EOR | volume 4 | January 2019
DOI: 10.1302/2058-5241.3.180022
www.efortopenreviews.org

EFORT open reviews

Fractures of the proximal ulna: current concepts in surgical management

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- Fractures of the proximal ulna range from simple olecranon fractures to complex Monteggia fractures or Monteggia-like lesions involving damage to stabilizing key structures of the elbow (i.e. coronoid process, radial head, collateral ligament complex).
- In complex fracture patterns a computerized tomography scan is essential to properly assess the injury severity.
- Exact preoperative planning for the surgical approach is vital to adequately address all fracture parts (base coronoid fragments first).
- The management of olecranon fractures primarily comprises tension-band wiring in simple fractures as a valid treatment option, but modern plate techniques, especially in comminuted or osteoporotic fracture types, can reduce implant failure and potential implant-related soft tissue irritation.
- For Monteggia injuries, the accurate anatomical restoration of ulnar alignment and dimensions is crucial to adjust the radiocapitellar joint.
- Caution is advised if the anteromedial facet (anatomical insertion of the medial collateral ligament) of the coronoid process is affected, to avoid posteromedial instability.
- Radial head reconstruction or replacement is essential in Monteggia-like lesions to restore normal elbow function.
- The postoperative rehabilitation programme should involve active elbow motion exercises without limitations as early as possible following surgery to avoid joint stiffness.

Keywords: coronoid process; elbow stability; Monteggia fracture; Monteggia-like lesion; olecranon; proximal ulna fracture; radial head

Cite this article: *EFORT Open Rev* 2019;4:1-9.
DOI: 10.1302/2058-5241.4.180022

Introduction

Fractures of the proximal ulna range in severity from simple olecranon fractures to complex Monteggia fractures or Monteggia-like lesions involving damage to stabilizing key structures of the elbow (i.e. coronoid process, radial head).[1,2] While these fractures are common injuries in the upper extremity at any age, in adults they peak during the seventh decade of life.[3] The anatomical restoration of ulnar alignment (in length, rotation and axis) has to be the primary goal of surgical treatment to regain an unrestricted elbow function. Thus, the surgeon carefully needs to address all aspects of the injury to allow early (active) rehabilitation and thereby prevent elbow stiffness.[4] An improper osseous reconstruction of the ulna as well as a failed/missed reattachment of elbow stabilizing structures will otherwise result in persistent pain, poor function and progressive joint degeneration due to chronic elbow instability.[5] Consequently, the appropriate treatment of proximal ulna fractures still remains a challenge for the orthopaedic surgeon. The aim of this review article is to illustrate the proper surgical management of these complex injuries using modern osteosynthetic implants and novel techniques while taking the complex biomechanics of the elbow joint into account.

Anatomy

The humeroulnar joint resembles a hinge between the humeral trochlea and the proximal ulna. The coronoid process of the proximal ulna is the most important stabilizer against posterior joint dislocation and the olecranon against anterior dislocation, respectively. The coronoid and the olecranon are separated by a cartilage-free ‘bare area’ of approximately 3–5 mm.[6,7] Recent studies have identified the anteromedial facet of the coronoid as a key factor for posteromedial stability of the elbow and thus its importance in an exact anatomical reconstruction.[8–11] Furthermore, the ulnar bowing (varus angulation = VA) as well as the proximal ulna dorsal angulation (PUDA) and the olecranon-diaphysis angle (ODA) have to be strictly considered when reconstructing the osseous anatomy (Fig. 1).[12,13,36] Despite knowledge of the specific proximal

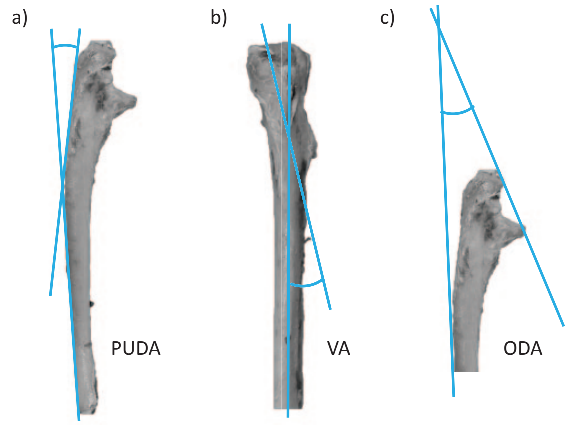

Fig. 1 Anatomy of the proximal ulna: (a) proximal ulna dorsal angulation (PUDA), (b) varus angulation, (c) olecranon-diaphysis angle (ODA).

ulna anatomy (e.g. PUDA), some 'anatomical' plates do not include these facts in their designs.[56,57] An improper reconstruction and denial of the exact elbow anatomy may result in sequelae such as elbow instability, persistent pain and osteoarthritis.[54,55] In general, a precise evaluation of the fracture mechanism in respect to the resulting gravitational stresses is paramount to understand possible injuries and aid the surgeon in finding all anatomical mishaps.

