Review Article

Complex Monteggia Fractures in the Adult Cohort: Injury and Management

Jaehon M. Kim, MD
Daniel A. London, MD, MS

Abstract

Monteggia fractures involve proximal ulna fracture associated with a radiocapitellar joint dislocation. The Bado classification is primarily based on the direction of the radial head dislocation. The Jupiter subtype classification of Bado II fractures further characterizes the severity of proximal ulna comminution and the involvement of the coronoid fragment. This latter classification can better prognosticate the challenges of surgical reconstruction and clinical outcomes. Surgery for all adult Monteggia fractures is required to restore the anatomic alignment of the ulna, which indirectly reduces the radiocapitellar joint. The complexity of the injury is considerably increased by comminution of the proximal ulna, the degree of radial head fragmentation, the reduction of the radial head, and ulnohumeral instability. Anatomic reduction is considered critical to achieving a favorable outcome.

Department of Orthopedics, Icahn School of Medicine at Mount Sinai, New York, NY.

Neither of the following authors nor any immediate family member has received anything of value from or has stock or stock options held in a commercial company or institution related directly or indirectly to the subject of this article: Dr. Kim and Dr. London.

Supplemental digital content is available for this article. Direct URL citation appears in the printed text and is provided in the HTML and PDF versions of this article on the journal's Website (www.jaaos.org).

J Am Acad Orthop Surg 2020;28: e839-e848

DOI: 10.5435/JAAOS-D-19-00625

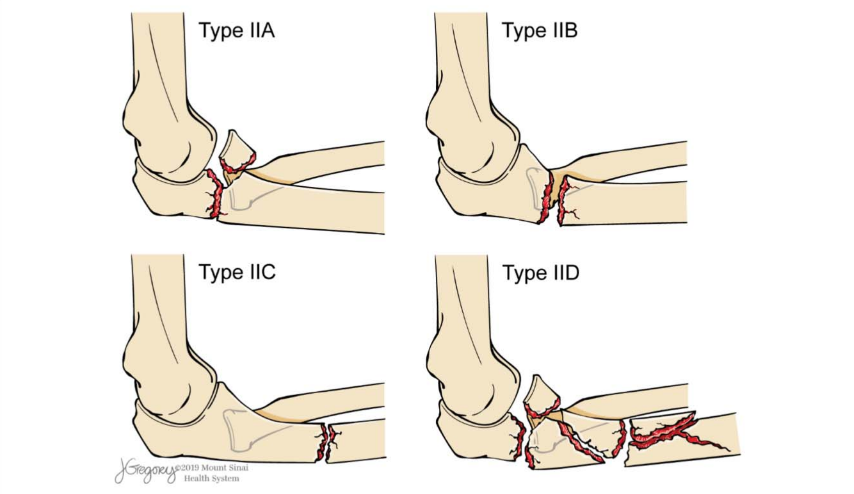
Monteggia fractures classically involve a proximal third ulna fracture associated with a radiocapitellar joint dislocation. These injuries were first defined by Dr. Giovanni Battista Monteggia in 1814 and later were eponymously named Monteggia fractures by Dr. Jules Perrin.[1] Monteggia fractures include a wide spectrum of patterns, which makes the literature comparisons challenging. In addition to the two primary criteria of Monteggia fractures, there is a notable variation in injury patterns, including radial head fractures, coronoid fractures, and ulnohumeral instability. The identification of these injuries is essential for proper treatment.

Classification/Spectrum of Injury

Jose Luis Bado first described the widely used Bado[1] classification in Uruguay, which was subsequently translated into English in 1967 (Supplemental Figure 1, Supplemental Digital Content 1, http://links.lww.com/JAAOS/A513). His system was determined by the direction of the radial head dislocation in the anterior (type I), posterior (type II), or lateral direction (type III). Type IV describes proximal ulna and radius fractures with an associated radiocapitellar dislocation in any direction. The original manuscript emphasized the level of the ulna fracture, the angulation of the fracture deformity, and the direction of the radiocapitellar dislocation.

Anterior dislocations of the radial head (Bado type I) have three potential mechanisms: (1) hyperpronation of the forearm resulting in the radial head dislocation and ulna fracture[2]; (2) hyper-extension of the elbow causing strong contraction of the biceps leading to dislocation of the

Figure 1



Schematic drawing of the Jupiter subclassification of Type II Monteggia fractures. **A**, Type 2A includes distal olecranon and triangular coronoid process fractures, (**B**) Type 2B includes a proximal ulna fracture at the metaphyseal-diaphyseal junction distal to the coronoid, (**C**) Type 2C includes a purely diaphyseal ulna fracture and (**D**) Type 2D includes an ulna fracture that extends from the trochlear notch including the coronoid fragment to the metaphyseal region often with notable comminution.

