A variety of conditions can manifest as elbow instability, making diagnosis and treatment problematic for the clinician. However, important progress has been made in the understanding of the unstable elbow that impacts treatment. Crucial has been an increased understanding of functional anatomy of the elbow and its relationship to the biomechanics of elbow stability. This article reviews the functional anatomy of the elbow, with an emphasis on the biomechanics of instability as well as emerging concepts in the treatment of the most common entities.

Anatomy

**Bony Articulation**
The elbow is a modified hinged joint composed of three distinct articulations: the radiocapitellar joint, the ulnohumeral joint, and the proximal radioulnar joint. The configuration of the joints provide for much of the stability of the elbow against varus and valgus stress at the extremes of extension and flexion. The ulnohumeral articulation provides 55% of the varus stability in extension and up to 75% in 90° of flexion; valgus stability is equally divided between the medial collateral ligament (MCL), the anterior capsule, and the bony articulation, in both full extension and 90° of flexion.

**Ligamentous Structures**

**Medial Collateral Ligament**
The MCL is composed of an anterior bundle, posterior bundle, and transverse ligament (Fig. 1). The anterior bundle is the most discrete and functionally important portion of the MCL, contributing 55% to 70% to valgus stability. The bundle originates on the anteroinferior aspect of the medial epicondyle and inserts onto the medial aspect of the coronoid process. The anterior bundle is further subdivided into distinct anterior and posterior bands that perform reciprocal functions. Sequential tightening occurs within the fibers of the anterior bundle, progressing from anterior to posterior as the elbow flexes. The anterior band is the primary restraint to valgus stress up to 90° of flexion; the posterior band is a secondary restraint at lesser degrees of flexion, but becomes more important between 60° and full flexion. The posterior bundle is thinner and weaker than the anterior bundle and provides secondary valgus stability at flexion beyond 90°. The transverse ligament contributes little to elbow stability, as it does not cross the elbow joint.

**Lateral Collateral Ligament**
The lateral collateral ligament (LCL) complex consists of the annular ligament, the radial collateral ligament, the lateral ulnar collateral ligament (LUCL), and a variably present accessory LCL. The radial collateral ligament originates from the lateral epicondyle and terminates indistinguishably in the annular ligament, which stabilizes the proximal radioulnar joint (Fig. 2). The LUCL originates from the lateral epicondyle, blending with fibers from the annular ligament but arching superficial and distal to it. This ligament is the primary restraint to varus stress and is deficient in posterolateral rotatory instability of the joint.

**Biomechanics of Elbow Instability**

O'Driscoll and colleagues described a mechanism for elbow subluxation and dislocation, in which increasing ligamentous and capsular damage progressed from lateral to medial across the joint (Fig. 3). In stage 1, the LUCL is disrupted, resulting in posterolateral rotatory subluxation of the elbow. In stage 2, additional injury occurs anteriorly and posteriorly, resulting in an incomplete posterolateral dislocation of the
elbow, radiographically represented by a perched dislocation. Stage 3 is divided further into three levels of severity. Stage 3A involves disruption of the medial side of the elbow joint, leaving only the anterior band of the MCL intact. The elbow pivots on the intact anterior band of the MCL, which allows complete dislocation by a posterolateral rotatory mechanism. The intact anterior MCL provides stability if the forearm is kept in pronation to prevent posterolateral rotatory subluxation during valgus stress testing. In stage 3B, the entire MCL complex is disrupted; valgus, varus, and rotatory instability are all present. In stage 3C, the entire muscular origins of the flexor and extensor origins have been stripped off the distal humerus. The instability becomes so severe that the elbow can dislocate, even if immobilized in a cast at 90° of flexion.7,8

**Acute Elbow Dislocation**

Acute elbow dislocation is a relatively common type of elbow instability. Dislocation constitutes 10% to 25% of all injuries to the elbow9 and has an annual incidence of six cases per 100,000, second in frequency only to shoulder dislocation.10 The mechanism of elbow dislocation is most commonly a fall onto an outstretched hand, resulting in an axial compressive and valgus load on the supinated extremity. Although radiographs reveal periarticular fractures in 12% to 60% of cases, operative exploration documents osteochondral injuries that went undetected in prior radiographs in nearly 100% of acute dislocations.11

**Evaluation and Nonsurgical Management**

A thorough neurovascular examination is required before and after reduction of the joint. The wrist and shoulder should be examined for concomitant upper extremity injury. The distal radioulnar joint and interosseous membrane should also be evaluated for tenderness to exclude an Essex Lopresti injury variant.

Following reduction, instability is assessed by gently moving the elbow through a range of motion. Most elbows

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**Figure 1** Medial collateral ligament. (Reprinted from Morrey BF. Anatomy of the elbow joint. In: Morrey BF (ed): The Elbow and Its Disorders (3rd ed). Philadelphia: Saunders, 2000, p. 23. Permission of Mayo Foundation for Medical Education and Research. All rights reserved.)