Clinical presentation and diagnostics

Patients with fractures of the proximal ulna and/or more complex pathologies involving the (sub-)dislocation of the elbow usually present with immobilizing pain and swelling of the joint. The asymmetry of the Hueter triangle may already suggest a possible dislocation and/or instability of the elbow. Careful evaluation of all nerves, and in particular the ulnar nerve, is obligatory (due to its close pathway next to the bone).[14] Furthermore, the blood flow of the ulnar and radial artery needs to be verified to exclude any vessel damage at the elbow level.

The mechanism of injury may already guide the surgeon in what to expect. Different loads across the elbow joint at the time of injury lead to specific fracture patterns and elbow instability.[5] In particular, rotatory forces of the forearm may cause posterolateral, posteromedial or trans-olecranon fracture dislocations. In order to accurately evaluate the injury pattern and thus plan the necessary therapeutic steps, a thorough and most of all, standardized diagnostic approach should be conducted. First, a standard two-plane x-ray of the elbow should be performed to confirm the clinical suspicion of a fracture and/or more complex dislocation. While simple olecranon fractures do not routinely require a computerized tomography (CT) scan, CT scanning (ideally as 3D reconstruction) in multi-fragmented fracture types is recommended to assess the extent of the injury and not to omit relevant (co)pathologies. For example, small fragments of the coronoid as a sign of a possible instability can easily be overlooked and might delay the correct operative treatment.[60] Magnetic resonance imaging (MRI) can be a useful add-on diagnostic tool; however, operative management is rarely adjusted as a result of MRI scanning.

Surgical management

Olecranon fractures

Introduction

Approximately 10% of all upper extremity fractures are isolated olecranon fractures.[15] The common pathomechanism is either a direct fall onto the elbow, or in rare cases an indirect pull of the triceps tendon while the forearm is in pronation, causing the olecranon to break. A vast abundance of different types of classifications concerning proximal fractures of the ulna exists, highlighting the difficulty of including all types of trauma.[16] However, concerning isolated fractures of the olecranon the Mayo classification should be preferred as the most practicable in clinical use.[17] It not only describes fracture morphology but also includes fracture stability and therefore serves as a guide for choice of surgical approach (Fig. 2).

Surgical strategy

The utmost priority in surgical management is the exact reconstruction of the olecranon alignment (sigmoid notch) in order to enable early functional training of the elbow and thus inhibit posttraumatic stiffness and its associated complications.[14] Thereby, the width of the trochlear notch (olecranon width = OW) is the most important parameter for a stable reconstruction.[37] Therefore, it is essential not to 'straddle' the pair of tongs of the olecranon or to leave the olecranon 'enlarged' (Fig. 3). If problems arise regarding the soft tissue (haematoma, skin lesions, open fractures), an external fixation might be necessary in rare cases. However, an internal fixation using a direct dorsal approach is favoured once conditions allow. Regarding the functional results of surgical approach of isolated, displaced olecranon fractures, no difference was found between tension-band wiring and plate fixation in the short-term follow-up.[70] Nevertheless, based on current data it should be stated that in elderly patients a non-operative treatment can also be applied with comparable results to surgical intervention for isolated olecranon fractures.[58]

Tension-band wiring. Even today, this technique represents a working procedure with good clinical outcomes if it is accurately indicated for stable oblique fractures types (Mayo Ia-IIa). However, its

