Monteggia Fractures in Children and Adults

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Abstract

The eponymous term "Monteggia fracture" is most precisely used to refer to dislocation of the proximal radioulnar joint in association with a forearm fracture. It is the character of the ulnar fracture, rather than the direction of radial head dislocation, that is useful in determining the optimal treatment of Monteggia fractures in both children and adults. Stable anatomic reduction of the ulnar fracture results in anatomic reduction of the radial head. The notoriously poor results of treatment of Monteggia fractures in adults improved dramatically after the development of modern techniques of plate-and-screw fixation, which facilitate early mobilization by ensuring anatomic reduction. The relatively good results associated with nonoperative treatment of pediatric Monteggia injuries reflect the prevalence of stable (incomplete) fractures in children. Unstable (complete) ulnar fractures are prone to residual or recurrent displacement and may require operative fixation. Late reconstruction of chronic Monteggia lesions in children can be complicated and unpredictable. The key to a good outcome after a Monteggia-type fracture-dislocation of the forearm remains early recognition of proximal radioulnar dissociation.

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Giovanni Battista Monteggia's pre–Roentgen era description of radiohumeroulnar dislocation in association with fracture of the ulna has earned for him one of the most solidly entrenched eponyms in orthopaedics.[1] The lasting success of the eponymic description of this injury can be traced to both its facilitation of an emphasis on timely recognition of radial head dislocation (which remains the most important element of management) and the infamy of the injury as one that is difficult to treat and frequently results in substantial disability. The eponym "Monteggia" has come to connote the frustration expressed by Watson-Jones,[2] who stated that "no fracture presents so many problems; no injury is beset with greater difficulty; no treatment is characterized by more general failure."

Paradoxically, as our understanding of forearm and elbow trauma has improved and a variety of traumatic injuries have been distinguished, the precise traumatic anatomy reflected by the eponym "Monteggia" has become less clear. Bado's inclusion of a number of so-called Monteggia-equivalent injuries on the basis of the similarity of their proposed injury mechanisms was detrimental in this regard because most of these injuries do not involve dislocation of the proximal radioulnar joint and are therefore associated with distinct difficulties in management.[1] Furthermore, some injuries associated with radiocapitellar dislocation (such as transolecranon fracture-dislocation of the elbow) are mislabeled as Monteggia lesions, when in fact the proximal radioulnar joint remains intact[3] (Fig. 1). The Monteggia lesion is most precisely characterized as a forearm fracture in association with dislocation of the proximal radioulnar joint.

The classification and treatment of Monteggia lesions has often focused on the radiocapitellar dislocation. Treatment recommendations have included open reduction of the radial head, fascial-loop reconstruction of the annular ligament, and transradiocapitellar pin fixation.[4,5] However, in adults, the advent of sound techniques of internal fixation has demonstrated that precise restoration of the length and alignment of the ulna will result in congruence of the proximal radioulnar articulation and that appropriate healing of the soft tissues (including the annular ligament) is predictable without open reduction of the radial head

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Fig. 1 Not every fracture with radiocapitellar dislocation is a Monteggia lesion. This radiograph of a 44-year-old man who suffered a high-energy blow to the flexed forearm in a bicycle accident shows that the distal humerus pulverized the trochlear notch of the proximal ulna; the forearm bones are dislocated anteriorly, but the proximal radioulnar joint remains intact. This injury is better classified as a transolecranon fracture-dislocation of the elbow, thereby emphasizing that it is a variant of anterior dislocation of the elbow.

or ligament repair.[6-8] Stable internal fixation of the ulna also allows early motion, and complete or near-complete return of elbow and forearm motion can be expected.

Published reports of Monteggia-type fracture-dislocations in children have also placed emphasis on the character of the ulnar fracture.[9-12] The greater proportion of satisfactory outcomes among children with Monteggia injuries reported in the literature is a reflection of the high prevalence of stable fracture types.[4,5,9-12] However, poor results do occur, and their avoidance, as in the adult, is dependent on both early recognition of the associated dislocation of the proximal radioulnar joint and stable anatomic reduction of the ulnar fracture. Complete ulnar fractures are frequently unstable and may require operative fixation.[9-11]

Persistent subluxation or recurrent dislocation of the radial head reflects malalignment of the ulnar fracture.[5-7] In adults, it has long been recognized that this must be identified immediately, or a poor result is inevitable.[4-6,8] In children, however, the option of open relocation of the radial head and fascial-loop reconstruction of the annular ligament, with or without ulnar osteotomy, has been touted as a viable option in the management of so-called chronic Monteggia lesions.[9,13,14] In our experience, reconstructive procedures for chronic Monteggia lesions have been unpredictable and plagued by numerous complications.[15] This places all the more emphasis on timely recognition of the injury and stable anatomic reduction of the ulnar fracture as the key elements in the management of Monteggia lesions in patients of all ages.