radial head, which is then followed by the ulna fracture[3]; or (3) direct trauma to the posterior ulna that then forces the radial head anteriorly until it dislocates.[4,5] Posterior dislocations (Bado type II) are associated with a longitudinal force applied to a supinated and partially flexed ulna, resulting in fracture.[6] There is also a hypothesis that patients with long-term corticosteroid use may be at increased risk for these injuries because of bone weakness resulting in their bone failing before their ligaments in the elbow.[7] Lateral dislocations (Bado type III) occur by direct trauma with a varus force acting on an extended elbow.[8] This type of Monteggia fracture is associated with posterior interosseous nerve (PIN) palsies, although these are only reported in case studies and primarily in pediatric populations. There currently is no literature that describes the overall incidence of nerve palsies with Monteggia fractures. At the time of Bado's publication, the treatment of Monteggia fractures was generally conservative in both adults and children. Therefore, reduction maneuvers in the opposite direction of the producing mechanism were paramount to treating these injuries.[1]

In 1991, Jupiter et al[9] developed a subclassification within the posterior Monteggia fracture group (Bado type II) based on the severity of the coronoid fragment and radial head fracture. The authors recognized the importance of the triangular or quadrangular fracture fragment at the level of the coronoid, which affects the functional disability of the injury when it is inadequately reduced. Specifically, there was a concern that the loss of the anterior cortex of the ulna at the coronoid process would result in treatment failure unless a plate is applied to the dorsal surface of the ulna. The contoured plate, acting as a "tension band plate," allows the opportunity to secure the anterior cortical fragments and resist the tendency of the proximal ulna to angulate anteriorly.

The Jupiter subclassification includes four main groups (Figure 1) based on the proximal ulna fracture pattern. Type IIA includes distal olecranon and triangular coronoid process fractures. In type IIB fractures, the proximal ulna fracture is at the metaphyseal-diaphyseal junction distal to the coronoid. Type IIC is a purely diaphyseal ulna fracture. The more complex type IID pattern includes an ulna fracture that extends from the trochlear notch, including the coronoid fragment, to the metaphyseal region with notable comminution.The Jupiter classification also includes an associated radial head fracture that is further subdivided by the number of fragments.[9] Ten of 13 patients in this series had a radial head injury, and seven of these were comminuted. No discussion existed about how the radial head fracture and subsequent surgical management affected the outcomes.

In our experience, the Jupiter classification more accurately determines the complexity of the surgical reconstruction and prognosticates clinical outcome. There are three main variables that directly affect the complexity of the injury: (1) coronoid fracture, (2) radial head fracture, and (3) ulnohumeral instability.[9-11]

The Mason[12] classification of the radial head and the number of fracture fragments is commonly considered by the surgeon to determine treatment. No clear treatment consensus exists, and the choice is often deferred to the surgeon's preference. The outcomes for isolated radial head open reduction and internal fixation (ORIF) and radial head arthroplasty are favorable.[13,14]

Evaluation and Initial Management

Monteggia fractures are unstable injuries, and the physical examination is challenging. Patients generally hold the elbow and forearm in a flexed position. Assessing the range of motion is difficult, if not nearly impossible, without adequate pain control or sedation. Distal neurovascular status should be carefully assessed, specifically examining for PIN dysfunction, which is in the direct vicinity of the proximal radius injury. Open skin and compartment swelling are important to document and can determine the urgency of definitive management.

Initial radiographs include anteroposterior and lateral images of the elbow, forearm, and wrist. In a normal elbow, a line drawn down the shaft of the radius and through the center of the radial head should bisect the capitellum in all views.[15] If this is not the case, then a radial head dislocation should be suspected. Owing to the overlying ulna on the lateral view, and frequent oblique projection of the humeral condyles, a radial head dislocation or partial intra-articular fracture are commonly obscured. Cortical shadows and increased opacity in the elbow joint can indicate coronoid or radial head fragments, which can increase the complexity of the surgery. The location of the displaced radial head fragments can be unpredictable, and they can be found distal to the radial neck, torn through the anterior capsule, and can even be underneath the triceps in the olecranon fossa. Preoperative knowledge of the fragment location facilitates intraoperative extraction.

A CT scan can be used to assess the proximal ulna fracture, particularly the size and pattern of the coronoid fragment. A careful analysis of sagittal and coronal cuts can assist the surgeon in determining how to direct the exposure to appropriately capture the anterior cortical fragment and the coronoid from the posterior approach. Understanding the extent of the radial head comminution can prepare the surgeon for the treatment options, generally between ORIF or radial head arthroplasty. Implants for both should be available because intraoperative findings can differ markedly from the preoperative predictions. Although not classically considered a part of the injury spectrum, subtle anterior ulnohumeral joint subluxation may be encountered with severe coronoid fragmentation, and the treating surgeon should remain aware of this possibility.[11]

Initial management involves closed reduction maneuvers to obtain proper ulnar length because this aids in the reduction of the radiocapitellar joint. Monteggia fractures are inherently unstable, and we advise against multiple reduction attempts, which can increase patient discomfort and likely cause soft-tissue damage. A long arm posterior or spiral splint generally provides enough comfort and stability.[16] Once closed reduction is complete, a repeat neurovascular examination should be performed. For closed injuries without concern for excessive forearm swelling and a stable neurovascular examination, patients can be discharged with urgent follow-up within a few days to schedule an elective surgery within 2 weeks. For severely comminuted fractures or if the radial head cannot be adequately reduced, we advocate admission and surgical fixation in a semiurgent fashion, although many patients request discharge if their pain is well controlled.