**Figure 2** Radial collateral ligament complex. (Reprinted from Morrey BF: Anatomy of the elbow joint. In: Morrey BF (ed): The Elbow and Its Disorders (3rd ed). Philadelphia: Saunders, 2000, p. 24. Permission of Mayo Foundation for Medical Education and Research. All rights reserved.)

are unstable to valgus stress. Competency of the medial structures to valgus stress is tested in pronation to prevent posterolateral rotatory instability. It is essential to evaluate the tendency for redislocation to occur in extension, which signifies a potentially unstable joint. Postreduction radiographs should then be evaluated to document concentric reduction of the elbow joint in two planes. Widening of the joint space may indicate an entrapped osteochondral fragment(s) or posterolateral rotatory instability.

If the reduction is concentric and the joint is stable, the joint is splinted within its arc of stability. Reevaluation should be performed in five to seven days. If the elbow subluxates or dislocates in extension or is noncongruent on radiographs, the forearm should be pronated and stability reassessed. If stability is restored with pronation, a hinged brace is applied with the elbow in full pronation. An extension block of 30° is sometimes necessary. Extension blocks should be gradually eased so that, by three weeks, the elbow allows full motion.

Prospective studies have shown no advantage of early collateral ligament repair over early motion following simple elbow dislocation. Josefsson and associates\(^1\) reported that nonsurgically treated elbows demonstrated less flexion contracture, averaging 10° at two and five years, than surgically treated elbows, in which flexion contracture averaged more than 15° at two and five years. Surgery is indicated when the elbow requires flexion beyond 50° to 60° to remain reduced and for dislocations associated with unstable fractures.

**Posterolateral Rotatory Instability**

O’Driscoll and coworkers\(^6\) have identified deficiency of the LUCL complex as the essential pathologic lesion leading to posterolateral rotatory instability. This lesion most commonly occurs as a consequence of acute dislocation. Although most studies have indicated that both the MCL and LCL complex are acutely disrupted with an elbow dislocation,\(^13\) the residual insufficiency most commonly involves the LCL complex.\(^7\) Deficiency of the LCL complex may also occur as an iatrogenic complication of a tennis elbow release.

The diagnosis of elbow instability is made on the basis of a history of elbow dislocation, followed by the patient complaining of painful clicking, catching, or snapping as the elbow goes from flexion to extension; pain may only present on the lateral aspect of the elbow. Symptoms typically occur during the extension portion of the motion arc with the forearm in supination. Symptoms that occur with flexion and pronation are, therefore, likely related to reduction of the subluxation. Pushing down on the arm rest of a chair when rising from a seated position or performing push-up exercises places the elbow in an at-risk position and may be used as provocative tests.

The most sensitive test reported is the lateral pivot shift apprehension test, performed with the patient supine.\(^6\) With the forearm fully supinated, the examiner grasps the wrist or forearm and slowly extends the elbow, simultaneously applying valgus and supination movements and an axial compressive force. This maneuver produces radiohumeral subluxation. Additional flexion results in a sudden reduction as the radius and ulna snap into place on the humerus (Fig. 4).

Stress radiographs may be helpful to confirm the actual diagnosis, because plain radiographs typically appear normal in posterolateral rotatory instability. Fluoroscopic evaluation performed during a pivot shift test is preferable, but gravity-assisted stress radiographs also frequently demonstrate the instability. Magnetic resonance imaging (MRI) is usually not required to make the diagnosis of posterolateral instability but may be helpful.\(^14\)

**Treatment**

An incompetent LUCL will not restabilize over time without intervention.\(^8\) For the less active patient who is willing to modify his activities, nonsurgical management may be appropriate. The majority of patients with recurrent instability who experience significant interference in daily activities require surgical reconstruction.

Reconstruction of the LUCL using a free tendon graft is recommended for patients with symptomatic recurrent lateral instability.\(^15\) The Kocher interval is entered and the anconeus muscle is reflected, allowing identification of the
crista supinatoris. Two holes are placed 7 mm to 10 mm apart at the base of the crista supinatoris, and a suture is passed through this tunnel to mark the isometric point on the humerus. Bone tunnels are made in the humerus at this isometric point. It is important that the graft be placed at the isometric point of the elbow or the reconstruction will constrain normal motion. A 3-ply passage of the graft across the joint is preferred.

Postoperative care consists of immobilization in pronation for 2 weeks, followed by a hinged splint with a 30° extension block for an additional 4 to 6 weeks. A mild flexion contracture is acceptable, as the most vulnerable position of instability is full extension. Thereafter, the patient is allowed use of the extremity, but varus stress should be avoided for four to six months. Athletic activities may resume between six to eight months.

Results
Nestor and colleagues reported on the results of LUCL reconstruction at the Mayo Clinic. If no other injuries were present, approximately 90% of elbows were rendered stable. If there were significant degenerative changes, the likelihood of a satisfactory result decreased to 50% although stability was achieved.

