MINI-SYMPOSIUM: ADULT ELBOW PROBLEMS

(iii) Elbow instability, mechanism and management*

Simon Bell*

Melbourne Shoulder and Elbow Centre, Monash University, 31 Normanby Street, Brighton, Victoria 3186, Australia

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Summary
Acute dislocations of the elbow without significant fracture are classified as simple. In all cases the medial and lateral ligaments are avulsed, usually as an osteo-periosteal sleeve. The majority are stable on reduction and immediate active mobilisation is encouraged. The incidence of recurrent dislocation and instability is very low. Acute dislocations associated with significant fractures are classified as complex. The most common associated fractures are of the radial head or coronoid process, and if both fractures are present this is termed the “terrible triad”. The principle of management is reduction of the joint, anatomical fixation of the fracture fragments, with repair or reconstruction of ligaments if indicated. If the elbow remains unstable, or if fracture or fixation or ligament repair is tenuous, then the use of a hinged external fixator is recommended.

The most common type of chronic instability is postero-lateral rotatory instability, which is related primarily to incompetence of the lateral ulnar collateral ligament. Conservative treatment is rarely successful and most require a reconstruction of the lateral ulnar collateral ligament with a graft. Medial instability is predominantly seen in throwing athletes with chronic stretch of the medial ligament that interferes with throwing capacity. If conservative management fails then the anterior bundle of the medial collateral ligament can be reconstructed with a tendon graft.

Introduction
Following the shoulder, the elbow is the most commonly dislocated joint in the body, and in children less than ten years old it is the most frequently dislocated articulation.1,2

Chronic instability may occur as a result of a single event, such as a fall on an outstretched hand, or repetitive stress resulting in laxity.3 This article will concentrate predominantly on instability in the adolescent and adult population.

Anatomy and stability of the elbow
Elbow stability is related to the inherent bony stability of the very congruent articular surfaces, and to the surrounding soft tissue stabilizers. These include the static soft tissue stabilizers, consisting of anterior and posterior capsule, both medial and lateral collateral ligaments, and the muscles crossing the elbow joint, which provide dynamic
stability, compressing the irregular but congruous joint surfaces against each other.

**Bony articulation**

The ulno-trochlear articulation is a hinge joint. The spool-shaped trochlea of the distal humerus is covered by articular cartilage over an arc of 300 degrees and has a highly conforming articulation with the greater sigmoid notch of the ulna, which is augmented by the prominence of the coronoid and olecranon processes. This configuration is the main factor responsible for the inherent bony stability of the elbow. The locus of rotation of the ulno-trochlear articulation is 2–3 mm in diameter, such that in practical terms the elbow is a uniaxial hinge joint with a fixed centre of rotation. The axis of rotation can be defined as passing through the centre of the arcs formed by the trochlear sulcus and the capitellum. This is important with regard to the application of a hinged external fixator.

The coronoid process anteriorly provides a bony buttress to resist the posteriorly directed forces that are generated by the flexor and extensor musculature during lifting. It has been demonstrated that at least 50% of the coronoid process must be present for the ulno-humeral joint to be functional. If the radial head has been excised then as little as 25% coronoid process resection can produce elbow instability. This is obviously important in the so called 'terrible triad' when a coronoid fracture and a radial head fracture are associated with a dislocation. The olecranon process posteriorly also contributes significantly to stability of the elbow. Overall, valgus stress is primarily resisted by the olecranon portion of the greater sigmoid notch, whereas varus stress is resisted primarily by the coronoid portion of the articulation.

The radio-capitellar and proximal radio-ulnar articulations allow forearm rotation and a gliding articulation during flexion and extension. The capitellum is spherical in shape and is separated from the trochlea by a groove in which the rim of the radial head articulates. The head is secured to the ulna by the annular ligament. The radial head is a secondary stabilizer to valgus stress. It is only of minor importance if the medial collateral ligament is intact, but it becomes a major contributor to valgus stability if the medial ligament is damaged.

**Soft tissue stabilizers**

The primary soft tissue stabilizers of the elbow are the medial collateral (MCL) and lateral collateral (LCL) ligaments.

**Medial structures**

The MCL is divided into anterior oblique (AOL), posterior oblique (POL), and the transverse ligament (Cooper’s ligament). (Fig. 1). The transverse ligament has no contribution to elbow stability.

Both the AOL and the POL originate on the central 65% of the anterior inferior surface of the medial epicondyle. The AOL lies under the flexor carpi ulnaris and is composed, of thick parallel fibers with a mean width of 4–5 mm. The AOL comprises 2 bands, named anterior and posterior. The anterior band is taut for the first 60 degrees of flexion and the posterior from 60–120 degrees of flexion.

Figure 1 Medial view of the elbow demonstrating the ligaments (from fracture article).

