Complex Elbow Instability

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Abstract

Complex elbow instability consists of dislocation of the ulnohumeral joint with a concomitant fracture of one or several of the bony stabilizers of the elbow, including the radial head, proximal ulna, coronoid process, or distal humerus. Recurrent instability is not often associated with simple dislocation, but an improperly managed complex dislocation may be a prelude to chronic, recurrent elbow instability. Complex instability is significantly more demanding to manage than simple instability. Radial head, coronoid, and olecranon fracture associated with dislocation each must be assessed and often require surgery. Long-term outcome with surgical management of complex elbow injuries is unknown. A few published series examine combinations of different injury patterns managed with various methods. Recently, however, several well-designed prospective outcome studies have evaluated management of several different individual fracture-dislocation patterns with a unified treatment algorithm. Fixation or replacement of injured bony elements, ligamentous repair, and hinged fixation may be used to successfully manage complex elbow instability.

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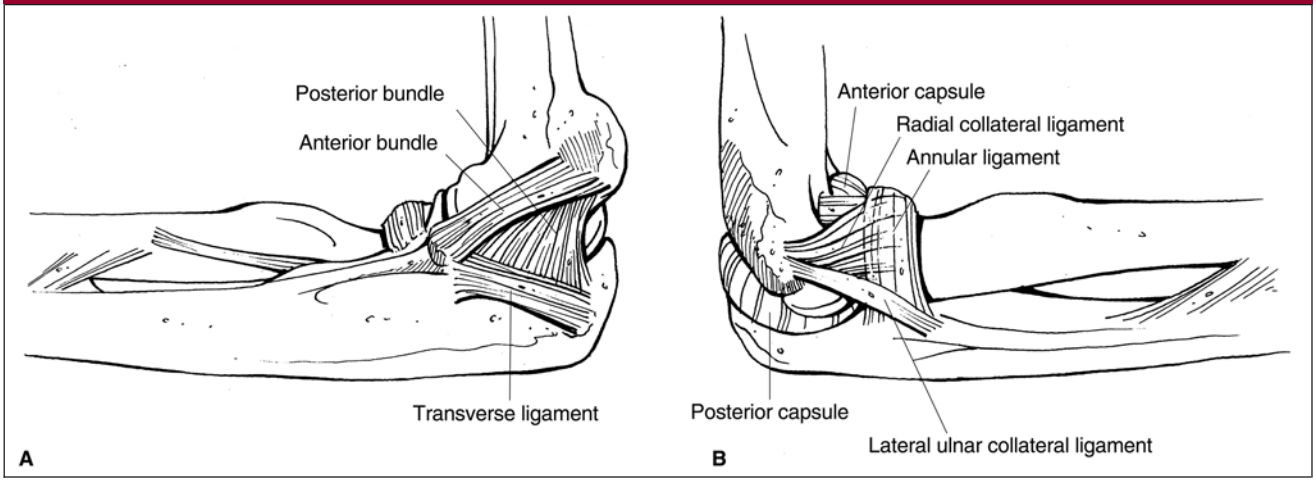
Elbow instability may occur after any one of a large group of diverse injuries, such as a fall on an outstretched hand, motor vehicle accident, or direct trauma, resulting in fractures or dislocations. Instability may be categorized anatomically as simple (with no associated fracture) or complex (with associated fracture) or chronologically as acute, chronic, or recurrent. These categories are not mutually exclusive. The elbow is one of the most commonly dislocated joints in the body, with an average annual incidence of acute dislocation of 6 per 100,000 persons.[1] Simple dislocations, which are much more common than complex dislocations, are described by the direction of the dislocated ulna. Posterolateral dislocation is the most common simple dislocation.[2] Complex dislocations may include fracture of the radial head, coronoid process, olecranon, or distal humerus. The risk of recurrent or chronic instability and posttraumatic arthrosis is increased significantly with complex dislocation.[3,4] Chronic unreduced dislocations and recurrent instability in complex injuries are very difficult to manage. In addition to surgical intervention, they often require the use of a hinged external fixator to hold the elbow in a reduced position.[5,6]

Early clinical series laid the groundwork for understanding the natural history of fractures of the coronoid process and radial head with and without associated dislocation.[1,3,4,7-9] Recent clinical research has focused on outcomes of

Figure 1



Structure of the medial collateral ligament complex **(A)** and the lateral collateral ligament complex **(B)**.

currently recommended methods of treatment. For radial head fracture, monoblock titanium replacement is recommended, or internal fixation with low-profile plates and miniscrews. Dislocation with associated radial head and coronoid process fracture (ie, terrible triad injury) is managed by fixation, arthroplasty, or ligament reconstruction. Recurrent instability is treated with hinged elbow fixators.[10-13] Long-term outcomes have been reported on nonsurgical management of radial head fractures.[14] The classification of coronoid process fractures recently described by O'Driscoll et al,[15] which is based on the fracture pattern, may better guide the surgical management of these injuries.

