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The Terrible Triad of the Elbow: A Narrative Review of Anatomy, Biomechanics, Classification, and Surgical Management

Mahmoud Abdo Mahmoud Selim[1], Abanoub Andraws Rezk[1], Adel Mohamed Salama[1], Fahmy Samir Fahmy[1], Ahmed El-Malt[1]

[1] Department of Orthopedic Surgery, Faculty of Medicine, Zagazig University, Zagazig, Egypt

Corresponding author: Abanoub Andraws Rezk

Abstract

The terrible triad of the elbow posterior elbow dislocation combined with fractures of the radial head and coronoid process is among the most unstable and historically challenging patterns of upper-extremity trauma. This review summarizes the applied anatomy and biomechanics of elbow stability, the classification systems used to describe coronoid and radial head fractures, the principles of clinical and radiological evaluation, and the evolution of surgical management from nonoperative care to structured, sequential fixation of the coronoid, radial head, and lateral collateral ligament complex. Current evidence on surgical approach selection lateral-only versus combined lateral-and-medial strategies remains genuinely mixed: the largest available network meta-analysis and several pairwise comparisons suggest combined approaches may achieve superior range of motion and functional scores, while lateral-only approaches carry a substantially lower risk of iatrogenic ulnar nerve injury. We summarize this evidence, alongside data on coronoid-fixation thresholds, postoperative rehabilitation, and complication rates, to provide a current, evidence-based overview for clinicians managing this injury.

Keywords: Terrible triad of the elbow; Elbow instability; Coronoid fracture; Radial head fracture; Surgical approach; Review

1. Introduction

The terrible triad of the elbow refers to the combination of posterior elbow dislocation with concomitant fractures of the radial head and the coronoid process of the ulna. The term was coined by Hotchkiss in 1996 to capture the historically poor outcomes and high complication rates associated with this injury pattern [1]. It typically results from a fall onto an outstretched hand with the forearm supinated and the elbow near extension, producing a valgus, posterolateral rotatory force that sequentially disrupts the lateral collateral ligament (LCL) complex, fractures the radial head, and shears the coronoid process [1,2].

Management of this injury has evolved substantially over the past three decades. Early nonoperative treatment closed reduction and prolonged immobilization was associated with a high rate of recurrent instability, stiffness, and post-traumatic arthritis, because it failed to address the structural damage to the coronoid, radial head, and ligamentous stabilizers [3,4]. Recognition that these three structures share the burden of elbow stability prompted a shift toward routine surgical reconstruction of all three, following a standardized sequence, which remains the dominant paradigm today [5]. This review summarizes the anatomical and biomechanical basis for that approach, the classification systems that guide treatment decisions, and the current evidence on surgical technique, approach selection, and outcomes.

2. Applied Anatomy and Biomechanics of Elbow Stability

Elbow stability depends on a combination of static and dynamic constraints, classically described as a “fortress” of primary and secondary stabilizers. The three essential static stabilizers are the ulnohumeral (coronoid-trochlear) articulation, the anterior bundle of the medial collateral ligament (MCL), and the LCL complex; when all three are intact, the elbow remains stable even if secondary stabilizers are compromised. Secondary stabilizers include the radiocapitellar joint, the common flexor and extensor origins, and the joint capsule, with the muscles crossing the elbow providing dynamic stability [6].

The coronoid process is a key osseous stabilizer, resisting posterior subluxation of the ulna relative to the humerus; the soft tissues attached to its base the anterior capsule and the anterior bundle of the MCL add to its functional importance beyond its role as bone alone [7]. Loss of more than half of the coronoid height is clinically associated with axial and rotational instability of the elbow, providing the rationale for the fragment-size thresholds used in coronoid classification and treatment decisions [7]. The radial head functions as a secondary stabilizer against valgus stress, particularly when the MCL is compromised, and contributes to load transmission across the radiocapitellar joint; its non-articulating "safe zone" (a roughly 90° arc of the radial head, within a broader ~110° non-articular region, localized between Lister's tubercle and the radial styloid with the forearm in neutral rotation) is the standard site for hardware placement during fixation [1]. The LCL complex, in turn, is the primary restraint to varus and posterolateral rotatory stress and acts as a sling supporting the radial head; its disruption is considered the essential first lesion in the injury sequence that produces the terrible triad [1,2].