With valgus force the AOL is the primary stabilizer of the elbow and the radial head is an important secondary stabilizer. Experimentally, if the radial head is removed and the ligaments are left intact, there is little change in stability, even with additional release of the POL. However, additional release of the AOL produces gross laxity.

The medial forearm muscles can resist valgus force irrespective of forearm rotation positioning. In the setting of acute medial ligament insufficiency the recommended position of immobilization is with the forearm in pronation.

**Lateral structures**

The LCL is composed of four collateral ligaments. These are the lateral radial collateral ligament (LRCL), the annular ligament (AL), and lateral ulnar collateral ligament (LUCL) and the variably present accessory lateral collateral ligament (ALCL) (Fig. 2). The LUCL originates from the lateral epicondyle and inserts into the supinator crest of the ulna.
and is posterior to the LRCL. The conjoint insertion of the LRCL and UCL measures 2 cms in width. Seki et al describes the lateral ligament as Y shaped, with an anterior and a posterior band, which both contribute to lateral elbow stability. Cohen described two types of conjointed lateral ligament and annular ligamentous insertions. In one a single conjointed ulnar attachment is present, in the other the AL and UCL have separate ulnar attachments. It has been stated that the UCL is the essential structure to resisting posterolateral instability, however experimentally isolated division of the humeral attachment of either the LUCL, or the LRCL does not result in instability. Division of both is necessary to produce instability. This is reflected in the need to repair and reconstruct both portions of the LCL with posterolateral reconstruction for instability.

Forearm muscles
Muscle activity is an important posterolateral stabilizer of the elbow as it compresses the highly congruous joint. It has been demonstrated that the elbow with LCL deficiency is more stable in passive pronation. This is an important consideration when managing acute lateral ligament injuries.

Anterior capsule
In a hyperextension injury the anterior capsule is torn first, then injury to the flexor pronator muscles occurs, followed by the anterior portion of the MCL complex, and occasionally the LCL. It has been noted that if there is a fracture of the coronoid process, the anterior capsule remains intact but there is a rent in the medial collateral ligament complex at the line of the coronoid process fracture. If there is not a fracture of the coronoid process there is a rent in the anterior capsule and the entire medial collateral ligament complex is avulsed from the medial epicondyle. Therefore reduction and fixation of a coronoid fracture not only recreates a bony buttress, but also reconstructs the anterior capsule.

Acute elbow dislocations
In a Swedish study of 178 acute elbow dislocations, Josefsson and Nilsson demonstrated a peak incidence in the 10–20 year old age group with approximately 10 dislocations per 100 000, and in the 50–60 year old age group an incidence of 4 per 100 000. The most commonly associated fracture affected the medial epicondyle (22), then radial head (17), lateral epicondyle (5), coronoid process (6), capitellum (4) and olecranon process (2). Three quarters of elbow dislocations in patients under 30 occur during sporting activities.

Classification
Elbow dislocations are classified by their direction, whether there are associated, fractures, and the timing (acute, chronic or recurrent).

Presence of associated fracture
If elbow dislocation occurs without fracture it is referred to as 'simple dislocation'. Often in this situation, however, minor avulsion fractures of several millimeters from the medial and lateral epicondyle regions, or of the coronoid tip, occur, which are of little significance and do not alter management. When acute dislocations are associated with significant fractures they are classified as 'complex dislocations'.

Direction of dislocation
Dislocations are also classified by the directional displacement of the radius and ulna in relation to the distal humerus. The most common is a posterior dislocation, with the subgroups of posterolateral or posteromedial. This article mainly discusses this type of dislocation, and it is generally agreed that the pathology of these three different directions of posterior dislocation is not different, nor is the management of the dislocation. Dislocations involving disruption of the proximal radio-ulnar joint are classified as divergent. They are rare and only reported as case reports. Anterior dislocation in the adult usually results in olecranon fracture or triceps disruption, which often requires surgical correction.

Simple dislocation
Pathomechanics of a simple posterior dislocation
For simple posterior dislocations the mechanism of injury can be thought of as a circle of soft tissue disruption starting from the lateral side and progressing to the medial side in 3 stages. Stage 1 is characterized by complete disruption of the lateral ulnar collateral ligament complex with partial or complete disruption of the remaining lateral collateral ligament complex. The result is posterolateral rotatory subluxation of the elbow that can spontaneously reduce. Stage 2 includes further disruption resulting in an incomplete elbow dislocation posterolaterally with X-rays demonstrating the coronoid process perched on the humeral trochlea. This can be reduced with minimal force. Stage 3 is subdivided into two components. Stage 3A describes disruption of all the soft tissues around and including the posterior part of the medial collateral ligament except for the anterior bundle. This bundle forms the pivot around which the elbow dislocates posteriorly by way of a posterolateral rotatory mechanism. Stage 3B features complete disruption of the medial collateral ligamentous complex of the elbow.

