The treatment of terrible triad injuries of the elbow continues to evolve. Radial head fixation and arthroplasty, coronoid process fixation, and repair of the lateral collateral ligament continue to be the mainstays of treatment. In the elbow with persistent instability after repair of these elements, application of a static external fixation, hinged external fixation, ulnohumeral joint pinning, or an internal hinge may be needed. In patients who undergo treatment after the acute injury period, the coronoid may require reconstruction using radial head autograft, iliac crest autograft, olecranon autograft, or allograft. (J Hand Surg Am. 2015;40(11):2297–2303. Copyright © 2015 by the American Society for Surgery of the Hand. All rights reserved.)

Key words Terrible, triad, elbow, fracture, instability.

THE TERRIBLE TRIAD OF THE ELBOW is posterior or posterolateral dislocation of the ulnohumeral joint with fractures of the radial head and coronoid process. The origins of the medial collateral ligament (MCL) and lateral collateral ligament (LCL) complexes avulse from the epicondyles and the anterior capsule fails with a transverse fracture of the coronoid tip.

The treatment of terrible triad injuries has evolved over the last decade. There is a consensus that the radial head injury and the LCL injury should be addressed, but there are differing opinions as to whether the radial head should be repaired or replaced, when the coronoid fracture should be addressed, or if the MCL requires repair. In addition, there has been an evolution in the late treatment of terrible triad injuries. This current concepts article focuses on these 2 areas of development.

CLINICAL PICTURE
In general, terrible triad injuries are the result of a fall onto an outstretched hand. It is postulated that there is a posterolateral load upon the elbow during the fall, which results in tension failure of the LCL and the MCL, and a compressive load that fractures the radial head. Some circumstantial evidence supports this concept.

Patients generally present with pain, swelling, and limited range of motion of the elbow. Patients may or may not describe a subluxation or dislocation event. Although neurovascular injuries are uncommon after this injury, ulnar neuropathy and radial nerve palsy have been described after surgical treatment of these injuries.

DIAGNOSIS
Radiographs of terrible triad injuries can be deceptive. In some cases, the elbow is reduced and there are small fragments of bone anterior to the ulnohumeral joint on a lateral radiograph and a radial head/neck fracture is noted on the anteroposterior view. The small triangular anterior fragment is a piece of the fractured coronoid tip and is a sign that a more substantial injury has occurred. Computed tomography scans are helpful for preoperative planning, especially for understanding the complexity of the radial head/neck fracture and the size of the coronoid fracture.

TREATMENT AND OUTCOMES
Upon presentation, if the ulnohumeral joint is dislocated, it should be reduced. In cases in which the elbow is unstable and re-dislocates easily, surgery is
recommended to maintain a congruent elbow joint. In cases in which the elbow joint stays grossly congruent after reduction, operative intervention can maximize elbow function and prevent residual instability. Patients with a stable elbow after reduction may be considered for nonsurgical treatment, but stability and final elbow function after nonsurgical treatment may not be predictable. The residual instability results because the malunited radial head does not provide an adequate buttress to the elbow; subsequently, the soft tissues heal at a different length.

**Radial head repair versus arthroplasty**

For terrible triad injuries, repair or replacement of the radial head helps prevent re-dislocation by restoring radiocapitellar contact. Radial head fracture fixation versus replacement is dictated in part by the number and character of the fracture fragments. Fixation of radial head fractures with more than 3 parts (shaft and 2 articular fragments) is prone to early failure of fixation, nonunion, and limited forearm rotation when the fracture heals.

If secure and stable fixation of the radial head cannot be achieved, the radial head should be replaced with a prosthesis. This determination is a matter of judgment. There is variation of opinion among surgeons in determining how many fracture fragments are present when utilizing 3-dimensional computed tomography scan and even after operative visualization of the fracture. Although surgeons often dread discarding intact radial head in the setting of partial articular fractures, some partial radial head fractures have small fragments and comminution at the fracture margin that can difficult to repair. In addition, partial articular fractures tend to involve the anterolateral part of the radial head that is critical to elbow stability. Failure of radial head fixation within days risks subluxation or dislocation of the elbow. If the fixation is adequate for 3 to 4 weeks, the repaired radial head may serve as a biological spacer that can be excised later if it becomes symptomatic.

