



Monteggia Fractures in Pediatric and Adult Populations

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educational objectives

1. To understand how the anatomy of the forearm contributes to the pathogenesis of various types of Monteggia fractures.
2. To identify the approaches in managing Monteggia fractures and how these differ in pediatric and adult patients.
3. To recognize the characteristics of a Monteggia fracture that portend a poorer functional outcome.
4. To understand the complications of Monteggia fractures and their treatment.

ABSTRACT

A Monteggia fracture is a fracture of the proximal ulna coupled with a radial head dislocation. These fractures are an uncommon class of forearm fractures. Numerous classification systems have been developed to characterize these fractures, with the Bado classification being the most common. Elbow radiographs are the primary diagnostic modality, demonstrating dislocation when a line drawn extending through the radial head from the radial shaft does not penetrate the capitellum in all views. Notable differ-

ences exist in the prevalence, treatment, and outcomes of Monteggia fractures for pediatric and adult patient populations, with adolescents often achieving a better prognosis. Nonoperative management with closed reduction and cast immobilization often prevails in pediatric patients, dictated by the pattern of the ulnar fracture more so than the direction of the radial head dislocation. However, in adults, operative intervention is frequently indicated because angulation and shortening of the ulna often occur after closed reduction. Although the orthopedic com-

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munity's understanding of these fractures has evolved, the fractures themselves remain a challenging clinical phenomenon. This article reviews the relevant anatomy and pathogenesis, classification, clinical presentation, diagnostic studies, management, outcomes, and complications of Monteggia fractures in children and adults.

Giovanni Battista Monteggia described the first 2 cases of what would become known as Monteggia fractures in Milan in 1814, relying on patient history and physical examination for diagnosis in an era predating formal radiography. This fracture pattern is 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."^{1,2} The eponymous term "Monteggia lesion" was subsequently coined by Jose Luis Bado in 1967 to denote this type of fracture.³ As additional studies have elucidated the characteristics of this injury and its variations, a broader definition of this term has been adopted by orthopedic traumatologists. Currently, a Monteggia fracture generally refers to a fracture of the proximal ulna with an associated dislocation of the radial head.

Monteggia fractures account for approximately 1% to 2% of all forearm fractures.⁴ The presentation of these fractures can be complicated by the simultaneous presence of other comorbid pathology, such as Galeazzi fractures.⁵ In addition, high-energy elbow fracture–dislocations, including transolecranon fracture–dislocations, may resemble Monteggia fractures on radiography and consequently result in misdiagnosis.^{6,7} Conversely, incidences in which a previously dislocated radial head reduces prior to evaluation by a physician, either due to spontaneous reduction or coincident with reduction of the fracture of the ulna, may further obfuscate appropriate diagnosis. However, once such a diagnosis is made, these fractures are challenging to treat suc-

cessfully with minimal complications or functional deficits.

Nonetheless, improvements in management have been made with the recognition that prompt assessment of Monteggia fractures is essential to mitigating limb dysfunction. Understanding the differences between pediatric and adult patients in terms of the incidence of specific types of fractures, treatment, and prognosis has also facilitated this progress. These improvements and the increasingly effective therapies they yield reflect the evolution of our understanding of Monteggia fractures.

ANATOMY AND GENERAL PATHOGENESIS

The forearm comprises 2 principal osseous structures: the radius and ulna. The radius, a cylindrical long bone, articulates proximally with the capitellum of the distal humerus (radiocapitellar joint), as well as the lesser sigmoid notch of the proximal ulna (proximal radioulnar joint). By inhibiting migration of the radius at the radiocapitellar joint, the radial head serves as the primary stabilizer of the proximal forearm.^{8,9} The proximal portion of the ulna consists of the olecranon. The trochlear notch of the olecranon and coronoid process serves as the articulation surface with the distal humerus (ulnohumeral joint). This surface, like the radial head, is lined with hyaline cartilage, with the exception of a bare area—a transverse region in the anterior aspect of the trochlear notch that is devoid of cartilage.¹⁰

