(iv) Elbow Instability

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Abstract

Acute elbow instability ranges from simple dislocations without significant fractures to complex dislocations involving fractures of the coronoid and radial head ("terrible triad"). Simple dislocations for the most part are stable after reduction, managed with early mobilisation and have good outcomes with relatively low complication rates. In contrast, complex fracture-dislocations render the elbow very unstable and therefore surgical intervention is usually necessary to restore bony and ligamentous stability to allow early range of motion. The risk of complications, including stiffness, chronic instability, heterotopic ossification and arthrosis, are high and clinical outcomes have traditionally been suboptimal. Detailed knowledge of the relevant anatomy is crucial in the understanding of injury patterns and in the application of successful systematic treatment algorithms that will minimise complications and improve outcomes.

Chronic instability is most commonly posterolateral due to incompetence of the lateral ulnar collateral ligament (LUCL). Patients present with episodes of recurrent subluxation or dislocation. Most symptomatic patients require surgical reconstruction of the LUCL (using tendon autografts or allografts) which produces favourable clinical results.

Keywords: collateral ligament; dislocations; elbow joint/anatomy; elbow joint/injuries; intra-articular fractures

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Introduction

The elbow is the second most commonly dislocated major joint in adults. It is also the most commonly dislocated major joint in the paediatric population with dislocations accounting for 10–25% of all elbow injuries. Dislocation of the elbow occurs at a mean age of 30 years and is 2–2.5 times more common in males. Forty percent are associated with sports.

Elbow instability ranges from simple dislocations with no associated fractures to more complex patterns of injuries with bony and ligamentous disruptions. Chronic instability presents with recurrent subluxation or dislocation episodes due to incompetence of the lateral ulnar collateral ligament (LUCL). An understanding

of the normal anatomy and pathoanatomy of the elbow joint is vital to appreciate the variable patterns of instability, how to assess and successfully manage them, and to avoid the potential pitfalls. The aims of this article are to initially discuss the functional anatomy of the elbow with particular reference to stability. Subsequently the assessment, classification, management, outcomes and complications of acute and chronic elbow instability are reviewed.

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Anatomy and Biomechanics

The elbow joint, although described to be the second most commonly dislocated joint after the shoulder, is one of the most inherently stable articulations of the skeleton. Stability is brought about by the osseous and articular congruency and the soft tissue components consisting of the static capsule and collateral ligaments and the dynamic muscles crossing the joint. Overall the ulnohumeral articulation, the MCL and LCL are the primary stabilizers of the elbow. The secondary stabilizers include the radial head, joint capsule, and the common flexor and extensor origins.

Osseous and Articular Anatomy

The osseous anatomy of the distal humerus and proximal ulna provide most of the inherent stability of the elbow. The trochlear notch surrounds almost 180 degrees of the trochlea increasing its capture. The spool-shaped nature of the trochlea, which is covered by articular cartilage with an arc of over 300 degrees, is a highly conforming articulation. The distal humeral articular surface is tilted 30 degrees anteriorly and this is matched by comparable posterior tilt of the trochlear notch. The coronoid process, which consists of a tip, body, anterolateral facet, and anteromedial facet acts as an anterior bony buttress to resist elbow subluxation in both flexion and extension. Interlocking of the coronoid and olecranon processes provides added ulnohumeral stability at extremes of motion. The radial head also contributes to force transmission and stability across the elbow joint providing an important anterior and valgus buttress to the elbow. It has been shown to result in a 30% reduction in valgus restraint after resection and is especially important in the presence of an associated injury to the anterior band of the medial collateral ligament (MCL) whereby it becomes the primary restraint to valgus stress.

Capsulo-Ligamentous Structures

The medial collateral ligament and lateral collateral ligament complexes, in combination with the anterior and posterior capsule, provide important static restraints to elbow instability.

