Orthopaedic Trauma

Adult Monteggia fractures: surgical treatment and management of complications

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ABSTRACT
Monteggia fractures in adults continue to be challenging injuries to manage. As experience with these complex fractures continues to evolve, a better understanding has emerged allowing for improved surgical techniques and patient outcomes. Certain subtypes of this injury recently have been shown to be correlated with poor outcomes and a high rate of revision surgery within the first year of the index procedure. By better understanding the injury pattern itself along with associated injuries (both bony and soft tissue) and their management, results can be improved. The purpose of this review was to outline the key features of adult Monteggia injuries as well as a treatment strategy based on the most current literature. Complications and common treatment pitfalls as well as their management also are reviewed.

Keywords
adult Monteggia, complications, elbow stability

INTRODUCTION
The mainstay of treatment of Monteggia fractures in adults is accurate anatomic reduction with stable fixation to allow early unrestricted range of motion. Recognition of associated injuries (bony and soft tissue) is imperative to properly manage these difficult fractures and to appropriately counsel patients about their injury, rehabilitation and expected outcomes.

CLASSIFICATIONS
The Monteggia fracture was initially described in 1814 as a “traumatic lesion distinguished by a fracture of the proximal third of the ulna and an anterior dislocation of the proximal epiphysis of the radius.” In 1967, Bado classified the lesion into four groups (Figure 1) based on the direction of dislocation of the radial head and the angulation of the ulnar fracture: anterior (type I), posterior (type II), lateral (type III). A Bado type IV lesion was defined as a fracture of both bones of the forearm with dislocation of the radial head. A key distinction between Monteggia fractures and transolecranon fractures-dislocations is the presence of a dislocation of the proximal radioulnar joint in Monteggia lesions.

In 1991, Jupiter et al. described subtypes of the type II lesion (Figure 2) based on the location of the ulnar fracture. A type IIa fracture involves the distal part of the olecranon and the coronoid process. A type IIb fracture occurs at the metaphyseal-diaphyseal junction distal to the coronoid process. A type IIc fracture occurs at the diaphysis. A type IID fracture extends to the proximal one-third to one-half of the ulna including the olecranon and coronoid.

MECHANISM OF INJURY AND ASSOCIATED INJURIES
Ring et al. described the important differences between adult and pediatric Monteggia injuries. Bado type I injuries are common in children but are less common in adults. (In contrast, type II fractures are rare in children.) In Ring et al.’s series, type II injuries were five times more common than type I injuries and tended to occur in older adults from lower energy mechanisms. In contrast to children and to type II fractures, type I injuries in adults typically are the result of high-energy trauma and have a higher incidence of neurovascular compromise and compartmental syndrome. Associated soft-tissue and bony injuries are common in type II Monteggia fractures. These may include fractures of the...
coronoid process and the radial head, and disruption of ligamentous stabilizers.

**PREOPERATIVE PLANNING**

Careful preoperative planning is the key to obtaining a successful surgical result. Understanding the fracture and recognizing the associated injuries will allow the surgeon to appropriately plan the surgery and ensure that all necessary equipment is available.

For injuries that involve fractures of the ulnar shaft without more proximal injuries as outlined previously, rigid fixation can be obtained using a 3.5 low-contact dynamic compression plate. In some injuries, such as Jupiter type IIA or type IID fractures, the coronoid and semilunar notch of the proximal ulna may be involved. Precontoured periarticular ulnar plates may be useful. In addition, minifragment screws and plates are helpful to hold the separate coronoid fragment or to repair the radial head fracture. A radial head arthroplasty system should be available if the radial head fracture proves to be too comminuted for stable anatomic reduction and fixation. Suture fixation of smaller coronoid fragments may be necessary and a #2 nonabsorbable suture typically is sufficient. Suture anchors may be necessary to repair concomitant ligament disruptions.

**OPERATIVE TECHNIQUE**

Patients typically are placed in a lateral or prone position to access the posterior aspect of the forearm and elbow. A posterior midline incision allows access to all components of the injury after elevating full-thickness medial and lateral flaps as necessary and then working through the appropriate deep intervals to access various fracture components.

