ELSEVIER
SAUNDERS

Hand Clin 23 (2007) 165–177

HAND
CLINICS

Monteggia Fracture-Dislocations

Srikanth Eathiraju, MD, Dorth, DNB(Orth),
Chaitanya S. Mudgal, MD, MS(Orth), MCh(Orth)*,
Jesse B. Jupiter, MD

Orthopaedic Hand Service, Yawkey Center, Suite 2100, Massachusetts General Hospital, 55 Fruit Street, Boston, MA 02114, USA

Fractures of the ulna accompanied by a radial head dislocation have been eponymously associated with Giovanni Battista Monteggia, after he first described this injury in 1814 when he made known the first two observations of "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]. This definition was later modified by Bado [1], who included under the term "Monteggia lesion" a group of traumatic lesions having in common a dislocation of the radio-humero-ulnar joint, associated with a fracture of the ulna at various levels or with lesions at the wrist.

This eponym is among the most widely recognized by orthopedic surgeons, to some extent because of the historically poor results associated with the treatment of these injuries, particularly in adults [2–4]. In 1955, Watson-Jones [4,5] noted only 2 good results among 34 Monteggia fracture-dislocations in adults. Earlier he had stated that "no fracture presents so many problems; no injury is beset with greater difficulty; no treatment is characterized by more general failure." Over the past decade, however, good results have been obtained by the prompt recognition of the injury pattern as well as anatomic reduction of ulna, including restoration of the normal contour and dimensions of the trochlear notch. Current plate-fixation techniques have improved the ability to achieve these goals [6,7]. While contemporary literature is replete with numerous reports concerning Monteggia fractures, these reports have to be interpreted with caution. Adult and pediatric populations have been grouped together despite differences in mechanism and patterns of injury, the prognosis, and the preferred method of treatment [1,2,8–11]. Monteggia lesions remain a relatively infrequent occurrence, with an incidence varying between 1% and 2% of all forearm fractures [3,12]. The equivalent lesions introduced by Bado are even more rare and are usually seen in children [13,14].

Anatomical considerations

The forearm is a unique two-bone structure with the radius and ulna being 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. The annular ligament is a strong band of tissue arising from the margins of the lesser sigmoid notch on the proximal ulna, which tapers in circumference distally conforming to the transition from the radial head to neck [15]. The quadrate ligament is described as a thin ligamentous structure that covers the capsule at the inferior margin of the annular ligament and attaches to the ulna [16].

It is also important to understand the unique nature of the proximal ulnar and radial anatomy. The trochlear (sigmoid) notch of the proximal ulna forms an ellipsoid arc of 190 degrees. The articular surface of the proximal ulna, which articulates with the distal humerus, consists of

* Corresponding author.
E-mail address: cmudgal@partners.org (C.S. Mudgal).

0749-0712/07/$ - see front matter
doi:10.1016/j.hcl.2007.01.008

hand.theclinics.com

essentially two surfaces: the proximal olecranon surface and the distal coronoid surface each consisting of two facets, a medial and lateral. The two articular surfaces of the proximal ulna are separated by a ‘‘bare’’ area, which is devoid of articular cartilage [17,18].

In a Monteggia fracture-dislocation, the annular and quadrate ligaments are ruptured, allowing dissociation of the proximal radioulnar joint as well as the radiocapitellar articulation, but the greatest portions of the interosseous membrane and the triangular fibrocartilage complex remain intact. Because of the preservation of these radioulnar interconnections, anatomic reduction of the ulnar fracture usually restores congruity of the proximal radioulnar joint and, therefore, the radiocapitellar articulation.

The radial head and neck are not collinear with the radial shaft, but instead form a 15-degree angle with it. The radial head has a slightly elliptical shape and has an offset concavity. The radiocapitellar contact forces are greatest in pronation, which is accompanied by a slight anterior translation of the radial head on the capitellum. This may explain why the anterolateral segment of the radial head is most frequently fractured. Furthermore, the anterolateral third of the radial head is more predisposed to fracture because it lacks thick articular cartilage and strong subchondral support. The radial head acts as a secondary stabilizer to valgus load, with the anterior bundle of the medial collateral ligament (AMCL) being the primary stabilizer [19,20]; however, their load-bearing functions are shared and interdependent. Removal of the radial head in the absence of a functioning AMCL will lead to gross instability and dislocation [21]. Together with the coronoid, it provides an anterior buttress against posterior displacement [21,22].

Classification

In 1962, Bado [1] set forth a system of classification based on the mechanism of injury, treatment, and results that established distinction among four types of Monteggia lesions (Fig. 1) (Table 1). Bado [1] also included a number of so-called Monteggia equivalent injuries based on the similarity of their proposed injury mechanism, further adding to the confusion because most of these injuries do not involve dislocation of the proximal radioulnar joint. Included in these equivalents were the following: anterior dislocation of the radial head, fracture of the ulnar diaphysis with fracture of the neck of the radius, fracture of the neck of the radius, fracture of the ulnar diaphysis with fracture of the proximal third of the radius with the radius fracture being proximal to the ulnar fracture, fracture of

Fig. 1. Lateral radiograph of the elbow showing a type I Monteggia lesion with an anteriorly dislocated radial head and a diaphyseal fracture of the ulna. (*Courtesy of* D. Ring, MD, Boston, MA.)

Table 1
Bado classification system of the Monteggia lesion

Bado classification	Description
Type I	Fracture of the ulnar diaphysis at any level with anterior angulation at the fracture site and an associated anterior dislocation of the radial head
Type II	Fracture of the ulnar diaphysis with posterior angulation at the fracture site and a posterolateral dislocation of the radial head
Type III	Fracture of the ulnar metaphysis with a lateral or anterolateral dislocation of the radial head
Type IV	Fracture of the proximal third of the radius and ulna at the same level with an anterior dislocation of the radial head

From Bado JL. The Monteggia lesion. Clin Orthop 1967;50:71–86; with permission.

the ulnar diaphysis with anterior dislocation of the radial head and fracture of the olecranon, and posterior dislocation of the elbow and fracture of the ulnar diaphysis, with or without fracture of the proximal radius.