Medial Instability
Acute MCL ruptures that occur with elbow dislocation generally heal and rarely result in valgus instability, with the exception of athletes. Injury to the MCL, initially recognized in javelin throwers, has been reported to occur with increasing frequency in other types of overhead athletes. Micro tears of the MCL occur once the valgus forces, generated during the cocking and acceleration phases of throwing, exceed the intrinsic strength of the MCL. Attenuation and even rupture of the MCL can result.

Patients with an acute MCL injury after throwing usually experience a “pop” and a sudden onset of pain, with swelling localized to the medial aspect of the elbow. Patients with chronic injury typically describe a gradual onset of localized medial elbow pain during the late-cocking and acceleration phases of throwing (Fig. 5). Athletes may describe pain that results in an inability to throw at more than 50% to 75% of their normal velocity. Up to 40% of patients with valgus instability present with ulnar nerve symptoms. Ulnar nerve symptoms may occur due to compression of the nerve by inflammatory components of the irritated ligament within the tunnel or with traction from repeated valgus loading.

Physical examination of the elbow for valgus instability is performed by applying a valgus stress while flexing the elbow between 20° to 30° to unlock the olecranon from its fossa (Fig. 6). This maneuver stresses the anterior band of the anterior bundle of the MCL. It is important to palpate the MCL during the application of valgus stress to localize point tenderness. Valgus laxity is manifested by an increased medial joint space opening, as compared to the contralateral side. It is now recognized that this test should be performed with the forearm in full pronation to prevent posterolateral rotatory instability. The milking maneuver can be used to test the functionally more important posterior band of the anterior bundle of the MCL. The maneuver is performed by pulling on the patient’s thumb with the patient’s forearm supinated; the shoulder is extended and the elbow flexed to 90°. The difference in valgus rotation between intact elbows and those in which the anterior bundle is deficient has been shown to be significantly greater at 70° to 90° of flexion than at 30°.

Routine radiographs may show changes consistent with chronic instability, such as calcification and occasionally ossification of the ligament. Stress radiographs can be used to confirm the diagnosis; a side-to-side difference of more than 2 mm is consistent with instability. MRI is currently the modality of choice for evaluating the MCL; complete ligamentous tears are readily identified. The use of intra-articular gadolinium may provide useful information for partial tears that occur on the inner surface of the MCL but may be missed on standard MRI. Arthroscopy has also been described for the diagnosis of MCL tears. Although the ligament cannot be directly visualized, the amount of joint...
Examination of ulnar collateral ligament is identified and bone tunnels are placed to allow isometric positioning of the graft. The harvested nerve. The ligamentous-capsular complex is then incised to allow access to the elbow joint and associated intra-articular pathology for treatment. The anatomic origin and insertion of the MCL are preserved but augmented with a graft reconstruction.

Surgical reconstruction begins with an approach centered over the medial epicondyle. Care must be taken to preserve the medial antebrachial cutaneous nerve. Next, the common flexor mass is split longitudinally, in line with its fibers in the posterior-third near the flexor carpi ulnaris (FCU); enough exposure can be obtained without a transverse incision of the flexor pronator muscles or transposition of the ulnar nerve. The ligamentous-capsular complex is then incised to allow access to the elbow joint and associated intra-articular pathology for treatment. The anatomic origin and insertion of the MCL is identified and bone tunnels are placed to allow isometric positioning of the graft. The harvested graft is placed in the bone tunnels and tensioned with the elbow at 45° flexion and neutral varus-valgus alignment. A concurrent ulnar nerve transposition may be performed in cases of concomitant ulnar neuritis, ulnar nerve subluxation, or pathologic nerve constrictions noted at the time of surgery. Routine transpositions are no longer performed, because of the risk of nerve injury secondary to segmental devascularization, intraoperative compression or traction, and postoperative scarring.

Postoperatively, the elbow is immobilized in supination and 90° of flexion for seven to ten days. Flexion and extension are protected in a hinged brace for an additional 4 weeks. At six weeks, elbow strengthening exercises are started, however, valgus stress is avoided until four months after surgery.

Results
In 1992, Conway and associates reported that 85% of 56 patients who had undergone MCL reconstruction, and had not undergone prior surgery, had a satisfactory result versus 55% of patients who had undergone prior surgery. More significantly, 74% of patients who had not undergone a prior procedure had excellent results, compared with 33% of those who had undergone an unsuccessful prior procedure. Andrews and Timmerman reported on 11 professional pitchers: nine underwent reconstruction of the ligament and two had primary repair. Seven of the pitchers who had reconstruction returned to competition. More recently, Thompson and coworkers reported on 83 athletes with medial elbow instability who underwent an MCL reconstruction with a muscle splitting approach but without ulnar nerve transposition. Postoperatively, 5% had transient ulnar nerve symptoms that resolved with nonoperative management. There were no reoperations for nerve dysfunction and no permanent nerve problems. At two to four year follow-up, 93% of the highly competitive athletes who had not had a prior surgical procedure had an excellent result.

References