In practice, in most cases of acute elbow dislocation, the entire medial and lateral ligaments are disrupted, usually as a still-intact osteoperiosteal sleeve, often with a small avulsion fracture from the epicondyle (Fig. 3). Josefsson et al reported on adult patients who had a posterior dislocation of their elbow without any significant fracture. After reduction all had an operation on the collateral ligaments through medial and lateral incisions. On examination under anaesthesia obvious valgus instability was present in all cases, however only a few had varus instability. On the medial side the muscular origins of the flexor muscles were often partially or totally torn. The medial collateral ligament was totally ruptured or avulsed from the epicondyle in all cases. Of the explored lateral collateral ligaments, all were completely ruptured or avulsed at the epicondyle. In all cases there was extensive damage to the anterior capsule and the brachialis muscle. It was therefore concluded
that complete dislocation of the elbow is always associated with complete rupture of both collateral ligaments and the anterior capsule. In another study Josefsson et al prospectively compared operative, and non-operative management of patients who had acute dislocation of the elbow. Recovery was quicker in the conservative group and at final follow up there was no difference between the two groups, suggesting that in most cases surgical intervention is not necessary following a simple acute dislocation.

Management of the acute simple posterior elbow dislocation

The patient with an acute posterior (including lateral or medial) dislocation is usually in moderate but not severe pain and the deformity is obvious. The neurological function and vascular status are carefully assessed and if abnormal this takes a priority in management, particularly if there is severe vascular injury. The distal radioulnar joint and interosseous membrane should be examined for tenderness. In most situations, such as in an emergency department, x-rays are mandatory prior to any attempt at reduction, as clinically it is difficult to distinguish between fractures and dislocation. Only in the rare circumstances, where there would be considerable delay in obtaining an x-ray, would reduction be carried out without an x-ray, such as in a football game some distance from any treatment facility.

Closed reduction is usually carried out under intravenous analgesia and sedation. If there is no neurological problem then the joint can also be infiltrated with local anaesthetic. With the elbow flexed at approximately 25 degrees longitudinal traction is applied to the forearm with an assistant applying counter-traction to the upper arm. Some additional supination of the forearm is often helpful and reduction is usually obvious, with the feeling of a clunk from the joint. In these cases the elbow is usually fairly stable following the reduction. If there is no sensation of sudden reduction the elbow may be potentially unstable. Ideally, following reduction, the elbow should then be assessed under fluoroscopy, at which time the joint is put through a range of motion. It is particularly important to assess if there is instability in extension, and at what degree this occurs, as this will influence further management. Instability with gentle varus, valgus and rotatory stress should also be assessed. However, as there is always complete disruption of the medial and lateral ligaments some instability will always be demonstrated. There should in general be an end point feel to the varus/valgus stress. If this is not present and there is a wide opening of the joint with varus/valgus stress under fluoroscopy, this indicates a possible disruption of the avulsed osteoperiosteal sleeve which may influence further management, with consideration of surgical repair. If there is a tendency for the elbow to sublux with extension then this is reassessed with the forearm in pronation. If the stability satisfactorily improves then a hinge-brace holding the forearm in pronation, and with an extension block at the appropriate degree is indicated. If more than 45 degrees of elbow flexion with the forearm in pronation is required to maintain reduction of the elbow, then this is an indication for surgical repair of the ligaments or the application of an external fixator.15,18

Following an acute posterior dislocation there is a significant incidence of later medial instability symptoms (Josefsson, Johnell et al. 1984; Melhoff, Noble et al. 1988; Eygendaal, Verdegaal et al. 2000). Therefore in a young active sportsperson, particularly a throwing athlete, if significant medial instability with stress is demonstrated with image intensification (Fig. 4), consideration should be given to either repair of the medial ligament, or support of the medial ligament with a hinged brace.

If the elbow is quite stable through a full range of motion following reduction the arm should be rested in a sling, and immediate active mobilization exercises commenced. Immobilization increases the chances of residual pain and stiffness, and the risk of further instability in this group is minimal. Melhoff et al demonstrated that, following reduction of an acute dislocation, immobilisation for more than 2 weeks prevented any chance for an excellent result, while immobilization for 4 weeks always yielded a fair or poor result19 (Table 1).

Complex elbow dislocation

Complex elbow instability consists of a dislocation of the ulno-humeral joint with a significant fracture of one, or several, of the bony stabilizers of the elbow. These include...
the radial head, proximal ulna, coronoid process or distal humerus. Following this type of dislocation there is frequently a tendency to chronic instability, and an increased incidence of post-traumatic arthrosis. The article on elbow fractures in this mini-symposium will discuss the management of olecranon and distal humerus fractures in more detail.

