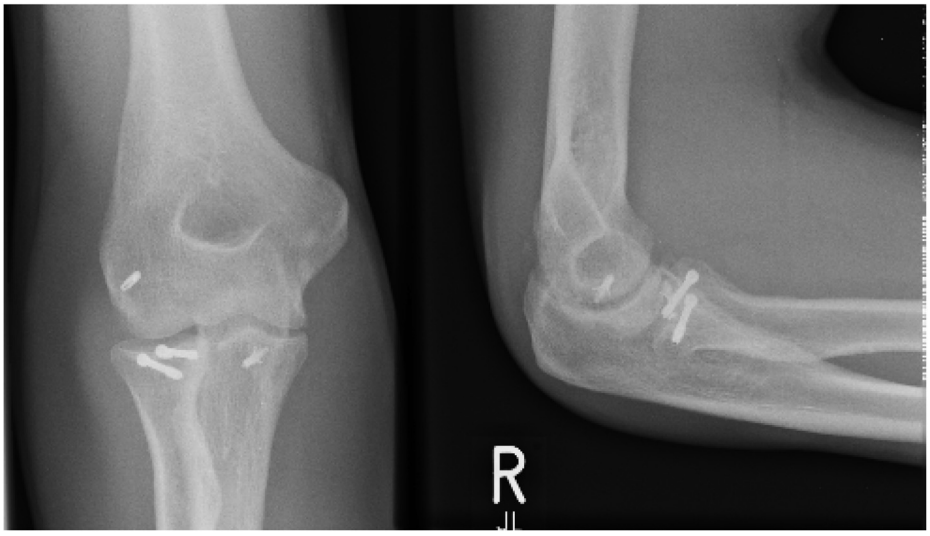


Fig. 12. Open reduction and internal fixation of radial head fracture.

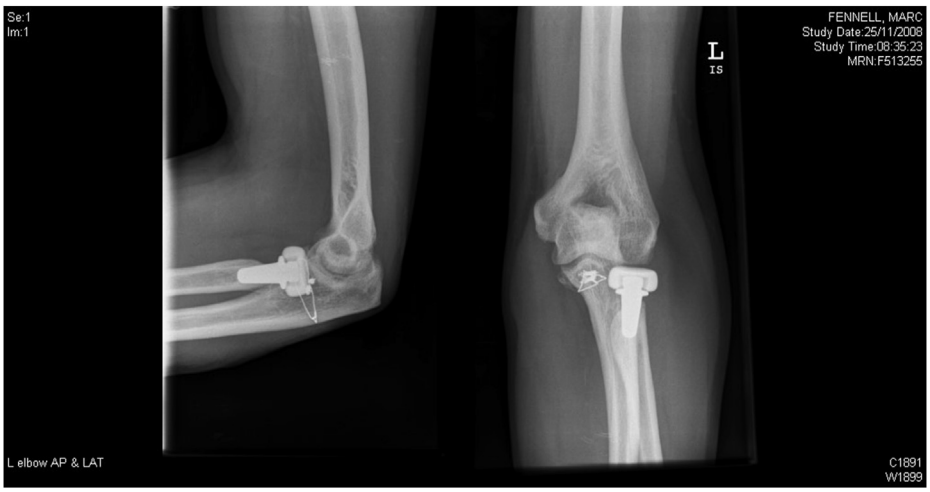


Fig. 13. Prosthetic replacement of radial head after fracture.

Fig. 14. *Trans*-olecranon fracture dislocation of elbow requiring plate fixation.

Fluoroscopic examination of the elbow should be performed throughout the procedure for the assessment of fixation and residual instability.[35]

1.11.2.1. Post-surgical care. A removable posterior splint may be applied for comfort and soft tissue healing. Active/active assisted mobilisation of the elbow should be started as soon as possible (within 24–48 h) after stable reconstruction of the elbow.[58] In patients where static fixators are used, these should ideally be removed after three weeks to avoid joint stiffness. Any hinged fixator should be limited to 30° of extension for four weeks followed by a hinged brace for another four weeks if needed.[15] At the end of six-to-eight weeks the elbow brace should be removed, and unrestricted range of motion is advised.[59]

1.12. Complications

The more complex the injury, the higher will be the likelihood of complications. There is a significant (22%–40%) reoperation rate as a result of injury and post-surgery complications[60–62]in these injuries.

The following are the most common complications[15]:

- ***Re-dislocation:*** as a result of soft tissue injury which give rise to this instability.
- ***Post-traumatic stiffness:*** very common, in particular when early therapy/range of movement exercises are delayed.
- ***Failure of internal fixation*****:** a common complication when radial neck fixation is performed, with poor vascularity leading to non-union and osteonecrosis.
- ***Malalignment:*** e.g., of the anteromedial coronoid process leading to varus subluxation and instability.[63]
- ***Post-traumatic arthritis*****:** as a result of cartilage damage and shearing forces due to persistent instability of the joint
- ***Heterotopic ossification:*** common with delay to the initial surgery e.g., in the multiple injured patient, elbow injuries in association with burns, head injury, poor soft tissue handling during surgery.[64]
- ***Neurovascular compromise:*** especially ulna nerve neuropathy in particular with malalignment or valgus instability.

- **Infection** following prolonged surgery or open injuries.[62]

2. Conclusion

The elbow is normally an inherently stable joint and stability is maintained by the configuration of bone joint congruency and ligamentous support. Dislocations usually follow one of the two main injury patterns: rotatory posterolateral (most common) or posteromedial. The description of instability as a progressive sequence following a predictable pattern has helped to understand traumatic elbow dislocations better. The recent addition of the three-column concept has further added to the understanding and treatment rationale, in particular the role of the middle column after disruption of the lateral column.

A simple dislocation is normally managed by manipulation and reduction (98% of cases). A complex fracture dislocation, in majority of cases, requires surgical fixation of fractures and soft tissues including ligaments and capsule.

The patient should be given a guarded prognosis as return to full function depends on obtaining a stable joint and early mobilisation. Complications such as post-operative stiffness, heterotopic ossification, peripheral neurological impairment and post-traumatic arthritis are not uncommon. The aim of any treatment is to restore stability to allow early mobilisation and a safe rehabilitation program.

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