Current Treatment Concepts for “Terrible Triad” Injuries of the Elbow

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Abstract: Elbow fracture-dislocations destabilize the elbow, preventing functional rehabilitation. If left untreated, they commonly result in functional compromise and poor outcomes. The “terrible triad” injury is classically described as a combination of a coronoid process and radial head fractures, as well as a posterolateral elbow dislocation. Surgical treatment to restore stable elbow range of motion has evolved in the past few decades based on increased understanding of elbow biomechanics and the anatomy of these injuries. This article highlights current concepts in the treatment of these complicated injuries. [Orthopedics. 2014; 37(12):831-837.]

Hotchkiss first used the term “terrible triad,” meaning fractures to the coronoid process and radial head with a resulting posterolateral elbow dislocation and refractory instability. The usual traumatic mechanism leading to this injury is a fall on the outstretched, supinated arm with a valgus stress through the elbow (Figure 1). This condition accounted for 4% of adult radial head fractures and 31% of elbow dislocations in a study by van Riet and Morrey. Terrible triad injuries are seen more commonly in men and have a peak occurrence in the fourth decade of life. Concurrent ipsilateral injuries to the distal radius, diaphyseal ulna, rotator cuff, and carpal bones have been described. The elbow is prone to stiffness, even with short-term immobilization. Seijas et al reported that most patients treated for terrible triad injuries regained their maximum range of motion during the first 3 to 4 months after treatment. Although outcomes have improved with increased understanding of elbow biomechanics and advancements in surgical techniques and implants, no clear consensus exists regarding how and in which order to address bony and ligamentous injuries. Several algorithms have been proposed, with most favoring, at a minimum, repair of the radial head, the coronoid process, and the lateral ulnar collateral ligament. In addition, due to multiple factors, definitive treatment can sometimes be delayed for these injuries and differences in outcome for acute vs subacute management.

Figure 1: Preoperative anteroposterior (A) and lateral (B) radiographs of a 35-year-old man who sustained a left “terrible triad injury.”
have been recognized. Treatment algorithms must be case and patient specific.

**ANATOMY OF THE ELBOW**

The elbow joint consists of 3 distinct articulations: the proximal radioulnar, the ulnohumeral, and the radio capitellar joint. All 3 components are essential for proper range of motion of the forearm and elbow.

The elbow has 2 degrees of motion: flexion-extension at the ulnotrochlear joint and supination-pronation at the radiocapitellar joint and the proximal and distal radioulnar joints. Normal range of motion is approximately 0° to 140° in extension and flexion, 85° in supination, and 80° in pronation. However, normal daily activity is associated with only 30° of extension, 130° of flexion, 50° of supination, and 50° of pronation.

The elbow’s stability depends on static and dynamic stabilizers. Static stability is maintained by osseous and capsuloligamentous restraints, whereas muscles crossing the elbow provide dynamic stability.

As described by O’Driscoll et al, the combination of static and dynamic stabilizers provides primary and secondary constraints that prevent elbow instability. Primary constraints are the ulnohumeral articulations, the medial collateral ligaments (especially the anterior bundle), and the lateral collateral ligament complex (especially the lateral ulnar collateral ligament). The secondary constraints are the radiocapitellar articulations, the common flexor-pronator tendons, the common extensor tendons, and the capsule.

The proximal radioulnar joint articulation contains the radial notch of the ulna, the lesser sigmoid notch of the ulna, and the rim of the radial head. A main component of the secondary constraints of the elbow, the radiocapitellar articulation contains the concave surface of the radial head and the capitellum of the distal humerus. The ulnotrochlear articulation is a main part of the primary constraints of the elbow. It contains the sagittal ridge and greater sigmoid notch of the ulna and the trochlea of the humerus. In full flexion of the elbow, the coronoind process locks into the coronoid fossa of the distal humerus to provide more stability. Stability in full extension is provided by the olecranon as it rotates into the olecranon fossa of the humerus.