Medial collateral ligament (MCL): the MCL is composed of three parts: the anterior oblique ligament (AOL), posterior oblique ligament (POL) and the transverse ligament (Cooper's ligament). The AOL

originates from the anterior inferior surface of the medial epicondyle and inserts at a mean of 18 mm distal to the coronoid tip on the sublime tubercle. The AOL is the strongest and most important structure consisting of anterior and posterior bands. As the origin of the MCL is slightly posterior to the axis of the elbow, there is a cam effect created so that the ligament tension increases with increasing flexion. The anterior band of the AOL is thus taut in the first 60 degrees of flexion and the posterior band taut from 60 to 120 degrees. The POL is a fan-shaped thickening of the capsule forming the floor of the cubital tunnel. Release of the POL has little if any effect on stability. The transverse ligament consists of horizontal capsular fibres between the coronoid and the tip of the olecranon and is not thought to contribute significantly to elbow stability. The AOL is the primary restraint to valgus force and the radial head is an important secondary stabilizer. After excision of the radial head with an intact AOL, there is little change in stability whereas release of the AOL in combination with excision of the radial head results in gross instability. Thus in the setting of an incompetent AOL after dislocation, an intact radial head is critical to resist valgus stress and the tendency for the elbow to subluxate posteriorly.

Lateral collateral ligament (LCL): the LCL provides varus and posterolateral rotatory stability of the elbow. It is composed of the lateral radial collateral ligament (LRCL), annular ligament (AL) and the lateral ulnar collateral ligament (LUCL). The LUCL originates from the lateral epicondyle, crosses the inferior aspect of the radial head, and inserts into the supinator crest of the ulna. The LUCL is the primary restraint to posterolateral rotatory instability and deficiency of this structure leads to chronic elbow instability. The LRCL lies anterior to the LUCL originating from the lateral epicondyle and inserting into the AL. The AL originates and inserts onto the anterior and posterior margins of the lesser sigmoid notch of the ulna and hooks around the radial neck stabilizing the proximal radioulnar joint.

Capsule: anteriorly, the elbow capsule humeral origin is proximal to the radial and coronoid fossae, and posteriorly, it is proximal to the olecranon process. The capsule attaches anteriorly to the anterior margin of the coronoid and the AL, and posteriorly along the articular margin of the sigmoid notch and proximal aspect of the olecranon fossa. The anterior capsule, which is typically torn in elbow dislocations, plays a role in ulnohumeral stability providing valgus stability in extension. The posterior capsule is also thought to contribute, resisting flexion and posteriorly directed forces.

Musculotendinous components: the muscular forces across the elbow provide a dynamic element of stability by compressing the joint surfaces against each other. The medial muscle complex (pronator teres, flexor digitorum superficialis, flexor carpi ulnaris, flexor carpi radialis) provides a varus moment thereby resisting valgus forces. The lateral muscle complex (extensor digitorum communis (EDC), extensor carpi radialis brevis and longus, anconeus, extensor carpi ulnaris) provides a valgus moment to resist varus forces which is especially important in the setting of LCL deficiency.

The "Ring" concept of elbow stability: the anatomical restraints described above can be simplified further and considered a 'ring' structure with anterior, posterior, medial and lateral columns that contribute to stability. This is useful when considering different patterns of injury and formulating a treatment strategy for the more complex instability cases.

The anterior column comprises the bony buttress provided by the coronoid process and radial head with supplementation by the anterior capsule and dynamic action of brachialis. The posterior column consists of the olecranon and posterior capsule with dynamic contribution from triceps. The lateral column comprises of the radial head, capitellum and LCL complex with radiocapitellar contact being the key to stability of this column. The radial head is an important secondary stabilizer to both valgus stress and posterolateral rotatory instability with the AOL and LCL being the primary stabilizers respectively. The medial column comprises the MCL complex, coronoid process, the medial condyle and epicondyle.

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Classification

Elbow instability can be classified by the direction of instability, the absence or presence of fractures (complex) and timing (acute versus chronic). The direction of dislocation refers to the direction of displacement of the radius and ulna in relation to the distal humerus with the most common being posterior which can be further subdivided into posterolateral or posteromedial.

The main injury patterns seen in association with elbow instability include:

Acute:

- Simple (small avulsion fractures may be present but no major associated fractures)
- Posterior dislocation with radial head fracture
- Posterior dislocation with fractures of radial head and coronoid (terrible triad)
- Trans-olecranon fracture-dislocations (Anterior / Posterior)

Chronic:

- Posterolateral rotatory instability (PLRI)

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Initial Assessment and Investigation

Elbow instability in the acute setting may occur as an isolated injury or be part of a high-energy multisystem trauma. It is important to ascertain this early and appropriately assess and manage the patient

according to their priorities of need. A detailed history, where appropriate, focussing on the injury mechanism and energy involved including hand dominance and the premorbid functional status of the patient will guide decision-making.