For fractures distal to the coronoid process, the key to restoration of the proximal radioulnar joint and elbow stability is anatomic reduction of the diaphysis of the ulna (Figure 3). If the elbow is unstable, or the radial head will not stay reduced, then the ulnar shaft alignment should be rechecked because a malreduction of this component of the injury is the most common reason for residual elbow instability (Figure 4). An open reduction of the joint rarely is required since restoration of the ulnar shaft alignment typically reduces the joint component of the injury. If it becomes necessary to open the joint, it can be accomplished through a Kocher approach done through the same posterior midline incision by simply elevating the lateral flap. The annular ligament typically is intact, and the radial head may need to be “shoe horned” back to its place under the ligament. If the ligament needs to be cut to reduce the radial head, it must be meticulously repaired.
For fractures involving the radial head and coronoid, a systematic approach to fixation is needed. Several key ulnar fracture fragments typically are present: olecranon fragment, coronoid fragment, avulsion fragments of the ulnar ligament insertions, and the shaft component (Figure 5, A). The ulnar nerve typically is identified and protected throughout the procedure as it crosses the cubital tunnel and travels into the flexor carpi ulnaris. The olecranon fragment, with its remaining attached triceps insertion, is reflected proximally to expose the distal humerus and elbow joint. Typically, the order of fixation consists of repair or replacement of the radial head, reduction and stabilization of the ulnar shaft including the coronoid process and associated bony avulsions of the ligamentous structures from the ulna, reduction and stabilization of the olecranon process to the ulnar shaft, and finally repair of the humeral origin of the lateral collateral ligament complex.

Anatomic reduction of the ulnar shaft is important to allow for an accurate assessment of ulnar length and to allow for proper positioning of the coronoid fragment. The coronoid and ulnar shaft often need to be reduced and provisionally held to appropriately size the neck length for radial head arthroplasty if required. The coronoid fragment is then used to confirm both visually and radiographically that the articular surface of the radial head trial prosthesis is collinear with the radial half of the coronoid and the lesser sigmoid notch (Figure 5, B). However, definitive fixation or replacement of the radial head must be completed before definitive ulnar fixation because after the olecranon and coronoid fractures have been reduced and fixed, access to the radial head is limited.

The radial head is either repaired or replaced depending on the degree of articular comminution and the presence of an associated radial neck fracture. In most instances, the traumatic soft-tissue injury allows for access to the radial head directly through the ulnar approach. However, if significant dissection is necessary along the radial side of the proximal ulna to access the radial head, a separate Kocher approach interval may be used through the same skin incision.

The coronoid fragment may be stabilized with either sutures or screws, with or without mini-fragment plates, depending on its size, morphology and the degree of comminution (Figure 5, C). Smaller coronoid fragments may be fixed using a nonabsorbable suture placed through transosseous drill holes exiting the dorsal ulnar cortex. The sutures should be placed early while the exposure to the coronoid is maximal, but they should be tied only after the reduction of the remaining components. Care must be taken not to disrupt the sutures during drilling for placement of screws into the shaft or olecranon component of the injury. Larger coronoid fragments may be repaired with lag screws (2.0 mm, 2.4 mm, or 2.7 mm) from the dorsal surface of the ulna. Coronoid fragments that include the sublime tubercle may be secured with minifragment plates.

The olecranon fragment is secured with a dorsal plate. A more rigid plate such as a 3.5 LCDCP or a precontoured olecranon plate is used (Figure 5, D and E). Less stout plates such as 1/3 tubular plates or reconstruction plates should be avoided in fractures that extend past the coronoid because they are not rigid enough to maintain reduction until union.