Capsuloligamentous stabilizers include the anterior and posterior joint capsule, and the medial and lateral collateral complex. The anterior capsule extends from the proximal margin of the coronoid fossa to the edge of the coronoid process distally and to the annular ligament laterally. The posterior capsule extends from the proximal edge of the olecranon fossa to the proximal edge of the medial and lateral greater sigmoid notch, and merges laterally with the annular ligament. The ulnar (or medial) collateral complex contains the anterior bundle, the posterior bundle, and the transverse ligament. The anterior bundle originates at the anteroinferior surface of the medial epicondyle and inserts on the sublime tubercle on the anteromedial aspect of the coronoid process. The anterior bundle provides significant stability against valgus force. The posterior bundle is part of the thickening of the capsule rather than a ligament. The lateral complex consists of the radial collateral ligament, the ulnar collateral ligament, the annular ligament, and the accessory collateral ligament. The radial collateral ligament and the lateral ulnar ligament share a common origin at the distal edge of the lateral epicondyle, with the radial collateral ligament inserting on to the anterior portion of the annular ligament and the lateral ulnar ligament inserting on to the posterior attachment of the annular ligament. The lateral ulnar collateral ligament is a main component of the primary constraint of the elbow that provides posterolateral and varus stability. The annular ligament starts at the anterior margin and ends at the posterior margin of the lesser sigmoid notch.

Four muscle groups provide dynamic stability to the elbow: the elbow flexors, elbow extensors, forearm flexors-pronators, and forearm extensors. The elbow flexors include the biceps, brachialis, and brachioradialis. The extensors include the triceps and the anconeus. The flexors-pronators include all muscles in the anterior compartment, whereas the extensors include those in the posterior compartment of the forearm.

**MECHANISMS OF TERRIBLE TRIAD INJURIES**

The mechanisms of terrible triad injuries can be separated into low-energy falls from standing height and high-energy accidents. Most of the low-energy mechanisms are in those patients with poor bone quality. Approximately 60% of terrible triad injuries are the result of minor falls on an outstretched arm from standing height. One-third of cases are the result of falls from greater heights, are bicycle related, or occur in sports-related injuries; motor vehicle accidents account for just 6% of cases. O’Driscoll et al described the mechanism failure according to the “Horii” circle, where the sequential failure of soft-tissue constraints starts from the lateral side and moves anteriorly and posteriorly to the medial side.

Although the coronoid fracture was once described as an avulsion fracture, it is now understood to most often be the result of shear forces caused by posterior translation against the humeral trochlea. Once the coronoid is fractured and the anterior bundle disrupted, valgus compression and radiocapitellar abutment occurs. This results in compression fractures to the radial head as the forearm dislocates posteriorly. The ultimate result is gross instability due to disruption of 3 of the primary and secondary static stabilizers of the elbow—the ulnohumeral...
articulation, the anterior bundle, the lateral ulnar collateral ligament, and the coronoid as anterior bony constraint of the distal humerus.

**CLASSIFICATION**

Multiple classification systems have been proposed for radial head and coronoid fractures. Mason’s classification of the radial head is most widely used and has been modified by others. In Mason’s classification, Type I describes a nondisplaced fracture of the radial head, Type II adds displacement of a partial radial head fracture, and Type III describes a comminuted fracture of the entire radial head (Figure 2). Broberg and Morrey further specified Mason’s system by defining Type I as fracture with less than 2-mm displacement, Type II as 2-mm or greater displacement and/or involvement of greater than 30% of the joint surface, Type III as radial head comminution, and Type IV as a fracture with associated elbow dislocation. Hotchkiss further added to the classification by including treatments and outcome to differentiate nonoperative, repairable, and non-repairable injuries of the radial head. In this system, a Type I fracture is less than 2 mm displaced without block of motion and amenable to nonoperative management; a Type II fracture has mechanical block to motion, greater than 2-mm displacement, and can be viewed as repairable; and Type III is a non-repairable comminuted fracture that will require excision and replacement.