Anatomy

The forearm is a unique two-bone structure with dual intra-articulations providing rotational movements (pronation and supination) that greatly expand the variety of ways in which objects can be positioned and manipulated by the hand. Forearm fractures behave like intra-articular fractures in that residual malunion will restrict these rotational movements (both inherently and by means of radioulnar joint incongruities) and contribute to posttraumatic arthroses at the proximal and distal radioulnar joints. This is reflected in recent investigations emphasizing the importance of anatomic reduction of both-bone forearm fractures. Accounting for the effects of associated soft-tissue injury, ipsilateral fracture, or complications on forearm rotation, Schemitsch and Richards[16] demonstrated that failure to restore the location and magnitude of the anatomic bow of the radius to within 4% to 5% of that of the unaffected arm was associated with more than 20% loss of forearm rotation; grip strength was also reduced in malunited fractures.

Dissipation of the energy of a traumatic forearm injury results in disruption of both the ulnar and the radial aspects of the forearm in all but a few cases (e.g., the so-called nightstick, or isolated, fracture of the ulna, which is typically the result of a direct blow). When one bone is fractured, a corresponding fracture or dislocation of the other bone is likely and should be sought. Monteggia-type fracture-dislocations of the forearm represent osseous failure of the ulnar portion of the forearm, with ligamentous failure on the radial side and resultant dislocation of the radial head.

The radius and ulna are interconnected at the distal radioulnar joint by the triangular fibrocartilage complex, in the midportion by the interosseous membrane, and at the proximal radioulnar joint by the annular and quadrate ligaments. In a Monteggia fracture, the annular and quadrate ligaments are ruptured, allowing dissociation of the proximal radioulnar joint (as well as the radiocapitellar articulation, due to associated elbow capsular disruptions), but the greatest portions of the interosseous membrane and the triangular fibrocartilage complex remain intact. As a result of the preservation of these radioulnar interconnections, anatomic reduction of the ulnar fracture will restore congruity of the proximal radioulnar joint (and, therefore, the radiocapitellar articulation) except in the extremely rare case in which soft-tissue interposition (by nerve, tendon, or ligament) occurs.[6]

The radial head contributes to valgus stability at the elbow. Persistent dislocation of the radiohumeroulnar joint can contribute to valgus instability with an increase

in the carrying angle of the elbow.[14] Radiohumeral arthrosis can also occur, leading to pain and progressive loss of flexion and extension. In addition, radial nerve palsy can develop after many years in a patient with persistent radial head dislocation.

Much of the difficulty traditionally associated with the management of Monteggia-type fracture-dislocations of the forearm stems from the fact that the associated dislocation of the radial head frequently goes unrecognized initially. Early recognition is facilitated by an awareness of the normal radiocapitellar relationship, which can be clearly identified on radiographs that include the elbow. A line down the center of the shaft and head of the radius should intersect the capitellum in all positions of flexion/extension in any projection.

One must also realize, however, that not all radiocapitellar dislocations are Monteggia lesions. Injuries with disruption of the ulnohumeral articulation (such as elbow dislocations) also have radiocapitellar dislocation. One such injury, in which failure of the ulnohumeral articulation occurs through the olecranon, resulting in an often complex proximal ulnar fracture with associated anterior dislocation of the forearm (its radioulnar articulations remaining intact), is referred to by Biga and Thomine[3] as a transolecranon fracture-dislocation of the elbow and by others as a fracture-dislocation of the olecranon (Fig. 1). This injury is frequently misidentified as a Monteggia lesion.[17] Radiocapitellar dislocation may also occur in high-energy traumatic injuries of the forearm, such as floating radius injuries (also described as bipolar or radioulnar dissociation injuries of the forearm) in which proximal radioulnar joint dislocation is only a small part of the osseous and ligamentous disruption.[18]

The posterior Monteggia fracture has long been recognized as a transitional lesion combining elements of ulnohumeral and proximal radioulnar instability.[7,19,20] Ulnohumeral instability can result from extension of the ulnar fracture into the ulnohumeral articulation (large anterior cortical fragment including the coronoid process) as well as from an element of posterolateral rotatory instability that is most likely due to rupture of the lateral ulnar collateral ligament at the time of injury. The mechanism of the posterior Monteggia lesion resembles that of a posterior elbow dislocation, and it may be that this injury represents an alternative pattern of skeletal disruption. In the posterior Monteggia lesion, failure occurs through the proximal ulna rather than the collateral ligaments and capsular structures of the ulnohumeral articulation. This is analogous but opposite to the mechanism of transolecranon fracture-dislocation of the elbow, which represents an anterior elbow dislocation with failure of the ulnohumeral articulation through the olecranon rather than the collateral ligaments.[3]

Bado[1] listed a number of injuries as Monteggia "equivalents" on the basis of similar injury mechanisms and methods of closed reduction. His Monteggia equivalents include the so-called pulled elbow (or nursemaid's elbow) in children, both-bone forearm fractures with fracture of the proximal third of the radius (radial fracture proximal to an ulnar fracture), isolated radial neck fracture, and dislocation of the elbow with fracture of the ulnar diaphysis, with or without fracture of the proximal radius. Clearly, these injuries have distinctive pathoanatomic features, and the management considerations are different from those for forearm fractures with associated proximal radioulnar joint dislocation. Even the more seemingly equivalent injuries encountered in children (fracture through the radial neck or proximal radial epiphysis in association with ulnar fracture) are best considered separately.[1,10]

Classification

Although Monteggia's original description was of a fracture of the proximal third of the ulna in association with radial head dislocation, subsequent authors have included fracture at any location on the ulna.[1,5] Bado has been honored by wide use of his numeric classification of Monteggia lesions, which reflects the fact that the radial head can displace anteriorly (type 1), posteriorly (type 2), or laterally (type 3), and that the radius may be fractured as well as dislocated (type 4).[1] This classification could just as easily be made according to the angulation of the fracture of the ulna: that is, apex anterior in type 1, apex posterior in type 2, and apex radial (varus angulation) in type 3.