The goal of managing complex elbow instability is to regain a concentric and stable reduction of the elbow that permits a functional range of painless motion. This outcome is often difficult to achieve. The surgeon must have a thorough understanding of the anatomy of the elbow, including the bony and ligamentous components necessary for stability. Additionally, the surgeon must understand the surgical options and treatment outcomes for complex instability. The most recent clinical and basic research studies have significantly expanded our knowledge of elbow instability and its management.

Functional Elbow Anatomy

Flexion and extension of the elbow are provided by the ulnohumeral joint. Pivoting (axial rotation) is provided by the radiohumeral and proximal radioulnar joints. The trochlea, which is covered by articular cartilage over an arc of 300°, is highly conformed to the proximal ulna. This articulation is predominantly responsible for the bony stability of the elbow.[16] The capitellum is spherical in shape and is separated from the trochlea by a groove in which the radial head rim articulates.

With respect to the humeral shaft, the distal humerus is tilted anteriorly 30° in the lateral plane and internally 5° in the transverse plane, and is in 6° of valgus in the frontal plane.[16] The center of rotation of the ulnohumeral joint is defined by its axis, which projects laterally from the center of the capitellum and medially from the anteroinferior aspect of the medial epicondyle.[17] The radial head and neck form an angle of 15° with the radial shaft; this angle must be considered during internal fixation. Similarly, the anterolateral one third of the radial head is void of cartilage, providing an optimal position for hardware. The sigmoid notch of the proximal ulna forms an ellipsoid arc of 190°, with a void of articular cartilage in the midportion allowing for osteotomy through a nonarticulating segment.[18]

Besides the osseous structures, the medial collateral ligament (MCL) and lateral collateral ligament (LCL) complexes are the other primary components of elbow anatomy. They have a significant role in elbow stability. The MCL complex includes an anterior, posterior, and transverse segment, of which the anterior bundle is the most important for stability (Figure 1, A).[16] The anterior bundle of the MCL originates from the anteroinferior surface of the medial epicondyle and inserts on the sublime tubercle of the coronoid process an average of 18 mm distal to the tip of the coronoid.[19,20] The LCL complex is composed of the radial collateral ligament, annular ligament, lateral ulnar collateral ligament, and an accessory lateral collateral ligament. The lateral ulnar collateral ligament originates from the lateral epicondyle, blends with the annular ligament, and inserts into the supinator crest of the proximal ulna (Figure 1, B). The

lateral ulnar collateral ligament is the primary provider of posterolateral stability.[21]

Complex Instability

Complex elbow dislocation consists of both ligamentous and bony injuries. These injuries are less frequent, more difficult to treat, and often have poorer results than simple dislocation. Injury to at least one osseous structure in conjunction with elbow dislocation increases the risk of recurrent instability and arthrosis.[3,4] The radial head and coronoid process are the most commonly fractured structures in these injuries.[22]

Both the fractures and the soft-tissue injuries must be addressed during treatment, which includes reducing the dislocation, managing the fracture (eg, fixation, replacement), and repairing the collateral ligament (lateral and possibly medial). Hinged external fixation is applied when instability persists. Injury categories include ligament injuries combined with radial head fractures, isolated coronoid process fractures, terrible triad injury, posterior Monteggia lesions, or anterior transolecranon fracture-dislocation.