The posterior Monteggia lesion (Bado Type II) has been further subclassified by Jupiter and colleagues [8] based on the location and type of ulnar fracture as well as the pattern of radial head injury (Table 2). The most important feature that needs to be recognized and addressed appropriately in the type II injury is the presence of an anterior ulnar cortical fracture. This fragment can be triangular or quadrangular, and represents an anterior ulnar cortical defect, which effectively increases the tendency of the ulna to angulate anteriorly at the fracture site (Fig. 2). Before 1951, the posterior Monteggia lesion was thought to be uncommon, accounting for only 10% to 15% of Monteggia fractures. This relatively low incidence may have been the result of inclusion of fractures occurring both in children as well as those in adults [2,10,11], because Bado type I injuries are more common in children and type II injuries are rare in children [6]. Penrose [23] as well as Pavel and colleagues [24] noted the predominance of what are now classified as Bado type II fractures in adult patients. Other authors also reported that posterior Monteggia fractures constituted 70% to 75% of all Monteggia fractures in adults [6,8], with most ulnar fractures occurring just distal to the coronoid process (type IIB). However, a recent study demonstrated a preponderance of Bado type I injuries among adult Monteggia fractures. Of the 68 adult Monteggia fractures in this series, 53 fractures were Bado type I [25].

The direction of dislocation of the radial head is related to the mechanism of injury and is also important epidemiologically, with posterior

Table 2
Subclassification of the posterior Monteggia lesion

Subtype	Description
Type IIA	Ulnar fracture involves the distal olecranon and coronoid process.
Type IIB	Ulnar fracture at the metaphyseal-diaphyseal juncture distal to the coronoid.
Type IIC	Ulnar fracture is diaphyseal.
Type IID	Complex ulnar fracture extends from the olecranon to the diaphysis.

From Jupiter JB, Leibovic SJ, Ribbans W, et al. The posterior Monteggia lesion. J Orthop Trauma 1991;5: 395–402; with permission.

Fig. 2. Lateral radiograph of the elbow in a patient who weighed in excess of 500 lbs, with a type II Monteggia lesion. Note the ulnar fracture that is just distal to the coronoid, with an accompanying break in the anterior cortex of the ulna (*thin arrow*). Also noted is the radial head fracture in its most common anterolateral quadrant location (*solid arrow*).

dislocation occurring primarily in middle-aged and elderly adults [1,8,23,24], lateral dislocations occurring more commonly in children, and anterior dislocation being common in children and young adults [1].

Associated fractures

Radial head fractures are commonly seen in posterior Monteggia fractures as the radial head shears against the capitellum as it dislocates posteriorly (see Fig. 2). Associated radial head fractures are seen in about 70% of posterior Monteggia fractures [6,8]. Radial head fractures were initially classified by Mason into three types as follows: Type I, nondisplaced fracture; Type II, marginal fractures with displacement; and Type III, comminuted fractures involving the entire radial head. This classification was later modified by Johnston [26], who added a fourth category to include radial head fractures associated with dislocations of the elbow. A more functional and treatment-based classification has been proposed more recently by Hotchkiss [27]. Type 1 fractures are small marginal fractures that are displaced less than 2 mm, do not restrict forearm rotation, and do not impact stability. Type 2 fractures are larger, displaced greater than 2 mm, and are still amenable to internal fixation. Type 3 fractures are comminuted and are treated with radial head replacement. In their series of 13 posterior Monteggia fractures, Jupiter and colleagues [8] documented radial head fractures in 10 patients. In their series of adult patients with Monteggia fractures, Korner and colleagues [7] observed associated radial head fractures in 16 patients, with 13 of these being seen in Bado type II fractures.

The same authors also reported eight patients with coronoid fractures, all of which were seen in Bado type II fractures [7]. Coronoid fracture patterns have been traditionally classified based on the size of the coronoid fragment by Regan and Morrey [28]. Their classification according to the size of the coronoid fragment (Type I, small fleck of bone off the coronoid tip; Type II, between a fleck and 50% of the height of the coronoid; and Type III, greater than 50% of the height of the coronoid) is widely used. However, the lack of reproducibility of this classification and the variability of radiographic technique has led to other classification systems that take into account the mechanism of injury and associated injuries and dictate surgical approach and treatment [29].

Mechanism of injury

Bado [1] attributed the anterior Monteggia lesion to extension and hyperpronation of the forearm. Other possible mechanisms include a direct posterior force acting on the ulnar shaft when it is overhead, as in a "nightstick" fracture [30] or a fall on the flexed elbow [9]. Tompkins [31] suggested that as a person falls on the outstretched hand, a violent contraction of the biceps muscle causes a dislocation of the radial head. The fracture of the ulna is caused by the pull of the intact interosseous membrane and the pull of the brachialis muscle.

The posterior Monteggia fracture has long been recognized as a transitional lesion combining elements of ulnohumeral and proximal radioulnar instability [8,23,24]. The mechanism of injury in the posterior Monteggia lesion resembles that of a posterior elbow dislocation, in which failure occurs through the proximal ulna rather than the collateral ligaments and capsular structures of the ulnohumeral articulation [23].

Ring and colleagues [6] noted that Bado type II lesions occurred following two different mechanisms of injury. Fractures resulting from low-energy injuries tended to occur in elderly female patients, whereas those associated with a higher energy were seen in younger, male patients. Some authors have suggested that the posterior Monteggia lesion might be a pathologic injury secondary to long-term corticosteriod therapy [32], while others have suggested that osteoporosis may be a risk factor for posterior Monteggia fractures, as it is more commonly seen among elderly women [6,8,23,24].