The direction of radial head dislocation is related to the mechanism of injury and is therefore useful in determining the appropriate reduction maneuver and position of cast immobilization.[1] Direction of dislocation is also important epidemiologically, with posterior dislocations occurring primarily in middle-aged and elderly adults,[1,7,19,20] lateral dislocations occurring more commonly in children, and anterior dislocations being common in children and young adults.[1]

Recognition of the importance of stable anatomic reduction of the ulnar fracture as the foundation of optimal treatment of Monteggia injuries has led to a decreased emphasis on the direction of radial head dislocation and an increased focus on the character of the fracture of the ulna[6,7,9-11] (Table 1). This is particularly true in children, in whom the variety of fracture

Table 1
Treatment of Monteggia Fracture-Dislocations in Children According to Ulnar Injury

Type of Ulnar Injury	Treatment
Plastic deformation	Closed reduction of the ulnar bow and cast immobilization
Incomplete (greenstick or buckle) fracture	Closed reduction and cast immobilization
Complete transverse or short oblique fracture	Closed reduction and intramedullary Kirschner-wire fixation
Long oblique or comminuted fracture	Open reduction and internal fixation with plate and screws

types that occur in immature bone results in distinct injury patterns that influence treatment considerations.[9-11]

Plastic deformation of the ulna in association with anterior radial head dislocation represents a substantial proportion of Monteggia lesions in children (31% of anterior Monteggia lesions in our recent series[11] [17% overall]) (Fig. 2, A). Plastic deformation of the ulna is poorly recognized and has often been characterized in the past as an isolated dislocation of the proximal radioulnar joint. Failure to identify the plastic deformation of the ulna in these apparently isolated radial head dislocations in children and young adults is likely to lead to recurrent or persistent dislocation and possibly a chronic Monteggia lesion, as the radial head reduction remains unstable until the plastic deformation is corrected.

An incomplete fracture of the olecranon in varus angulation with associated lateral subluxation of the radial head has been described by numerous authors as representing a distinct injury occurring in young children. In our opinion, this represents a lateral Monteggia injury in which the ulnar fracture is a buckle-type fracture through the metaphysis of the proximal ulna (Fig. 2, B).

Greenstick fractures are another type of incomplete fracture seen commonly in immature bone (Fig. 2, C). Monteggia injuries with incomplete fractures can usually be