The dislocated elbow will appear deformed often with the forearm held in a position of varus and supination. Examination should focus on assessing the neurovascular status of the limb, which should be documented prior to performing any reduction manoeuvres. Damage can occur with entrapment of neurovascular structures after reduction that may necessitate urgent surgical intervention. The distal radioulnar joint (DRUJ) should be carefully examined to exclude an associated interosseous membrane injury. Anteroposterior and lateral radiographs are usually adequate to assess and treat simple dislocations. Radiographs are required after reduction to confirm a congruent joint and look for associated fractures. A line drawn through the centre of the radial neck should intersect the centre of the capitellum, regardless of the radiographic projection. When dealing with complex dislocations computerized tomography (CT) with three-dimensional (3D) reconstructions are necessary to assess the pattern of injury, the size and position of fracture fragments and to assist in surgical planning. Magnetic resonance imaging (MRI) is not usually necessary in the management of acute elbow instability.

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Simple Dislocation

This is most commonly a posterior and lateral dislocation with no major associated fractures. Minor avulsion injuries from the medial/lateral epicondyle or coronoid tip may be seen in around 10% of cases but these are generally insignificant. Anterior dislocations are uncommon (1%–2% of elbow dislocations) and usually associated with significant olecranon fractures or triceps disruption. A divergent dislocation is a rare injury associated with high-energy trauma.

The mechanism for the typical posterior dislocation is a fall onto the outstretched hand; the elbow flexes slightly, the body internally rotates and the forearm external rotates to create a supination moment at the elbow. The mechanical axis being medial to the elbow in this position also creates a valgus moment which, when combined with axial forces, initiates a cascade of soft tissue injuries sequentially from the lateral to the medial side of the elbow. This progressive tissue disruption has been classified into three stages.

Stage 1 is characterized by complete disruption of the LUCL with partial or complete disruption of the remaining LCL complex resulting in posterolateral subluxation.

Stage 2 includes damage to the capsule and can result in an incomplete posterolateral dislocation with the coronoid perched on the humeral trochlea.

Stage 3 is reached following continued force, whereby the MCL is disrupted and elbow dislocates posteriorly.

The goals of treatment for simple dislocations are to obtain a concentric stable reduction and allow early active range-of-motion (ROM). The elbow is expeditiously reduced under analgesia and sedation or full anaesthesia in the operating theatre. Reduction involves flexion to approximately 25 degrees and longitudinal traction combined with supination at the forearm and countertraction at the upper arm by the assistant. A reduction 'clunk' is favourable and suggests a stable reduction.

Following reduction the elbow should be examined for stability, which can be done more reliably under anaesthesia in the operating theatre with fluoroscopic imaging. The assessment involves recording the degree of extension at which the elbow dislocates as well as performing varus, valgus and posterolateral rotatory stress testing. Varus and valgus instability are performed with the elbow in full extension and 30 degrees of flexion. Some varus and valgus instability will invariably be present as both medial and lateral ligaments are disrupted in complete dislocations. If the elbow dislocates in extension, then this assessment should be repeated with forearm pronation. If this results in a more stable elbow, a hinged brace can be applied with an extension block at the appropriate degree and forearm pronation. If more than 45 degrees of elbow flexion with forearm pronation are required to maintain a reduction, then surgical repair of the ligaments and application of a hinged dynamic external fixator is indicated.

The vast majority of patients who have a stable reduction can be rested in a sling or splint for comfort for a period of 3–7 days. Full plaster casts should be avoided as these are frequently heavy and tend to pull the elbow into a subluxated position. Active elbow exercises are begun as soon as pain allows. Immobilization exceeding 2, and especially 4 weeks, is associated with poorer outcomes with residual pain and stiffness. Patients should be followed for the first few weeks after injury to ensure that the elbow remains stable and rehabilitation should be closely supervised in the acute phase. Prospective studies have failed to show any benefit from early collateral ligament repair versus closed reduction and early motion after a simple elbow dislocation. Surgical treatment should therefore be reserved for a few carefully selected cases when managing simple dislocations. Most patients who sustain a simple elbow dislocation regain function with an adequate range of motion without surgery. Excellent results with full range of motion, normal strength, absent pain, and good stability may be expected in 50% of patients. Good results, defined as less than 15 degrees of motion loss, minimal discomfort, and normal stability, may be expected in one third and fair or poor results are generally associated with complications and severe injuries and occur in around 15% of cases.