Preoperative considerations

When faced with a patient with a Monteggia fracture dislocation, one must pay particular attention to the mechanism of injury, as it can often give an indication of the energy involved. The dominance of the upper limb as well as the patient's age and functional demands should be noted. A thorough clinical examination is mandatory, with particular attention paid to a complete neurological examination. Radial nerve involvement is seen more commonly in patients with associated fractures of the radial head and in patients with posterior Monteggia-type fractures in which the radial head may be dislocated posteriorly or posterolaterally. Often times, to understand and assess fracture geometry, fragment size, and configuration and to plan surgical tactics, plain radiographs can be inadequate. Computerized tomography (CT), including three-dimensional (3D) reconstructions, is invaluable in the assessment of the injury and in planning surgical tactics.

Meticulous preoperative planning is essential for optimal management of these injuries. When faced with extensive comminution of the proximal radius and ulna, radiographs of the opposite side may be used to template the reconstructive effort and placement of implants. A complete array of implants should be available, including smooth as well as threaded Kirschner wires, headless screws, mini-fragment plates for fixation of radial head fractures, radial head implants, suture anchors, limited contact dynamic compression plates (LC-DCP), and cannulated screws.

Operative treatment

Numerous authors have espoused the virtues of open reduction and internal fixation of the ulna, closed radial head reduction, and early rehabilitation [2,3,6,8,9,11,33,34]. The importance of an anatomic reduction of the ulna to achieve a stable radioulnar and radiocapitellar joint has been widely accepted [6–9,35,36]. We favor the lateral position, with the upper limb flexed over a bolster. A sterile tourniquet and perioperative intravenous antibiotics are used routinely.

A posterior approach is used to access the ulnar fracture and may also be used for a radial fracture, if necessary (Fig. 3).

The ulnar fracture

A satisfactory device for internal fixation must hold the fracture rigidly, eliminating as completely as possible angular and rotary forces [6]. Simple fractures of the ulnar shaft are fixed using dynamic compression plates (Fig. 4). We routinely use a six- to eight-hole LC-DCP to fix these fractures, making certain that at least six cortices are firmly engaged on either side of the fracture. In the presence of comminution, care is taken to maintain soft tissue attachments of all major fragments and therefore their vascularity. Anatomic reduction of the ulna is almost always accompanied by stable, concentric, and congruous reduction of the radial head.

The major forces about the elbow occur in the plane of elbow flexion. One of the most common pitfalls in the treatment of this injury, especially when the ulnar fracture is proximal, is placement of a plate on either the medial or lateral surface of the proximal ulna. In this location, the plate does not function as a tension band and is incapable of resisting bending stresses that occur in the plane of elbow flexion. Moreover, very few screws can obtain purchase in the small metaphyseal proximal fragment. This inevitably leads to loss of fixation with recurrence of an apex-posterior deformity and posterior dislocation of the radial head (Fig. 5A) [6,8,37]. Studies have shown that in

Fig. 3. Our preferred position for operative treatment of this injury. The marked incision may also be made as a simple posterior incision. After raising medial and lateral flaps, this same approach can be used to address fractures of the radial head as well.

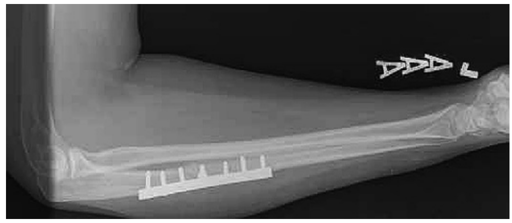

Fig. 4. Postoperative lateral radiograph of the patient seen in Fig. 1. Note the interfragmentary screw placed through the plate, with six cortices of fixation on either side of the fracture. Reduction and fixation of the ulnar fracture was accompanied by stable, concentric and congruous reduction of the radial head. (*Courtesy of* D. Ring, MD, Boston, MA.)

proximal ulnar fractures, a plate placed on the dorsal surface of the proximal ulna and contoured to wrap around the olecranon process provides more reliable fixation of complex proximal ulnar fractures (Fig. 5B) [6–8,17]. A tension band wire or intramedullary screw fixation of very proximal fractures do not provide adequate stability in the presence of associated subluxation of the radiocapitellar joint, fracture of the radial head, and, in particular, fractures of the coronoid [38]. The advantages of using 3.5-mm LC-DCP over other plates include the following: (1) it has uniform stiffness and flexibility, which facilitates contouring around the olecranon process; (2) it is more ductile and resists fatigue failure at extreme bending stresses; and (3) it has a low profile [35].

Pearl: The dorsal cortex is used to restore the length of the ulna in these comminuted fractures. In very proximal ulnar fractures, this may be associated with restoration of adequate trochlear width. Failure to restore the articular surface in the depths of the trochlear notch appears to be of little consequence, because this area is largely devoid of articular cartilage and is a relatively nonarticular area. The coronoid fragment is best approached through the fracture itself. The proximal olecranon fragment is mobilized and the coronoid can be fixed to the ulnar shaft under direct vision through the fracture.

Pearl: When comminution is extensive, a distractor may be used to restore length. This minimizes soft tissue dissection and preserves perfusion of various fracture fragments. A 3.5-mm Schanz pin is placed across the olecranon fragment into the distal humerus with the elbow flexed to 90 degrees. A similar-sized pin is placed well into the distal shaft of the ulna. A 3.5-mm LC-DCP is carefully contoured to the