Watters et al compared 39 patients with terrible triad injuries who were treated with either open reduction internal fixation (ORIF) of the radial head or radial head arthroplasty. Three of 9 patients who underwent ORIF had instability of the elbow 18 months after surgery compared with 1 of 30 patients who had radial head arthroplasty. In a retrospective comparison, Leigh and Ball found that patients with terrible triad injuries who underwent radial head arthroplasty had slightly, but significantly, higher average Disabilities of the Arm, Shoulder, and Hand scores indicating more disability than patients who underwent ORIF (10.3 vs 9.2), a difference unlikely to be clinically meaningful and possibly due to selection bias.

Fixed monopolar, fixed bipolar, and loose smooth monopolar spacer prosthetic radial head designs are available. There are some biomechanical data suggesting that bipolar arthroplasty provides less ulnohumeral stability than the other designs. In the native radial head or monopolar arthroplasty, as the radius begins to displace posteriorly with respect to the capitellum, there is an increased resistance to posterior ulnohumeral subluxation; however, in bipolar arthroplasties, posterior displacement of the radius is associated with decreased resistance to ulnohumeral subluxation. Bipolar arthroplasties are associated with osteolysis around the stem. Monopolar spacer arthroplasties with an unfixed stem are associated with radial neck lucency and capitellar changes, although these radiographic findings do not correlate with symptoms. Fixed monopolar arthroplasties are associated with stress shielding around the radial neck of well-fixed stems, although—again—these findings are not associated with symptoms.

When resources are limited, a loose monoblock prosthesis can be fashioned from methylmethacrylate cement. Sometimes, a screw is used to help make the neck of the prosthesis. Cement is inexpensive and a cement spacer helps stabilize the elbow as well as a metal spacer.

The major issue with all radial head arthroplasty designs is a prosthesis that is too long: so-called “overstuffing” of the radiocapitellar joint. A prosthesis that is too long can be painful. The abnormal length increases radiocapitellar joint pressures, erosion of the capitellum, subluxation of the ulnohumeral joint, and loss of elbow flexion. Doornberg et al have suggested that the lateral edge of the coronoid is a useful reference point for sizing of the radial head, and in general, the prosthesis should not lie more than 1 mm proximal to this landmark. Rowland and colleagues found that a lateral portion of ulnohumeral joint space that is not parallel on anteroposterior postoperative radiographs was not a good indicator of overstuffing. A nonparallel medial joint space was a better indicator of overstuffing, but imperfect. It seems that overstuffing of the radial head may not be radiographically apparent until over-lengthening is greater than 6 mm.

**Coronoid fixation**

*Relevant biomechanics:* Studies of the *in vitro* effect of combined injuries to the elbow on rotatory stress and the influence of repair or reconstruction of specific injury
Components on elbow stability support the following concepts:

1. Medial collateral ligament repair may be able to compensate for small coronoid deficiency. Beingessner et al.\textsuperscript{16} evaluated Regan and Morrey type I coronoid fractures (small fractures of the tip) and MCL insufficiency in an elbow with a prosthetic radial head and a competent LCL. In cadavers, repair of a small coronoid fracture did not improve kinematics during valgus gravity loading, and the authors concluded that MCL repair was a better option for adding more stability than repairing a small coronoid fracture in the treatment of terrible triad injuries.

In a varus posteromedial rotatory instability model, Pollock et al.\textsuperscript{17} evaluated subtypes of anteromedial coronoid facet fractures exposed to varus and valgus stress. Some anteromedial facet fractures involve the coronoid tip; with loss of 5 mm of the tip and the medial rim of the coronoid, repair of the LCL could not restore elbow stability when exposed to valgus stress. These data might apply to terrible triad injuries in that coronoid tip injuries greater than 5 mm in size with a repaired or restored radial head and repaired MCL and LCL complexes may not be stable to valgus forces, whereas fractures less than 5 mm could potentially be managed by repair of both the MCL and LCL \textit{in lieu} of coronoid fixation.