Radial Head Fracture Associated With Dislocation

Radial head fracture is the most common bony injury to the adult elbow.[15] Hotchkiss[23] modified the Mason classification system to include treatment options for each type of isolated radial head fracture. In general, isolated type I fractures may be treated nonsurgically, type II and III fractures should be fixed or excised. Favorable long-term (>20 years) outcomes of nonsurgically managed isolated Mason type II and III fractures have recently been reported, indicating that there is still reason for controversy.[14] More than 75% of fractured elbows develop some degree of arthritis, yet this seems to be of minor relevance. In the presence of persistent pain, results of delayed excision are favorable.[14] Surgical fixation of type II and III fractures with miniplates and screws also has been recommended, with favorable overall results.[7] Fixation of comminuted fractures (type III and IV) using low-profile miniplates has 90% good or excellent results.[11] In contrast, the results of another recent study suggest that internal fixation should be reserved for minimally comminuted fractures with three or fewer articular fragments.[12] Controversy still exists regarding which fractures are optimally treated with reduction and internal fixation as well as whether a fracture may be too comminuted to fix.

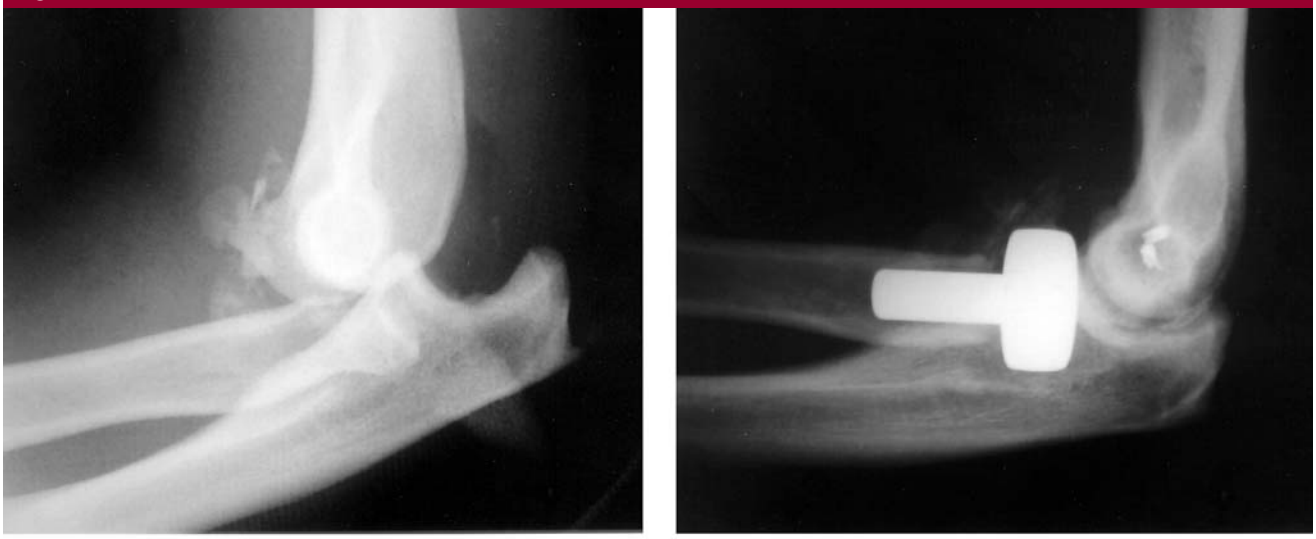
Radial head reconstruction or replacement is required in the setting of complex elbow instability because of its role as a secondary valgus stabilizer.[24,25] The radial head provides 30% of valgus stability. In the setting of an intact MCL complex, however, its removal results in no subluxation with valgus stress; subluxation occurs only with forced external rotation.[24,26-28] With intact ligaments and an absent radial head, removal of 30% of the coronoid fully destabilizes the elbow; stability is restored with metallic radial head replacement.[28]

Maintaining an intact or replaced radial head is much more important with deficiency of the MCL. With an intact radial head, release of the anterior portion of the MCL produces mild increased laxity; subluxation occurs only after subsequent excision of the radial head, emphasizing its role as a secondary stabilizer to valgus stress.[27] Silastic radial head replacement does not restore the valgus stability of the native radial head after MCL release.[26,29] Metallic radial head replacements, with either monoblock or bipolar radial heads, improve valgus stability that approaches but does not completely achieve that of the native radial head when associated with MCL insufficiency.[30] Thus, after a fracture-dislocation, internal fixation of radial head fractures may restore valgus stability better than replacement. However, caution is warranted when making this assumption because it is true only when the fixation construct is as strong as the native radial head.