Mason Type I is rarely associated with terrible triad injuries, accounting for just 5% of cases. The other 95% of injuries are nearly equally distributed between Mason Type II and Type III injuries (84 vs 81; \( P = .8 \)). Although few studies have used the Broberg and Morrey system for classification of radial head injuries in terrible triad injuries, there appears to be a similar distribution pattern. An attempt at radial head reconstruction in fractures with more than 3 fragments is thought to result in poorer outcomes relative to radial head replacement.

Regan and Morrey’s system is 1 of the 2 common classification systems for coronoid fractures, the other being the classification according to O’Driscoll et al. In the Regan and Morrey classification, Type I coronoid fractures involve only the coronoid tip. Type II describes a single or comminuted fracture involving less than 50% of the coronoid height. Type 3 is a single or comminuted fracture involving greater than 50% of the coronoid. The classification proposed by O’Driscoll et al describes 3 coronoid fractures and their respective subclasses regarding location and mechanism. Type I describes transverse tip fractures of the coronoid, Type 2 anteromedial facet fractures, and Type 3 coronoid base fractures.

Among studies using the O’Driscoll et al system to grade coronoid injuries, Type I is the most common pattern, accounting for 92% of injuries, compared with 7% being classified as Type II and just 1% being classified as Type III.

**INITIAL EVALUATION**

Patients with terrible triad injuries are often seen after high-energy mechanisms such as motor vehicle accidents. In addition to local symptoms such as pain, swelling, and deformity of the elbow, ipsilateral and contralateral upper-extremity fractures as well as injuries to other parts of the body can be found. A full primary and secondary trauma survey according to Advanced Trauma Life Support (ATLS) guidelines, including a full assessment of the musculoskeletal system, should be performed. Next, a full orthopedic survey should also be performed to look for other musculoskeletal injuries. Areas of deformity and ecchymosis must be noted, including open laceration at the elbow area, which may constitute an open fracture. Ipsilateral shoulder deformities or wrist tenderness can be signs of associated injuries. A neurovascular examination is mandatory before and after reductions or manipulation. The ulnar nerve is the most vulnerable and commonly injured nerve in complex elbow trauma.

Reduction should be attempted with the arm in supination to help the coronoid process clear the trochlea. In addition, coronal displacement as well as posterior displacement must be corrected by posterior to anterior application of pressure on the olecranon tip while flexing the elbow to obtain reduction.

A terrible triad injury, like other elbow fracture-dislocations, can also distort anterior structures in the antecubital fossa, including the brachial artery. This has been reported but rarely leads to ischemia and compartment syndrome.

**DIAGNOSTIC IMAGING**

Standard radiographs of the elbow are mandatory before and after reduction (Figure 1). Concentric reduction of the ulnohumeral and radiocapitellar joints must be verified. Although conventional radiographs obtained after elbow reduction allow injury assessment and planning, especially in terrible triad injuries, computed tomography (CT) can facilitate detailed fracture visualization, including involvement of the coronoid process and the radial head. Three-dimensional CT reconstruction of the elbow can complement preoperative planning.
TREATMENT

Nonoperative Treatment

Recurrent instability is a hallmark of terrible triad injuries, and surgical management is indicated for most patients medically fit for operation. A small subset of patients who maintain concentric reduction of a traumatic injury with stable range of motion to approximately 30° of extension may be amenable to conservative treatment. These cases usually have coronoid tip avulsions (Type 1) with nondisplaced and mechanically not blocking radial head fractures. In this setting, both a functional examination under fluoroscopy and CT are important to fully understand the extent of injury and to confirm the nonoperative treatment.