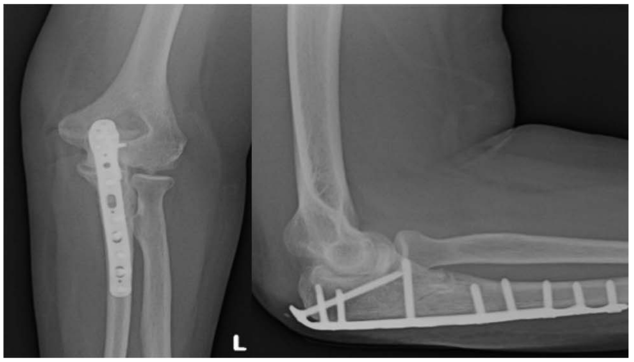
Definitive Management

Older studies, including a high proportion of patients that received nonoperative management, reported inconsistent and unsatisfactory outcomes in treating Monteggia fractures.[17-19] The current treatment of choice is operative unless contraindicated by poor health. We routinely perform surgeries for complex elbow injuries, including Monteggia fractures, in the octogenarian and nonagenarian cohort with regional anesthesia and minimal sedation. The outcomes of surgical fixation are superior and more reliable than nonoperative treatment.[20-22] If a patient must be treated conservatively, then they require splint or cast immobilization for 6 to 8 weeks with frequent skin assessments. Nonunion and persistent joint dislocation are common outcomes for widely displaced fractures treated nonoperatively.

For surgical management of these injuries patients are positioned supine on the operating room table with concomitant use of the Articulated Sterile Intraoperative Positioning System (McConnell Orthopaedic Manufacturing), which allows the operative arm to be draped across the chest. A lateral decubitus position with the operative arm across the chest resting on a bump is also popular. In this latter position a sterile padded Mayo stand can aid in positioning the limb in extension.

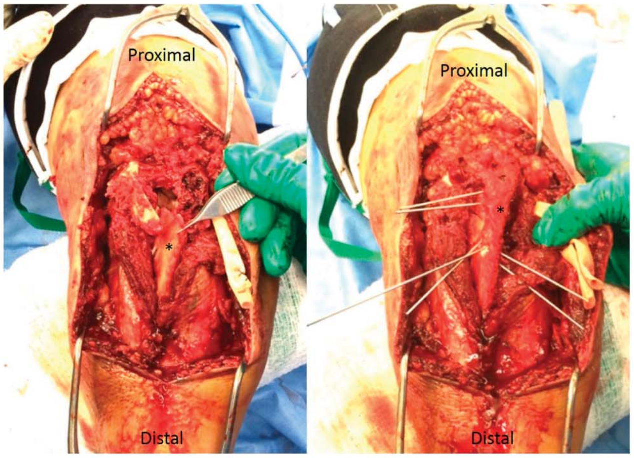
There is a wide spectrum of injury patterns that can considerably complicate surgical reconstruction. A simple pattern with a proximal ulna fracture and radial head dislocation is straightforward utilizing the posterior approach and fracture fixation using a modern contoured plate (Figure 2). The anatomic reduction of the ulna is critical since it indirectly reduces the radiocapitellar joint. If there is a concern for a tear of the lateral collateral ligament complex off the lateral epicondyle, then a large fasciocutaneous flap can be raised laterally for clinical assessment. The lateral collateral ligament complex repair can be expeditiously performed using suture anchors (2.5 to 3.0 mm or #2 nonabsorbable suture) to the lateral epicondyle or using a bone tunnel technique to the isocentric origin. Patients can initiate early motion with therapy, usually within 2 weeks.

Figure 2



Postop radiograph of a simple Monteggia fracture with a proximal ulnar fracture and a radiocapitellar dislocation. Anatomic reduction of the proximal ulna restores the elbow joint. The clinical outcome is favorable with a pain-free, functional range of motion.

Figure 3



Photgraph showing the medial and lateral borders of the posterior crest of the ulna are exposed. With extensile exposure, the anterior cortical bone can be exposed including the coronoid fragment. We use fracture reduction forceps medially to capture the coronoid. Multiple 1.6 mm K-wires can be placed to hold the reduction tentatively. The K-wire should be placed on the medial and lateral side of the ulna so that it does not interfere with the posterior plate placement.

The complexity of the Monteggia reconstruction escalates with coronoid comminution (Jupiter IIA and IID). Unlike radial head fractures, there is no reliable or accepted "back-up" reconstructive option for the coronoid. The surgeon must restore the anatomy of the coronoid to maintain sigmoid-trochlear congruency. Segmental fracture instability with deforming forces makes maintaining the reduction challenging while simultaneously applying the dorsal plate. Although not mutually exclusive, we favor additional soft tissue stripping to achieve anatomic reduction rather than settling for poor reduction at the expense of soft tissue preservation (Figure 3).

The extensor and flexor musculatures are elevated off the lateral and medial border of the ulnar crest. The reflection of the flexor/pronator muscles from the medial border of the ulna allows the exposure of the triangular coronoid fragment. The surgeon must identify and protect the ulnar nerve and the anterior bundle of the medial collateral ligament, which are the only critical structures at risk through this exposure. This approach can be implemented without the need for a separate medial or anterior incision.