**Management of complex elbow dislocations**

It is most important to have optimal initial primary management with this type of problem, as it is very difficult to treat chronic problems resulting from primary mismanagement of complex instabilities. The overall goal is to gain a concentric and stable reduction of the elbow that permits a functional range of motion. The spectrum of injury in this group is large, from the low velocity single bone fracture, to high velocity trauma involving fractures of all osseous structures. In all cases the first priority is to restore bony anatomy as anatomically as possible, in particular with reconstruction of the articular surfaces. If it is not possible to reconstruct the radial head, then prosthetic replacement is usually indicated. Following this the joint is congruently reduced. Ligamentous stability then needs to be restored. This may involve a repair of torn ligaments, or if adequate stability cannot be maintained with this, then primary reconstruction of the ligaments is necessary. It is important to regularly check radiologically the maintenance of the concentric reduction of the joint and anatomical alignment of bony fragments, as fracture fragment displacement and/or subluxation of the joint can occur even with the elbow in a cast. If, following the initial surgery, there is continued instability or doubt as to the strength of bony or soft tissue fixation, then a hinged external fixator can be utilized. Post-operatively it may be necessary to make the restoration of motion a secondary priority, with the first priority being maintenance of anatomical reduction of the joint surfaces with continued joint stability. If bony anatomy is anatomical, and stability is maintained, then a later stiff elbow can be mobilized fairly simply with appropriate capsular releases. However if there is poor anatomical reconstruction of the bony anatomy, or if congruent reduction of the joint is not maintained, then later reconstruction can be very difficult or impossible.
Dislocation with radial head fracture

One of the most common complex acute instability problems is the radial head fracture associated with dislocation of the elbow. The management in this situation depends on a number of factors, including whether the radial head is reconstructable or requires prosthetic replacement, the degree of damage to the medial collateral ligament, and whether a potential Essex-Lopresti lesion is present. The classification and specific management of these fractures is dealt with in detail in the fracture article in this mini-symposium.

Following reduction of the elbow, stability of the medial ligament should be assessed with stress under fluoroscopy. If the radial head is stable longitudinally, with just a small marginal fracture, then the fracture fragment should be reduced and fixed, or excised. Providing the elbow is stable through a good range of motion, it can then be then treated as a simple dislocation. If there is major fracture of the radial head, resulting in potential longitudinal instability, such as with an associated surgical neck fracture, then this needs to be internally fixed or replaced with a prosthesis. If associated significant medial ligament laxity is present, then the medial ligament should be repaired.

For operations involving the radial head or lateral ligament a lateral incision can be utilized if the surgeon is confident that no surgery on the medial side is necessary. If there is any doubt, then the elbow should be approached through the universal longitudinal posterior incision. The most commonly described approach in this situation is the extended Kocher, with development of the interval between the extensor carpi ulnaris and anconeous. It is often easier to internally fix the radial head fracture through a Kaplan type approach between the extensor digitorum communis and extensor carpiradialis longus (Fig. 5) with division of the annular ligament anterior to the common extensors. In a traumatic situation, where a repair of the lateral ulnar collateral ligament is required, together with fixation of a radial head fragment, then a combination of the Kocher and a Kaplan approach is extremely useful (Fig. 5) which is similar to the lateral column approach. This is preferred to the extended Kocher approach as it avoids elevation of the common extensor origin from the underlying capsule and lateral collateral ligament complex at the lateral humeral epicondyle. It is also a useful approach if reattachment of the lateral ligament is necessary, as it preserves the common extensor tissues over the lateral ligament.

Dislocation with coronoid process fracture

Another commonly seen complex dislocation of the elbow is associated coronoid process fracture and the classification of these injuries is described in this mini-symposium. The decision to internally fix the fracture is mainly related to the potential instability of the joint. Morrey has described a line from the tip of the olecranon, parallel to the long axis of the ulna, that corresponds to a type II fracture (Regan and Morrey classification) with involvement of 50% of the coronoid. It is generally felt that if more than 50% of the process is fractured then it should be reduced and fixed (Figs. 6 and 7). The potential instability, however, in this situation, is related not only to the size of the fracture fragment but also to the extent of soft tissue, especially anterior capsule, damage. If there is a moderately large fragment present, but the elbow is quite stable through a full range of movement even with stress fluoroscopy, the fragment may not require fixation. If there is marked instability with extension with a relatively small fragment,
then the fragment should be fixed, and the capsular damage in the region repaired. Fixation of a coronoid process fracture is best carried out through a longitudinal posterior incision, with a medial approach. The posterior medial muscles of the proximal ulna are released subperiosteally from the ulna and are retracted anteriorly\textsuperscript{25} (Fig. 8). The flexor carpi ulnaris fascia is left attached to the subcutaneous border of the ulna for later repair, following which the flexor digitorum profundus is mobilized subperiosteally from the ulna, together with the ulnar nerve, to expose the coronoid process. The approach is fairly extensile and gives adequate exposure for plate fixation of the coronoid process (Fig. 9). The type of fixation depends on the size of the fragment. Smaller fragments do not require anatomical repair as this procedure is really a reattachment of the avulsed soft tissues back to the ulna. Sutures are woven around the soft tissues attached to the fragment. These are passed through drill holes through the ulna and then tied in the posterior ulnar region. Large fragments require anatomical reduction with plate fixation, and contoured plates designed for this are now available. An alternative surgical approach, as described by Hotchkiss, is to open the plane between flexor carpi ulnaris and palmaris longus (Fig. 10).\textsuperscript{26} This is described in the section on the chronically dislocated elbow.