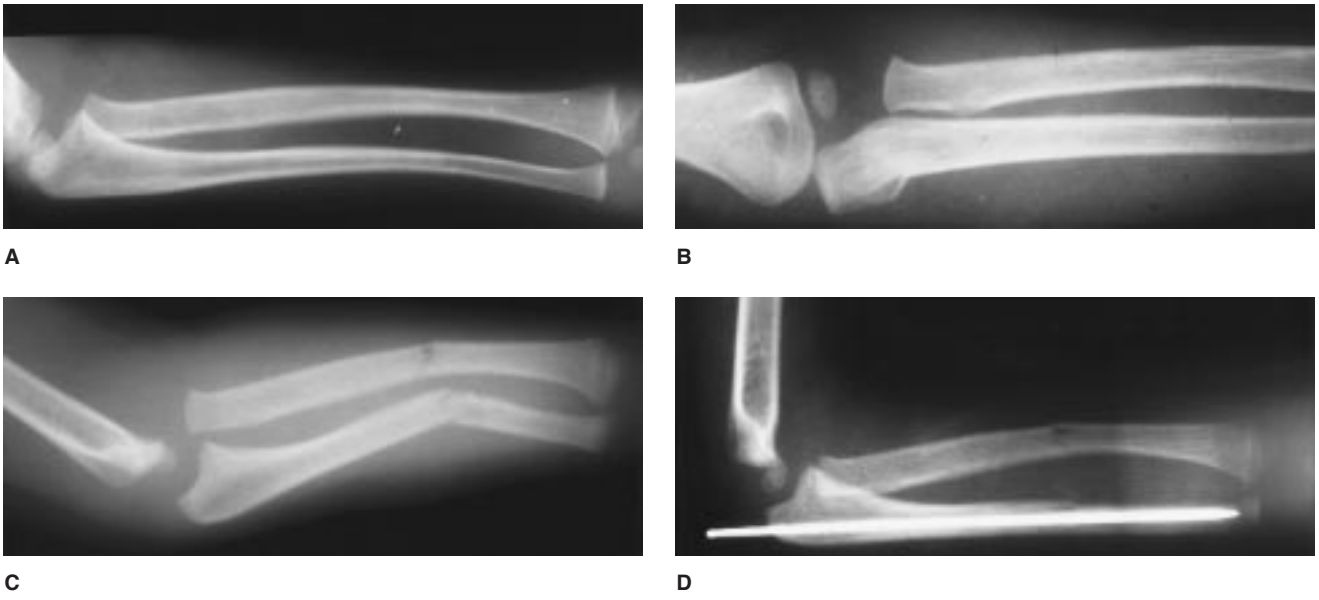


Fig. 2 A large percentage of Monteggia fractures in children have relatively stable ulnar fracture patterns. **A,** Radiograph of a 9-year-old boy with plastic bowing of the ulna and anterior dislocation of the radial head after a fall from a swing. **B,** A buckling-type fracture of the proximal ulna with lateral subluxation of the radial head occurred in a 2-year-old girl who fell from a chair. **C,** Greenstick fractures of the radius and ulna with anterior dislocation of the radial head occurred in a 4-year-old girl after a fall from the monkey bars. Because of the marked ulnar angulation and the associated radial fracture, the surgeon decided to stabilize the ulnar fracture with an intramedullary Kirschner wire **(D)**.

treated successfully by closed reduction and cast immobilization, because the maintenance of bone continuity and periosteal integrity prevents shortening and the reduction is more stable.[10-12] Nonoperative treatment will be successful for most Monteggia injuries in children because (1) the majority of the fractures are inherently stable, (2) they require a shorter time for both the osseous and the ligamentous injuries to heal, (3) they can be immobilized for the duration of the initial healing period (3 to 6 weeks) with little trouble regaining motion lost through stiffness, and (4) they may have the potential for remodeling of mild residual angular deformities (less than 10 degrees).

Complete fractures in childhood Monteggia injuries represent the exception to this rule. The complete disruption of bone continuity is likely to be associated with substantial soft-tissue trauma in these injuries. Shortening and angulation of complete fractures after closed reduction and cast immobilization is not uncommon. Achievement of stable anatomic reduction of the ulnar fracture (and, correspondingly, the radial head), often requires operative fixation.[5,9-11] Moreover, it is important to distinguish complete fractures with transverse or short oblique fracture patterns (which can often be held in adequate alignment with intramedullary wire fixation alone [Fig. 3, A and B]) from long oblique and comminuted fractures of the ulna (which tend to shorten or angulate even with an intramedullary wire in place [Fig. 3, C and D]).[11]

When an associated fracture of the radius occurs in a childhood Monteggia injury (Bado type 4), it is usually an incomplete fracture that is stable after manipulative reduction.[11] Provided that an anatomic reduction is obtained, the radial fracture usually plays a minor role in the injury, although in some cases it can increase the instability of the radial head reduction to such a degree that operative fixation must be considered (Fig. 2, C and D).

The ulnar fracture that occurs in posterior Monteggia lesions is intrinsically unstable as a result of the predictable disruption of the anterior cortex, which typically includes an anterior triangular or quadrangular fracture fragment either including or just distal to the coronoid process (Fig. 4).[7,19,20] Fracture of the radial head as it collides with the capitellum while dislocating posteriorly is present in most cases, adding further complexity to the injury.[7,19,20]

The various types of proximal ulnar fractures that can occur in this setting have been characterized and classified by Jupiter et al.[7] In a type A fracture (Fig. 4), the anterior

