Management of terrible triad injuries of the elbow has improved in the last 2 decades based on an understanding of injury patterns, fracture morphology, and management pitfalls. But some intimidation with these injuries remains, in part because some of the surgical techniques are challenging and because there is still debate about certain steps in surgery and choices in management. This article highlights important aspects of the care of terrible triad injuries to clarify the anatomy and pathophysiology, to highlight pitfalls of treatment, and to point out areas that might benefit from innovation.

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Introduction

The combination of an elbow dislocation, a coronoid fracture, and a fracture of the radial head has been termed the “terrible triad” of the elbow because it is associated with recurrent or persistent subluxation and dislocation. In the past 2 decades, the terrible triad has been managed somewhat based on an understanding of injury patterns, fracture morphology, and management pitfalls. However, difficulties remain. There is trepidation and intimidation with these injuries, in part because some of the surgical techniques are still challenging (eg, repair of a fracture of the coronoid or radial head) and in part from debate and about certain steps in surgery and choices in management. This article aims to highlight important aspects of the care of terrible triad injuries elucidated in recent years, to clarify the anatomy and pathophysiology, and to highlight pitfalls of treatment, as well as areas of debate and areas that might benefit from innovation.

Initial Management

A dislocated elbow should be reduced in the Emergency Department, but many of these injuries are unstable without surgery and reduction can be difficult to maintain (Fig. 1). In these cases, repeat reduction is not helpful, and the elbow can be left dislocated while surgery is planned.

Imaging

A computed tomography (CT) scan, particularly a 3-dimensional (3D) reconstruction if available, can be helpful in planning the management of the coronoid and radial head fractures. Three-dimensional reconstructions can be made using software in radiology departments or using freeware (eg, OsiriX). The unfractured bones can be digitally subtracted from the images to improve fracture visualization. In our opinion, a 3D view is more intuitive, easier to interpret, and reflective of what the surgeon would find in the operating room, thereby reducing surprises.

Are CT scans necessary for effective treatment? An experienced surgeon would anticipate that the coronoid fracture...
would be transverse and have the capsule attached and that the radial head fracture, even if only part of the head, is often complex and difficult to reconstruct. Surgeons who are prepared to suture and replace a coronoid fracture, replace a radial head, reattach the lateral soft tissues to the lateral epicondyle, and address residual instability with cross-pinning or external fixation do not need CT scans. In our opinion, patients treated for terrible triad fracture-dislocations in low-resource care environments can be treated using standard radiographs alone, the radial head can be replaced with a prosthesis made of methacrylate cement, the lateral soft tissues and coronoid can be repaired with sutures, and persistent instability can be treated using cross-pinning, with comparable or equivalent efficacy to more costly techniques. Nevertheless, visualizing the injury with a 3D CT scan, if available and cost-effective, helps plan the surgery and execute it in one’s mind in a way that might make the surgery easier and more effective.

**Pathoanatomy**

Dislocation of the elbow typically causes complete capsuloligamentous injury and a variable degree of avulsion of the common flexor and extensor muscles from the epicondyles.\(^1\) The coronoid fracture is typically a single transverse fragment that includes the insertion of the anterior capsule and averages 30% of the total height of the coronoid process (Fig. 2).\(^8\) The radial head can involve the anterolateral or the entire radial head and is typically unstable, displaced, and fragmented. Although each individual component of the terrible triad injury can affect elbow function and stability, in combination, there is a risk of severe posterolateral rotatory instability.

**Lateral Collateral Ligament (LCL) Complex**

LCL complex is usually avulsed from the lateral epicondyle, often with a substantial portion of the common extensor muscle origin, leaving the epicondyle bare.\(^9\) This is not always apparent before surgery (Fig. 3A). When the muscle fascia is incised, it becomes apparent (Fig. 3B).

Preoperatively, there may be clues to this disruption. On physical examination, the elbow often feels grossly unstable not only to posterolateral rotatory stress but to simple varus and valgus stresses. There is often a ballotable hematoma or effusion that extends right to the skin over the lateral epicondyle. Gently palpating the lateral epicondyle, one may feel bare bone through skin. Often this is accompanied by...
bruising that begins at the epicondyle and streaks distally along the line of the deep rents in the extensor muscle fascia.