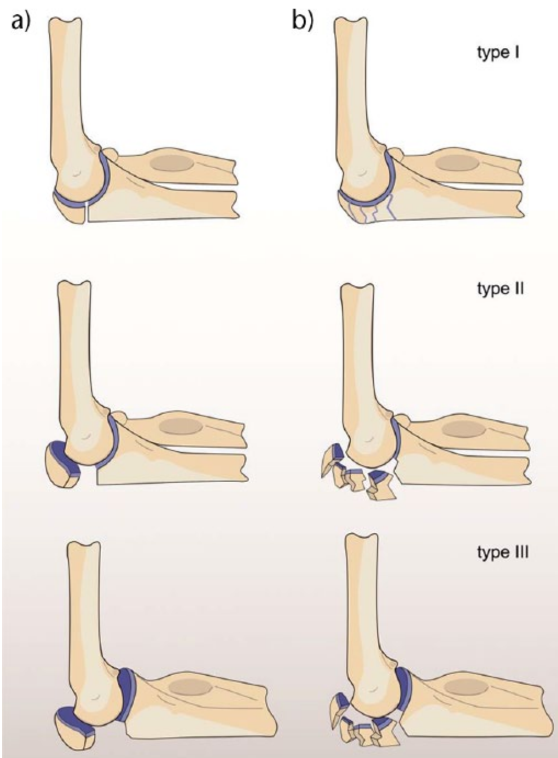

Fig. 2 Mayo classification: type-I = undisplaced; type-II = stable/displaced; type-III = unstable/displaced; (a) simple, (b) comminuted.

biomechanical limitations become evident in comminuted fractures.[18] Surgeons should therefore be sensitized for possible technical pitfalls to improve the quality of patient treatment and to avoid redundant complications (i.e. perforating K-wires or delayed union).[1,19–21]

Plate osteosynthesis. The management of comminuted and instable fractures (Mayo IIb-IIIb) using locking compression plates (LCP) via the dorsal approach has been well established in recent years and therefore consequently replaced the 'classic' low contact dynamic compression plate (LCDCP).[19,22] The usage of pre-contoured implants including variable angle locking screws allows the surgeon to reduce the fragments against the implant and to securely buttress the articular surface. It has been proven that dorsal locked plating is an effective and safe treatment for comminuted olecranon fractures allowing early joint motion and yielding satisfactory functional results.[2,22,23] In addition, especially for small tip fractures and/or in highly comminuted osteoporotic bone in the elderly, the use of an 'off-loading triceps suture' (e.g. with a non-absorbable suture tape) is shown as a good treatment option to neutralize the distraction forces caused by the extensor mechanism and therefore to decrease the risk of fixation failure with loss of reduction and displacement of fracture fragments.[59]

However, the critical issue is the limited clinical tolerance of the dorsal positioned plate with a partially high rate of posterior impingement and/or soft tissue irritation. These implant-related complications due to the exposed position of the dorsal ulnar do often require plate removal. As an alternative, using two low-profile plates on the medial and lateral aspect of the ulna cortex can possibly decrease soft tissue irritation.[24] Furthermore, the double contoured plating has the theoretical advantage of superior stability by increasing the number of screws and enabling bicortical fixation of proximal ulnar fragments (Fig. 4).[25]

Monteggia and Monteggia-like lesions

Introduction

These injuries are rare but complex entities, accounting for 2–7% of all forearm fractures and 0.7% of all elbow

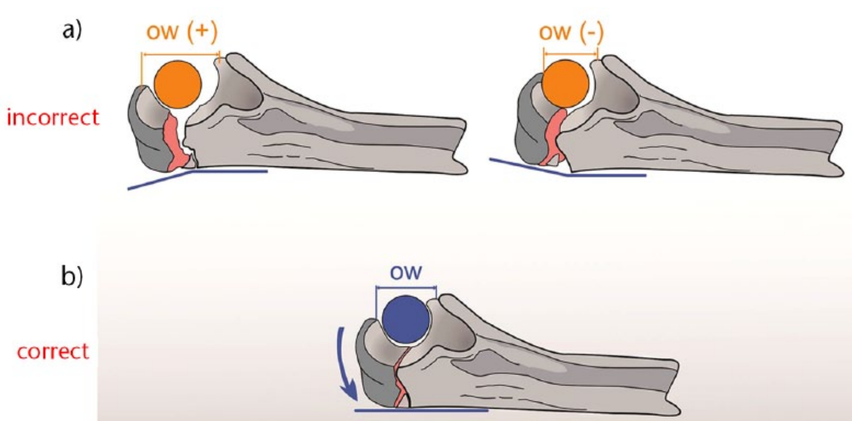

Fig. 3 (a) incorrect reconstruction: constriction (left) or enlargement (right) of the olecranon width (OW) due to an incorrect dorsal alignment; (b) correct reconstruction.