**Dislocation with the terrible triad**

The combination of dislocation with the two fractures described above, radial head and coronoid process, is...
termed the "terrible triad", and is best assessed radiologically with CT scan 3D reconstructions (Fig. 11) In this situation the elbow is usually quite unstable and always requires internal fixation of the fractures. The recommendation in most cases is internal fixation or prosthetic replacement of the radial head fracture, and fixation of the coronoid fracture, even if relatively small (Fig. 12). This can all be carried out through a posterior (universal) incision with a combination of the techniques for radial head fixation and coronoid process fixation described above. At the time of exposure of the fractures the ligament disruption should be repaired. This gives the best chance of a stable elbow and early mobilization. If the coronoid process fracture is large and comminuted and there are concerns about the stability of the coronoid fixation, then an external hinge fixator should be considered. 

Dislocations involving fractures of the humerus, olecranon/ulnar shaft region are usually associated with high speed trauma. They are often extremely complex problems to manage, with multiple variations in the treatment options available. The operative management plan is anatomical reduction of the fractures, followed up by ligamentous repair as indicated, with additional support from a hinged external fixator if indicated. The priority is for anatomical bony reconstruction and maintenance of stability, rather than trying to achieve an immediate good range of motion (Fig. 12).

**Posterolateral rotatory instability**

In 1991 O’Driscoll introduced the term posterior lateral rotatory instability (PLRI) of the elbow to describe instability caused by injury predominately to the lateral ulnar collateral ligament (LUCL). This is the most common
form of recurrent post-traumatic instability of the elbow. PLRI is not a new problem, and a few studies and case reports prior to O’Driscoll describe this condition under the guise of recurrent dislocation of the elbow and radial head. In patients with PLRI the proximal radioulnar joint must remain intact, and due to inadequacy of the lateral ligament complex, the radial head subluxes or dislocates posteriorly. This tends to occur with the forearm supinated, which stresses the posterolateral structures, and slightly flexed, which releases the olecranon tip from the olecranon fossa allowing rotation of the ulno-humeral joint.

A valgus stress applied to the elbow causes rotation of the ulno-humeral joint, compression of the radio-capitellar joint, and posterior subluxation of the radial head. The entire lateral ligament, as well as the lateral musculature, play significant roles. Injury to the LUCL alone is not sufficient to cause instability and both the LUCL and the LRCL need to be divided before PLRI occurs.12

Most patients describe a history of trauma, and a full elbow dislocation is the inciting event in 75% of patients younger than 20 years of age. Varus extension stress without true dislocation is more likely the initiating event in older patients.29 Some patients with lateral epicondylitis may also develop iatrogenic PLRI following an over-aggressive lateral epicondyle release, with division of a portion of the lateral ligament, and it has also been reported following radial head excision.30 The symptoms vary from obvious instability, through recurrent subluxation, to subtle reports of pain and discomfort. Occasionally patients will report clicking, popping, snapping or locking. True dislocations tend to be rare. Patients tend to report the elbow slipping in and out of joint, particularly when the arm is supinated and slightly flexed. Differential diagnosis includes lateral epicondylitis, radial tunnel syndrome, valgus instability, and pure proximal radial head dislocation.

Physical diagnosis

Valgus instability is tested with the forearm in supination and pronation, with supination stressing the posterolateral structures, and at times producing palpable subluxation of the radial head. Provocative tests include the lateral pivot shift test (Fig. 13) which is not easy to perform on a patient who is awake, and therefore feelings of pain or apprehension can be considered a positive result. Other provocative manoeuvres that simulate the pivot shift test include an inability to perform a wall push-up if the arm is internally rotated, and difficulty pushing up from a seated position with the hands in neutral rotation.31 The ‘tabletop relocation test’ is similar, with the patient’s hand over the lateral edge of a table, a press manoeuvre is then carried out, which causes pain at 40 degrees of elbow flexion.32 Many patients can demonstrate the instability, for example by placing their hand on their thigh and moving the elbow back and forwards to produce the subluxation.