3. Classification Systems

Coronoid fractures are most commonly described using the Regan-Morrey classification, which divides fractures into three types based on fragment size: type I (avulsion of the tip), type II (a fragment involving 50% of the process or less), and type III (a fragment involving more than 50%) [7]. This system correlates with outcome: in the original 35-patient series, excellent-to-good results were achieved in 92% of type I, 73% of type II, and only 20% of type III fractures, with reoperation and heterotopic ossification most frequent in type III injuries underscoring why larger fragments are generally treated surgically [7]. The O'Driscoll classification offers a complementary, location-based system, distinguishing tip fractures, anteromedial facet fractures, and basal fractures; anteromedial facet involvement is clinically important because it threatens varus stability independent of fragment size, and in our own institutional protocol this fracture pattern is treated through a separate medial approach rather than laterally [8].

Radial head fractures are classified using the Mason system, originally described in 1954: type I fractures are minimally displaced with intra-articular displacement under 2 mm and no mechanical block to rotation; type II fractures are displaced more than 2 mm or angulated, with possible mechanical block; and type III fractures are severely comminuted with a mechanical block to motion. Johnston added a fourth type in 1962, denoting a radial head fracture with an associated elbow dislocation the category into which terrible triad injuries fall and Hotchkiss and others later proposed further clinically oriented modifications to guide treatment [9]. In practice, type I fractures are typically managed nonoperatively, while type II fractures amenable to anatomical reduction are fixed, and severely comminuted type III/IV fractures are more often treated with radial head arthroplasty rather than attempted reconstruction.

4. Clinical Evaluation and Imaging

Diagnosis begins with a history consistent with a fall onto an outstretched, supinated arm, followed by inspection for swelling, ecchymosis (medial ecchymosis in particular raising suspicion for MCL injury), and gross deformity, and a careful neurovascular examination given the proximity of the ulnar and posterior interosseous nerves to the zone of injury. Plain anteroposterior and lateral radiographs after closed reduction typically confirm the diagnosis and allow an initial assessment of coronoid and radial head fracture size, though coronoid fragments — particularly small or comminuted ones — are frequently underestimated on plain films. CT imaging, ideally with three-dimensional reconstruction, is recommended in most cases to accurately characterize fracture morphology, fragment size, and comminution, and is considered important for surgical planning given how often plain radiographs understate the true extent of coronoid involvement [3].

5. Surgical Management

5.1 Evolution of treatment philosophy and sequence of fixation

Contemporary management follows a structured, sequential approach to restoring the three essential stabilizers: the coronoid process is generally addressed first (via suture fixation, K-wires, or screws depending on fragment size and comminution), followed by the radial head (open reduction and internal fixation where feasible, or arthroplasty for severely comminuted, unreconstructable fractures), and finally the LCL complex and common extensor origin. Whether the MCL requires formal repair remains one of the central controversies in this field and is addressed below. This sequence, and the principle that all three structures generally warrant assessment and, where indicated, fixation, follows directly from the biomechanical understanding that each stabilizer compensates incompletely for loss of the others [3–5].

5.2 Surgical approach: lateral, medial, or combined

Three general approach strategies are described: an isolated lateral approach, exploiting the interval created by the LCL and radial head injury to access the coronoid, radial head, and lateral ligament complex through a single incision; a combined lateral-and-medial (or lateral-and-anteromedial) approach, adding direct medial exposure of the coronoid and MCL; and, less commonly, an isolated medial or posterior approach. The lateral-only strategy avoids medial soft-tissue dissection and is associated with a substantially lower risk of iatrogenic ulnar neuropathy — reported at 22–37% across medial approaches to the coronoid in a recent series, compared with rates near zero in large lateral-only cohorts [10,9]. However, the comparative evidence on functional outcomes is genuinely mixed. The largest synthesis to date, a 2026 network meta-analysis of 14 studies and 866 patients, found that combined lateral-plus-anteromedial reconstruction achieved both the highest proportion of excellent-to-good Mayo Elbow Performance Scores (MEPS) and the lowest overall complication rate among the strategies compared, while anterior-based approaches (anterolateral/anteromedial) best restored range of motion; lateral-only approaches ranked comparatively lower on both functional measures, despite a still-acceptable complication profile [11]. Earlier pairwise analyses by Meena et al. and by Chen and Bi reported similar functional advantages for combined approaches, generally at the cost of longer operative time [12,13]. Approach selection therefore involves a genuine trade-off between the functional ceiling suggested by combined reconstruction and the lower morbidity of a lateral-only strategy, and should be individualized to fracture pattern — in particular, whether the anteromedial facet or medial epicondyle is involved, which typically mandates medial exposure regardless of the surgeon's general preference.