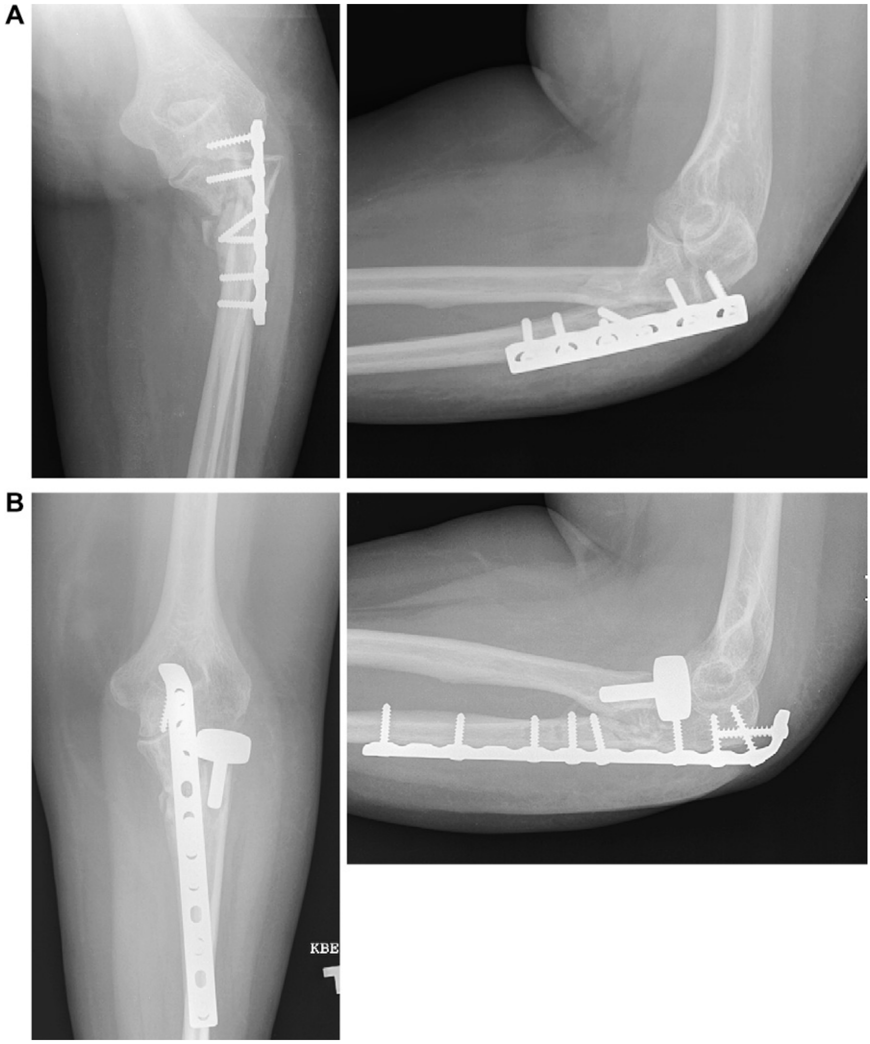

Fig. 5. (*A*) In proximal ulnar fractures associated with a type II lesion, placement of a plate on the medial surface of the ulna often leads to loss of fixation because of the inability of the plate to resist bending stresses at the elbow. Limited fixation in the olecranon, coupled with an anterior cortical break, cause the fracture to flex, leading to failure of fixation and posterior dislocation of the radial head. (*B*) Radiographs of the same patient after revision fixation with a contoured dorsal LC-DCP. The screw capturing the anterior coronoid fragment is obscured by the radial head, which was replaced with a modular unipolar prosthesis.

ulna. As distraction is completed and ulnar length is restored, the plate is fixed to the ulna with screws and the distractor is removed (Fig. 6).

Pearl: It is very important to carefully contour the plate to wrap around the proximal ulna. This allows placement of screws in an orthogonal orientation and increases both the number of screws in the proximal fragment as well as the strength of the construct. While our preference is to use a contoured LC-DCP, other authors have used a contoured wrist fusion plate, which essentially uses the same principles outlined above [39].

The radial head

Usually the radial head reduces spontaneously after anatomic reduction and fixation of the ulna. If it does not, then either the reduction of the fracture is inadequate or there is soft tissue interposition. The usual offenders preventing relocation of the radial head include the capsule and

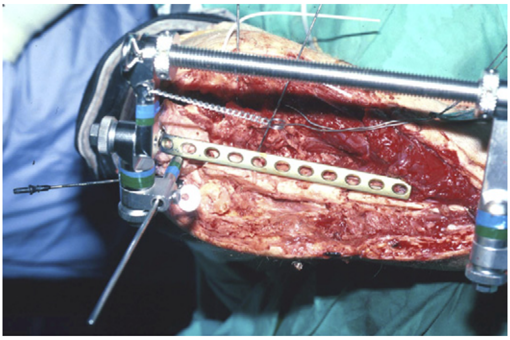

Fig. 6. In patients with extensive comminution of the ulnar shaft, a distractor is applied and used to maintain length and reduction of the ulnar fracture until the contoured LC-DCP is formally fixed to the ulna.

the annular ligament [3,10], nerve interposition [40,41], osteocartilagenous fragments [31], or biceps tendon [25]. Acquisition of a true lateral view of the elbow upon completion of the ulnar construct is critical in ascertaining concentric, congruous relocation of the radial head.

The question of whether a fractured radial head associated with a Monteggia lesion should be resected, repaired, or replaced remains unanswered [6,42]. The radial head fracture has to be carefully assessed. Small fragments that do not block forearm rotation may be ignored if impacted or undisplaced or both. If they are displaced they may be simply excised. More commonly however, the radial head fracture is substantial and can adversely influence outcome if not addressed appropriately. Fractures that consist of three fragments or less are considered suitable for repair, while more comminuted fractures are treated by radial head replacement [43].

Pearl: The capsular structures may be retracted with sutures or with long right-angled retractors rather than Bennett-type retractors. This reduces the chance of injury to the posterior interosseous nerve. If a long plate is required to fix the radial neck, it is prudent to initially expose and protect the posterior interosseous nerve. Placement of hardware about the radial head can be challenging. Most fractures can be fixed with screws that may be countersunk under the articular cartilage or headless screws may be used. In either situation, the emphasis is on avoiding placement of screws in a location that will interfere with forearm rotation. The 2.0-mm and 1.5-mm implants are usually satisfactory, and screw length in the average adult radial head varies between 20 and 24 mm (Fig. 7) [29].