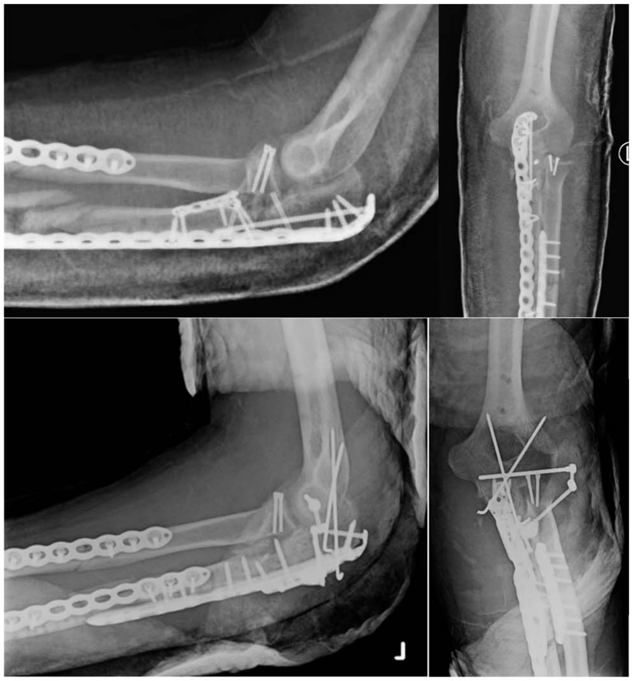
While direct visualization of the coronoid is still challenging, the fracture pattern is visible, and the reduction is possible through the cortical read. Sharp reduction forceps can access the anterior coronoid fragment, which can be reduced to the posterior cortex. Occasionally, multiple large fragments have to be reduced simultaneously to restore stability. This reduction maneuvering can be quite frustrating and adds considerable operative time. Once the reduction is achieved, multiple K-wires are placed medially and laterally to maintain the reduction (Figure 3). Extra operative time and dissection is well worth the investment to achieve near anatomic alignment, and may be less destructive overall.

For coronoid fractures that are not amenable to fixation with a plate-screw construct, a suture-lasso technique can be considered.[23] Nonabsorbable suture is passed through two drill holes placed through the coronoid fragment and proximal ulna. The suture can then be tied over the proximal ulna or the posterior plate. With medial sided dissection, coronoid specific plates can be applied, although this can be challenging from the posterior approach. For large bone defects or unreconstructable coronoid fragments, various bone grafts have been used including iliac crest bone graft and radial head osteochondral graft.[24-26] The results are considered unpredictable due to heterotopic ossification (HO) and bone resorption.[26]

The coronoid fracture with an associated ligamentous avulsion can lead to ulnohumeral instability with injury patterns still consistent with a Monteggia fracture.[11] In a small case series of six patients with instability, the functional outcomes were indicative of greater disability and reduced range of motion compared to patients with Monteggia fractures with stable ulnohumeral joints. Fifty percent of the unstable patients required additional procedures, including non-union fixation of the ulna and external fixation for persistent instability.[11] Stable fixation of comminuted coronoid fragments is challenging, but the exposure is feasible through the posterior approach. Limited salvage options exist if the fragmentation of the bone occurs.

Inadequate reduction of the coronoid fragment directly affects the achievable outcome. The triangular coronoid fragment is often “elevated” off the proximal ulna anteriorly. If the ulnohumeral joint is stable, the malreduction of the coronoid will limit elbow motion in multiple directions. In the most severe spectrum of injury, which presents with ulnohumeral instability, the coronoid fragment is critical to maintaining the reduction of the joint. Elbow subluxation, sometimes subtle, requires additional surgery to restore a congruent joint (Figure 4). Revising prior coronoid fixation is challenging. Furthermore, poor bone stock and delayed treatment often lead to fracture fragmentation and more difficult reduction. Surgeons must explore secondary options to restore ulnohumeral joint congruency in the case of inadequate coronoid fixation.

Figure 4



This patient sustained a severely comminuted Monteggia fracture with a coronoid fragment. The radiographs demonstrate inadequate coronoid reduction and fixation with multiple screws, which led to anterior ulnohumeral joint subluxation. Subsequent revision surgery was challenging because of the fragmentation of the coronoid and persistent subluxation. The coronoid fixation was abandoned, and the joint was stabilized with an internal joint stabilizer and supplemental transarticular pinning. The patient maintained reduction and achieved over an 100° arc of motion at the 6 months follow-up.

Dynamic and static external fixators, which traditionally have been a popular, but cumbersome option, can be utilized. The presence of an ulna fracture can limit the area of pin placement, and potentially lengthen the distance between the pin fixation point and the elbow joint. In our institution, we favor the use of an Internal Joint Stabilizer (Skeletal Dynamics) or trans-articular pins with 2 mm wires to maintain a more direct reduction.[27] The internal joint stabilizer has a baseplate secured to the proximal ulna and an axis pin through the isocentric point of the distal humerus with a hinge construct. This system allows direct ulnohumeral joint stabilization and early motion.[28] The placement of an internal joint stabilizer on top of an olecranon plate is possible with careful implant selection, but can compromise overlying soft tissue coverage.