Operative Treatment

Surgical fracture fixation and ligament reconstruction is the treatment of choice in the majority of terrible triad injuries. Approaches. Lateral or medial approaches as well as a single posterior midline incision as a global approach can be used. Most terrible triad injuries can be repaired using a lateral approach only. When using a posterior global approach, bilateral full-thickness fasciocutaneous flaps are raised, allowing access to both the medial and the lateral aspects of the elbow. Traumatic ruptures of fascial and capsular structures are commonly found. These traumatic windows can facilitate access; often, however, they need to be extended using standard deep approaches to visualize key structures. On the lateral side, inspection of the radial head is usually achieved using Kocher’s interval between the anconeus and the extensor carpi ulnaris, with the common extensor origin elevated anteriorly to provide visualization of the lateral ulnar collateral ligament injury. An arthotomy is then made or extended along the anterior border of the lateral ulnar collateral ligament to allow assessment of the radial head injury. If necessary, increased exposure of the radial head can be gained by extending the Kocher interval proximally via anterior reflection of the common extensor origin from the lateral humerus, or by an additional approach through Kaplan’s interval between the extensor carpi radialis longus and the extensor digitorum communis. If the radial head is deemed appropriate for fixation, then the coronoid process is approached from the medial side. If a radial head excision and replacement is indicated, the radial head fragments are excised and used for prosthesis sizing before approaching the coronoid laterally through the defect.

As in lateral dissection, a traumatic window can be used for the medial approach. If it is insufficient for assessment of the coronoid fracture, then the Hotchkiss medial “over the top” approach between the flexor-pronator origin and brachialis and the flexor carpi ulnaris and triceps can be used. Reconstructive Strategy. Algorithm-driven approaches can help standardize surgical strategy. After determining the type of surgical approach, it is important to decide whether the radial head fracture is considered technically repairable. If it is, then open reduction and internal fixation is attempted. If the radial head is comminuted with greater than 3 fragments or presents subacutely, then radial head replacement is generally performed. The decision regarding salvage or replacement directs the surgical approach to the coronoid process: if the radial head is excised, the resulting defect allows an approach to the coronoid from the lateral side, which spares a separate medial incision. In cases where the radial head is reconstructed, a separate medial approach is recommended. In the majority of cases, the medial collateral ligament is not repaired. Most authors recommend medial collateral complex repair only when, after radial head and coronoid process repair as well as lateral ulnar collateral ligament reconstruction, the elbow remains unstable. Finally, in cases where, even after medial-lateral reconstruction of bony and ligamentous restraints, the elbow remains unstable, a hinged external fixator is indicated, which can restore congruent and stable early elbow motion (Figure 3). Static external fixators or temporary Steinmann pins can be used if a dynamic hinged fixator is unavailable. Static treatment should not exceed 3 weeks because significant stiffness can occur then.

Coronoid and Radial Head Repair. Several techniques are available for repair of the coronoid process, depending on fragment size and surgeon preference. Transosseous FiberWire (Arthrex, Inc, Naples, Florida) sutures, passed either freehand or using a targeting device through the ulnar, grasp the anterior capsule and coronoid tip and can provide good stability. In larger coronoid fragments, cannulated headless compression screws or suture anchors may also be used. Larger Type II and Type III fragments, as well as anteromedial fractures, may be repaired with plate fixation, which is often facilitated by medial exposure.

After fixation of the coronoid, anterior capsule, or both, the radial head is repaired or replaced, based on prior assessment. Plate fixation of radial head or neck fractures needs to be positioned in the so-called “safe zone”—the nonarticular portion of the radial head—to avoid impingement during rotation. This area lies on the lateral aspect of the radial head if the forearm is held in neutral rotation. Modular radial head prostheses allow intraoperative customization of stem, neck, and head sizes for optimal fit. When sizing the neck length, the implanted head should project proximal to lesser sigmoid articulation. In some cases, it may be necessary to excise greater portions of the radial neck to ensure optimal fit and avoid overstuffing of the radiocapitellar joint (Figure 2).

Ligament Repair and Closure. Following repair or replacement of the radial head, the lateral ulnar collateral ligament, which is usually avulsed
off the lateral epicondyle, needs to be reattached using suture anchors or transosseous sutures passed through ulnar drill holes. Drill holes should tunnel through the insertion of the lateral ulnar collateral liga-
ment on isometric point on the center of the lateral epicondyle (Figure 3); improper place-
ment of the humeral tunnels may reduce stability or restrict motion.\textsuperscript{11} Care must be taken when tensioning the lateral ul-
nar collateral ligament to not over tighten the lateral side in cases of medial collateral complex instability. Placing the medial collateral complex-
deficient, unstable elbow in supination when tightening the lateral ulnar collateral ligament can minimize this problem.