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Complex Fracture-Dislocations

Dislocations of the elbow with associated fractures are much more challenging to treat. The combination of ligamentous injury with fracture of the coronoid and radial head has the highest rate of complications and

hence is named the 'terrible triad'. Re-dislocation is likely with closed treatment and therefore these injuries usually require surgery to stabilize the elbow such that early motion can begin. Careful assessment with 3D CT reconstructions and a stepwise approach to address each component of the injury can yield more predictable results. To achieve this, the anterior bony buttress provided by the coronoid process and radial head must be restored and the static ligamentous components, particularly of the lateral column, need to be repaired.

Prior to embarking on surgery, the surgeon should ensure that the necessary equipment and implants are available. Small or mini-fragment systems are required to fix the coronoid and radial head fractures. Counter-sunk screws may be needed for articular fragments around the radial head. A metallic modular radial head implant should be available if the radial head cannot be reconstructed. Bone anchors or trans-osseous sutures may be used for ligament repair and finally a dynamic or static external fixator system should be accessible should the elbow remain unstable after reconstruction.

Surgical approach: the patient is positioned supine on the operating table with the arm supported on a hand table. A lateral approach is generally preferred as this allows the surgeon to address the coronoid, the radial head and the LCL. The deep exposure follows either the Kocher interval between anconeus and extensor carpi ulnaris or more anteriorly the extensor digitorum can be split. Typically the LCL (with or without the common extensor origin) has avulsed from the lateral epicondyle and the injury is readily exposed. In some cases an additional medial approach is needed to fix large coronoid fragments or repair the MCL. Alternatively a posterior skin incision with full thickness skin flaps can be used. This allows access to both the medial and lateral aspects of the elbow thereby precluding the need for a second medial skin incision should a medial approach be required.

Structured approach to achieve stability: the injured structures are now addressed in the following sequence:

Coronoid: access to the coronoid is gained through the window provided by the radial head fracture. If the radial head is not reconstructable and therefore needs replacing, its excision allows for excellent coronoid exposure. If on the other hand the radial head can be fixed then the fragments can be put aside for later fixation whilst the coronoid is dealt with. Coronoid fractures have been classified by Regan and Morrey based on size: type 1 (tip avulsion fracture), type 2 (less than 50% total height) and type 3 (>50%). The larger the coronoid fragment the greater the degree of instability. Type 1 fractures that are too small for screws can be repaired using suture fixation. This can be achieved by passing a suture around the tip, incorporating the anterior capsule, through two bone tunnels from the dorsum of the ulna into the fracture site. However there is recent evidence that suture repair has little effect on elbow stability and some authors suggest that it is not necessary. Type 2 and 3 fractures can be fixed with one or two cannulated screws passed from the dorsal ulna cortex. Large anteromedial facet fractures may require plate fixation via a separate medial approach.

Radial head: the radial head fracture is addressed after the coronoid. The decision to fix or replace the radial head is based on the fracture configuration and degree of comminution. Radial head fractures are classified according to Hotchkiss's modification of Mason's classification. Type 1 is a

non-displaced/minimally displaced fracture, type 2 a two-part fracture that is at least 2 mm displaced which may block rotation and type 3 a severely comminuted fracture. In the setting of a terrible triad injury, the radial head fracture is usually either type 2 or type 3 that requires fixation or replacement with a metallic prosthesis. The radial head must not be excised in the setting of a terrible triad injury as the elbow will remain very unstable.

Radial head fragments can be fixed using counter-sunk headless or mini-fragment screws or with a small pre-contoured plate if there is extension into the neck. Prominent metalwork must be placed within the 'safe zone', that does not articulate with the proximal radioulnar joint, to avoid a block to forearm rotation. This 90-degree arc is found most easily by applying the plate directly lateral with the arm in neutral rotation. If the radial head is deemed unreconstructable then prosthetic replacement should be performed. The implant must be metallic rather than silicone which is not rigid enough to support the lateral column and is prone to breakage and particulate synovitis. The aim is to recreate the height and width of the native radial head, which can be achieved by matching it to the reassembled fragments. A modular implant allows variation in the stem diameter as well as the head diameter and thickness. It is important not to over-stuff the joint; the implant should be at the same height or just distal to the coronoid process.

Lateral collateral ligament: once the bony stability has been restored, the ligamentous structures should be evaluated. Repair of the LCL complex to the lateral epicondyle, which is critical to elbow stability, can be achieved using suture anchors or through bone tunnels. Either way, it is important to perform an isometric repair at the centre of elbow rotation. The elbow is held at 90 degrees of flexion and full pronation to optimize the tension of the repair.