Together, the posterior olecranon (the insertion site of the triceps brachii muscle) and anterior coronoid (the insertion site of the brachialis muscle) processes stabilize against translational forces across the ulnohumeral joint. The medial (ulnar) and lateral (radial) collateral ligament complexes resist valgus and varus stresses, respectively, across the elbow. In addition, the radius and the ulna are further bound and stabilized by the interosseous membrane. Spanning the shafts of these

2 bones, this structure consists of 3 volar groups and 1 dorsal fiber group that aid in transferring load between the radius and ulna.¹¹ Typically, the interosseous membrane distributes 60% of the axial force to the radiocapitellar joint and 40% to the ulnohumeral joint.⁸ The forearm is stabilized distally by the triangular fibrocartilage complex at the distal radioulnar joint.

Although specific mechanisms of injury are associated with different types of Monteggia fractures, the majority share a common pathogenesis. The proximal radioulnar joint interconnects the radius and the ulna through the annular and quadrate ligaments. The annular ligament is a ring of fibers originating from the lesser sigmoid notch on the proximal ulna. The circumference of this ligament decreases as it follows the transition from the radial head to the neck distally.¹² The quadrate ligament is a thin fibrous structure covering the elbow joint capsule at the inferior aspect of the annular ligament and connects to the region of the lesser sigmoid notch of the ulna.¹³

In a Monteggia fracture, the force from the ulnar fracture is transmitted along the interosseous membrane, leading to a rupture of the annular and quadrate ligaments. The energy also disrupts the proximal portions of the interosseous membrane, thereby allowing dissociation of the proximal radioulnar joint, as well as the radiocapitellar articulation. This results in the characteristic findings of radial head dislocation. Because the majority of the interosseous membrane is not damaged in this process, the proximal radioulnar joint (and consequently the radiocapitellar joint) is often anatomically realigned with reduction of the ulnar fracture. Furthermore, an important structure to note is the posterior interosseous nerve, which is an extension of the deep branch of the radial nerve distal to the supinator muscle. It supplies purely motor innervation to the extrinsic extensors of the wrist, with the exception of the extensor carpi radialis longus.



Table 1

Features of Different Bado Fracture Types

Type	Cases ^a (%)	Mechanism of Injury	Other Features
1	70/15	Direct trauma ¹⁹ : blow directed to the posterior elbow fractures diaphysis of ulna and forces the radial head anteriorly. Hyperpronation theory ¹ : pronation force on an outstretched arm causes an ulnar fracture and radial head dislocation. Hyperextension theory ²⁰ : biceps contraction resists forearm extension, causing radial head dislocation and the impact causes an ulnar fracture.	Most common type of Monteggia fracture in children.
2	6/79	Axial forces up the forearm with semiflexed elbow fractures the posterior cortex of the ulna, leading to a posterior radial head dislocation. ^{17,21}	Most common type of Monteggia fracture in adults (debated ²¹). Associated with instability of the ulnohumeral joint. ²² Has a 70% radial head fracture rate, and a high rate of posterior interosseous nerve injury. ^{12,23}
3	23/2	Varus force on extended elbow causes ulna greenstick fracture (typically at olecranon), then lateral radial head dislocation. ²⁴	More frequently associated with the inability to reduce the radial head (annular ligament interposition). Pathogenesis is defined mainly for children.
4	1/4	Poorly understood but presumed to be similar to that of Bado type 1.	Most rare of Bado types.