Following repair of the lat-
eral ulnar collateral ligament, the elbow is tested through a range of flexion from 30° to 120° under fluoroscopy to as-
sess for stability as well as ulnar nerve traction if a med-
dial approach was used for coronoid repair. Repair of the anterior bundle of the medial collateral ligament is not ne-
necessary if the elbow is stable following lateral ulnar collat-
eral ligament repair,\textsuperscript{5,11} but can be indicated for persistent in-
stability.\textsuperscript{11} Prophylactic ulnar nerve decompression or trans-
position at initial treatment is optional and up to the surgeon to prevent postoperative ulnar nerve dysfunction.\textsuperscript{5-8} Persis-
tent instability or incongruent reduction despite lateral ulnar collateral ligament and me-
dial collateral ligament repair will call for either static or dynamic external fixation. An alternate strategy is placement of a hinged fixator without me-
dial collateral ligament repair. Further research is needed to refine the treatment algorithm.

**Postoperative Care and Complications**

Patients receive a long arm splint for temporary soft-tissue rest in 90° of elbow flexion. Supervised rehabilitation be-
gins within the first week and is guided by the extent of the surgical procedure and the achieved elbow stability. Ac-
tive extension and flexion in a hinged elbow brace is initiated to usually 30° of terminal ex-
tension. Mobilization proceeds during the first 6 to 8 weeks, increasing the motion arc by 10 degrees per week. Progres-
sive nighttime extension splitting can facilitate extension. Forearm rotation is permitted at this time in 90° of elbow flexion, protecting medial collat-
eral ligament and lateral ul-

Two case examples are illus-
trated in Figures 1 through 8. Case 1 demonstrates an acute presentation of a terrible triad injury with a comminuted ra-
dial head that was replaced. Coronoid process and lateral ulnar collateral ligament re-
construction ensued as well as a hinged external fixator to permit early mobilization. The case was instrumented from the lateral side, except for a medial incision to re-
trieve a displaced radial head piece. The medial collateral complex was not repaired; in-
stead, a hinged external fixator was placed and early active motion begun (Figures 1-4). Case 2 demonstrates a delayed presentation of a terrible triad injury (Figures 5-8). A global posterior approach was used in this case. Figure 8 shows the full functional outcome in this case.

Complications include in-
stability as well as stiffness, in-
fec tion, pain, ulnar neuropathy, malunion, nonunion, heterotopic ossification arthrosis, osteo-
arthritis, and contracture.\textsuperscript{3,10,11,34} Re-operation is necessary in as
many as 28% of patients.\textsuperscript{11,13} Instability is thought to be more
common in smaller avulsion-type coronoid fractures, possi-

![Figure 3: Postoperative anteroposterior (A) and lateral (B) radiographs demonstrating concentric reduction of the ulnohumeral joint in a hinged external fixator and lateral ulnar collateral ligament reinsertion using an anchor and radial head replacement.](image)

![Figure 4: Clinical photograph 2 weeks postoperatively demonstrating the healed lateral approach and the clinical aspect of a hinged external fixator assembly.](image)

![Figure 5: Preoperative anteroposterior (A) and lateral (B) radiographs of a 45-year-old patient presenting with elbow pain 4 weeks after injury. Subluxation of the ulnohumeral joint, radial head fracture, and coronoid avulsion are seen.](image)
bly due to the more challenging fixation. Although loosening of radial head prostheses has been well described, newer designs as well as modular components may improve biomechanical performance and prosthetic survival.\(^{11,12}\)

**CONCLUSION**

Although terrible triad injuries have been traditionally described as having a poor long-term prognosis, good and excellent results have been achieved with increased understanding of elbow anatomy and physiology. Surgical treatment is the standard of care when concentric stable reduction cannot be achieved. A standardized approach to reconstruct bony and ligamentous anatomy is necessary to achieve the goal of early mobilization. Ongoing research must answer the many open questions in the treatment of these severe injuries.

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