For a time, silicone was the most widely available prosthesis, and clinical experience suggested that replacement with silicone yielded better results than did simple resection. A high failure rate (17% to 29%) has been reported, with breakage or silicone synovitis requiring revision after silicone head replacement.[31,32] Clinical series reporting the results of monoblock titanium[33] and Vitallium[34] replacements for comminuted radial head fracture indicate 68% good or excellent results at 3 years[33] and 71% pain relief with no residual instability at 4.5 years.[34] Isolated fractures, fracture-dislocations, and combined radial head and coronoid/olecranon fractures were reported in these series. Harrington et al[35] reviewed monoblock titanium radial head replacement in 20 patients who had fracture-dislocations with coronoid or olecranon fracture. At 12-year follow-up, 80% had good or excellent results; however, only 30% were completely pain free, and 45% had evidence of arthritis. Most recently, Ashwood et al[10] reported the results of 16 patients who underwent titanium monoblock radial head replacement and LCL repair for Mason type III fractures (Figure 2). At a mean of 2.8 years after injury, 81% had a good or excellent result. The authors emphasized the benefits of early (<2 weeks) surgical treatment followed by early motion with no period of splinting.[10] Because all series include heterogenous groups of injuries, it is difficult to make assumptions regarding the outcome of treatment of radial head fractures with associated dislocation.

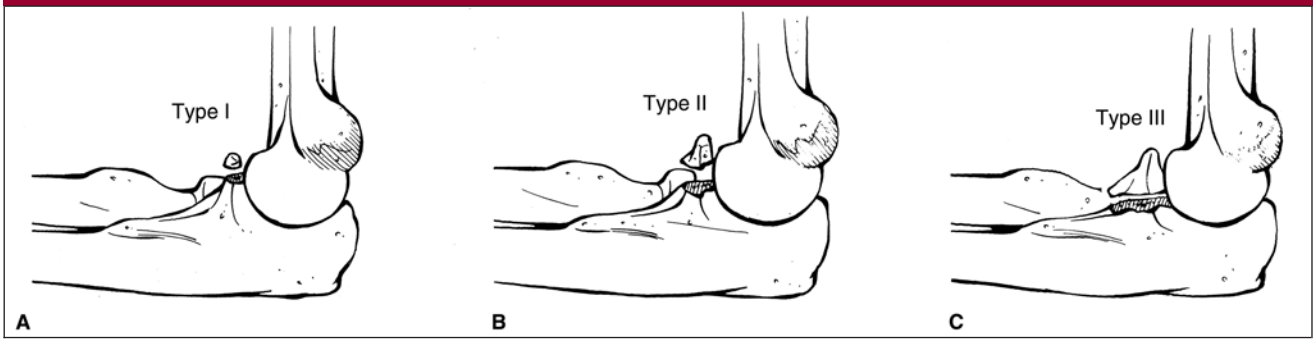
With radial head fracture in the setting of complex elbow instability, the head should be either fixed or re-

Figure 2



A, Preoperative lateral radiograph demonstrating posterolateral fracture-dislocation of the radial head. The anterior half of the radial head at the time of surgery was extremely comminuted into multiple fragments. **B,** Metallic radial head replacement and lateral collateral ligament reconstruction with suture anchors were performed. Emphasis was placed on appropriately sizing the radial head to ensure that the proximal aspect of the implant was at the level of the coronoid and the anchor for the ligament repair was in the center of the capitellum circumference.