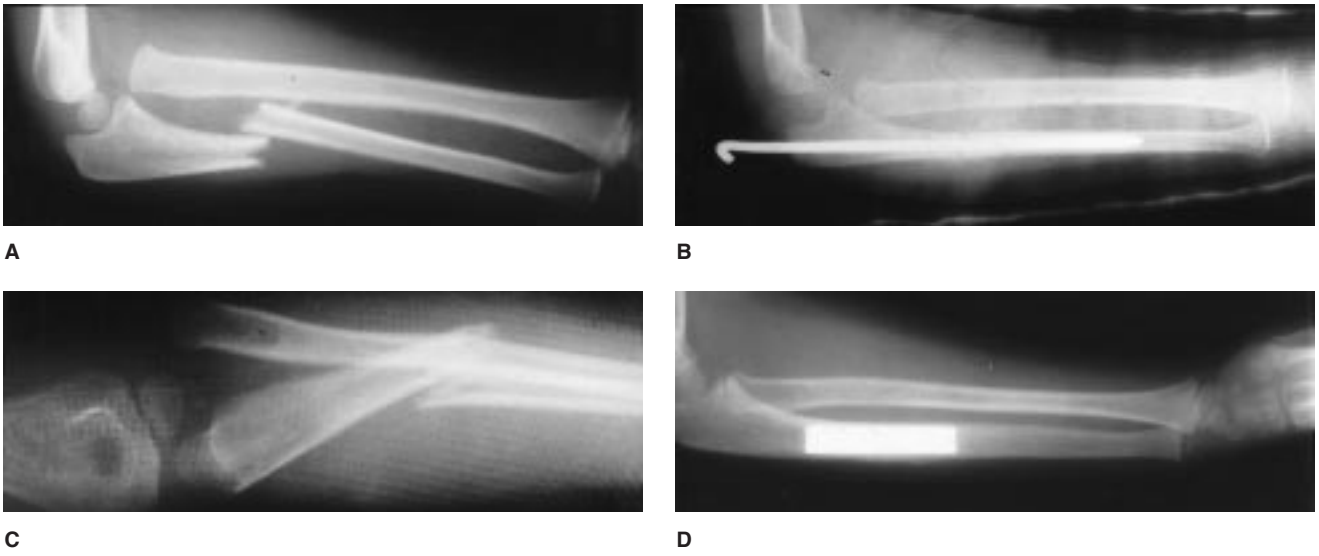


Fig. 3 Childhood Monteggia injuries with complete fractures of the ulna are inherently unstable and prone to persistent or recurrent radial head subluxation. **A,** Radiograph of a 6-year-old boy who sustained an anterior Monteggia fracture with a complete transverse fracture of the ulna. Closed reduction was attempted, but was unsuccessful. **B,** An intramedullary Kirschner wire was inserted into the proximal fragment via the olecranon apophysis. By using the wire for leverage, the fracture was manipulated into anatomic position without opening the fracture site. The wire was then advanced into the distal fragment, thereby establishing stable anatomic reduction. **C,** Radiograph of a 5-year-old boy who sustained a markedly angulated and shortened lateral Monteggia fracture in a fall from a tree. There was concern that this long oblique fracture of the ulna would shorten (with resultant proximal radioulnar joint incongruity) with intramedullary fixation alone. Therefore, a four-hole semitubular plate was used for fixation after anatomic reduction **(D)**.

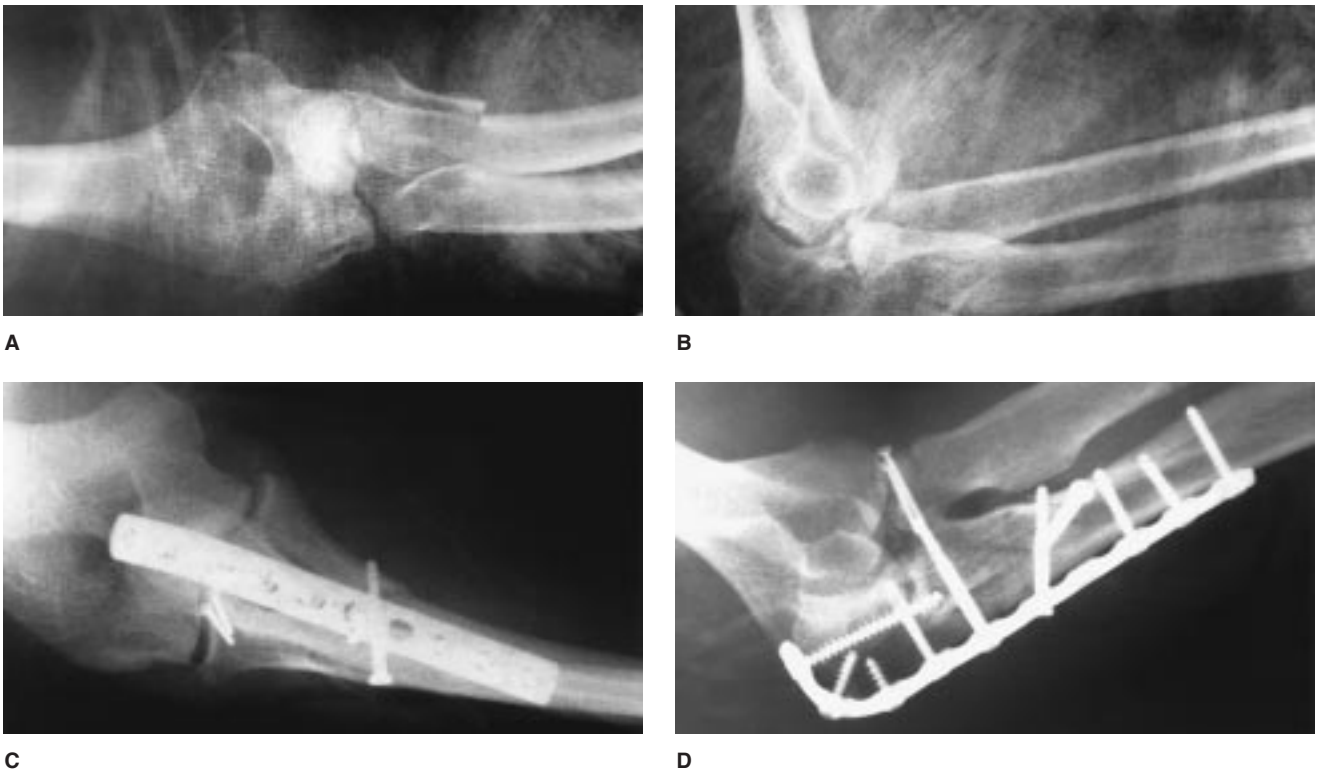


Fig. 4 A 64-year-old man sustained a posterior Monteggia fracture in a backward fall from a standing position. Anteroposterior **(A)** and lateral **(B)** radiographs taken after splint immobilization demonstrate a fracture of the proximal ulna with apex dorsal angulation and posterior dislocation of the radial head, which is also fractured. Although it is difficult to see on these images, the coronoid is fractured as a separate fragment (type A posterior Monteggia fracture, according to Jupiter et al[7]), thereby adding a component of ulnohumeral instability to the injury. **C** and **D,** The reduction was stabilized with a 3.5-mm compression plate that extends to the tip of the olecranon process. The coronoid is fixed in anatomic position by two screws inserted through the plate. The fracture of the radial head has been reduced and fixed with two 2.7-mm screws.

fragment includes the coronoid process; in a type B fracture (Fig. 5), it is just distal to it. A type C fracture is diaphyseal. Type D is a complex fracture pattern involving the entire proximal third to half of the ulna. Most fractures are either type A or type B.