Medial collateral ligament: after repair of the coronoid process, radial head, and LCL, the elbow should be fluoroscopically examined for stability. If the elbow remains unstable between 30 and 130 degrees, repair of the MCL complex is required. Finally in the rare situation where the elbow is not stable after MCL repair then additional support with a static or dynamic hinged fixator should be used. A dynamic fixator is preferred but if not available then a static construct can be applied for up to 3 weeks.

Postoperative care and clinical outcomes: after surgery, most authors recommend a brief period in a well-padded splint at 90 degrees of flexion for 7–10 days to allow the soft tissues to settle. It is important however to note that a cast cannot be relied upon to maintain a concentric reduction. Once the splint is removed, supervised active and active-assisted exercises are begun. Slight subluxation or sagging of the joint is often seen on radiographs in the early postoperative period but this usually resolves by starting active flexion exercises. Shoulder abduction, which creates a varus moment at the elbow, and therefore places stress on the repaired lateral ligament complex, should be avoided.

Whilst in the past outcomes following terrible triad injuries have been poor, the results achieved following a standard surgical protocol similar to that outlined above have been satisfactory and more consistent. Pugh et al reported on a multicentre series of 36 patients who underwent fixation or replacement of the radial head, repair of the coronoid when possible, and fixation of ligamentous and capsular injuries. At a mean follow-up of 34 months the flexion-extension arc averaged 112 degrees with 136 degrees of forearm rotation. At follow-up, 15 patients were rated as excellent, 13 as good, seven as fair, and one as poor by

the Mayo Elbow Performance Score. The authors found that those patients who had prolonged periods of immobilization had poorer results, which parallels the findings in simple dislocations.

Trans-olecranon fracture-dislocations: anterior trans-olecranon fracture-dislocations are usually associated with high-energy trauma to the dorsal aspect of the forearm with the elbow in mid-flexion. The proximal ulnar fracture is usually complex, includes a large coronoid fragment, extension into the ulnar diaphysis, comminution of the trochlear notch and fragmentation of the olecranon. Both the radius and ulna are dislocated anteriorly but remain associated differentiating these injuries from an anterior Monteggia lesion. The capsulo-ligamentous restraints usually remain intact due to the significant osseous injury and therefore anatomical restoration and fixation of the proximal ulna with plates and screws results in a stable congruent reduction that allows for immediate motion.

Posterior olecranon fracture-dislocations, unlike the anterior types, often involve lateral ligament injuries, radial head fractures and coronoid fragments. The aim of surgery is to anatomically restore the proximal ulna with restoration of the trochlear notch and coronoid by repair or replacement of the radial head to stabilize the lateral column and possible repair of the lateral ligament complex.

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Chronic Posterolateral Rotatory Instability

Chronic instability warrants discussion at this point but an in depth report is beyond the remit of this article. Although both the MCL and LCL are acutely disrupted with an elbow dislocation, residual chronic instability most commonly involves the LCL complex giving rise to posterolateral rotatory instability (PLRI). This was originally described as a clinical entity by O'Driscoll et al in 1991. Whilst this is not a common problem, Mehlhoff et al reported that around a third of patients who had a simple dislocation of the elbow treated by closed reduction had some long-term symptoms of instability.

PLRI typically occurs with the elbow in supination and extension with a valgus load resulting in compression at the radiocapitellar joint without the restraint of the LUCL component of the LCL. The radius and ulna rotate away from the humerus as a single unit, causing the radial head to subluxate or dislocate posterolaterally. It should be noted that PLRI is a spectrum of instability which may progress from initial subluxation of the elbow in a posterolateral direction, to incomplete dislocation with the coronoid perched underneath the trochlea and finally to complete dislocation with the coronoid resting behind the humerus. This spectrum is identical to the stages of acute dislocation that are described earlier.

Presentation and diagnosis: not all patients present with recurrent full dislocation episodes. More typically patients present with a history of recurrent laterally-based pain, clicking, catching, or the sensation that the elbow is slipping out of the joint. These symptoms typically occur with elbow extension and forearm supination such as when pushing up from a chair. Most patients describe at least one traumatic

episode with or without dislocation although iatrogenic causes such as lateral surgical approaches or tennis elbow release should be considered in the history. Long-standing cubitus varus deformity from paediatric supracondylar humerus fractures and connective soft tissue disorders are also recognized causes of PLRI.