Pearl: When plate fixation is required, the plate must be placed within the "safe zone" of the radial head [44]. This ensures that the hardware will not interfere with forearm rotation. The 110-degree safe zone is defined intraoperatively by making three reference marks on the line bisecting the anteroposterior diameter of the radial head in neutral rotation, full supination, and full pronation. The safe zone lies between a point that anteriorly is two- thirds of the way between the mark made in neutral rotation and full supination. The posterior limit of the safe zone is halfway between the marks made in neutral rotation and full pronation. Most commonly, 2.0- and 2.4-mm plates are used. It must be emphasized that impaction in this location is common and that recognizing it and bone grafting areas after elevation of impacted fragments increases the efficacy of fixation and chances of union at the fracture site [29]. In type 3 fractures the radial head is replaced with a modular implant [27]. Currently we favor the use of a modular unipolar prosthesis (see Fig. 5B). The emphasis is placed on restoring height and width of the radial head using the radial head and capitellum as templates for size and width, and the coronoid as a guideline for appropriate height of the radial head implant, so as to avoid "overstuffing" the radiocapitellar articulation.

The coronoid

Fixation of the coronoid may be achieved in one of several ways [45–47]. A small fragment may not be amenable to bony fixation. In such instances, a suture is passed around the tip of the coronoid to include the anterior capsule. Two drill holes are then made from the dorsal cortex of the ulna to emerge within the fractured surface of the coronoid. To enhance the accuracy of placement of these drill holes an anterior cruciate ligament tibial tunnel placement guide can be used. The sutures are passed through the drill holes to emerge on the dorsal surface of the ulna where they are tied with the elbow at 90 degrees of flexion. However, this suture tying is deferred until the definitive treatment of the radial head fracture is completed. Another method to fix the coronoid fragment is to use cannulated screws. These can be placed in a postero-anterior direction and the passage of the guide wire can be guided with fluoroscopy, as well as under direct vision through the hiatus left by the radial head fracture.

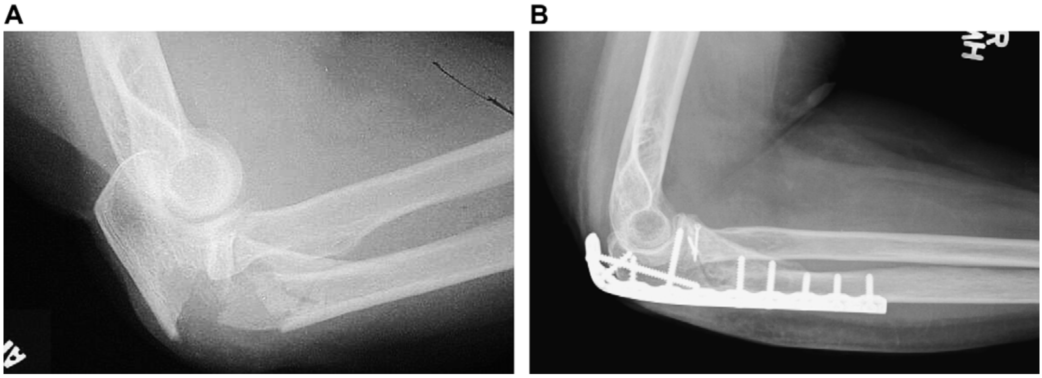

Fig. 7. (*A*) Lateral radiograph in a patient with a type II Monteggia lesion. The characteristic features of the radial head fracture and the anterior ulnar fracture, which includes the coronoid, are well visualized. (*B*) Postoperative radiograph depicting the internally fixed radial head fracture, a contoured dorsal LC-DCP and a long screw placed through the plate into the coronoid. Note the orthogonal placement of screws in the proximal fragment so as to provide a strong "interlocking" screw construct in this weak metaphyseal bone.

The role of bone grafting

The routine use of autologous iliac bone grafts in comminuted fractures has recently been questioned. Wei and colleagues [48] found no difference in union rates regardless of whether comminuted diaphyseal forearm fractures are grafted or not. However, in the face of extensive comminution, or bone loss, or both, bone grafting of the fracture must be considered. Contemporary thought is largely based on subjective assessment by the individual surgeon and conclusive scientific evidence either supporting or denying the role of bone grafting in these fractures is at this time lacking.

Postoperative management

The elbow is supported in a removable splint for few days. Active motion is encouraged within the first 2 weeks. Usually, this motion program is begun within the first week after confirming the stability of the surgical wound. We emphasize active motion, with gravity assistance for both flexion and extension. Patients are alerted to avoid the use of potential trick maneuvers using the shoulder and trunk. Attention is also paid to simultaneous mobilization of the shoulder.

Outcomes

Uniformly good results are seen in children regardless of Bado type [9,36]. The results of treatment of Bado type I Monteggia lesions in adults are usually good, as the radial head is normal and there is no coronoid fracture [7]. Numerous investigators have reported poor clinical outcomes with certain type of Monteggia lesions in adults [6,8,33,36]. Among Bado type II lesions, types IIA and IID are noted to have a greater proportion of poor/fair results compared with Bado types IIB and IIC, and this difference has been proposed to be because of the involvement of the coronoid process [6–8].

In 1974, Bruce and colleagues [2] reported the results of 35 patients with Monteggia fractures. Of the 21 adult patients in their series, only 5 patients achieved a good outcome, based on their method of evalution. In 1982, Reckling [3] reported the results of 40 adult patients with Monteggia fractures; only 9 patients had an optimal outcome in their series. Both of the above studies documented the results of treatment before the routine use of standard compression plates, as developed by the Association for the Study of Internal Fixation (AO/ASIF) and others.