Fig. 4 Mayo type IIB fracture including comminution of the proximal olecranon fragment and central impression of a 73-year-old lady treated with low-profile double plate osteosynthesis (Olecranon plates 2.8, Medartis, APTUS, Basel, Switzerland).

dislocations in adult patients.[26] The original Monteggia injury is defined as an ulnar-based forearm fracture in association with a proximal radioulnar joint/radial head dislocation, while the so-called Monteggia-like lesion includes various patterns of a complex proximal ulnar fracture combined with a fracture subluxation/dislocation of the humeroradial articulation.[27] It is of crucial importance not to underestimate or miss these injuries due to their poor functional outcome if treated incorrectly.[28] Hence, the surgeon must carefully evaluate the fracture pattern, know its biomechanical genesis and plan its therapy accordingly.

Current classification systems are geared to morphologically describe the fracture in detail, but their prognostic value is limited. Monteggia injuries, Monteggia-like lesions and trans-olecranon fracture dislocations are frequently confused, and it can prove very difficult to classify some lesions.[29]

Trans-olecranon fracture dislocations are quite often misdiagnosed as anterior Monteggia fractures. However, these injuries represent a separate fracture entity with an intact proximal-ulnar joint in most cases.[30] The humeral trochlea thereby 'drive' through the trochlear notch of the ulna, resulting in fracture extension to the coronoid and/or the proximal ulnar shaft; this is why anatomical fixation of all fracture fragments is essential to address concomitant ligament instability. Therapeutic management is in accordance with that of comminuted olecranon fractures, with stable restoration (locked plating) of the appropriate contour and dimensions of the trochlear notch.

In clinical use, two classifications have now been established for Monteggia injuries: the Bado classification and the Jupiter classification.

Bado classification[27]. The Bado classification remains the best known classification of Monteggia fractures, linking the mechanism of injury to the direction of radial head displacement. The classification depends on the direction of the radial head's dislocation and the angulation of the fracture of the ulna.[27] Type I denotes a proximal ulnar shaft fracture with the dislocation of the radial head in anterior direction resulting from the typical trauma mechanism of forced forearm pronation during hyperextension of the elbow. The type II injury, which is the most common (80% of all Monteggia fractures), consists of a proximal or middle-third ulna fracture with a posterior or posterolateral dislocation of the radial head and is usually caused by axial loading on a partially flexed elbow.[31,32] A fall on the elbow with hyperextension and pronation in combination with forced abduction or varus stress results in a type III injury. This injury consists of a fracture of the metaphyseal ulna with lateral or anterolateral dislocation of the radial head. A Bado type IV fracture is a proximal- or middle-third ulna fracture along with anterior dislocation of the radial head and additional fracture of the proximal third of the radial shaft. The trauma mechanism of this injury is comparable to that of type I fractures, but is the result of higher energy/greater impact.

Jupiter classification[34]. Jupiter classified Bado's type II fracture in order to guide necessary treatment strategies. Based on the location and type of ulna fracture sustained as well as the pattern of radial head injury Jupiter defined four subtypes:[34,35] type IIA fractures involve the most proximal aspect of the ulna (olecranon) and the coronoid process; type IIB fractures occur at the ulnar metaphyseal–diaphyseal junction, distal to the coronoid process; type IIC fractures occur at the diaphyseal level; and type IID fractures are comminuted, extending from the olecranon to the ulnar diaphysis (Fig. 5).

Besides radiographs in the anterior–posterior and lateral view, a CT scan (with 3D-reconstruction recommended) is mandotory in every Monteggia fracture case to completely understand fracture morphology and to initiate the appropriate treatment.[5]

Surgical strategy

As mentioned above, the accurate restoration of the normal contour and dimension of the proximal ulna (length,