^aData presented as the percentage of cases of Monteggia fractures in children¹⁷/adults.¹⁸

CLASSIFICATION SYSTEMS

To account for clinical and radiographic distinctions between ulnar fractures and associated radial dislocations, Bado³ developed a classification scheme for the various types of Monteggia fractures. His system distinguished fractures primarily based on the direction of the radial head dislocation, which corresponds with the direction of angulation of the fractured ulna due to the tethering effect of the interosseous membrane. Using this approach, he classified Monteggia fractures into 4 overarching types. type 1 fractures refer to an anterior dislocation of the radial head, type 2 fractures denote a posterior dislocation, and type 3 fractures demonstrate a lateral dislocation, all with an associated fracture of the ipsilateral proximal ulna. A type 4 fracture is defined as an anterior dislocation of the radial head with fractures of both the radius and the ulna, often at the same level.

To further characterize variations seen with ulnar fractures in posterior radial head dislocations, Jupiter et al¹⁴ developed a series of subclassifications for

Bado type 2 fractures. Specifically, they identified 4 unique subtypes: an ulnar fracture involving the coronoid process and the olecranon (type 2A), a fracture located distal to the coronoid process at the junction of the metaphysis and diaphysis (type 2B), an ulnar fracture that is strictly diaphyseal (type 2C), and an ulnar fracture, which is a complex fracture from the olecranon to the diaphysis (type 2D).

In addition to his 4 principal fracture types, Bado³ also reported several Monteggia-equivalent fractures. These included isolated (anterior) radial head dislocations, both-bone proximal-third forearm fractures with the radial fracture more proximal than the ulnar fracture, elbow dislocations with an ulnar diaphyseal fracture with or without a proximal radius fracture, and isolated radial neck fractures. The Monteggia-equivalent fractures were identified based on their hypothesized mechanisms of injury and are typically less common than the more traditional Bado types.

Furthermore, noting that many of the early studies investigating Monteggia fractures were performed on skeletally

mature individuals, Letts et al¹⁵ reviewed 33 cases of Monteggia fractures in pediatric patients. Through their analysis, they devised a more extensive, alternative classification system for pediatric patients centered on features of the injured ulna. This system included an anterior ulnar bend (plastic deformation, type A), an anterior ulnar greenstick fracture (type B), and an anterior complete ulnar fracture (type C), all with associated anterior dislocation of the radial head, as well as a posterior radial head dislocation (type D, equivalent to Bado type 2) and a lateral dislocation of the radial head (type E, equivalent to Bado type 3) with a proximal ulnar fracture. However, in a series of 102 Monteggia fractures in adolescents, Olney and Menelaus¹⁶ validated the Bado classification for use in pediatric patients.

Of these approaches to classification, the Bado system is most commonly used to describe Monteggia fractures. Despite similarities in fracture patterns among the Bado types, significant differences exist in the prevalence and mechanism of injury, among other features (Table 1).



Table 2

Clinical Presentation and Physical Examination of Monteggia Fractures

Inspection	Palpation	Range of Motion	Other
Overlying skin may demonstrate hematoma, localized swelling, or gross deformity.	Varying degrees of tenderness to palpation at elbow. Radial head may be palpable in antecubital fossa (Bado types 1, 4), posteriorly (Bado type 2), laterally (Bado type 3).	Limitations predominantly with forearm supination and pronation and elbow flexion. Crepitus may be noted. Pain with motion.	Check neurovascular status for brachial, distal radial, and ulnar pulses. Nerve palsies may be present (eg, posterior interosseous nerve injury with radial wrist deviation on extension and finger drop).

DIAGNOSTIC STUDIES

Although clinical presentation may suggest a Monteggia fracture (Table 2), the diagnosis is most often confirmed by plain radiography. Anteroposterior, lateral, and oblique radiographic views of the forearm should be acquired to evaluate the radiocapitellar, radioulnar, and ulnohumeral joints and the radius and the ulna shafts for evidence of a fracture or dislocation. Particular attention should be paid to the characteristics of the ulna, most notably in pediatric patients, for signs of plastic deformation or other pathology. Views of the wrist and distal forearm should also be obtained to assess for distal fractures.