In 1998, Ring and colleagues [6] reported on 48 adult patients with Monteggia lesions followed-up for a mean of 6.5 years. They documented satisfactory results using the Broberg and Morrey [49] scale in 39 patients. In 2004, Korner and colleagues [7] reported on 49 adult patients with Monteggia fractures. Using the Mayo Elbow Score they noted satisfactory outcomes in 35 patients. It is important to understand that most of the unsatisfactory results in both of these studies were seen in patients with associated fractures of the coronoid and radial head. Similar observations have been made by other authors as well. Givon and colleagues [9] reported a series of

Monteggia and Monteggia-equivalent lesions treated during a 10-year period and concluded that Bado type I equivalent lesions had worse motion than other types. In addition, injuries with an associated radial head fracture had worse motion than those without [9]. In their analysis of 11 patients who had Bado type II lesions, using the Broberg and Morrey [49] scale, Jupiter and colleagues [8] reported fair or poor scores in 5. In 2005, Egol and colleagues [42] observed that Monteggia lesions with associated radial head or neck fractures seemed to have worse clinical outcomes than those with radial head dislocation alone. Korner and colleagues [7] concluded that the functional outcome depends on the type of Monteggia fracture, with poor results being seen in those Monteggia fractures associated with radial head and coronoid fractures.

With respect to fractures of the radial head, good results have been reported following open reduction and internal fixation (ORIF) of simple fractures (Mason type II) of the radial head. The results after repair of Mason type III radial head fractures are less predictable [6,43,50]. The question remains as to whether it is better to treat a severely comminuted fracture of the radial head associated with a Bado type II fracture with simple excision or with prosthetic replacement [6]. Ring and colleagues [6] had better results in patients who had resection rather than attempted internal fixation. In their series, 10 of 12 patients who had resection of radial head without prosthetic replacement had satisfactory results. However, others recommend against early resection of the radial head to maximize outcome. They argue that the radial head plays an important role as a secondary stabilizer in the presence of ulnohumeral instability. Retention of the length of the radial column by fixation or replacement is indicated for injuries associated with ulnohumeral instability [33,42,51].

A critical analysis of the data therefore reveals some salient features, which will be of benefit in guiding management and outlining patient and surgeon expectations:

1) Type II injuries appear to have a larger proportion of suboptimal outcomes.
2) Concomitant fractures of the radial head and coronoid have an adverse impact on outcome, as they can affect both elbow and forearm function.
3) Fractures of the ulna, which occur at the level of the coronoid, or are associated with comminution in this region or both, are likely to have a suboptimal outcome, especially if the compression-resistant anterior buttress of the ulna is not restored.
4) Dorsal contoured plating of the proximal ulna will restore anatomy and provide tension band fixation, resisting anterior bending forces through the fracture.

Complications

Literature is replete with complications of Monteggia lesions and these include stiffness, subluxation or dislocation of the radial head, malunion, nonunion, synostosis, infections, and nerve palsies [6,8,35,36,38]. Prognostically, factors associated with an unfavorable outcome include a delay in treatment as well as certain types of Monteggia lesions (Bado type II and Monteggia equivalent lesions) [6–9]. Primary problems with malalignment of the ulna are restriction of forearm rotation, potentiation of ulnohumeral instability, and in the case of very proximal ulnar lesions, incongruity and arthrosis of the ulnohumeral joint [38]. While malalignment of the ulna occurs relatively infrequently with contemporary techniques of plating described here, when it does occur, it can adversely influence function of the elbow as well as the forearm.

Nerve injuries complicating Monteggia fractures

Because of the intimate relationship of the posterior interosseous nerve as it passes dorsolaterally around the radial neck to enter the substance of the supinator muscle, it is more prone to injuries compared with other nerves in this region. While the exact mechanism of injury is unknown, it is theorized that stretching or contusion of the nerve by the radial head, or compression against the proximal edge of the supinator, leads to nerve injury [52].

Bado [1] in his classic monograph on the Monteggia lesion, noted that nerve injuries do occur in association with the Monteggia fractures, but he gave few details. The reported incidence of nerve injuries associated with the Monteggia lesions has varied greatly. Boyd and Boals [34] reported only five instances of nerve injuries among 159 Monteggia lesions. All of the five cases involved the radial nerve, of which four recovered spontaneously. In a study of 25 consecutive acute Monteggia lesions, eleven patients had an associated posterior interosseous nerve palsy. However, all patients recovered spontaneously within 2 to 9 weeks [10]. Bruce and colleagues [2] reported 11 cases of nerve palsy among 35 patients with Monteggia injuries, with all of them having complete and spontaneous recovery. Stein and colleagues [52] reported on 11 patients with Monteggia lesions of which 7 had associated nerve injuries. Their experience with spontaneous recovery was less favorable; therefore, most of these patients were surgically decompressed. They recommended exploration and decompression if there was no recovery of nerve function within 12 weeks after injury [52].

Nonunion

In general, the rate of nonunion in forearm fractures is less than 2%. The rate of nonunion after Monteggia lesions, specifically after Bado type IV lesions, is considerably higher. A nonunion of the proximal ulna is often associated with pain, stiffness affecting both the ulnohumeral and forearm articulations, and occasionally instability of the ulnohumeral joint. Treatment consists of osteosynthesis of the ulnar nonunion with use of a contoured dorsal dynamic compression plate and autologous bone graft. There are some data to suggest that a judiciously placed intramedullary nail might have a role in the treatment of proximal ulnar nonunions, especially in patients with poor soft tissue envelopes [53].

When faced with an ulnar nonunion, several factors need to be considered as part of the decision algorithm. These include (1) symptoms; (2) the physiologic age of the patient; (3) the functional abilities and demands of both the patient as well as the affected upper limb; (4) the condition of the soft tissue envelope and extensor mechanism; (5) the size and condition of the proximal fragment as well as the adequacy of any existing implants (Fig. 8); (6) the condition of the articular surface especially following comminuted articular fractures; (7) coexistent problems that may need to be addressed at the time of the reconstruction, such as heterotopic ossification, radioulnar synostosis, and stiffness; and finally (8) the presence of infection. The presence of infection or a poor soft tissue envelope or both may require multiple procedures before undertaking a formal bony reconstruction.