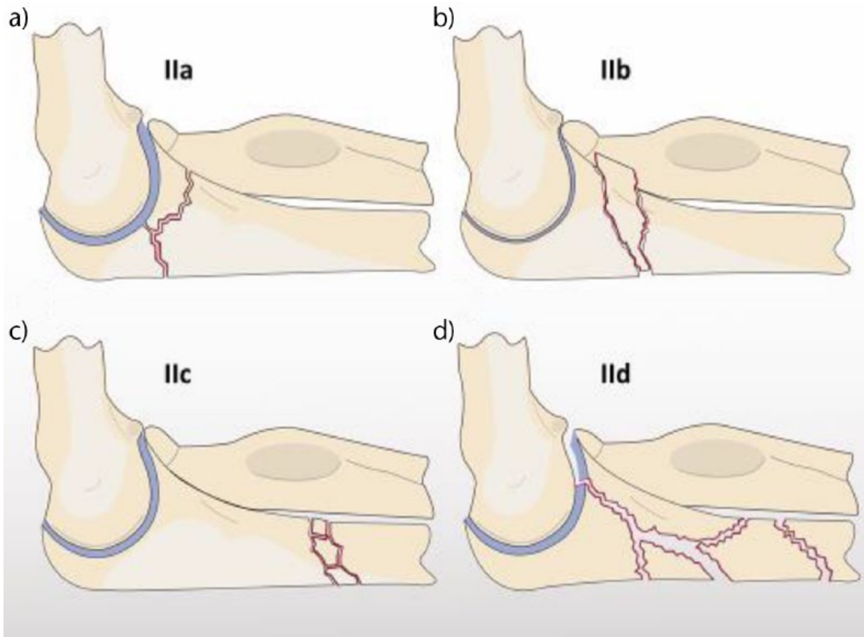

Fig. 5 Jupiter's classification of posterior Monteggia fractures (Bado type II).

PUDA, ODA, OW) must be the primary goal in restoring elbow function (Fig. 3, Fig. 6).[36,37] Furthermore, the unique bony architecture of the proximal ulna with its anteromedial varus angulation (VA) in the proximal third needs to be anatomically reduced due to its great importance for the maintenance of the articular geometry of the elbow.[6] In Monteggia fractures in particular, surgeons must be careful about using 'anatomically preshaped' ulna plates that potentially do not fit to the PUDA, resulting in subluxation of the radial head.

To address all these anatomical parameters we recommend an extended posterior approach with the patient positioned prone. However, the same advantages can be achieved in the lateral decubitus, which might be preferred in some cases. Usually the radial head realigns after anatomic reconstruction of the ulna with no need for an open reduction in Monteggia fractures. In Monteggia-like lesions the radial head fracture as well as the coronoid fracture itself is preferred addressed 'through' the ulnar fracture via the dorsal approach (Fig. 7). In Monteggia-like lesions the reconstruction starts with the radial head which is also possible after dorsal mobilization of the anconeus muscle (Boyd's approach).[38] The operative algorithm should then address any fractured part of the coronoid process as the key step of the procedure, followed by the ulnar shaft. For a better visualization of the coronoid it might be necessary in some cases to use an additional medial approach in order to anatomically reduce the fracture.[39] Necessary ligament reconstructions should be performed last.[39,40]

Monteggia fracture treatment. Similarly to the case of olecranon fractures, locking plates should be favoured in Monteggia and Monteggia-like lesions due to their superior biomechanical stability.[41] Fractures involving the coronoid process have to be treated due to their type of instability according to O'Driscoll's classification.[42] In particular, this system takes into account the anatomical localization of the fracture with respect to the anteromedial facet (type I = fracture of the apex; type II = fracture of the anteromedial facet; type III = fracture at the coronoid base). The anatomical insertion of the medial collateral ligament (MCL) at the sublime tubercle of the anteromedial facet was included in this systematization as the most important criterion for coronoid fracture management, resulting in posteromedial instability if ignored.

In Monteggia injuries small coronoid tip fragments can be ignored or sutured together with the anterior capsule if grossly displaced. Larger coronoid fragments, especially those involving the anteromedial facet, require fixation in any case to recover MCL stability.[43] Sometimes, anteromedial facet fractures have to be separately restored with additional plating via a further medial approach. Base coronoid fractures can be indirectly fixed with cortical screws from posterior or using a suture loop technique. Even so, as reported in terrible triad injuries, Garrigues et al have shown greater stability with fewer complications for the 'lasso' technique when compared to ORIF with anchors or screws.[61] Furthermore, fractures of the anterolateral facet as well as of the supinator crest should also be taken