Figure 3



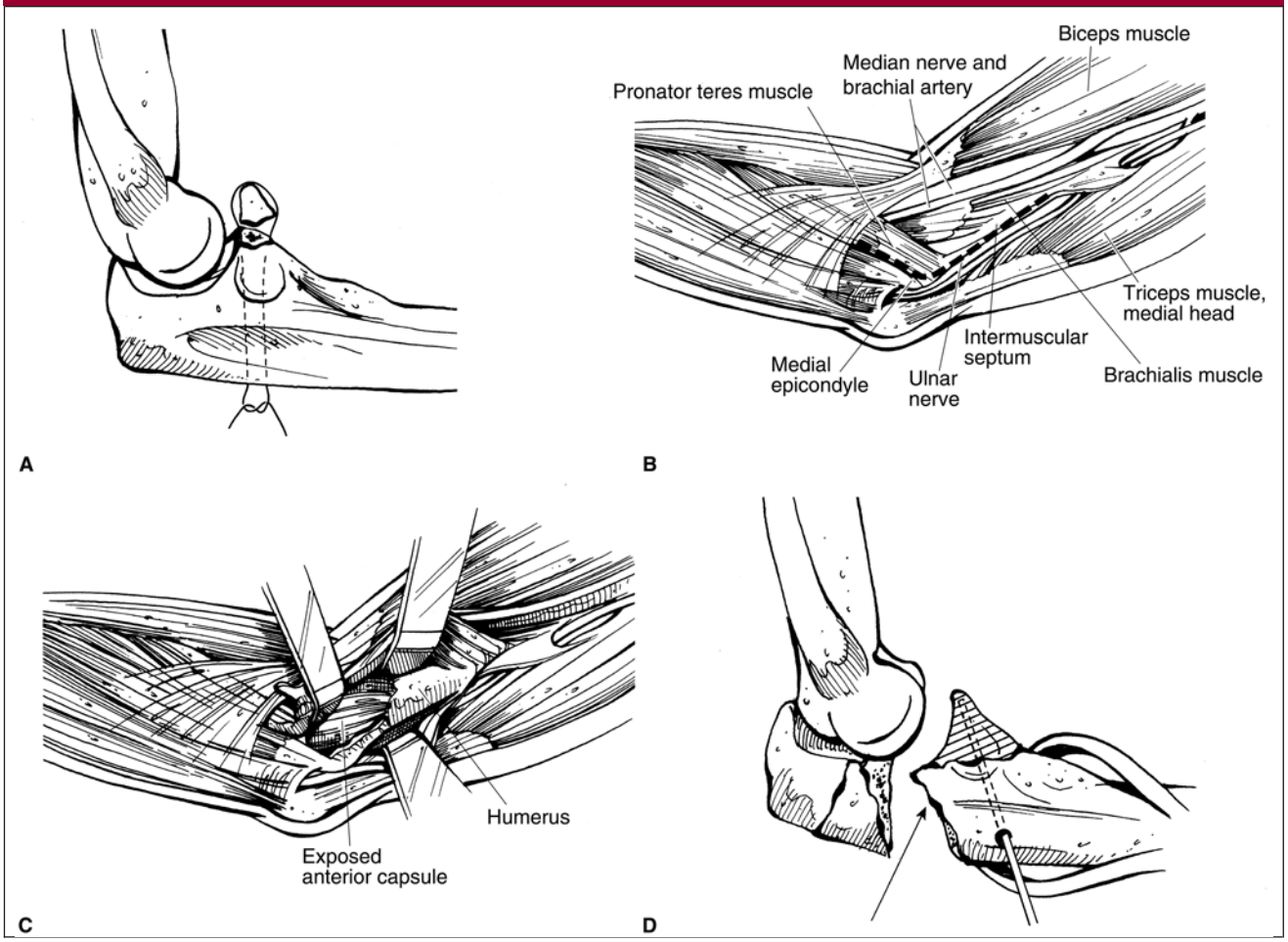
Regan-Morrey classification of fractures of the coronoid process. **A,** Type I is a simple avulsion. **B,** Type II demonstrates a single or comminuted portion involving approximately 50% of the coronoid process. **C,** Type III is a fracture involving >50% of the articulation. (Reproduced with permission from Cohen MS: Fractures of the coronoid process. *Hand Clin* 2004;20:443-453.)

placed with a metallic radial head implant. Analyzing the literature on fixation versus replacement in the setting of instability is difficult because most series include a mixture of radial head fractures with and without associated instability. For arthroplasty, modular metallic radial head implants have made implantation much easier because they provide the option of assembly in situ. For the surgeon, internal fixation requires confidence in performing this demanding procedure.