Proximal radioulnar synostosis

This disabling complication usually leads to an unsatisfactory outcome and is seen in fractures involving the proximal aspects of the radius and ulna, in high-energy injuries, as well as in patients with closed head injury. Recommendations for limiting the risk of synostosis include the avoidance of simultaneous exposure of both bones, with each bone being approached through a separate muscular incision and the encouragement of early active mobilization [6]. In selected situations, consideration may be given to perioperative radiation of the involved area in an attempt to reduce heterotopic ossification.

Posttraumatic elbow stiffness

The loss of elbow motion may be viewed as an anticipated consequence or as a complication of elbow trauma. The pathological components of elbow contracture consist of static components, which include the capsule, ligaments, and ectopic ossification, and dynamic components, which include the muscles. Protracted immobilization has been well documented to play a role in postoperative and posttraumatic stiffness. The techniques of elbow contracture release have advanced to the point that it can be considered a safe and relatively effective procedure. The indications for surgical intervention to resolve an established loss of elbow motion after trauma are viewed best in the context of the functional arc of elbow motion, which has been defined as an arc of motion between 30 and 130 degrees [54]. However, in some patients this arc of motion may be inadequate and restoration of near complete motion may be necessary. The evolution of arthroscopic techniques might be able to address even smaller degrees of contracture with limited morbidity. The decision to undertake an elbow release must be discussed thoroughly with the patient, and the patient has to be cognizant of the extensive rehabilitation and be willing to participate in it.

Chronic adult Monteggia fracture

Neglected Monteggia fractures are rare in adults. Chronic radial head dislocation usually leads to severe deformity and disability. Relocation of the radial head in chronic Monteggia fractures by various means is well documented [55]. Most reports dealing with chronic radial head dislocations relate to pediatric injuries. In adults, excision of the radial head has been the treatment of choice for chronic, symptomatic radial head dislocations. However, excision of the radial head may be associated with subsequent

Fig. 8. (*A*) Antero-posterior and lateral radiographs of a patient with a type II Monteggia lesion with extensive comminution of the ulna as well as the radial head. (*B*) Postoperative radiographs of the patient show an ulnar nonunion. Clearly the plate is too short, and the patient developed severe stiffness of the elbow with a 40-degree arc of motion. In addition, the radial head implant is too large, and is accompanied by some heterotopic ossification in the vicinity of the proximal radioulnar articulation. Forearm rotation was limited to a 20-degree arc of motion.

instability, weakness, pain, and proximal migration of the radius [56]. Jepegnanam [56] showed that reconstruction of the elbow by relocation of radial head and ulnar osteotomy may have a favorable outcome. However, he also concluded that long-term follow-up is required to study the pressure effects of a relocated radial head on the radiocapitellar joint.

Summary

Monteggia fracture-dislocations are infrequent injuries. Contemporary techniques of internal fixation help to optimize functional outcomes; however, prompt recognition and treatment of this injury are critical. Moreover, recognition of various components of the injury pattern can help to guide treatment and outline patient expectations as well as avoid pitfalls while maximizing outcomes. Contoured dorsal plating of the proximal ulna with relocation of the radial head followed by early rehabilitation can be expected to lead to satisfactory outcomes in most patients.

References

[1] Bado JL. The Monteggia lesion. Clin Orthop 1967; 50:71–86.

[2] Bruce HE, Harvey JP Jr, Wilson JC Jr. Monteggia fractures. J Bone Joint Surg Am 1974;56(8):1563–76.

[3] Reckling FW. Unstable fracture-dislocation of the forearm. J Bone Joint Surg Am 1982;64(6):857–63.

[4] Watson-Jones R. Injuries of the forearm. In: Fractures and joint injuries. 3rd edition. Baltimore (MD): William and Wilkins; 1946. p. 520–35.

[5] Watson-Jones R. Injuries of the forearm. In: Fractures and joint injuries. 4th edition. Baltimore (MD): William and Wilkins; 1955. p. 572–81.

[6] Ring D, Jupiter JB, Simpson NS. Monteggia fractures in adults. J Bone Joint Surg Am 1998;80(12): 1733–44.

[7] Korner J, Hoffmann A, Rudig L, et al. Monteggia fractures in adults: critical analysis of injury pattern, management, and results. Unfallchirurg 2004; 107(11):1026–40.

[8] Jupiter JB, Leibovic SJ, Ribbans W, et al. The posterior Monteggia lesion. J Orthop Trauma 1991;5(4): 395–402.

[9] Givon U, Pritsch M, Levy O, et al. Monteggia and equivalent lesions: a study of 41 cases. Clin Orthop 1997;337:208–15.

[10] Smith FM. Monteggia fracture: an analysis of twenty-five consecutive fresh injuries. Surg Gynecol Obstet 1947;85:630–40.

[11] Speed JS, Boyd HB. Treatment of fractures of the ulna with dislocation of the head of the radius (Monteggia fracture). JAMA 1940;115:1699–705.

[12] Burwell HN, Charnley AD. Treatment of forearm fractures in adults with particular reference to plate fixation. J Bone Joint Surg Br 1964;46:402–24.

[13] Letts M, Locht R, Wiens J. Monteggia fracture-dislocations in children. J Bone Joint Surg Br 1985;67: 724–7.

[14] Reckling FW, Cordell LD. Unstable fracture-dislocations of the forearm (Monteggia and Galeazzi lesions). Arch Surg 1968;96:999–1007.

[15] Martin BF. The annular ligament of the superior radioulnar joint. J Anat 1958;52:473–81.

[16] Spinner M, Kaplan EB. The quadrate ligament of the elbow—its relationship to the stability of the proximal radioulnar joint. Acta Orthop Scand 1970;41:632.

[17] Ring D, Jupiter JB, Sanders RW, et al. Transolecranon fracture-dislocation of the elbow. J Orthop Trauma 1997;8:545–50.

[18] Tashjian RZ, Katarincic JA. Complex elbow instability. J Am Acad Orthop Surg 2006;14:278–86.

[19] Morrey BF, An KN. Articular and ligamentous contributions to the stability of the elbow joint. Am J Sports Med 1983;11:315–20.