2. There may be a threshold coronoid deficiency that results in instability that cannot be compensated by radial head arthroplasty and collateral ligament repair alone. Schneeberger et al.\textsuperscript{18} evaluated posterolateral rotatory instability resulting from isolated or combined injuries of the radial head or coronoid. Removal of the radial head in the setting of intact collateral ligaments resulted in posterolateral laxity. If 30\% of the coronoid was then excised, the elbow dislocated consistently at 60° of elbow flexion, but stability could be restored with implantation of a radial head prosthesis. However, if 50\% of the coronoid was excised, radial head replacement did not prevent dislocation. When the coronoid was repaired and the radial head was replaced, the elbow did not dislocate. Fern et al have also found that, with loss of 75\% of the coronoid, LCL repair and radial head arthroplasty without repair of the coronoid do not restore valgus stability.\textsuperscript{19}

\textbf{Types of coronoid fixation:} Fixation of the coronoid tip fracture helps stabilize the elbow and prevent its subluxation or dislocation. But the fixation technique is unfamiliar to some and difficult to perform and the need for routine repair of the coronoid fracture is debated. Papatheodorou et al.\textsuperscript{20} reported on a series of 14 terrible triad injuries treated without coronoid repair. No patients had residual instability, the mean Disabilities of the Arm, Shoulder, and Hand score was 14 (range, 0–38), and the mean Broberg-Morrey Score was 90 (range, 70–100), which is considered an excellent result.

Conversely, this injury pattern acquired its name from a predisposition for subluxation and dislocation after operative treatment, and fixation of the coronoid may enhance elbow stability and helps minimize these problems.\textsuperscript{21,22} It is not currently possible to predict which terrible triad injuries will be problematic. Furthermore, the repair sequence should be from inside out: coronoid, radial head, and LCL complex. If the latter 2 alone prove inadequate, then either the repairs need to be taken down to get at the coronoid, a separate medial exposure will be needed to address either the MCL or the coronoid fragment, or the elbow will have to be immobilized with a fixator or cross pins. Based on this rationale, we and others routinely repair the coronoid tip fracture.\textsuperscript{21–23}

A number of techniques have been described for coronoid fixation ranging from transosseous suture fixation (the so-called “lasso” technique), suture anchor fixation, and screw fixation. Garrigues et al.\textsuperscript{24} compared these 3 techniques and found that transosseous suture fixation had the lowest incidence of subluxation or dislocation of the elbow among patients evaluated an average of 18 months after surgery. Three of 5 patients treated with screw fixation of the coronoid had implant failure and the other 2 patients had nonunion.

In situations in which there is a partial articular fracture of the radial head, arthroscopic repair of the coronoid may be reasonable as lateral access to the coronoid is limited. Hausman et al.\textsuperscript{25} and Adams et al.\textsuperscript{26} have described arthroscopic coronoid repair using screws, Steinmann pins, or suture fixation looped around the ulna. These techniques are still under development, but there is some hope that they may help patients in these situations avoid a medial incision for coronoid repair and allow for earlier recovery (Figs. 1–5).

\textbf{Ligament repair} There is consensus that the LCL origin should be reattached to the lateral epicondyly in all elbow injuries; however, there continues to be some debate as to whether or not the MCL should be reattached to the medial epicondyle. Forthman et al.\textsuperscript{23} describe 22 patients with terrible triad injuries successfully treated.
with coronoid fixation, radial head repair or replacement, LCL reattachment, but no MCL repair. Pugh et al\textsuperscript{22} described an algorithm used in 34 patients in which the MCL was repaired if there was residual instability after addressing the coronoid, radial head, and lateral collateral ligament. Instability was defined as posterior or posterolateral subluxation when the elbow was moved through a range of 20° to 130° of extension and flexion with the forearm in neutral rotation. Six patients had MCL repair and, of those 6, 2 had external fixation as well. In the series by Papa-theodorou et al,\textsuperscript{20} the coronoid was not repaired and no attempt was made to repair the MCL or apply any adjunctive fixation.