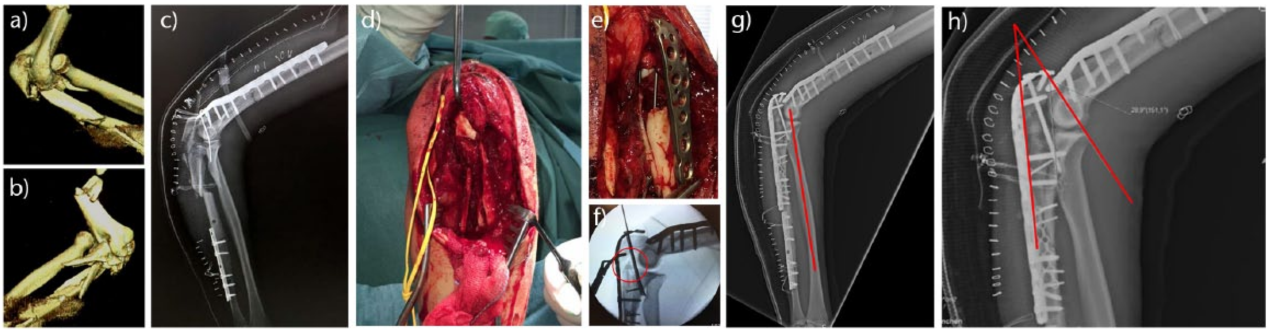

Fig. 6 Monteggia fracture (type I) combined with a distal humeral fracture of a 39-year-old female resulting from a motorbike accident: (a) and (b) preoperative 3D-CT scans showing the massive comminution of the proximal ulna involving the coronoid process; (c) in a two-step procedure, the distal humerus and an additional second distal ulnar shaft fracture were first restored and the radiohumeral joint was temporarily fixed with a K-wire; (d) and (e) intraoperative situs of the proximal ulna during secondary ulna reconstruction presenting a massive osseous defect; (f) the bone defect was filled with a bony allograft (red circle) while reducing the fracture fragments against the anatomically preshaped proximal ulna plate (Olecranon LCP, DePuy Synthes, Oberdorf, Switzerland); (g) and (h) postoperative controls showing the realignment of the ulnar length with a centred radiocapitellar line (red line) as well as the correct olecranon diaphysis angle (red angle).

Note. CT, computerized tomography.

into account to restore the attachment of the annular ligament.[44]

Radial head surgical management. The reconstruction of the radial head in Monteggia-like lesions is of crucial importance to bear axial loads and to stabilize the elbow against posterolateral and valgus stress. Furthermore, the radial head acts as a tensor for the lateral collateral ligament complex (LCLC). Hence, it becomes evident that a resection of the radial head can only be seen as a salvage option in selected cases and can never be accepted as regular treatment strategy – in particular given recent advances in available modern implants and/or arthroplasty.[45–47]

Undisplaced or minimally displaced fractures of less than 2 mm (Mason I) can be treated non-surgically.[39,48,49] Mason type II and III fractures require internal fixation using cortical screws and/or low-profile radial head locking plates (Fig. 7).[50] For the usage of radial head plates the 'safe zone' must be exactly adhered to, in order to avoid implant complications or restrictions in pronosupination.[51,52] If the radial head cannot be adequately fixed the primary replacement of the radial head is strongly recommended. Again, the isolated radial head resection is obsolete in the author's treatment algorithm.

If the dislocation/subluxation of the radial head persists following ulnar reconstruction (radiocapitellar line not centred), the bony reconstruction of the ulna with special respect to PUDA and ulnar bowing (VA) is either insufficient or a soft tissue interposition (i.e. joint capsule, annular ligament, osteochondral fragments) is underlying. Consequently, the ulnar reconstruction must be re-evaluated or the interposition removed.

Complications

Concerning olecranon fractures, most complications are implant-related due to soft tissue irritation. In a systematic review, Ren et al found more complications for tension-band wiring when compared to plate fixation and therefore recommended olecranon fracture plating as the treatment of choice nowadays.[62] Higher rates of prominent hardware with the need for removal following tension-band wiring were found in several studies over the last decade.[65,66,70] Complications such as ulnar neuropathy, deep infection, implant failure or delayed/non-union are relatively rarely reported. However, an uneven reconstruction of the articular surface can cause sequelae such as limited elbow range of motion and posttraumatic arthritis.