Imaging

X-rays are often normal. Occasionally a bony avulsion can be seen from the lateral epicondyle, or a small defect in the postero-inferior region of the capitellum. In long standing cases degenerative changes may be present. MRI plays a limited role in diagnosis though an experienced radiographer with special sequencing can demonstrate damage to the posterolateral ligamentous structures.

Arthroscopy

Diagnostic arthroscopy can be useful in patients with an uncertain diagnosis, particularly where pain is present, which may indicate underlying chondral damage. The pivot shift can be performed while viewing from the anterior medial portal, or the inferior portal, using a 2.9 mm. arthroscope, and the posterior radial head subluxation can be viewed. There is also a positive elbow drive through sign.31

Treatment

If, following an acute injury, there is suspicion of injury to the lateral ligament complex the elbow should be stabilized with the arm in pronation and a hinged brace for 4–6 weeks to promote healing and prevent instability. It is worthwhile performing an x-ray of the elbow, particularly a lateral view with the arm in the splint, one week following the dislocation. If there is widening of the humero-ulnar space (the drop sign described by Coonrad)33 then consideration should be given to immediate repair/reconstruction of the lateral ligament complex. For chronic instability surgery is the only real option.

Surgical reconstruction

There are many open techniques described to repair and reconstruct the lateral ligament complex, in particular the
lateral ulnar collateral component. The elbow is approached through a modified Kocher’s approach exposing the entire lateral ligament complex from the lateral epicondyle to the supinator crest. The laxity is confirmed; with supination the radial head subluxes inferiorly with obvious laxity of the lateral structures. In the acute situation, if the ligament is avulsed from either end, which occurs most commonly from the humeral end, this can be repaired by reattaching the ligament to the bone. In the chronic situation where loose capsule and ligaments are present, the anterior capsule, posterior capsule, and residual LUCL are plicated. Reconstruction of the LUCL is then needed, which requires a tendon graft. In most reports palmaris brevis is utilized, though the author prefers the gracilis tendon, harvested from the ipsilateral leg, as it is of better length and thickness. Good fixation can be obtained, and the extra length can be used to reinforce the lateral ligament if this is felt necessary. Described techniques of graft fixation include passing the tendon through bony tunnels with an interconnecting bridge of bone, a single drill hole and an interference fit screw, or the use of fixation anchors.

In the author’s present technique two drill holes are made at the supinator crest, which are joined together. A suture is passed through the tunnel and, during elbow flexion and extension, the isometric point over the lateral epicondyle is determined, which is always more anterior and superior than would be expected. A drill hole, sized to match the graft, is then placed from the humeral isometric point through the lateral epicondyle into the olecranon fossa. The gracilis tendon is passed through the ulnar tunnel and the two limbs are then sutured together leaving long suture tails which pull the graft into the tunnel. A 5.5 mm interference absorbable screw in the humeral tunnel fixes the graft (Fig. 14) It is quite common for the lateral ligament to be so stretched that the LUCL graft alone does not adequately stabilize the joint. Plication of the lateral ligament is then necessary, which can be reinforced by suturing the residual tail of the gracilis graft, already fixed in the humeral tunnel, to the annular ligament. Yadao has described an alternate technique with the graft passing initially through the humerus and stabilized using the docking technique. The two limbs of the graft are then retrieved through a tunnel in the ulna and fixed with an interference screw. The elbow needs to be immobilized for a splint with the elbow flexed 70 to 90 degrees with the arm in full pronation. After two weeks limited flexion from 45–90 degrees is initiated with the elbow protected in a hinged elbow brace with the forearm in pronation. Full range of motion of the brace is allowed at three weeks. A full painless range of movement should be achieved by six weeks. At 10–12 weeks the brace can be removed. The results of this type of procedure have been fairly satisfactory, however there is a reported up to 20% incidence of continued instability, and also up to 20% have ongoing pain. A mild flexion contracture is considered acceptable, as it protects against instability.

**Medial instability**

**Acute traumatic rupture of the medial ligament**

This can occur following a severe valgus stress, as might occur in rugby or Australian rules football. In this situation the instability is clinically obvious with stress testing. There is usually severe bruising. The management depends on the status of the muscles of the flexor pronator origin. If the muscle is intact then the torn ligament can be treated conservatively with a slab or cast for 2 weeks, followed up with a hinged brace for 6 weeks. If the flexor pronator muscles are ruptured this is usually clinically obvious with a palpable defect, but can be confirmed if necessary with an ultrasound examination. In this situation, with no muscle support for the torn ligament, operative management is indicated. The elbow is approached through a medial incision. Usually no dissection is required as there is a large defect deep to the skin extending through the muscle belly to the joint.