A modern contoured ulna plate with a combination of locking and cortical screws provide a stable construct for reliable bone healing.[9,29] While tension band constructs have been successfully utilized, we agree with Ring et al[29] that the dorsal contoured plates provide a stiffer construct and a more reliable outcome. The implant is carefully selected to ensure that the coronoid fragment purchase can be achieved with the posterior-to-anterior screw trajectory. Many implants allow variable locking fixation proximally, thereby providing stiff articular fixation and appropriate screw trajectory to capture the coronoid.[30] While tension band constructs and lateral plating may be feasible in selected cases, high non-union rates

Figure 5

This patient sustained a Monteggia fracture with notable metaphyseal comminution. Despite the contoured dorsal plating, there was a concern for fracture stability. Radiograph of a second medial perpendicular plate was applied for additional fixation points and improved stability. The patient maintained joint reduction and fracture fixation with early initiation of motion.

have been reported.[29] Even in cases of segmental fractures and comminution, the posterior cortical read can restore the anatomic alignment with dorsal contour plates in the majority of the cases. With proximal diaphyseal or meta-diaphyseal ulna fractures, where an olecranon fixation point is not needed, we still prefer the use of an extended olecranon plate due to its well-designed anatomic contouring. The fracture can be indirectly reduced to the plate while assessing radial length via the radiocapitellar reduction and the alignment of the distal radius ulnar joint.

When considering plates for ulna fixation, surgeons must also take into account the variations of the ulnar anatomy, especially the lateral and anterior angulations of the middle and proximal thirds. Grechenig et al[31] found a 17.5° mean varus angulation of the proximal third of the ulna in 83% of their specimens and a mean anterior deviation of 4.5° at the junction of the middle and proximal thirds in 70% of their specimens. Sandman et al[32] determined biomechanically that the magnitude of angular malalignment at the proximal ulnar impacts the ability of the radial head to maintain a reduction. Specifically, fixing the ulna fracture in extension promotes anterior radial head subluxation and conversely, fixing the ulna fracture in flexion promotes posterior subluxation.

In rare cases when the plate-screw construct does not allow enough screw fixation of the metaphyseal comminution, a secondary plate (around 2.7 mm) can be placed medially or laterally to provide additional fixation (Figure 5). This level of comminution and complexity will likely result in stiffness and HO. The patient should be alerted about the possible need for a contracture release several months later.

In situations where restoring ulnar length and alignment does not allow for the reduction of the radial head, then entrapment of soft-tissues should be considered. The annular ligament, anterior capsule, biceps tendon, brachial fascia, radial nerve, and median nerve have all been identified as hindrances to reduction.[33] In these situations, the radiocapitellar joint needs to be opened, via either a Kocher or Kaplan approach, and visually inspected, followed by the resection of any blocking tissue. Recently, Hamaker et al[34] identified a series of 119 Monteggia fracture patients, in which 17 (14%) failed to reduce after fixation of the ulna fracture. In 16 out of 17 patients, the anterior portion of the annular ligament was found to be incarcerated in the radiocapitellar joint. In another series, Eglseder et al[33] found nine patients with irreducible radial heads out of 68 patients (13%). Furthermore, more distal injuries, such as to the distal radioulnar joint have also been identified as causes of persistent dislocation.[35]

For fracture variants with radial head fractures, treatment options include radial head ORIF, radial head arthroplasty, and radial head excision. The Mason[12] classification of the radial head and the number of fracture fragments is commonly considered by the surgeon to determine treatment. No clear treatment consensus exists, and the choice is often deferred to the surgeon's preference. The outcomes for isolated radial head ORIF and radial head arthroplasty are favorable.[13,14] The controversy regarding ORIF versus arthroplasty is beyond the scope of this review.

To approach the elbow, the posterior longitudinal incision is extended to raise a large fasciocutaneous flap laterally. To avoid synostosis, the authors prefer a separate lateral extensor split approach (Kaplan) for direct access to the radiocapitellar joint. By maintaining the forearm in full pronation (after ulna fixation), PIN injury can be minimized. For surgical fixation of the radial head, we prefer headless compression screws placed in a conical fashion over plates.[36] For radial head arthroplasty, a smooth stem arthroplasty is preferred if the radial head and neck comminution are not reconstructable.

The radial head/neck fracture can extend distally down the shaft, and this fracture extension is often nondisplaced and frequently not recognized in preoperative imaging studies. In the authors' experience, a standard radial head arthroplasty with a slightly under-sized smooth stem, thereby requiring minimal broaching, can be safely placed without additional implant fixation of the shaft. Cerclage wiring and circumferential suture can also be placed, but with risks of injuring the PIN and potentially causing synostosis. Radial head arthroplasty with extended stems are available but rarely required.

The diameter of the radial head arthroplasty is generally undersized by 2 mm from the measurement of the native radial head. To avoid overstuffing of radial head, the lateral ulnohumeral joint space should be assessed radiographically. The gapping or asymmetry of the ulnohumeral joint in the AP view indicates over-lengthening of the radial head and neck construct.[37] The proximal edge of the radial head is positioned approximately 2 mm distal to the lateral edge of the coronoid with AP view of the proximal ulna.[38] Assessment of over-stuffing requires critical evaluation, and the combination of the ulna fracture and joint instability can make this determination more challenging.