In addition, although typically clearly identifiable, a radial head dislocation may be missed. This most frequently occurs when a distracting injury, such as a severe fracture of the ulna, is present. Such missed dislocations are more likely to occur with Bado type 4 fractures, where the evaluating physician's attention is focused on the radial and ulnar shaft fractures. To aid in diagnosing a radial head dislocation, a line can be drawn through the radial shaft extending through the radial head using an elbow radiograph. If the radial head is in its normal anatomic position, the line should penetrate the capitellum in all radiographic views, especially the lateral image (Figure). Repeat radiographs should be obtained 1 week later when radiographs are equivocal.²⁵

MANAGEMENT

Appropriate management of Monteggia fractures varies depending on the pa-

tient population. However, several tenets of treatment remain the same regardless of whether the patient is an adolescent or an adult. Specifically, several fractures can be observed in a Monteggia fracture pattern, which warrant treatment. In addition to the characteristic ulnar fracture and radial head dislocation, these include a fracture of the radius, ulnohumeral dislocation, proximal radioulnar dislocation, and distal radioulnar joint injury.⁶

Furthermore, in many cases, closed reduction may be attempted as an initial step in management. If an adequate reduction is unobtainable, the capsule or annular ligament may be interposed within the joint, or an osteochondral loose body may have developed from the shearing forces present during radial head dislocation, thereby preventing appropriate anatomic reduction. In the case of an open fracture, intravenous antibiotics should be initiated, followed by irrigation and debridement of the wound with open reduction and internal fixation (ORIF).

Regardless of the method, the overarching goals of Monteggia fracture treatment include early recognition of the fracture pattern, reduction of the radial head, union of the fracture, restoration of the ulna length and appropriate ulna alignment, and reestablishment of the contour of the trochlear notch. Furthermore, prevention of stiffness through mobilization is a vital goal of treatment (especially in adults) to minimize any loss in forearm supination or pronation and to restore flexion and extension of the ipsilateral

wrist and elbow.

Pediatric Population

Nonoperative management of Monteggia fractures in adolescents is more successful than in the adult population. This phenomenon is likely secondary to a variety of factors, including the ability of adolescents to remodel residual deformities <10°, the shorter healing period required for bone or ligament injuries in this population, the intrinsic stability of Monteggia fractures in children, and the ease with which adolescents regain range of motion (ROM) after protracted immobilization.⁷

Investigations into the efficacy of different approaches to the care of pediatric Monteggia fractures have demonstrated that the characteristics of the ulnar fracture, rather than of the radial head dislocation, dictate treatment.^{7,26} As such, management varies depending on whether the ulna has undergone plastic deformation or an incomplete, complete, or long oblique fracture. Plastic deformation refers to bending or bowing of the bone, without a fracture, as a result of the reduced mineral content in the pediatric cortical bone. In such cases, closed reduction of the ulnar bow should be performed through longitudinally directed traction or by applying sequential, transversely directed forces proximal and distal to the apex of the bow, with the fulcrum along the apex, to gradually reverse the deformity in each plane over the entire length of the ulna.

Failure to correct the bow may result in permanent forearm deformity for the



Figure: Lateral radiograph of a Bado type 2 Monteggia fracture. A dashed red line is drawn through the shaft of the radius and passes below the capitellum, indicating a posterior dislocation of the radial head.

patient and, in the absence of an obvious fracture, may contribute to the irreducibility of the radial head. The affected forearm should then be immobilized within a cast with full supination and 110° of elbow flexion for 6 weeks. This position relaxes the biceps muscle while tensing the interosseous membrane, thereby stabilizing the reduction. Incomplete fractures of the ulna may also occur. These fractures, including greenstick fractures, are treated similarly to plastic deformation with closed reduction and cast immobilization.