The ligament can usually be easily repaired if avulsed from the bone, either with sutures through drill holes, or with anchors. In substance ligament tears are more difficult to repair, and if this cannot be satisfactorily achieved, then reconstruction with a graft, as with chronic instability, is required. The flexor pronator muscles are then sutured. The reconstruction needs to be protected for 3 months, initially in a splint, and then in a hinged brace.

**Acute rupture of the medial ligament when throwing**

This was originally described in javelin throwers, and the instability is usually not gross. There is often an associated pop, with later pain and swelling over the medial aspect of the elbow. In most cases only the anterior bundle of the ligament is ruptured, and the flexor pronator group is intact. An MRI is useful in demonstrating the extent of the ligament damage. If there is uncertainty as to the extent of the instability then examination under GA is necessary, with fluoroscopically assisted valgus stress testing (Fig. 4). If there is no instability, indicating a partial thickness tear, non-surgical treatment is indicated, often with the use of a hinged brace. If significant instability is shown, then in a throwing athlete repair of the ligament is
indicated, as even minor later instability interferes with throwing ability and predisposes to stretching of the ligament. The approach for this is as for reconstruction in chronic cases, with splitting of the flexor-pronator group.

**Chronic medial instability**

Medial elbow symptoms related to recurrent medial instability are usually associated with chronic overuse from athletic activities that involve throwing, rather than following an acute tear. Throwing applies significant valgus stress to the elbow, resulting in repetitive micro-trauma to the MCL, and ultimately attenuation of the ligament. In patients with recurrent chronic medial elbow instability there is pain and tenderness over the medial aspect of the elbow, which is aggravated by throwing. Ulnar nerve symptoms may occur, there are often posterior impingement features on extension, and there can be concomitant medial epicondylitis. On examination, in these cases, there is usually tenderness over ulnar collateral ligament complex, in particular over the distal ulnar attachment, and the ulnar nerve is often Tinel positive. The extent of valgus instability is best assessed with the elbow at 25 degrees with the forearm in supination. The ligament can then be stressed with a valgus force, and the extent of instability, or any pain stressing the ligament is noted. Specific diagnostic tests include the well known milking test, however the ‘moving valgus stress test’ seems to be the most helpful. Essentially this test involves creating a valgus stress to the medial ligament through a range of motion. This attempts to simulate the stress to the ligament with throwing, and with a positive test the symptom of pain is reproduced, which should occur between 70 and 120 degrees. There may also be features of medial epicondylitis, demonstrated clinically by pain with resisted pronation and/or flexion of the wrist. Posterior pain on forced extension indicates posterior impingement. Recurrent medial instability is primarily a clinical diagnosis but a valgus stress x-ray may help to confirm the diagnosis, and opening the medial side of the joint more than 3 mm is diagnostic of medial instability.37

**Treatment of medial instability**

In the throwing athlete conservative treatment is often very effective. This involves the standard treatment for all overuse soft tissue injuries, including anti-inflammatoryatories, and local injection of cortisone or autologous blood. Very commonly the problem has developed secondarily to a poor throwing action which places undue stress on the medial ligament. In these cases the key to treatment is modification of the throwing action, and appropriate rehabilitation exercises. In cases which fail to respond to conservative treatment, reconstruction of the MCL is indicated. Plication sutures should repair the tendon but it should always be augmented with a graft. Jobe et al first described reconstruction of the MCL using a tendon graft placed through bony tunnels in the humerus and ulna. Their technique involved dividing the flexor pronator origin and performing a submuscular transposition of the ulnar nerve. This has since been modified and in 1996 the “safe zone” for MCL exposure through a muscle splitting approach was reported, and is now the standard approach. Associated intra-articular pathology should be treated, in particular any impinging bone or soft tissues removed arthroscopically. Calcification should be removed. Bone tunnels should be placed to allow isometric positioning of the graft. The graft should be securely placed in the tunnels and adequately tensioned. The ulnar nerve and the medial and brachial cutaneous nerves should be preserved.

The muscle splitting approach is carried out through a short medial incision. The dense fibrous raphe along the anterior margin of FCU is divided, and the underlying muscle is split to expose the ulnar collateral ligament. The author’s graft preference is the ipsilateral gracilis tendon. The anatomical attachments of the anterior bundle of the MCL are determined. Graft fixation to the region of the ulnar attachment is achieved either by passing the graft through two drill holes with an interconnecting bridge of bone, or with a single drill hole and an interference fit screw. The attachment to the medial epicondyle is into a single drill hole ‘docking’ the two tendons into the same hole. Fixation can be achieved by an interference screw, or passing the tendons through separate exit drill holes, and suturing the tendons together, or by using whip sutures in the two tendons which are tied to each other. The reconstruction needs to be protected for 3 months, initially in a splint, and then in a hinged brace. Results have been fairly good, with up to 92% excellent results reported.