Coronoid Fracture

Very little has been written about managing fractures of the coronoid process. The results of management are difficult to infer because they are combined with other fractures in most reported series. Regan and Morrey[9] described a classification system of coronoid fractures based on the size of the fractured portion of the coronoid and noted that the rate of dislocation, failed results, and residual stiffness increased with the size of the coronoid fracture. They recommended fixation of fragments involving >50% of the process (Figure 3). Since then, several authors have recommended that, in the setting of in-

Figure 4



Coronoid fracture fixation techniques. **A,** Lasso repair, in which the suture is placed around a small coronoid piece and then passed through drill holes posteriorly in the ulna. **B,** Medial approach to the coronoid. **C,** The flexor/pronator is partially reflected just anterior to the flexor carpi ulnaris. **D,** Posterior reduction of the coronoid process through a proximal ulna fracture (arrow).

stability, most coronoid fractures be fixed independent of size.[15,36,37]

A large coronoid process fragment should be fixed with an anteromedial plate or with screws originating from the posterior border of the ulna. The anterior capsule with a small fragment should be repaired so as to reproduce an anterior buttress. Referred to as a Lasso repair, this technique requires whipping a stitch around the small fragment and the anterior capsule, passing the suture ends through drill holes in the ulna, and tying the sutures over the posterior ulna cortex (Figure 4). The fracture can be approached medially, reflecting a portion of the flexor-pronator mass distally after ulnar nerve isolation; laterally through a fractured radial head; or posteriorly through a fractured olecranon before olecranon or radial head repair.

Most recently, O'Driscoll et al[15] introduced a classification system of coronoid fractures based on anatomic location of the fracture fragments (Figure 5). Fractures are classified into those involving the tip (fracture line does not extend medially past the sublime tubercle or into the coronoid body), anteromedial fragment (fracture line exits the medial cortex in the anterior half of the sublime tubercle and laterally extends just medial to the tip of the coronoid), and base (involving the coronoid body with >50% of the height). Identifying the anteromedial fractures is a key element of this classification system. Despite the small size of these fractures and their often subtle radiographic presentation, they may predispose to rapid arthritis if left unreduced.[15]

Terrible Triad Injury

Dislocations with associated radial head and coronoid process fractures have been termed terrible triad injuries because they are difficult to

manage and result in poor outcomes secondary to recurrent acute instability, chronic instability, and arthritis.[38] Until very recently, limited data existed regarding management of these injuries. Most cases have been reported as part of large series of patients with a mixture of complex elbow injuries. Broberg and Morrey[3] reported on 5 of 24 adult patients with dislocations associated with fractures of the coronoid and radial head that were managed surgically with partial resection, complete resection, or Silastic implant arthroplasty of the radial head. No reference is made, however, as to how the coronoid fractures were repaired, if at all. All patients had good results based on the Mayo Performance Index, with mild pain at an average of 5 years.[3]

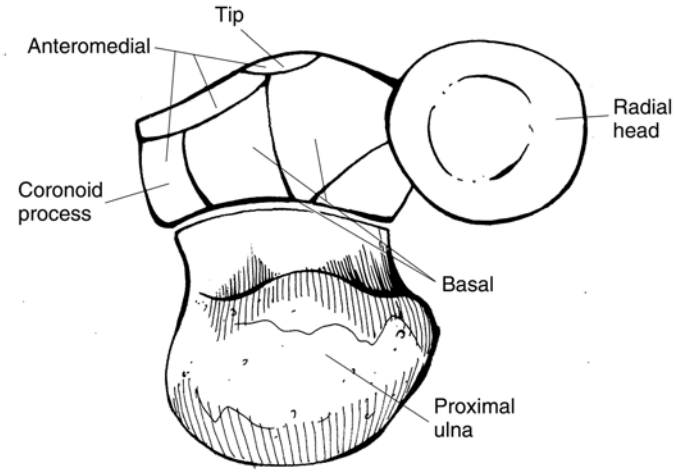
Josefsson et al[4] reported on radial head resection without ligament repair in eight patients with combined coronoid process and radial head fractures; 50% redislocated within 2 months. More recently, Ring et al[36] noted that satisfactory results were obtained only with retention of the radial head and repair of the lateral ulnar collateral ligament. Pugh et al[37] reported the most homogeneous series of patients treated with a standardized protocol, including radial head fixation or metallic head replacement, coronoid fracture fixation, and LCL complex repair. Thirty-four of 36 patients evaluated at an average of 3 years after injury had concentric stability, with 82% satisfactory results and an average flexion arc of 112°.[37]

Management of terrible triad injury requires fixation of the radial head fracture or metallic arthroplasty, fixation of the coronoid fracture (with Lasso repair of the anterior capsule, screw fixation, or an anteromedial plate fixation), and reconstruction of the LCL complex (Figure 4). The LCL is typically avulsed from the lateral condyle; the injury generally is not a mid-substance tear. Repair of the collateral ligament complex is performed by first finding the center of rotation, which is located at the center of the capitellar circumference on the lateral condyle, and then placing a bone tunnel or suture anchor at this position. A nonabsorbable suture is then used in a running locking stitch through the ligament to reattach it to the tunnel or anchor. The anconeus and extensor carpi ulnaris fascia are then repaired over the ligament as secondary stabilizers. Hinged external fixation may be required when instability persists.