Coronoid Fracture
Using 3D CT images, Doornberg et al found that the average height of the coronoid fracture fragment in a terrible triad injury was 39% of the total height, ranging from 19%-59%, numbers that do not include the cartilage tip of the fragment. In other words, these fragments, although small, are larger than one might think. It is not clear whether smaller coronoid fractures contribute to instability via loss of bony buttress (biomechanical studies would suggest not), loss of anterior capsule, or both, or whether the coronoid fracture is a marker for a more severe soft tissue injury than typical of other fracture-dislocations. The fragment always includes the anterior capsular insertion, which is 4-5 mm distal to the tip of the olecranon.

Treatment
The goal of treatment is to keep the ulnohumeral joint concentrically reduced for the 3-4 weeks that the collateral ligaments need to heal, while limiting injury (eg, restriction of forearm rotation from radial head malunion) and treatment-related complications.

Nonoperative Treatment
A small subset of terrible triad injuries, with small coronoid and radial head fractures that remain concentrically reduced in patients who can avoid shoulder abduction and flex their elbow actively with confidence, can be treated effectively without surgery (Fig. 4). The patients we have treated nonoperatively were seen a few days or a week after injury and were either out of the splint moving well or were very motivated to avoid surgery.

Operative Treatment
The general operative strategy is to work primarily on the lateral side of the elbow to expose and define the injury, component by component, chronologically from the “outside” to the “inside”—LCL or common extensors, then radial head fracture, and then coronoid fracture—and then stabilize these components sequentially in the reverse order from “inside” to the “outside.” First, consideration is given to repairing the fractured coronoid; then the radial head is replaced or repaired; and finally, the origins of the LCL and common extensor musculature are reattached to the lateral epicondyle.

Positioning
We usually position the patient with the arm on a hand table. The surgeon can rotate the shoulder and work on alternate sides of the hand table to expose the lateral and medial aspects of the elbow. This provides easy access for a small image intensifier with the arc oriented parallel with the floor. We prefer to use a sterile tourniquet.

Figure 3 (A) After elevation of a lateral flap, there is no clear rent in the fascia. (B) When the fascia is incised, it becomes apparent that the origin of the lateral collateral ligament and common extensors is avulsed from the lateral epicondyle. (Color version of figure is available online.)

Figure 4 A lateral radiograph 3 months after injury in a patient with a terrible triad injury treated nonoperatively.
Exposure
A direct posterior skin incision with a lateral skin flap raised to provide access to the muscle interval where most of the work is done also provides access posteriorly to pass sutures for the coronoid. A medial flap can be elevated if the ulnar nerve or medial collateral ligament complex is addressed. Starting with a midline posterior incision has few drawbacks and leaves the most flexibility for subsequent surgery if needed. Alternatively, separate lateral, posterior, and medial skin incisions can be used for each interval, perhaps limiting hematoma or fluid collection and overall dissection.

Several muscle intervals are described for access to the radial head, the capitellum, the lateral collateral ligaments, and the common extensor origin, as well as to the lateral aspect of the coronoid. We find that an “available interval approach” is the most common and practical way to expose this injury. The damage to ligaments, muscle, and tendon associated with fracture-dislocations of the elbow often present the surgeon with a convenient window of disrupted structures. After raising skin flaps, we look for a hole in the fascia with joint fluid and blood leaking out. Sometimes this takes a little poking with small blunt-tip scissors in areas that look injured. This fascial rent is typically roughly in the interval between the extensor carpi radialis brevis and the extensor digitorum. If there is no rent and this interval is not apparent, one can start by elevating the origin of the extensor carpi radialis longus (ECRL) from the supracondylar ridge of the distal humerus—a distinct and reliable anatomical landmark. Working distally down the anterior part of the distal humerus, one eventually encounters the capitellum. The common extensor muscles are split at the 50:50 anterior-posterior divide point of the capitellum. As the LCL origin and the common extensor muscles are often avulsed from the lateral epicondyle, there is typically very good exposure once the ECRL origin has been elevated and the common extensor muscles split. Sometimes it can help to split the supinator a bit distally.

The Radial Head Fracture
The fracture of the radial head provides exposure to the coronoid. Even a partial articular fracture usually provides enough exposure. The fragments are usually displaced and unstable with little or no soft tissue attachment and can be moved out of the way or extracted and set aside even if the plan is to attempt internal fixation.