The remaining adult Monteggia injuries are associated with either anterior or (less commonly) lateral dislocation of the radial head. They are most likely to occur in younger, skeletally normal adults after high-energy falls forward on an outstretched upper extremity, but may also occur after a direct blow to the forearm.[1,5,6,8] The ulnar fracture in each case is often comminuted, but has not otherwise been classified. Residual cortical contact between the main fracture fragments facilitates accurate restoration of length, rotation, and alignment when compared with more comminuted fractures.

Management

Acute Monteggia Lesions in Children

Closed reduction and cast immobilization of childhood Monteggia injuries with incomplete fracture of the ulna (plastic deformation or buckle-type or greenstick fracture) is easiest when performed under general anesthesia. An image intensifier should be available for real-time and static imaging to verify anatomic alignment of the fracture and congruent reduction of the radiohumeroulnar joint. The direction of radial head dislocation (anterior or lateral) and whether or not an associated incomplete fracture of the radius is present are rarely of any consequence provided stable anatomic reduction of both forearm bones is achieved.[10-12] This is almost always the case, although in some greenstick fractures with marked angulation or associated fracture of the radius, the risk of late displacement may be high enough to merit consideration of operative fixation.[11]

Gentle longitudinal traction and manipulation are used to correct

the ulnar malalignment, while flexion, supination, and direct pressure over the radial head ensure its reduction. Most ulnar fractures are easy to realign; however, one must keep in mind that a great deal of force is often required to fully reduce deformity caused by plastic deformation. Immobilization in 110 degrees of flexion and full supination may enhance the stability of the reduction by virtue of tightening of the interosseous membrane and relaxation of the biceps; this is an important element of nonoperative treatment.[5]

We recommend operative fixation of complete fractures of the ulna in association with proximal radioulnar joint disruption in children.[11] These fractures are likely to redisplace after closed reduction and cast immobilization.[9-12] We have encountered few complications from the insertion of an intramedullary wire or a small plate-and-screw construct[11] (Fig. 3).

Transverse and short oblique fractures are adequately treated with intramedullary wire fixation.[9-12] Intramedullary fixation rarely provides the precise anatomic reduction that can be achieved with a plate and should not be used in adult Monteggia injuries.[7,8,19,20] In children, however, a stout wire placed in the narrow intramedullary canal of the ulna provides more stable fixation than can be achieved in an adult, and the small residual malalignment is likely to remodel (Fig. 3, A and B). In addition, early motion is not as essential in children, as adjunctive cast immobilization rarely causes persistent stiffness. The intramedullary wires are left protruding from the skin and are removed in the office 3 weeks after their insertion. Pin-tract infection was not encountered in our series.[11]

Intramedullary wires cannot be relied on to maintain reduction of complete fractures that are either long oblique in pattern or comminuted. These fractures are likely to displace or shorten even with an intramedullary wire in place and should be fixed with a plate and screws (Fig. 3, C and D). As a result of the rapidity of osseous repair and the tolerance of cast immobilization in children, use of a plate-and-screw construct that is smaller (typically a one-third or semitubular plate) and shorter (two or three holes [four to six cortices] proximal and distal to the fracture) than that recommended for adults is usually adequate.[11] We continue to remove plates on a routine basis 6 to 12 months after injury and have had no complications from either the insertion or the removal of the plates.

Fig. 5 **A,** A posterior Monteggia lesion occurred in a 50-year-old man as a result of a fall. The ulna is fractured just distal to the coronoid (type B, according to Jupiter et al[7]), and the radial head is dislocated posteriorly with an associated fracture of the anterior articular margin. **B,** Fixation with a long intramedullary screw allowed some residual apex posterior angulation, with corresponding posterior subluxation of the radial head. **C,** Radiograph shows further angulation with recurrent dislocation of the radial head. There is also a suggestion of posterolateral rotatory instability of the ulnohumeral joint, with the distal humerus perched slightly atop the coronoid process and the joint space widened. **D,** Lateral radiograph obtained after plate fixation and excision of the radial head demonstrates that ulnohumeral stability has been restored.

Chronic Monteggia Lesions in Children

It is extremely important to achieve stable reduction during the initial treatment period. If follow-up is delayed beyond 1 week and

the child returns with recurrent dislocation or subluxation, the fracture is likely to be partially healed and the radiohumeroulnar articulation may begin to fill in with fibrous tissue, thereby hindering closed reduction.[11]

Persistent dislocation in a child may lead to elbow instability and limitation of elbow motion (particularly forearm rotation), but many children adapt suprisingly well to the deformity. In fact, it is apparent in the early reports of the operative treatment of chronic Monteggia lesions that the authors were defending the merits of their procedure against the general impression that no intervention was required, as children with persistent radial head dislocation nearly always function well.[13,14] However, there is concern that elbow function will gradually decrease as the valgus instability, cubitus valgus, and limited motion (especially flexion) worsen and pain develops.