Figments containing the insertions of the medial or lateral ligament complexes can be repaired using minifragment plates or suture anchors (Figure 5, F). The humeral origin of the lateral ulnar collateral ligament must be repaired. Typically, one or two suture anchors are placed into the appropriate position on the lateral epicondyle and the avulsed tissue is repaired to its origin.
The stability of the elbow must be tested clinically and radiographically at the conclusion of the case. Ideally, the elbow will be stable throughout a full range of motion. For patients with anterior Monteggia lesions, the elbow may be more stable with the forearm in supination. Conversely, for patients with posterior Monteggia lesions, especially type IIA or type IID lesions that may involve lateral ligament disruption, the elbow may be more stable in pronation.

POSTOPERATIVE PROTOCOL
The patient's arm is placed in a splint with the arm in the position of maximal stability for 24 to 48 hours. Early active range of motion is begun when the wound is stable. A resting splint in the position of maximal stability may be beneficial between exercises. For patients requiring a lateral ligament repair, a protocol involving active flexion and extension in pronation should be instituted. The patient may supinate with the arm flexed to 90 degrees or beyond. Varus stress should be avoided at all times, and all exercises should be performed with the arm at the side. If the olecranon fragment is tenuous, active extension against gravity should be avoided.

OUTCOMES AND COMPLICATIONS
Treatment of Monteggia fractures continues to be demanding. Watson-Jones noted serious disability in 32 of 34 adult patients who sustained this injury. Complications may be numerous including loosening of the fixation, nonunion, radioulnar synostosis, post-traumatic arthritis, elbow subluxation, or recurrent dislocation. Ring et al. described 48 patients with Monteggia fractures with a mean follow-up of 6.5 years. Six of the eight patients with poor results had Bado type II injuries. Konrad et al. performed a retrospective review with an average follow-up of 8.7 years. Satisfactory results were achieved in 34 of 47 patients. Factors that correlated with a poor outcome included posterior Monteggia fracture-dislocations (Bado type II), fractures involving the olecranon and coronoid (Jupiter type IIA), fractures of the radial head, coronoid fractures and complications requiring further surgery. In their series, 26% of patients required a second operation within 12 months of the initial procedure. Patients with a Bado type I fracture typically showed excellent or good functional results. The authors speculated that this was likely due to the low incidence of additional fractures of the radial head or coronoid process. Strauss et al. reviewed a group of patients with posterior Monteggia fractures. A subgroup of these patients had an associated ulnohumeral dislocation. This group had reduced motion and outcome scores compared to the group without associated dislocation.

MANAGEMENT OF COMPLICATIONS
Numerous studies have emphasized the importance of recognizing the fracture pattern as the first step in avoiding complications with Monteggia fractures. Knowledge of the known common associated soft-tissue injuries is essential so that vascular injuries or compartmental syndrome is not missed, particularly in Bado type I fractures. In fractures that do not involve the coronoid or radial head, anatomic alignment and stable fixation of the ulnar shaft is essential. In injuries that involve the radial head and
coronoid, these fractures must be recognized and stabilized. Repair of simple fractures of the radial head should be performed. Although the data from series of Monteggia injuries are not sufficient to determine if radial head replacement or excision is required for these fractures, we do know that the radial head is an important elbow stabilizer and that radial head arthroplasty improves elbow kinematics and stability in patients with complex elbow instability. Preservation of the radiocapitellar joint will increase the stability of the elbow in patients with a fracture of the coronoid process.
or posterolateral rotatory instability secondary to lateral ligament disruption which often is associated with Monteggia fractures. The author recommends replacement of the radial head if it is not reparable.

Post-traumatic synostosis may lead to poor outcomes in these fractures. Ring et al. recommended avoiding exposure of both bones through a simultaneous exposure (such as a Boyd approach) whenever possible. Often the soft tissues are already disrupted in this area, and this approach has been carried out by the injury itself so avoiding soft-tissue stripping is impossible. However, when possible, it is preferable to approach each bone through a separate deep interval. A posterior midline skin incision may still be used, but the deep dissection can be through various intervals by elevating the medial and lateral flaps as needed.

Choosing appropriate fixation for Monteggia injuries is essential. Typically these injuries require plate fixation for the ulnar portion of the injury. Tension band wiring should be avoided.