How hard should you work to repair it rather than replacing it with a prosthesis? One consideration is how easily reconstructible it is. Although the surgeon’s natural bias is to preserve a patient’s own anatomy when possible, a prosthesis can readily restore elbow stability and avoids some of the problems associated with internal fixation such as early failure, nonunion, and restriction of forearm rotation.

One- or 2-part partial articular fractures and fractures that separate the entire head in 1 piece with a clean break are generally amenable to repair. We prefer to replace the head when we judge that struggling to reconstruct the radial head would either greatly extend the length of the operation, when the resulting construct would be too delicate to withstand early motion, or when the complexity and deformity portend a poor prognosis for union or forearm rotation. In series of limited size, some authors have found short-term results to be similar whether the radial head is replaced or repaired. When placing a plate on the radial head and neck, it is important to avoid placing implants where they will interfere with the proximal radioulnar joint.

Though long-term results of radial head replacement are difficult to interpret, we have come to conceptualize these implants in a very different way than we think of implants used for total joint arthroplasty. When replacing the radial head, we prefer a simple monoblock implant with an intentionally loose smooth stem. Other designs include a fixed monoblock or bipolar prostheses, some of which attempt to be more anatomical. However, we believe that in the setting of fracture-dislocation, the function of the prosthesis is best seen as a spacer that improves stability of the elbow in the short term rather than a long-term anatomical replacement of the radial head. When resources are limited, a prosthesis can be made out of methacrylate cement and a K-wire or screw. Others would argue that a loose prosthesis can cause pain (which present data contradict) and that a fixed anatomical prosthesis helps protect the ulnohumeral joint (a concept that would be difficult to prove).
It is important not to overstuff the joint with an overly long radial head implant. This can cause subluxation of the elbow, capitellar erosions, and limited flexion (Fig. 5). A useful guide is that the reconstructed articular surface should end up no more than 1 mm proud of the corner of the lesser sigmoid notch or that the center of dish of the radial head is even with this point.

The Coronoid Fracture

There is some debate about the importance of repairing very small coronoid fractures. Some biomechanical studies have suggested that when the coronoid fragment is small enough, then functional stability can be restored with radial head replacement and LCL repair alone. We advocate routine repair of the coronoid fracture, particularly if a surgeon does not frequently operate on complex elbow trauma. We are concerned that human nature is to try to do less, particularly in an unfamiliar situation. The bad consequences of leaving an elbow unstable after surgery are clear, repairing the coronoid provides noticeable increases in stability, and we cannot predict which elbows would be unstable without repairing the coronoid (Fig. 6). Given these factors and because we work from inside out and would need to take down the LCL and radial head repairs to address the coronoid if the elbow remained unstable, we routinely fix it.

The transverse tip fractures of the coronoid that are typically associated with a terrible triad injury can be addressed through the lateral exposure. Exposure to the coronoid is improved by displacing or removing fragments of the fractured radial head and by releasing the origin of the ECRL from the supracondylar ridge of the distal humerus. Once this exposure has been performed, it is safe to place retractor anterior to the distal humerus, but placement anterior to the radial head and neck should be avoided.

We rely on suture repair for the vast majority of the small transverse coronoid fractures associated with elbow fracture-dislocations. Sutures passed through drill holes in the proximal ulnar metaphysis and coronoid base are passed through the anterior capsular attachments to the coronoid. A drill guide, such as the guide used to drill the tibial tunnel in anterior cruciate ligament reconstruction, can facilitate accurate placement of the tunnels for suture passage. For relatively large coronoid fracture fragments, the sutures can be passed through drill holes in the coronoid fracture fragment. Confirm reduction of the fracture with tensioning of the suture. The alignment of the coronoid does not have to be perfect as long as it renders the elbow stable. The anatomical attachment point for the anterior capsule is on the anterior surface of the coronoid, not at the very tip. Crossing the tunnels through the proximal ulna and coronoid base can make it easier to keep from skiving off the angled bone of the proximal ulna diaphyseal-metaphyseal junction and make it easier to stay within the bone. If possible, place the drill holes slightly off the very ridge of the ulna to avoid prominence of the suture knot. The suture ends are retrieved dorsally and tied after all of the injuries have been addressed.