The literature documenting the various methods of late reconstruction is suprisingly optimistic. The general consensus is that if the surgeon can effect stable reduction of the radial head—whether by reconstruction of the annular ligament alone, with or without temporary transcapitellar pin fixation; by ulnar osteotomy and open reduction alone, with or without internal fixation of the ulna; or by a combination thereof, with or without radial shortening—elbow function will improve.[13,14] It may be wise to interpret the literature with caution, however, considering that, historically, the findings from many of these case reports and small series of patients have been used to a large extent to argue in favor of intervention as opposed to observation or in support of a new surgical technique.

Most authors concede that the results of reconstruction of the chronic Monteggia lesion are less predictable when the radial head has developed deformity due to abnormal growth in its dislocated position. With an increase in the interval between injury and treatment, the procedure becomes more complex, requiring ulnar lengthening and sometimes radial shortening to achieve reduction. The influence of the age of the patient apart from these delay-related factors is uncertain, but it is well known that younger children recover from operative interventions and tolerate immobilization better than older children and adults.

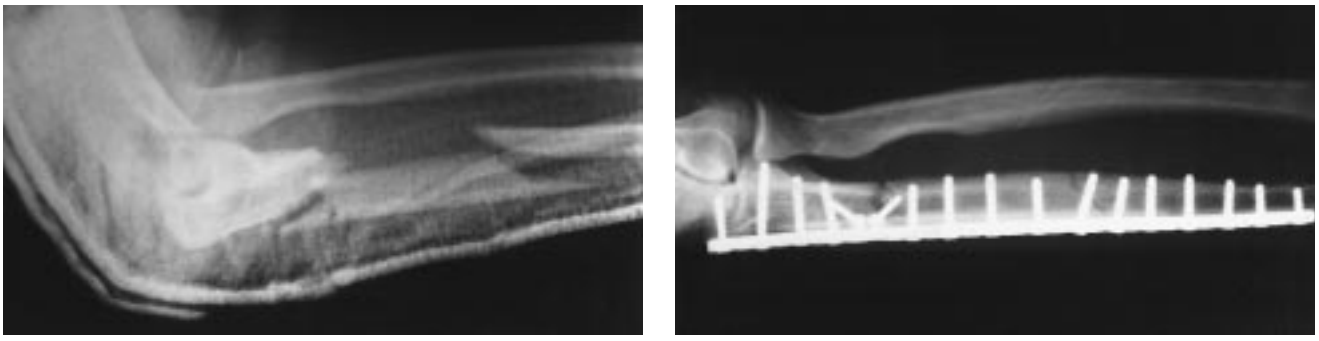
Recent experience with reconstruction of chronic Monteggia lesions at Boston Children's Hospital has tempered our enthusiasm for these procedures.[15] The operation itself has proved technically difficult and prone to numerous complications. Furthermore, most patients have substantial residual limitation of motion. Because of the lack of alternatives and a concern that persistent dislocation will lead to deterioration of elbow function, we continue to recommend a reconstructive procedure for younger patients without significant radial head deformity or overgrowth, preferably within 1 year of injury. We carefully advise the parents of the potential for complications and the limited expectations. The most important part of the procedure may be the ulnar osteotomy with rigid internal fixation, as the chronic Monteggia lesion is essentially an ulnar malunion. We also perform annular ligament reconstruction with use of the triceps fascia after open radial head relocation. Radial and ulnar nerve release and prophylactic forearm fasciotomies are also now standard.

Monteggia Lesions in Adults

The advent of modern methods of internal fixation (AO/ASIF) has had a dramatic effect on the results of operative treatment of Monteggia injuries in adults.[6-8] The existing literature on which the pessimistic prognosis for this injury has been based discusses adult patients treated with either closed reduction and cast immobilization or operative fixation with intramedullary rods or small plates.[4,5,8] Intramedullary rods are inadequate for maintaining anatomic alignment of the forearm bones in adults and cannot prevent shortening of the ulna in the presence of comminution.[4-7] The small pre–AO/ASIF-era plates used in these earlier series improved the ability to maintain ulnar alignment somewhat, but were still inadequate.[4,5] Moreover, nonunion was commonplace.[4] Most recent investigations have found that when ulnar length and alignment are restored in a timely and stable fashion with the use of modern techniques of internal fixation, early motion is possible, and good results can be expected.[4,5,7,8]

In adult Monteggia injuries, fixation with a 3.5-mm DC or an LC-DCP plate is required (Fig. 6). If the fracture is comminuted, purchase with five or six screws proximal and distal to the fracture should be obtained if possible (Fig. 7). As with other forearm fractures, autogenous cancellous bone grafting (typically from the iliac crest) is recommended for comminuted fractures (i.e., most Monteggia fractures in adults).