On examination most patients demonstrate a full pain-free range of motion with negative varus and valgus stress testing. The most sensitive test for clinically diagnosing PLRI is the lateral pivot-shift test which may be difficult to elicit with the patient awake and is therefore best performed under general anaesthetic. The patient is placed supine on the examining table with the arm overhead and shoulder externally rotated to stabilize the humerus. The elbow is placed in extension and forearm in full supination while the examiner applies a valgus load thus re-creating the mechanism of elbow instability. As the elbow is slowly flexed, the radial head is felt to "clunk" back into position as it relocates. This test is analogous to the pivot-shift test performed for anterior cruciate ligament instability. In the clinic setting it may also be useful to ask patients to push-up from a chair with their forearms in supination; pain or instability experienced as the elbow extends is recorded as a positive result. Finally the posterolateral draw test (analogous to the draw test in the knee) can be performed.

Imaging studies include plain radiographs, stress radiographs, fluoroscopy and magnetic resonance arthrography (MRA). Plain radiographs are usually normal but may show a bony avulsion from the lateral epicondyle or widening of the radiocapitellar joint. Stress radiographs with fluoroscopy are more useful. These are taken at the point of maximal rotatory subluxation in the pivot-shift test and show widening of the ulnohumeral joint space on the lateral and anteroposterior views and posterior subluxation of the radial head on the lateral view. MRA may identify injuries to the LCL complex although they are difficult to interpret and require an experienced radiologist. Diagnostic elbow arthroscopy can be performed to demonstrate the radial head subluxating posteriorly under direct vision during the pivot-shift test. A 'drive-through' sign may also be present where the camera easily passes through the ulnohumeral joint from the posterolateral portal.

Management: patients with mild symptoms may benefit with a neoprene sleeve and extensor strengthening to regain dynamic stability although most patients with significant chronic symptomatic instability require surgery. Direct repair is not possible due to the attenuation of the LCL complex and therefore reconstruction of the LUCL using either autograft or allograft tendon is recommended. Arthroscopic reefing techniques have recently been published although the gold standard involves open reconstruction. A number of different tendon graft sites have been successfully used including palmaris longus, plantaris, gracilis and semitendinosis.

A lateral Kocher approach is used through the interval between extensor carpi ulnaris and anconeus exposing proximal to the lateral epicondyle and distal to the supinator crest of the ulna. At this point the pivot-shift manoeuvre can be performed to identify the capsular and ligamentous laxity. The capsule is incised for inspection of the joint and later imbrication. The graft should pass from the isometric point of the lateral epicondyle to the supinator crest of the ulna. Graft fixation is achieved by bone tunnels with an interconnecting bridge of bone. Two 3.5 mm bone tunnels are drilled in the ulna just posterior to the supinator crest. The isometric point of the elbow is identified by placing a temporary suture through the ulnar bone tunnels and holding it against the lateral epicondyle whilst slowly flexing and extending the

elbow. Once this is located, three bone tunnels are created in the humerus with the distal one being at the isometric point. It is imperative that the graft is placed at the isometric point to maintain constraint throughout ROM especially in extension. The graft is then passed through the tunnels, tensioned with maximal pronation and 40 degrees of flexion and tied in place over the bone bridge. Imbrication of the anterior and posterior limbs can also be performed to augment the repair. Postoperatively the elbow is immobilized in a splint at 70–90 flexion with the forearm pronated to take the tension off the graft. A hinged brace is applied after 2 weeks to prevent extension beyond 30 degrees to protect the reconstruction for a further 4 weeks.

The results of surgical techniques that reconstruct the LUCL overall are favourable. Sanchez-Sotelo et al reported that 75% of 44 of patients had an excellent result and 86% had a satisfactory outcome after reconstruction or repair of the LUCL. Five of the 44 patients had recurrence of instability after the index surgery. Significantly better results were achieved in patients with a post-traumatic origin, subjective symptoms of instability, and an augmented reconstruction using a tendon graft.

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Complications of Elbow Instability

Nerve and vessel injury: nerve injury occurs in approximately 20% of acute dislocations and usually involves the ulnar nerve although may involve the median nerve especially after reduction of the elbow. The injury most commonly results in transient paraesthesia but may occasionally be a permanent palsy. Stretching and distortion of the anterior structures during a dislocation or reduction may result in spasm, intimal damage, thrombosis or rupture of the brachial artery. Careful assessment and documentation of the neurovascular status of the limb is therefore vitally important.