5.3 The coronoid-fixation debate

Whether every coronoid fragment requires fixation is debated. Several series have reported that type I and II (Regan-Morrey) coronoid fractures can be treated successfully without direct coronoid fixation, provided the radial head and lateral ligament complex are adequately reconstructed and elbow stability is confirmed on intraoperative stress testing — in one series, only 4 of 24 patients (16.7%) managed by a standardized, stability-guided protocol required coronoid fixation, with reliable outcomes and no recurrent instability [14,15]. Where fixation is performed, the anterior capsule and coronoid fragment can be secured with a suture “lasso” technique alone for small or comminuted fragments, or supplemented with Kirschner wires or a retrograde screw for larger fragments.

5.4 Radial head: fixation versus arthroplasty

Radial head fractures amenable to anatomical reconstruction (generally Mason type II, and selected type III patterns with three or fewer major fragments) are fixed with headless compression screws placed within the non-articulating safe zone to avoid mechanical impingement during forearm rotation. Fractures with more extensive comminution are more reliably treated with radial head arthroplasty, with implant height referenced to the lesser sigmoid notch to avoid over- or under-stuffing the radiocapitellar joint, which can otherwise produce painful impingement or residual instability, respectively.

5.5 Residual instability and the role of external fixation

Following fixation of all injured structures, intraoperative stress testing under fluoroscopy is used to confirm stability throughout the flexion-extension arc. A positive “drop sign” — an ulnohumeral gap of 4 mm or more on the lateral projection — indicates persistent subluxation and is an indication for supplemental stabilization, most commonly with a hinged dynamic joint distractor external fixator, aligned to the flexion-extension axis of the trochlea and capitellum. This protects the reconstruction while permitting early, protected motion, which is central to minimizing postoperative stiffness.

6. Postoperative Rehabilitation

Early, protected motion is a consistent theme across contemporary protocols, reflecting the strong association between prolonged immobilization and postoperative stiffness. Brief immobilization (typically under one week) is used for soft-tissue comfort and protection, after which active and active-assisted range-of-motion exercises are initiated. Identified risk factors for postoperative stiffness include immobilization beyond two weeks, high-energy injury mechanism, and a delay of more than one week from injury to surgery, reinforcing the emphasis on both early fixation and early motion [16].

7. Outcomes and Complications

With modern, structured fixation protocols, functional outcomes have improved substantially relative to historical series, leading some recent reviews to conclude that terrible triad injuries are “no longer terrible,” with good-to-excellent outcomes now achievable across a range of surgical strategies [17]. Nonetheless, complications remain clinically significant: pooled data from a systematic review of 312 patients across 16 studies reported an overall reoperation rate of 22.4% and heterotopic ossification in 12.5% of patients [18], and larger single-center lateral-approach series report ulnar nerve symptoms in around 19.5% of patients and stiffness in roughly 14.7% [19]. These figures illustrate that no single approach eliminates complication risk, and that outcome reporting should be interpreted in the context of surgical approach, fixation strategy, and rehabilitation protocol.

8. Current Controversies and Future Directions

Three questions dominate the current literature. First, the approach question discussed above — whether the modest functional advantage suggested for combined reconstruction in pooled analyses justifies its added morbidity and operative time relative to a lateral-only strategy — remains unresolved and is likely to depend on fracture-specific factors rather than a single universal answer. Second, the necessity of coronoid fixation for smaller fragments continues to be debated, with evidence on both sides and no large randomized comparison to date. Third, most published series, including the foundational protocol studies, report relatively short follow-up (commonly 6–12 months), leaving the long-term risk of post-traumatic osteoarthritis and late instability incompletely characterized. Larger, prospective, comparative studies — ideally multicenter, with standardized outcome instruments and longer follow-up — are needed to resolve these questions.

9. Conclusion

The terrible triad of the elbow is best understood through the biomechanical principle that the coronoid, radial head, and LCL complex together provide the bulk of elbow stability, and that restoring each structure — following a structured, sequential surgical protocol — underlies the substantial improvement in outcomes seen over the past two decades. Current evidence supports individualizing the choice between lateral-only and combined surgical approaches to the specific fracture pattern and the surgeon's assessment of the trade-off between functional ceiling and approach-related morbidity, rather than applying either strategy uniformly. Continued high-quality comparative research is needed to refine these decisions further.

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