The LCL complex

The LCL usually avulses from its attachment point on the lateral epicondyle at the isometric point of rotation at the capitellum, distal and anterior to the nubbin of the apophysis on the epicondyle. The LCL may be repaired either with a bone anchor or through transosseous drill holes, tying the suture posterior to the lateral ridge of humerus.

Finally, reduce the ulnohumeral and radiocapitellar joints and tension and tie the coronoid and LCL sutures. Cycle the elbow through an arc of flexion and extension with gentle tension on the sutures to remove slackness before tying them. One of us likes to leave the tails long enough to pass under

Figure 6 It is difficult to predict whether coronoid repair is necessary to stabilize each given fracture. It is therefore our practice to repair every one. (A) Lateral radiograph after radial head prosthetic replacement and repair of the coronoid fracture. (B) Lateral radiograph after fixation of the radial head and reattachment of the lateral collateral ligament to the lateral epicondyle. The surgeon thought the coronoid was too small to repair.

Figure 7 Test elbow stability in full gravity extension. (Color version of figure is available online.)
Dislocations of the elbow

What if the Elbow Still Dislocates?

With repair of the coronoid, repair or replacement of the radial head, and reattachment of the origin of the lateral collateral ligament complex to the lateral epicondyle, the elbow is usually stable and repair of the medial collateral ligament is generally not necessary. But if the elbow dislocates or markedly subluxates even after these structures are repaired, medial instability may be the cause. Test the final stability by placing the elbow in full gravity extension with the forearm in neutral and checking a lateral image (Fig. 7). If a clunk or reduction from this position occurs or if there is subluxation or dislocation seen on the image, additional treatments can be considered. Options include reattaching the origin of the medial collateral ligament and the common flexor muscles to the medial epicondyle or stabilizing the elbow with a temporary external fixator (hinged or static) or by temporarily cross-pinning the elbow joint.

Slight subluxation or sagging of the joint in the early postoperative period is analogous to pseudosubluxation of the shoulder and can usually be addressed with active flexion exercises and the avoidance of shoulder abduction (Fig. 8).

Recovery

It takes a year to recover from this injury. Initially, patients are encouraged to make a tight fist repeatedly and to use their hand for light functional tasks to avoid stiffness and resolve edema and ecchymosis. When patients are ready (could be the next day, but within a week or 2 is fine), they are instructed in active, self-assisted stretches of the forearm and the elbow. Readiness can be judged by confidence and success doing finger exercises.

Patients often ask, “Will I need therapy?” In fact, this can occur at the first office visit and before surgery. This often reflects a passive attitude toward recovery (ie, who is going to fix my arm). Patients may feel detached from a painful limb. They may hold the arm as if they carried it in, as if it is not theirs. They need to understand that recovery is their job—they need to take an active role. We instruct patients who ask if they would need therapy that they would need to do lots of exercises to stretch their elbow and regain motion. A therapist can be a good coach and companion, but a therapist can also reinforce passivity, vulnerability (by pushing on the patient), and catastrophic thinking (by saying things like “work to pain but not beyond … pain creates inflammation”). We let patients decide how much coaching they desire. Given the choice and clear instruction on the exercises we find that most patients are happy to work on their own.

Most patients regain full finger motion within a week and full forearm rotation within 2 months (if there is no heterotopic bone or implants in the way), but elbow flexion and extension can improve for more than a year. Patients who are slow to regain motion should be evaluated for ulnar neuropathy, heterotopic ossification, subluxation, malunion, and errant implants. If the stiffness is entirely due to capsular contracture, then their slow progress is usually owing to overprotection. Stretching can be counterintuitive when one is in pain and recovering from injury. It is natural to feel protective and prepare for the worst when in pain. It may feel like the healing or repair would come undone. It can be difficult to understand that these are healthy stretches and working out the tightness is necessary to an optimal recovery. This is not something one can talk another into. Patience is important because patients usually figure out for themselves, usually as they begin to do things with the arm that are meaningful to them, realize that the arm would be useful, and begin to get past the sense that the arm would never be dependable.

Patients can start handling increasing amounts of weight 1 month after surgery. By 3 months, there is sufficient healing for all activities. We never use braces. A sling for comfort is discarded as comfort allows.

References