**FIGURE 6.** Postoperative radiographs of a 55-year-old woman who sustained a Bado type II (Jupiter type IIb) Monteggia fracture after a ground level fall. She was treated with radial head arthroplasty and open reduction internal fixation of her ulnar shaft with a 3.5-mm reconstruction plate (A). Her plate broke 4 months postoperatively when she went on to a nonunion (B). She was referred to the author 8 months after her index procedure with complaints of subjective instability and pain in her elbow. Intraoperatively, a large anterior butterfly fragment that was distal to her coronoid had healed to the shaft. However, it had not healed to the proximal segment. The nonunion was debrided, and the ulna was reduced and stabilized using a stiff periarticular dorsal plate (C). There was significant scarring around her radial head arthroplasty, and it was left in situ since its size was reasonable (D). At 1 year follow-up from her revision, she lacked 10° of extension relative to her normal side and had full pronation, supination, and flexion and was comfortable and back to her normal activities (E).
be avoided in any comminuted fracture or any fracture that involves the coronoid or the ulna distal to the coronoid; it has little to no role in the treatment of these injuries. Nonrigid plates should be avoided for ulnar shaft fractures because they are prone to early failure and nonunion (Figure 6). Ring et al.13 reviewed a series of 17 patients with malalignment after operative treatment of a posterior Monteggia fracture. Fifteen patients had loose fixation and 12 patients had subluxation or dislocation of the ulnohumeral joint. They recommended dorsal contoured plating to improve proximal fixation. In particular, in Jupiter IIA and IID fractures, dorsal plating that wraps around the tip of the olecranon allows for more secure fixation of the small proximal segment. In this series, the coronoid was fixed with either screws or it was reconstructed with a portion of the radial head.

Recurrent instability may be the result of inadequate management of the ulnar shaft component of the injury. Nonunion and failure of fixation may result in recurrent radial head dislocation if the initial injury deformity is recreated. In this scenario, proper alignment of the bone will restore elbow stability. Similarly, inadequate fixation of the olecranon and coronoid fragments leads to an inadequate trochlear notch with resultant subluxation. In this situation, reducing and securing the fragments will improve elbow stability.11

Persistent instability also may be caused by problems with the initial management of the radial head, the coronoid and the ligamentous structures. Proper repair of each of these components of the injury is essential during the index procedure. Ring et al.13 described a standard protocol for treatment of persistent dislocation or subluxation of the elbow after fracture dislocation. A surgeon with expertise in treating these injuries and with experience with late reconstruction is desirable. First the radial head needs to be treated with either proper fixation or arthroplasty. Reconstruction of the coronoid process may be necessary using a portion of the radial head. Repair or reconstruction of the lateral ligamentous complex and even temporary hinged fixation may be necessary.

In patients with mild residual subluxation after proper fixation of all components of the injury, treatment with active elbow exercises and avoidance of varus stress may resolve the problem. Duckworth et al.16 described this protocol for patients with terrible triad injuries, and this author has had success with this protocol for other complex elbow injuries, including Jupiter type IIA and IID Monteggia fracture dislocations with very mild residual subluxation.

CONCLUSION

Our understanding of Monteggia fractures continues to evolve. Proper preoperative planning, intraoperative techniques and rehabilitation will provide patients with better outcomes for these challenging injuries.

REFERENCES AND RECOMMENDED READING

Papers of particular interest, published within the annual period of review, have been highlighted as:
• of special interest
•• of outstanding interest


Original article describing the classification of Monteggia lesions, their mechanisms of injury, and reduction techniques.


Review of 159 patients treated at a single institution describing the principles of surgical management of Monteggia lesions and their outcomes.


Describes and classifies posterior Monteggia lesions in adults and outlines associated injuries that must be recognized to optimize outcome.


Outlines patterns and key differences between adult and pediatric Monteggia injuries and discusses the importance of recognizing radial head, coronoid, and ligamentous lesions related to these injuries.


10. Discusses the expected outcomes and pitfalls related to current treatment of Monteggia fractures in adults in a series of 47 patients.