Compartment syndrome: intramuscular bleeding and oedema formation within the flexor compartment of the forearm may result in a compartment syndrome. A high index of suspicion is required to make this diagnosis and prompt surgical treatment to avoid muscle and nerve ischaemia with potentially irreversible disability.

Stiffness: loss of elbow motion is the most common complication of both simple and complex elbow dislocations. This is thought to occur due to thickening and fibrosis of the anterior joint capsule. A simple dislocation often results in the loss of 10–15 degrees of terminal extension and the risk of loss of motion is greatly increased if the period of immobilization exceeds 2–3 weeks. Loss of motion is typically greater in those with a complex elbow dislocation and therefore the goal of treatment is to restore the components of the elbow to allow a stable reduction so that early active motion can be achieved. Residual stiffness more than approximately 1 year after injury is usually refractory to bracing and therapy and may require open or arthroscopic release to improve function.

Heterotopic ossification (HO): heterotopic bone formation occurs in up to 75% of cases and commonly involves the LCL and MCL with minimal functional limitation. Motion-limiting ossification occurs in less than 5% of cases. HO is typically seen on radiographs and forms 4–6 weeks after injury. Risk factors for HO include injury to the central nervous system, burns and patient factors such as age, gender and a possible genetic element. Forceful manipulation of the elbow for post-traumatic stiffness has also been associated with an increased risk of HO whereas gentle active and continuous passive motion reduces the risk. HO prophylaxis with the use of low-dose radiation or non-steroidal anti-inflammatory drug (NSAID) therapy should be considered in high risk patients. Motion-limiting HO can be resected once it has been established that the ossification process has matured (3–4 months after injury) with the presence of a well-defined trabecular pattern on standard radiographs.

Chronic instability: chronic instability after complex fracture-dislocations may be related to mal-union, non-union, bone loss or attenuation of ligamentous structures or a combination of these. They are extremely challenging to manage especially if there is articular malalignment or loss of bone and may require complex osteotomies with bone grafting and concomitant ligament reconstruction with protection by a hinged external fixator postoperatively. Purely ligamentous attenuation may be the sequela of both simple and complex dislocations and may result in subtle instability such as PLRI as described above. A fracture of the anteromedial facet of the coronoid in combination with injury to the LCL, if not adequately stabilized, can result in posteromedial varus rotatory instability (PMRI) of the elbow.

Arthrosis: this is more prevalent with increasing complexity of the injury and energy due to chondral damage at the time of the initial injury and also delayed damage in association with residual instability which may be subtle. The older, less active patient may be treated with total elbow arthroplasty whereas the younger active patient poses a significant challenge with treatment options including medical therapy, debridement arthroplasty or interpositional arthroplasty to avoid joint replacement that is associated with early failure requiring revision surgery.

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Conclusion

Elbow instability incorporates a vast spectrum of disorders that range from simple acute dislocations to more complex dislocations with multiple injury components. An understanding of the functional anatomy of the elbow is vital when treating these injuries to appreciate the involved components and plan a surgical strategy. The vast majority of simple dislocations are managed with closed reduction and early active motion with good outcomes and low complication rates. Complex fracture-dislocations require a stepwise surgical approach to restore bony anatomy and repair soft tissue components to provide stability, allow early motion and yield satisfactory results. The commonest form of recurrent instability is PLRI, which is primarily due to incompetence of the LUCL. Conservative treatment is rarely successful and most patients require ligament reconstruction using tendon allo- or auto-grafts.

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(iii) Elbow Instability, Mechanism and Management

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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.

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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. 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. This article will concentrate predominantly on instability in the adolescent and adult population.

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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 ulnotrochlear 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). 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 is the strongest of the medial ligaments and histologically 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. The POL is a fan-shaped thickening of the capsule that forms the floor of the cubital canal and inserts along the midportion of the medial margin of the semi-lunar notch. It is thinner than the AOL and histologically is within the layers of the medial elbow capsule. 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: the lateral radial collateral ligament (LRCL), the annular ligament (AL), the lateral ulnar collateral ligament (LUCL) and the variably present accessory lateral collateral ligament (ALCL). 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 LUCL measures 2 cm in width. It has been stated that the LUCL 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.

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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). If elbow dislocation occurs without fracture it is referred to as a 'simple dislocation'. When acute dislocations are associated with significant fractures they are classified as 'complex dislocations'. The most common direction is a posterior dislocation, with subgroups of posterolateral or posteromedial.