Figure 5

O'Driscoll Coronoid Fracture Classification

Fracture	Subtype	Description
Tip	1	≤2 mm of coronoid height
	2	>2 mm of coronoid height
Anteromedial	1	Anteromedial rim
	2	Anteromedial rim and tip
	3	Anteromedial rim and sublime tubercle (± tip)
Basal	1	Coronoid body and base
	2	Transolecranon basal coronoid fracture



The O'Driscoll coronoid fracture classification system, including tip, anteromedial, and basal fractures. (Reproduced from O'Driscoll SW, Jupiter JB, Cohen MS, Ring D, McKee MD: Difficult elbow fractures: Pearls and pitfalls. *Instr Course Lect* 2003;52:112-134.)

Posterior Monteggia Lesion

Jupiter et al[39] described a variant of the posterior Monteggia fracture pattern, which included posterior dislocation of the radial head and a proximal ulna fracture with an anterior triangular fracture fragment at the level of the coronoid process. These injuries usually occurred secondary to low-energy falls in women in middle age and older. Radial head fracture and LCL complex disruption were common. Overall, the results were only good, and it was recognized that failure to adequately stabilize the coronoid fragment led to poor results.[39]

In a follow-up study, Ring et al[40] retrospectively reviewed the records of patients treated for Monteggia

Figure 6

Lateral **(A)** and anteroposterior **(B)** views of transolecranon fracture-dislocation of the elbow managed with open reduction and fixation of the olecranon. **C,** Long direct posterior plating of the ulna was performed. Because the lateral collateral ligament complex was intact, no ligament repair was required.

fractures during a 10-year period at Massachusetts General Hospital. Eighty-five percent of patients with posterior Monteggia fracture patterns had satisfactory results, even though all patients with unsatisfactory results had radial head fractures and 67% had coronoid process fractures.[40] Recognizing that the anterior coronoid fragment requires stable fixation is critical in achieving an optimal outcome.

Transolecranon Fracture-Dislocation

Transolecranon fracture-dislocation involves a comminuted proximal ulna/olecranon fracture with anterior subluxation or dislocation of the radiocapitellar joint, disruption of the ulnohumeral joint, and anterior displacement of the entire forearm with maintenance of the radioulnar relationship. Transolecranon fracture-dislocation differs from posterior Monteggia fracture in that the radius and ulna are both dislocated anteriorly and remain associated.[41] Transolecranon fracture-dislocation commonly results from a high-energy blow to the dorsal aspect of the forearm with the elbow in midflexion. Ring et al[41] reported on a series of 13 patients treated with open reduction and plate fixation of the ulna; 85% had good or excellent results at 2-year follow-up. This injury pattern is typically associated with large type III coronoid fractures, intact collateral ligaments, and a paucity of radial head fractures. Patients with these fractures have a better outcome than do those sustaining a traditional terrible triad injury.[41] Application of low-profile wrist fusion plates to the proximal ulna has led to excellent results[42] (Figure 6). Proximal ulna-specific internal fixation plates have recently been developed.

Fixation is obtained by posterior plating of the entire proximal ulna fracture. Medial or lateral plate placement does not allow adequate resistance to tension forces.[15] Indirect plating of comminuted proximal olecranon fractures with limited soft-tissue stripping and reduction of large coronoid fragments through the olecranon fracture may facilitate fixation. Temporary external fixation that provides distraction across the fracture zone may be useful in patients with severe comminution. Common errors include failure to recognize and adequately fix the coronoid fragment, which may require medial exposure and plate fixation with a second small plate.

Dynamic External Fixation

Complex elbow instability that persists despite surgical repair may be managed with external fixation. External fixators also can be used in the acute setting in which stability has been difficult to achieve. Both static and dynamic external fixators have a role in managing these difficult injuries. Static fixators are easy to apply, are more readily available, and may be used temporarily in the setting of persistent instability. Static fixators, however, do not allow elbow motion and have a limited life span because of pin site loosening.