The authors believe that radial head management in the setting of a complex Monteggia fracture is more fraught with complications. Egol et al[39] retrospectively reviewed 20 patients with Monteggia variants that included radial head fractures. They found that 70% of their patients developed arthritic changes, While there was no correlation between method of treatment and The Disability of the Arm, Shoulder and Hand (DASH) scores, range of motion was greater in patients that did not require operative fixation of their radial head fracture.

A complex Monteggia reconstruction is demonstrated in Figure 6. Through a posterior approach, the proximal ulna was anatomically aligned and provisionally held with multiple K-wires. A contoured dorsal plate provided secure locking fixation of the comminuted segment including posterior-to-anterior screw fixation of the coronoid fragment. In this case, the coronoid was further augmented with 25-gauge cerclage wire to prevent anterior and distal displacement. The radial head fracture was addressed through a separate extensor split approach over the extensor mass. This allowed good exposure for arthroplasty and subsequent lateral collateral ligament repair with suture anchors.

Figure 6

This patient fell from a height and sustained a complex Monteggia fracture with severe comminution of the ulnar metaphysis and a triangular coronoid fragment. Radiograph of the olecranon plate with posterior to anterior screw secured the coronoid fragment supplemented with a cerclage wire.

Outcomes

Within the past 10 years, several retrospective case series have reported their outcomes of Monteggia fractures (Supplemental Table 1, Supplemental Digital Content 2, http://links.lww.com/JAAOS/A514).[10,34,40-42] We made several broad conclusions from the literature. First, the use of a dorsal contoured plate on the proximal ulna is nearly universal. Second, proper identification and treatment of radial head and coronoid fractures are required. Third, notable variations are observed in the outcome depending on the spectrum of injury. Owing to the heterogeneity of the patient populations, a compilation of the outcomes based on the Jupiter classification or the complexity of injury is not possible. Based on small case series and authors' narratives within the articles, the coronoid fracture, in particular, tends to be problematic. Overall, the patient with an adequately reconstructed Monteggia fracture should expect a favorable functional range of motion and outcome scores.[10,34,40-42]

Hamaker et al has the largest series with 119 patients and an average of 12 months follow-up. However, this series is quite heterogenous with 81 Bado I, 23 Bado II (and no Jupiter subclassification), seven Bado III, and eight Bado IV fractures. From their

Table 1

Compiled Percentage and Type of Complications Requiring a Return Trip to the Operating Room From the Case Series Published in the Past 10 Years.[10,34,40-42]

Complication	Number (N = 242)
Removal of hardware	17 (7%)
Nonunion	12 (5%)
Contracture releases	8 (3%)
Debridement for infection	7 (3%)
Tendon transfers	3 (1%)
Neurolysis	2 (1%)
Recurrent instability	2 (1%)
Others	2 (1%)
Total:	53 (22%)

series, they reported an average flexion-extension arc from 12° to 127° and a pronosupination arc of 69° of pronation and 70° of supination. Thirty-seven patients did not achieve a functional arc of motion, and 23 required a second surgery.[34]

Shore et al[42] reported on 50 patients with various Bado type II fractures. They had an average of 16 months of follow-up, with an average flexion-extension arc from 18° to 128° and a pronosupination arc of 59° of pronation and 60° of supination. These authors also did not report any functional outcomes and had 15 complications including four infections, one recurrent dislocation, one nonunion, and five patients who required removal of hardware.

Jungbluth et al[10] have reported the most extensive cohort with patient-rated outcome measures. Their cohort included 46 patients (35 Bado II and 11 Bado I) with an average of 65 months of follow-up. Their patients range of motion was similar, with a flexion-extension arc from 8° to 133° and 86° of pronation and 82° of supination. They had four nonunions, two infections requiring surgery, and 10 patients developed HO. Unique to this series, they demonstrated good patient-reported outcomes with a Broberg and Morrey score of 86.6, DASH of 15.1, and Mayo Elbow Performance Score of 90.7.

Complications

Complications correlate to the severity of the injury. Based on aggregated data from the past 10 years, the total revision surgery rate is nearly 20%, with the top two causes being the removal of hardware and proximal ulnar nonunions (Table 1).[10,34,40-42] Stiffness and HO can be unpredictable in any elbow surgery, but secondary surgery for contracture release is rare.