Restoration of anatomic length, rotation, and alignment of the ulna can prove difficult in the presence of extensive comminution. The use of a distractor or a plate-tensioning device for indirect reduction is preferable to extensive stripping of the periosteum and surrounding musculature from the bone and the use of circumferentially applied clamps, which risk violation of the interosseous membrane (and may increase the risk of radioulnar synostosis). After provisional plate fixation, anatomic reduction of the ulna and radiocapitellar alignment



A B

Fig. 6 **A,** A 28-year-old male construction worker sustained this segmental ulnar fracture with anterior dislocation of the radial head in a fall from scaffolding. **B,** Anatomic reduction and stable internal fixation with a dynamic compression plate allowed early mobilization.

in all planes through a full arc of flexion and extension should be verified with the use of intraoperative image intensification and radiography before placement of the remaining screws.

Particularly in posterior Monteggia lesions, the plate should be placed on the dorsal (tension) side of the ulna.[7] The plate should be contoured to the proximal curve of the olecranon so that its proximal tip sits under the triceps insertion (Fig. 4). This provides adequate fixation of the proximal portion of the plate to the often osteopenic metaphyseal bone of the proximal ulnar fracture fragment. This construct, in combination with either interfragmentary-screw or cerclage-wire fixation of the anterior cortical fragment, will optimize resistance to recurrent apex posterior angulation of the ulna. In the presence of an associated coronoid fracture (type A posterior Monteggia lesion), restoration of the ulnohumeral articulation and stable reduction of the coronoid fragment are necessary to ensure elbow stability and minimize the risk of future ulnohumeral arthritis. Open reduction and internal fixation of the radial head fracture (or primary excision with prosthetic replacement when this is not possible) may be as important in posterior Monteggia fractures as it is in other fracture-dislocations of the elbow.

Posterolateral rotatory instability may contribute to ulnohumeral instability in these injuries (Fig. 5). Ulnohumeral stability should be evaluated intraoperatively. If posterolateral rotatory instability is present, placement of the forearm in full pronation may enhance ulnohumeral stability and allow a full range of elbow flexion and extension in a hinged brace. Otherwise, the lateral collateral ligament complex should be repaired.

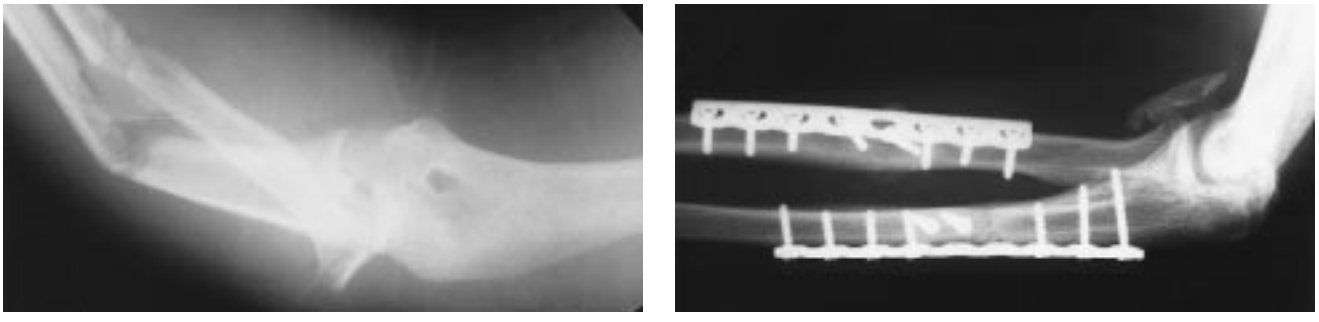


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Fig. 7 A 20-year-old man sustained comminuted fractures of both forearm bones in a fall from a height. **A,** The proximal radioulnar joint was disrupted, making this injury a Monteggia-type fracture-dislocation of the forearm (Bado type 4). **B,** Stable anatomic plate fixation of both radial and ulnar fractures resulted in anatomic reduction of the proximal radioulnar joint. Note the heterotopic ossification in the anterior soft tissues.

In the treatment of Monteggia injuries in adults, fixation of the ulnar fracture should be stable enough to allow gentle early postoperative range-of-motion exercises. No matter how precise the restoration of anatomy, prolonged immobilization can cause disabling stiffness, which will compromise the result.

Bado type 4 injuries in adults are rare and are generally the result of very-high-energy injury mechanisms (Fig. 7). Vigilance is required for the detection of associated distal forearm injuries, including distal radioulnar joint disruption, rupture of the interosseous membrane, carpal injury, and neurovascular injury, particularly compartment syndrome. The principle of restoring anatomic length and alignment of the skeleton in order to allow proper healing of the soft-tissue contributions to stable, congruent articular reduction is applicable in this situation, but can be substantially more complex than in other Monteggia-type lesions.

Summary

It is the character of the ulnar fracture, rather than the direction of radial head dislocation, that is useful in determining the optimal treatment of Monteggia fractures in patients of all ages. Late reconstruction of Monteggia lesions can be unpredictable even in children. However, a good result can be expected after an acute Monteggia injury provided the injury is recognized in a timely fashion and a stable, anatomic reduction of the ulnar fracture is achieved. One should not hesitate to use operative fixation of Monteggia fractures in children if necessary to achieve these goals. Application of a plate on the dorsal side of the ulna and consideration of autogenous cancellous bone grafting are mandatory in adults.

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