Dynamic or hinged fixators are more complicated to apply, but they allow early elbow motion and controlled passive motion. Indications for external fixation include temporary stabilization of bony and ligamentous elbow injuries, persistent elbow instability despite ligamentous repair and bony fixation, fixation of the coronoid process with an unstable elbow, protection of comminuted radial head or capitellum fractures after fixation, and maintenance of elbow stability in the setting of comminuted coronoid fractures not amenable to internal fixation.[43] Hinged fixators also have a role in providing stability in chronic unreduced dislocation.[5]

Examples of hinged fixators include ring (Compass Universal Hinge, Smith & Nephew, Memphis, TN) and monolateral (Dynamic Joint Distractor, Howmedica Osteonics, Rutherford, NJ; Opti-ROM, EBI, Parsipanny, NJ) systems. The key point in applying a hinged fixator is placing the distal humeral axis pin. Application is often technically demanding. It can be performed with either a single- or double-pin technique, depending on the extent of surgical exposure and availability of surgical assistants. The axis pin is placed such that the pin exits laterally in the center of the capitellar circumference on the lateral condyle and medially just distal and anterior to the medial epicondyle. Once the axis pin is placed, the fixator is attached to the humerus and ulna, which, in the case of the Compass Universal Hinge, is done with one medial and one lateral humeral half-pin and two posterior half-pins along the posterior border of the ulna.

Several authors have reported satisfactory results using hinged fixators in the setting of persistent instability despite reconstruction of the bony and ligamentous structures.[6,13,44] McKee et al[6] reported the use of the Compass Universal Hinge in 16 patients who failed treatment that included open reduction, ligament reconstruction, internal fracture fixation (radial head, coronoid process, olecranon, capitellum, and trochlea), and radial head replacement. The average duration of hinged external fixation was 8 weeks. Only one patient had recurrent instability, requiring a transarticular pin to stabilize the elbow. The mean Mayo Elbow Performance Score (MEPS) was 84 points (range, 0 to 100), with 12 good or excellent results.[6]

Ruch and Triepel[13] retrospectively reviewed the results of eight patients treated with a monolateral hinged fixator for recurrent elbow instability. The patients had injuries to the MCL, LCL, radial head, olecranon, medial condyle, or coronoid process. Patients were treated with a fixator when complete bony or ligamentous repair could not be completed because of bone or soft-tissue loss or when treatment was delayed such that joint congruity could not be maintained after open reduction. At a mean follow-up of 1.5 years, the average elbow flexion-extension arc of motion was 97°, and the average Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire score was 21 points (range, 0 to 100, with <10 indicating greater success).[13]

Ring et al[44] reviewed a series of 13 patients treated for subluxation or dislocation of the elbow at least 1 month after elbow fracture-dislocation. Seven patients had a terrible triad injury, and six had a posterior Monteggia pattern injury. The average duration of hinged external fixation was 6 weeks. At an average 57-month follow-up, stability was restored in every patient, with an average MEPS of 84, DASH score of 15, and flexion arc of motion of 99°.[44] Hinged external fixation is a good treatment option for patients with severely comminuted fractures that limit coronoid fixation, or for patients in whom soft-tissue deficits preclude MCL repair. Hinged external fixation is also indicated for chronic instability after failure of bony and/or ligamentous repair.

Summary

The severity of elbow instability ranges from very simple to extremely complex. Disruption of several of the bony and soft-tissue elements that confer stability to the elbow may lead to recurrent instability. Management of complex instability is much more demanding than it is for simple dislocation, with a significantly increased chance of recurrent instability and arthritis. Radial head fractures should be repaired or replaced. Coronoid process fractures should be assessed based not only on their size but also in relation to displacement and the stability of the elbow joint. More complex injuries, such as terrible triad injuries, posterior Monteggia lesions, and transolecranon fracture-dislocations, are much less common. Fixation or replacement of all of the injured bony elements, repair of the LCL complex, and, potentially, hinged external fixation are standard treatment methods that may improve an otherwise poor prognosis and produce satisfactory results in most patients.

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Evidence-based Medicine: Level III and IV case-controlled series, along with Level V expert opinion, are repeated. There are no Level I or II prospective cohort studies.

Citation numbers printed in **bold type** indicate references published within the past 5 years.

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