[20] Morrey BF, Tanaka S, An KN. Valgus stability of the elbow. A definition of primary and secondary constraints. Clin Orthop 1991;256:187.

[21] Cohen MS, Hastings H. Rotatory instability of the elbow. J Bone Joint Surg Am 1997;79:225–33.

[22] O'Driscoll SW, Bell DF, Morrey BF. Posterolateral rotatory instability of the elbow. J Bone Joint Surg Am 1991;73:440–6.

[23] Penrose JH. The Monteggia fracture with posterior dislocation of the radial head. J Bone Joint Surg Br 1951;33(1):65–73.

[24] Pavel A, Pittman JM, Lance EM, et al. The posterior Monteggia fracture: a clinical study. J Trauma 1965; 5:185–99.

[25] Eglseder WA, Zadnik M. Monteggia fractures and variant: review of distribution and nine irreducible radial head dislocations. South Med J 2006;99(7): 723–7.

[26] Johnston GW. Follow-up of one hundred cases of fractures of head of the radius with a review of literature. Ulster Med J 1962;31:51–6.

[27] Hotchkiss RN. Displaced fractures of the radial head: internal fixation or excision. J Am Acad Orthop Surg 1997;5:1–10.

[28] Regan W, Morrey BF. Fractures of the coronoid process of the ulna. J Bone Joint Surg Am 1989;71: 1348–54.

[29] O'Driscoll SW, Jupiter JB, Cohen MS, et al. Difficult elbow fractures: pearls and pitfalls. Instr Course Lect 2003;52:113–34.

[30] Barquet A, Caresani J. Fractures of the shaft of the ulna and radius with associated dislocation of the radial head. Injury 1981;12(6):471–6.

[31] Tompkins DG. The anterior Monteggia fracture: observations on etiology and treatment. J Bone Joint Surg Am 1971;53(7):1109–14.

[32] Haddad ES, Manktelow AR, Sarkar JS. The posterior Monteggia: a pathological lesion? Injury 1996;2: 101–2.

[33] Reynders P, De Groote W, Rondia J, et al. Monteggia lesions in adults: a multicentric bota study. Acta Orthop Belg 1996;62(Suppl 1):78–83.

[34] Boyd HB, Boals JC. The Monteggia lesion: a review of 159 cases. Clin Orthop 1969;66:94–100.

[35] Simpson NS, Goodman LA, Jupiter JB. Contoured plating of the proximal ulna. Injury 1996;27(6): 411–7.

[36] Ring D, Jupiter JB. Current concepts review: fracture-dislocations of the elbow. J Bone Joint Surg Am 1998;80(4):566–80.

[37] Frankel VH, Burstein AH. Orthopaedic biomechanics: the application of engineering to the musculoskeletal system. Philadelphia: Lea and Febiger; 1970. p.176–77.

[38] Ring D, Tavokolian J, Kloen P, et al. Loss of alignment after surgical treatment of posterior Monteggia fractures: salvage with dorsal contoured plating. J Hand Surg [Am] 2004;29(4):694–702.
[39] Nowinski RJ, Nork SE, Segina DN, et al. Comminuted fracture-dislocations of the elbow treated with an AO wrist fusion plate. Clin Orthop 2000; 378:238–44.
[40] Morris AH. Irreducible Monteggia lesion with radial-nerve entrapment: a case report. J Bone Joint Surg Am 1974;56(8):1744–6.
[41] Watson JA, Singer GC. Irreducible Monteggia fracture: beware nerve entrapment. Injury 1994;25: 325–7.
[42] Egol KA, Tejawani NC, Bazzi J, et al. Does a Monteggia variant lesion result in a poor functional outcome? A retrospective study. Clin Orthop 2005;438: 233–8.
[43] Ring D, Quintero J, Jupiter JB. Open reduction and internal fixation of fractures of the radial head. J Bone Joint Surg Am 2002;84:1811–5.
[44] Smith GR, Hotchkiss RN. Radial head and neck fractures: anatomic guidelines for proper placement of internal fixation. J Shoulder Elbow Surg 1996;5: 113–7.
[45] Ring D, Jupiter JB. Operative fixation and reconstruction of the coronoid. Tech Orthop 2000;15: 1–8.
[46] Ring D, Jupiter JB. Fracture-dislocation of the elbow. Hand Clin 2002;18:55–63.
[47] Zlotolow DA. Proximal ulna fractures and dislocations. Curr Opin Orthop 2006;17(4):355–63.
[48] Wei SY, Born CT, Abene A, et al. Diaphyseal forearm fractures treated with and without bone graft. J Trauma 1999;46:1045–8.
[49] Broberg MA, Morrey BF. Results of treatment of fracture-dislocations of the elbow. Clin Orthop 1987;216:109–19.
[50] Esser RD, Davis S, Toavao T. Fractures of the radial head treated by internal fixation: late result in 26 cases. J Orthop Trauma 1995;9:318–23.
[51] Strauss EJ, Tejawani NC, Preston CF, et al. The posterior Monteggia lesion with associated ulnohumeral instability. J Bone Joint Surg Br 2005;88(1): 84–9.
[52] Stein F, Grabias SL, Deffer PA. Nerve injuries complicating Monteggia lesions. J Bone Joint Surg Am 1971;53(7):1432–6.
[53] Muckley T, Heinholzer C, Berger A, et al. Compression nailing of ulna nonunion after Monteggia lesion. J Trauma 2005;59(1):249–53.
[54] Morrey BF. The posttraumatic stiff elbow. Clin Orthop 2005;431:26–35.
[55] Hasler CC, Laer LV, Hell AK. Open reduction, ulnar osteotomy and external fixation for chronic anterior dislocation of the radial head. J Bone Joint Surg Br 2005;87:88–94.
[56] Jepegnanam TS. Salvage of the radial head in chronic adult Monteggia fractures: report of four cases. J Bone Joint Surg Br 2006;88(5):645–8.