**Persistent subluxation or dislocation**

In patients with persistent subluxation or dislocation after repairs, adjunct fixation is recommended. During surgery, once the injured structures are repaired, the elbow is supported at the upper arm to allow gravity extension of the elbow with the forearm in neutral. Subluxation in this position merits consideration of additional treatment: either reattachment of the MCL to the epicondyle, hinged external fixation, static external fixation, ulnohumeral joint pinning, or—experimentally—an internal hinge mechanism. The complications of external fixation—including pin breakage, pin infection, and radial nerve injury—limit its appeal. Concerns about pin breakage, joint infection, and joint damage limit the appeal of cross-pinning. The incidence of complications is higher when external fixation is used than when ulnohumeral joint pinning is used.\textsuperscript{27}

Orbay and Mijares\textsuperscript{28} described using a temporary Steinmann pin bent and placed through the axis of the ulnohumeral joint then attached to the proximal ulna as an internal hinge device to treat persistent instability of the elbow. An average of 14 months after surgery, all 10 patients treated with this technique did not have subluxation or dislocation. Some might consider this technique an alternative to repair of the coronoid process, but additional research is needed.

**COMPLICATIONS**

Complications of terrible triad surgical treatment include heterotopic ossification, stiffness, nerve injury, and recurrent subluxation or dislocation of the elbow. Because case series are relatively small, it is difficult to estimate the incidence of complications. The most

![FIGURE 1: Radiographs of a 40-year-old man who fell while skiing and sustained a terrible triad injury with coronoid fracture and partial articular radial head fracture. Arrow 1 points to the coronoid fragment and arrow 2 points to the marginal radial head fracture. A Lateral radiograph. B Anteroposterior radiograph.](image1)

![FIGURE 2: Computed tomography of the same patient demonstrates coronoid fracture.](image2)
challenging of these problems is recurrent subluxation or dislocation.

In patients who are treated longer than 2 weeks after injury, standard repairs are often insufficient to limit the risk of recurrent dislocation or subluxation. As time elapses, there can be soft tissue changes or bony erosion that further limit stability. Patients who undergo treatment before 6 weeks have better functional scores than those patients who undergo treatment after 6 weeks.29

The approach to treatment uses similar principles as in the acute terrible triad injury; however, the main

**FIGURE 3:** Arthroscopy-assisted coronoid fixation using cannulated screws and a suture passed through the screws to secure the coronoid fragment. **A** The base of the fracture has been prepared, and an external aiming guide is visible in anticipation of guidewire placement. **B** Threaded guidewires have been passed into the fracture base. **C** The coronoid fragment is reduced, and the guidewires are advanced. **D** After placement of cannulated screws over the guidewire, a nonresorbable suture has been passed through the cannulated screws for additional fixation. After the coronoid was repaired, an open incision was made to repair the partial articular radial head fracture and the lateral collateral ligament.

**FIGURE 4:** Postoperative radiographs demonstrate this joint congruency. **A** Lateral radiograph. **B** Anteroposterior radiograph.
difference is reconstruction rather than repair of the coronoid. In patients in whom the distal humerus is subluxated over the coronoid base, there may be impaction or loss of bone, making simple repair of the coronoid insufficient. In these cases, coronoid reconstruction with bone graft can be considered. Radial head is a preferred graft option if available, but in revision cases, radial head may not be available to be used for repair. Papandrea et al have reported a series of 9 bone allografts, but noted that many allografts undergo resorption on radiographic follow-up. Olecranon autograft has also been described as a graft by Moritomo et al. The harvested autograft should be less than 50% of the olecranon, and caution should be exercised not to disrupt the triceps tendon attachment.

In all late reconstructions of terrible triad injuries, it is almost universally recommended that adjunct fixation using a static external fixator, hinged external fixator, joint pinning, or internal hinge mechanism should be utilized.

DISCUSSION

Our understanding of terrible triad injuries is incomplete. Further biomechanical studies may be helpful in elucidating the relationship between the MCL and the coronoid in providing stability to the elbow. Future studies of in vitro varus loading of the elbow after terrible triad repair may refine our understanding of how to rehabilitate these injuries. In addition, we do not clearly know when radial head fractures can be fixed and preserved.

Continued improvement of arthroscopic techniques to repair the coronoid process may be beneficial in treating injuries with partial articular fractures of the radial head as well as patients with posteromedial varus rotatory instability. Arthroscopic repair may allow us to retain the radial head more frequently. In addition, with the development of an internal hinged stabilizer, it may be possible to neutralize forces on the radial head to prevent fixation failure.

Study of the long-term outcomes of these injuries will be beneficial. Clinical manifestations of osteolysis and capitellar wear after radial head arthroplasty may become more prevalent with extended follow-up.

REFERENCES