Type IID Monteggia fractures, with severe comminution and segmental fragmentation of the proximal ulna, have limited bone-to-bone contact with an inadequate reduction. Inherently, these unstable elbows with deforming forces result in more challenging surgery. Accepting suboptimal reduction and fixation frequently leads to nonunion and persistent instability.[10]

The risk of HO is higher with severe soft-tissue trauma and fracture comminution, with reports as high as 20% to 75%.[10,40] In Monteggia fractures, HO generally develops laterally along the collateral ligaments and near the radial neck, which affects both the flexion-extension arc and forearm rotation. Surgical excision and contracture release are typically performed 6 months after the time of the initial surgery but can be expedited in cases of severe ulnar nerve neuropathy from stiff elbow flexion.[43]

The incidence of radioulnar synostosis is unclear because the literature often cites HO and elbow contractures without clearly defining synostoses. In our experience, radioulnar synostosis is rare and more likely to occur with extensive dissection between the ulna and the radius. The development of a synostosis may be more likely with the need for dual plating. The excision of a synostosis is challenging because of posttraumatic scarring, the requirement for deep dissection, and the potential injury to the PIN. However, the outcome is favorable, with satisfactory rotations achieved in most patients.[44]

In one case series, PIN injuries occurred in 6% of patients with Monteggia fractures.[34] Owing to inconsistent follow-up, the recovery of the PIN palsy was unclear. Neurolysis and tendon transfers are both valid options. Avoiding distal dissection, such as what is needed for plating the radial head and neck, is prudent as this increases the risk of PIN injury.

Summary

Monteggia fractures encompass a large spectrum of injury. The severity of the injury and the complexity of the reconstruction are affected by (1) coronoid comminution, (2) radial head fracture, and (3) ulnohumeral instability. The recommended treatment is surgical stabilization with a dorsal contoured plate. A simple Monteggia fracture with minimal ulna comminution can be treated with plate fixation with indirect reduction of the radiocapitellar joint. With severe fragmentation of the coronoid, adequate fixation can be challenging, especially in cases of metaphyseal comminution at the base which can limit bone contact. Anatomic reduction of the coronoid directly affects motion and, in some cases, ulnohumeral joint stability. Although the overall surgical outcome is favorable, available case series do not delineate the difference in functional results depending on the severity of injury.

References

References printed in **bold type** are those published within the past 5 years.