However, complete ulnar fractures, including short oblique fractures, require operative management if they are displaced. After reduction, elastic intramedullary titanium nail fixation of the ulna is performed; alternatively, K-wires may be used in younger patients after closed reduction, although this technique has been largely replaced by nail osteosynthesis.²⁷ This approach successfully stabilizes the fixation due to the narrow width of the pediatric intramedullary canal, a large percentage of which is occupied by the nail or wire. If used, K-wires are removed 3 to 4 weeks postoperatively. In addition, comminuted or long oblique fractures of the ulna also necessitate surgical treatment. Unlike short oblique or transverse fractures, these fractures are most suc-

cessfully fixed through ORIF with a plate and screws rather than intramedullary nail fixation.

Pediatric Monteggia fractures diagnosed several weeks after injury can result in persistent pain and instability. Numerous surgical approaches, including radial osteotomy, open reduction of the displaced radial head, and repair of the annular ligament, have been described for the treatment of these cases.^{28,29} Some studies advocate for the implementation of a combination of these techniques. David-West et al²⁵ performed a retrospective study of missed Monteggia injuries in children and concluded that ulnar osteotomy, open reduction of the radial head followed by transcapitellar pin stabilization, and reconstruction of the annular ligament yielded clinically acceptable results. Other investigations recommend fewer interventions. This is observed in the retrospective review by Ladermann et al³⁰ of the medical records and radiographs of missed Monteggia fractures presenting with malunion of the ulna and radial head dislocation. These authors espoused the use of an ulnar osteotomy with lengthening and angulation, bone grafting, and internal fixation without the need for open reduction or annular ligament repair.

Adult Population

Unlike in pediatric patients, angulation and shortening of the ulna after successful closed reduction and accompanying reduction of the dislocated radial head often occurs with adult Monteggia fractures. Consequently, operative treatment is needed for the majority of adult patients. Although intramedullary nailing or K-wire fixation may be used with success in children, these techniques often fail to attain proper anatomic alignment in adults. Instead, anatomic reduction and fixation of the ulna is achieved through ORIF.^{18,31}

In this procedure, a posterior skin incision between the flexor carpi ulnaris and the extensor carpi ulnaris may be performed.³¹ Using this approach and exposure, a 3.5-mm dynamic compression plate or a limited-contact dynamic compression plate is then fixed to the dorsal surface of the fractured ulna and contoured around the olecranon process by engaging at least 6 cortices proximally and distally with screws. The subsequent reduction of the ulna often leads to reduction of the radial head due to the predominantly intact interosseous membrane in Monteggia fractures. Intraoperative fluoroscopy may be used to confirm reduction of the radial head and ulnar fracture, as well as stability of the plate fixation.

However, in a comminuted fracture of the ulna, ORIF with placement of 5 to 6 screws proximal and distal to the fracture site should be performed.⁷ In addition, although its use is debated in the literature, autologous iliac crest bone grafting may be used to facilitate fracture healing in comminuted fracture patterns.¹²

Other comorbid injuries may accompany the classic ulnar fracture and radial head dislocation pattern in Monteggia fractures. Specifically, high-energy elbow trauma can result in the fracture or dislocation of the radial head. However, the operative technique performed for the treatment of such an injury depends on the degree of fragmentation; radial head fractures with ≤ 3 fragments can be fixed with



screws, whereas fractures involving >3 fragments require primary excision with radial head replacement.³² Furthermore, coronoid process fractures present in conjunction with a Monteggia fracture are treated with cannulated screw fixation to aid in restoring elbow stability. Similarly, patients presenting with an elbow dislocation in association with fractures of the radial head and coronoid can be treated with repair of any medial or lateral collateral ligament damage, as well as operative fixation or replacement of the radial head and fixation of the ulna, with acceptable functional outcomes.³³

The postoperative course is defined by immediate immobilization followed by gentle, early ROM exercises. After surgical repair, the upper extremity should be immobilized in a long-arm splint in full supination and 100° of elbow flexion for Bado type 1, 3, and 4 Monteggia fractures. Bado type 2 fractures should be splinted in the same position, but in 70° of flexion to prevent radial head subluxation because this injury is already predisposed to posterior dislocation. Adult patients receive physical therapy, often beginning within the first 2 weeks after injury, for increasing ROM of the elbow and shoulder with gravity assistance to mitigate postoperative stiffness.