**Late unreduced elbow dislocation**

The chronically dislocated, or subluxed, elbow is a difficult problem often associated fractures of the coronoid process and/or radial head (Fig. 15). The ligaments, which have been avulsed predominately from the humeral attachments, together with the overlying musculotendinous envelope, heal in a displaced position posterior to the epicondyles. Operative treatment involves mobilization of this entire musculotendinous/ligamentous envelope from its displaced position. The elbow is then relocated, fractures need to be reduced and internally fixed, followed by repair (if possible) of the ligaments. In long standing cases the mobilized flaps are simply sutured back to each other. A hinged external fixator is then needed and the movement of the elbow directs

![Figure 15](image-url) Chronically dislocated elbow.
the tissues to heal to the most suitable attachment to the epicondyles.

The procedure is carried out through a posterior (universal) incision. The approach is then similar to that for mobilization of a stiff elbow. On the lateral side a column type approach is utilized (Fig. 5). Starting proximally the interval between the triceps posteriorly and the extensor carpi radialis longus and brachioradialis anteriorly, is developed and extended distally in the interval between the anconeus and extensor carpi ulnaris. The tissues are mobilized as musculoligamentous flaps until the radius and ulna are freely mobile. Fractures of the radial head should be internally fixed, or the head replaced with a prosthesis, with attention to maintaining correct length of the radius, which can only be assessed once the humero-ulnar joint is concentrically reduced. If possible the lateral ligament is reattached.

If it is still not possible to reduce the elbow then a medial approach also is necessary. This is as described by Hotchkiss for mobilization of the stiff elbow by a medial approach26 (Fig. 10). This again should be commenced proximally, defining the interval between brachialis and triceps, identifying and protecting the ulnar nerve. The interval dissection is continued distally between palmaris longus anteriorly, and flexor carpi ulnaris posteriorly, until the ulna is mobile enough to be reduced. Fractures of the coronoid process can be reduced and fixed through this approach. As there is no prosthetic coronoid devices available for a chronic large coronoid process deficiency every attempt is made to utilize bone and chondral surface in the region. If there is still some portion of the coronoid process articular surface remaining this can be refixed and buttressed with bone graft. If the radial head needs to be sacrificed then a portion of this can be used to replace the coronoid process. Moritomo described reconstruction of the coronoid process using a graft from the ipsilateral olecranon. Allograft reconstruction has also been described, however the authors report this is an unpredictable procedure.40

Hinged fixator

At this stage the elbow joint is completely unstable, as there are no attachment of the soft tissues to the humerus, and hinged external fixation is always required. The Compass hinge has been popular, as has the Mayo joint distractor. The EBI hinge (Biomet, Parsippany, NJ, USA), in its latest version, allows a large degree of freedom of pin placement both in the humerus and ulna, with still the ability to place the hinge in the correct position and angle to the centre of rotation of the joint (Fig. 16). Once the epicondyles, lateral aspect of the capitellum, and medial aspect of the trochlea are exposed the centre of rotation of the two can be marked with a diathermy. A guide wire can be drilled through this centre of rotation using a standard anterior cruciate reconstruction drill guide. The hinge of the EBI fixator can be loaded onto this guide pin, which is then connected to the pins in the humerus and ulna. When inserting these pins it is important to insert them appropriately through the muscle and skin to allow for later closure of the muscle and skin flaps. The mobilized musculoligamentous flaps are closed medially and laterally, with reattachment of ligaments to the epicondyles if this can be achieved. The posterior incision is closed, preferably with interrupted sutures or staples. Post-operatively the elbow and arm are elevated and cooled. Continuous passive motion (CPM) is then commenced, which can be continued at home, and active movement is encouraged (Fig. 17a and b). A gear mechanism can be added to the fixator to statically mobilize the elbow in either flexion or extension. The fixator can usually be removed by 6 to 8 weeks but further night splinting may be necessary for several months.
Total elbow replacement

Despite the latest techniques there is a significant failure rate when treating late fracture-dislocation of the elbow. This is particularly the case when there is absent bone. The "final solution" to be considered in these patients is a total elbow replacement with a semi-constrained prosthesis. The results of elbow replacement in this situation were reported by Ramsey et al in 19 cases.41 Sixteen elbows had a satisfactory result and the average post operative range of motion was from 19–131 degrees.

Practice points

Most simple dislocations once reduced are stable, immediate active movement should be encouraged.

Many complex dislocations are inherently unstable. Often anatomical ORIF of the fractures and/or radial head replacement is required.

Research directions

Techniques for dealing with loss of articular cartilage and bone, in particular the coronoid process, need to be improved.

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References

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Elbow instability, mechanism and management


Suggested further reading