For Monteggia fractures, the variety of complications ranges from ulna mal- or non-unions, nerval irritations (ulnar and radial nerve), restrictions in elbow motion up to elbow stiffness, heterotopic ossification (HO), radioulnar synostosis and persistent radial head subluxations or dislocations depending on the injury severity.[53,67,68] Bado type-II fractures in particular were found to be associated with poorer outcomes and, moreover, the involvement of the radial head and/or the coronoid process were detected as negative prognostic factors for long-term outcome.[69]

Postoperative management

The goal of any surgical intervention for proximal ulna fractures should be an early functional elbow rehabilitation considering all repaired structures. The elbow is placed in a plaster cast in 90° flexion for about two weeks. Depending on soft tissue conditions, nevertheless, active

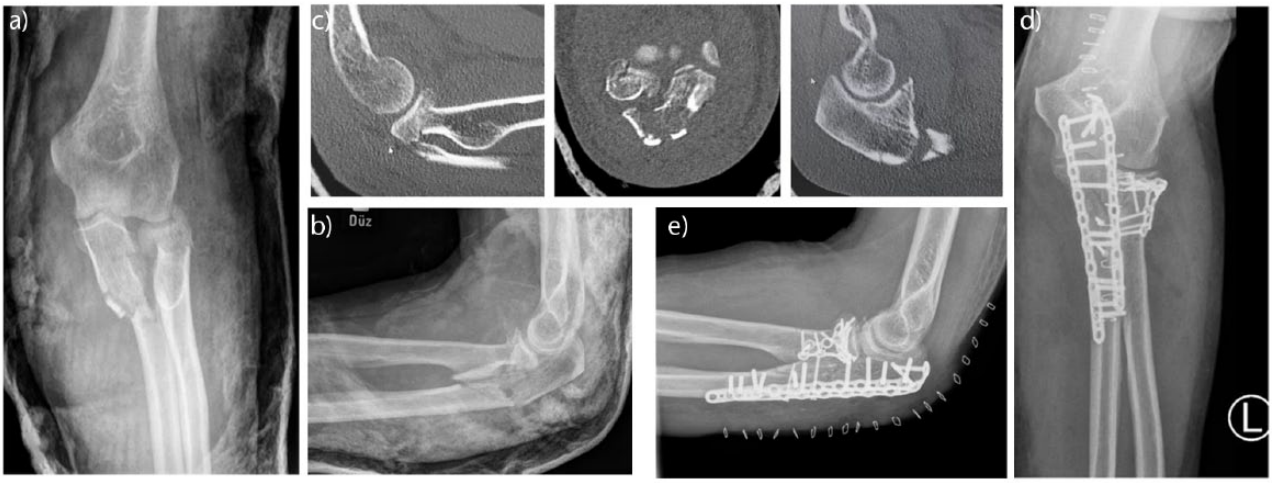

Fig. 7 (a) and (b) Monteggia-like lesion (type IID); (c) CT scans illustrate the radial neck fracture, the comminution of the coronoid base and the additional coronoid tip fragment as well; (d) and (e) postoperative views: the radial head/neck was fixed with free cortical screws and an anatomically preshaped radial head plate and the coronoid and ulna shaft were likewise restored performing double contoured, locked plating (Olecranon plates 2.8 Medartis, APTUS, Basel, Switzerland) with additional free cortical screws.

Note. CT, computerized tomography.

and active-assisted early motion (starting with gravity-assisted flexion and extension under physiotherapeutic control) at day two or three after surgery are recommended to prevent postoperative elbow stiffness. The active muscle contraction around the elbow increases elbow stability. This effect can be additionally intensified if the elbow is trained in an overhead position.[63,64] Pronation and supination are practiced with the elbow in 90° of flexion. Fracture union should be evaluated via x-ray six weeks postoperatively. Maximum weight-bearing and return to sports can be commenced three to six months after surgery.

Conclusions

The surgical management of proximal ulna fractures and its more complex patterns (Monteggia and Monteggia-like lesions) requires a precise treatment plan. An understanding of the mechanism of injury allows the surgeon to anticipate possible problems, while the use of CT with 3D-reconstruction is mandatory. The exact reconstruction of the bony anatomy of the ulna including the coronoid process is the primary goal in any operative strategy accompanied by radial head repair/replacement. These injuries should be managed by a highly experienced trauma surgeon or transferred to a specific upper extremity centre in some circumstances. According to the current literature, the application of an adequate treatment algorithm and the use of modern implants for fracture fixation have resulted in better functional outcomes in recent times. For postoperative management, active elbow exercises without restrictions should be commenced directly after surgery to prevent joint stiffness.

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ICMJE CONFLICT OF INTEREST STATEMENT

S. Siebenlist declares payment for lectures from Arthrex and Medartis, activities outside the submitted work.

FUNDING STATEMENT

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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