OUTCOMES AND COMPLICATIONS

The complexity of Monteggia fractures contributes to the variable outcomes seen in patients with this fracture. Marked differences are observed in the outcomes of adolescents and adults, with pediatric patients generally achieving uniformly good results. Although missed Monteggia fractures in adolescents may lead to debilitating deformities, open reduction performed within 3 years of the initial injury or in adolescents younger than 12 years yielded good radiographic and functional outcomes.³⁴ Outcomes in the adult population are more variable. In a retrospective analysis of 47 adult Monteggia fracture cases, Konrad et al³⁵ identified several negative prognostic indicators for

patients undergoing operative treatment. They found that Bado type 2 fractures, Jupiter type 2A fractures, coronoid process fractures, radial head or neck fractures, and complications necessitating additional surgery correlated with poorer clinical outcomes. Other studies also demonstrated that Bado type 2 fractures associated with an ulnohumeral dislocation and Monteggia variants have lower functional outcome scores.^{22,36} However, patient sex and the method of ulnar fixation do not appear to correlate with outcomes.³⁵

Several different complications may occur with Monteggia fractures. Nerve injuries can result from stretching the nerve across bony surfaces after traction. Specifically, posterior interosseous nerve palsy, occurring most commonly in Bado type 2 fractures due to contusion by the radial head or compression against the supinator muscle, may lead to radial wrist deviation on extension and finger drop. Rarely, ulnar nerve palsy can result from a valgus deformity of the elbow and a protracted radial head dislocation. These neural injuries typically resolve spontaneously within 9 to 12 weeks.¹⁷ In addition, proximal radioulnar synostosis, the abnormal fusion of adjacent bones, principally seen with fractures of the proximal radius and ulna, may occur and impair the patient's forearm supination and pronation.

Malunion or nonunion rates are notably higher than the average forearm fracture nonunion rate of 2%.¹⁸ Furthermore, posttraumatic elbow stiffness may result from protracted immobilization in adult patients; this is not as prevalent in pediatric cases, regardless of the duration of immobilization. Surgical intervention to release elbow contractures may be indicated when the approximate 30° to 130° functional arc of elbow ROM is impaired. Furthermore, recurrent radial head dislocations and pain from implanted surgical hardware can lead to debilitating reductions in ROM. The use of low-profile fixation plates can aid in minimizing irritation to surrounding soft tissues and, therefore,

limit such pain. In addition, ulnohumeral osteoarthritis, most commonly observed in the coronoid process fracture and elbow instability, and compartment syndrome can complicate Monteggia fracture cases.

CONCLUSION

Monteggia fractures are a rare class of forearm fracture defined as a fracture of the proximal ulna with an associated radial head dislocation. These fracture-dislocations are classically characterized according to the Bado classification, with Bado type 1 (anterior dislocation) fractures occurring more commonly in adolescents and Bado type 2 (posterior dislocation) fractures occurring more frequently in adults. The diagnosis of a Monteggia fracture is often made by review of anteroposterior, lateral, and oblique radiographs of the elbow. In addition, the management of these injuries varies depending on the patient population, with adolescents often treated nonoperatively with closed reduction and immobilization by casting, but adults typically requiring operative treatment with plate and screw fixation.

Comorbid fractures at the level of the elbow, including radial head and coronoid process fractures, must be identified and addressed because these lead to poorer functional outcomes. Noted complications of these fractures include neuropraxias, particularly of the posterior interosseous nerve, and postoperative stiffness, which can be mitigated with early mobilization and physical therapy. Continued improvement in the outcomes of Monteggia fracture cases has been evidenced over the past decade, due in large part to increased recognition of these fractures and the differences in management between pediatric and adult patient populations. ■

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