Simple Dislocation — Pathomechanics

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. 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. 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. 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 dislocation is usually in moderate but not severe pain and the deformity is obvious. The neurological function and vascular status are carefully assessed. In most situations, x-rays are mandatory prior to any attempt at reduction. Closed reduction is usually carried out under intravenous

analgesia and sedation. 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.

Ideally, following reduction, the elbow should then be assessed under fluoroscopy. It is particularly important to assess if there is instability in extension, and at what degree this occurs. If there is a tendency for the elbow to sublux with extension then this is reassessed with the forearm in pronation. 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.

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. Melhoff et al demonstrated that immobilisation for more than 2 weeks prevented any chance for an excellent result, while immobilization for 4 weeks always yielded a fair or poor result.

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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. Following this type of dislocation there is frequently a tendency to chronic instability, and an increased incidence of post-traumatic arthrosis. The overall goal is to gain a concentric and stable reduction of the elbow that permits a functional range of motion. 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. Ligamentous stability then needs to be restored. 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.

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. Following reduction of the elbow, stability of the medial ligament should be assessed with stress under fluoroscopy. If there is major fracture of the radial head, resulting in potential longitudinal instability, 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.

Dislocation with Coronoid Process Fracture

The decision to internally fix the fracture is mainly related to the potential instability of the joint. It is generally felt that if more than 50% of the process is fractured then it should be reduced and fixed. 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.

Dislocation with the Terrible Triad

The combination of dislocation with radial head and coronoid process fractures is termed the "terrible triad." 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. 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.

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Posterolateral Rotatory Instability

In 1991 O'Driscoll introduced the term posterior lateral rotatory instability (PLRI) of the elbow to describe instability caused by injury predominantly to the lateral ulnar collateral ligament (LUCL). This is the most common form of recurrent post-traumatic instability of the elbow. 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.

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. Some patients with lateral epicondylitis may also develop iatrogenic PLRI following an over-aggressive lateral epicondyle release. The symptoms vary from obvious instability, through recurrent subluxation, to subtle reports of pain and discomfort.

Physical Diagnosis

Provocative tests include the lateral pivot shift test 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 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. 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.

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. For chronic instability surgery is the only real option.

Surgical Reconstruction

The elbow is approached through a modified Kocher's approach exposing the entire lateral ligament complex from the lateral epicondyle to the supinator crest. 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. The author prefers the gracilis tendon, harvested from the ipsilateral leg. Graft fixation can be obtained through bony tunnels with an interconnecting bridge of bone, a single drill hole and an interference fit screw, or the use of fixation anchors.

The elbow needs to be immobilized in 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.

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Medial Instability

Acute Traumatic Rupture of the Medial Ligament

This can occur following a severe valgus stress. If the flexor pronator muscles are 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, operative management is indicated. The ligament can usually be easily repaired if avulsed from the bone, either with sutures through drill holes, or with anchors. The reconstruction needs to be protected for 3 months, initially in a splint, and then in a hinged brace.

Chronic Medial Instability

Medial elbow symptoms related to recurrent medial instability are usually associated with chronic overuse from athletic activities that involve throwing. Throwing applies significant valgus stress to the elbow, resulting in repetitive micro-trauma to the MCL, and ultimately attenuation of the ligament. In cases which fail to respond to conservative treatment, reconstruction of the MCL is indicated. The 'moving valgus stress test' seems to be the most helpful diagnostic test — it involves creating a valgus stress to the medial ligament through a range of motion and attempts to simulate the stress to the ligament with throwing. A positive result reproduces pain between 70 and 120 degrees. Opening of the medial side of the joint more than 3 mm on valgus stress x-ray is diagnostic of medial instability.

In the throwing athlete conservative treatment is often very effective, including anti-inflammatories, local injection, and modification of the throwing action. In cases which fail to respond, reconstruction of the MCL is indicated using a tendon graft placed through bony tunnels in the humerus and ulna. Results have been fairly good, with up to 92% excellent results reported.

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Late Unreduced Elbow Dislocation

The chronically dislocated, or subluxed, elbow is a difficult problem often associated with fractures of the coronoid process and/or radial head. Operative treatment involves mobilization of the 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. A hinged external fixator is then needed. The fixator can usually be removed by 6 to 8 weeks but further night splinting may be necessary for several months.

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Total Elbow Replacement

Despite the latest techniques there is a significant failure rate when treating late fracture-dislocation of the elbow. 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. Sixteen elbows had a satisfactory result and the average post-operative range of motion was from 19–131 degrees.