1. Bado JL: The Monteggia lesion. *Clin Ortho Relat Res* 1967;50:71-86.
2. Evans EM: Pronation injuries of the forearm, with special reference to the anterior Monteggia fracture. *J Bone Joint Surg Br* 1949;31B:578-588, illust.
3. Tompkins DG: The anterior Monteggia fracture: Observations on etiology and treatment. *J Bone Joint Surg Am* 1971;53:1109-1114.
4. Speed JS, Boyd HB: Treatment of fractures of ulna with dislocation of head of radius: (Monteggia fracture). *JAMA* 1940;115:1699-1705.
5. Smith FM: Monteggia fractures; an analysis of 25 consecutive fresh injuries. *Surg Gynecol Obstet* 1947;85:630-640.
6. Penrose JH: The Monteggia fracture with posterior dislocation of the radial head. *J Bone Joint Surg Br* 1951;33-B:65-73.
7. Haddad ES, Manktelow ARJ, Sarkar JS: The posterior Monteggia: A pathological lesion? *Injury* 1996;27:101-102.
8. Wright P: Greenstick fracture of the upper end of the ulna with dislocation of the radio-humeral joint or displacement of the superior radial epiphysis. *J Bone Joint Surg Br* 1963;45:727-731.
9. Jupiter JB, Leibovic SJ, Ribbans W, Wilk RM: The posterior Monteggia lesion. *J Orthop Trauma* 1991;5:395-402.
10. **Jungbluth P, Tanner S, Schneppendahl J, et al: The challenge of Monteggia-like lesions of the elbow: Mid-term results of 46 cases. *Bone Joint J* 2018;100-B:212-218.**
11. Strauss EJ, Tejwani NC, Preston CF, Egol KA: The posterior Monteggia lesion with associated ulnohumeral instability. *J Bone Joint Surg Br* 2006;88:84-89.
12. Mason ML: Some observations on fractures of the head of the radius with a review of one hundred cases. *Br J Surg* 1954;42:123-132.
13. **Patel A, Li L, Rashid A: Fixation versus replacement for comminuted radial head fractures in adults. *Orthop Proc* 2017;99-B:65.**
14. Ring D: Radial head fracture: Open reduction and internal fixation or prosthetic replacement. *J Shoulder Elbow Surg* 2011;20:S107-S112.
15. Storen G: Traumatic dislocation of the radial head as an isolated lesion in children; report of one case with special regard to roentgen diagnosis. *Acta Chirugica Scand* 1959;116:144-147.
16. **Gluck MJ, Beck CM, Sochol KM, London DA, Hausman MR: Comparative strength of elbow splint designs: A new splint design as a stronger alternative to posterior splints. *J Shoulder Elbow Surg* 2019;28:e125-e130.**
17. Ring D, Jupiter JB, Simpson NS: Monteggia fractures in adults. *J Bone Joint Surg Am* 1998;80:1733-1744.
18. Bruce HE, Harvey JP, Wilson JC Jr: Monteggia fractures. *J Bone Joint Surg Am* 1974;56:1563-1576.
19. Reckling FW: Unstable fracture-dislocations of the forearm (Monteggia and Galeazzi lesions). *J Bone Joint Surg Am* 1982;64:857-863.
20. Strauss EJ, Alaia M, Egol KA: Management of distal humeral fractures in the elderly. *Injury* 2007;38:10-16.
21. Hausman M, Panozzo A: Treatment of distal humerus fractures in the elderly. *Clin Orthop Relat Res* 2004;425:55-63.
22. **Campbell ST, DeBaun MR, Goodnough LH, Bishop JA, Gardner MJ: Geriatric olecranon fractures treated with plate fixation have low complication rates. *Curr Orthop Pract* 2019;30:353-355.**
23. Ring D, Jupiter JB, Zilberfarb J: Posterior dislocation of the elbow with fractures of the radial head and coronoid. *J Bone Joint Surg Am* 2002;84:547-551.
24. Chung CH, Wang SJ, Chang YC, Wu SS: Reconstruction of the coronoid process with iliac crest bone graft in complex fracture-dislocation of elbow. *Arch Orthop Trauma Surg* 2007;127:33-37.
25. **Bellato E, Rotini R, Marinelli A, Guerra E, O'Driscoll SW: Coronoid reconstruction with an osteochondral radial head graft. *J Shoulder Elbow Surg* 2016;25:2071-2077.**
26. van Riet RP, Morrey BF, O'Driscoll SW: Use of osteochondral bone graft in coronoid fractures. *J Shoulder Elbow Surg* 2005;14:519-523.
27. Ring D, Bruinsma WE, Jupiter JB: Complications of hinged external fixation compared with cross-pinning of the elbow for acute and subacute instability. *Clin Orthop Relat Res* 2014;472:2044-2048.
28. **Sochol KM, Andelman SM, Koehler SM, Hausman MR: Treatment of traumatic elbow instability with an internal joint stabilizer. *J Hand Surg* 2019;44:161.e1-161.e7.**
29. Ring D, Tavakolian J, Kloen P, Helfet D, Jupiter JB: Loss of alignment after surgical treatment of posterior Monteggia fractures: Salvage with dorsal contoured plating. *J Hand Sur Am* 2004;29A:694-702.
30. **Wegmann K, Engel K, Skouras E, et al: Reconstruction of monteggia-like proximal ulna fractures using different fixation devices: A biomechanical study. *Injury* 2016;47:1636-1641.**
31. Grechenig W, Clement H, Pichler W, Tesch NP, Windisch G: The influence of lateral and anterior angulation of the proximal ulna on the treatment of a Monteggia fracture—An anatomical cadaver study. *J Bone Joint Surg Br* 2007;89:836-838.
32. Sandman E, Canet F, Petit Y, Laflamme GY, Athwal GS, Rouleau DM: Radial head subluxation after malalignment of the proximal ulna: A biomechanical study. *J Orthop Trauma* 2014;28:464-469.
33. Eglseder WA, Zadnik M: Monteggia fractures and variants: Review of distribution and nine irreducible radial head dislocations. *South Med J* 2006;99:723-727.
34. **Hamaker M, Zheng A, Eglseder WA, Pensy RA: The adult Monteggia fracture: Patterns and incidence of annular ligament incarceration among 121 cases at a single institution over 19 years. *J Hand Surg* 2018;43:85.1-85.e6.**
35. Cheung EV, Yao J: Monteggia fracture-dislocation associated with proximal and distal radioulnar joint instability: A case report. *J Bone Joint Surg Am* 2009;91:950-954.
36. **Lipman MD, Gause TM, Teran VA, Chhabra AB, Deal DN: Radial head fracture fixation using tripod technique with headless compression screws. *J Hand Surg Am* 2018;43:575.e1-575.e6.**
37. Frank SG, Grewal R, Johnson J, Faber KJ, King GJW, Athwal GS: Determination of correct implant size in radial head arthroplasty to avoid overlengthening. *J Bone Joint Surg Am* 2009;91:1738-1746.
38. van Riet R, van Glabbeek F, de Weerdt W, Oemar J, Bortier H: Validation of the lesser sigmoid notch of the ulna as a reference point for accurate placement of a prosthesis for the head of the radius.

J Bone Joint Surg Br 2007;89-B: 413-416.

39. Egol KA, Tejwani NC, Bazzi J, Susarla A, Koval KJ: Does a Monteggia variant lesion result in a poor functional outcome?: A retrospective study. *Clin Orthop Relat Res* 2005;438:233-238.

40. Beingessner DM, Nork SE, Agel J, Viskontas D: A fragment-specific approach to type IID Monteggia elbow fracture–dislocations. *J Orthop Trauma* 2011;25:414-419.

41. Guitton TG, Ring D, Kloen P: Long-term evaluation of surgically treated anterior Monteggia fractures in skeletally mature patients. *J Hand Surg* 2009;34:1618-1624.

42. Shore BI, Guitton TG, Ring D: Posterior Monteggia fractures in adults with and without concomitant dislocation of the elbow. *Shoulder Elbow* 2012;4:204-208.

43. Chen S, Yu Sy, Yan H, et al: The time point in surgical excision of heterotopic ossification of post-traumatic stiff elbow: Recommendation for early excision followed by early exercise. *J Shoulder Elbow Surg* 2015;24:1165-1171.

44. Giannicola G, Spinello P, Villani C, Cinotti G: Post-traumatic proximal radioulnar synostosis: Results of surgical treatment and review of the literature. *J Shoulder Elbow Surg* 2020;29:329-339.