Review article

High-energy injuries of the wrist

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ABSTRACT

High-energy injuries to the wrist gather complex fractures of the distal radius, radiocarpal dislocations, perilunate dislocations, and other intracarpal dislocations. Depending on the energy of the injury and the position of the wrist at the time of impact, the patient, often a young male with a high functional demand, presents one of these injuries associating fracture(s) and ligament injury. The trauma is often bilateral, with proximal lesions (elbow) very often associated with contusion or compression of the median nerve. Diagnosis is confirmed by wrist X-rays, which are sufficient to determine treatment for radiocarpal and perilunate dislocations. In cases of distal radius fractures or other intracarpal dislocations, a preoperative CT is necessary. Reduction of the dislocation and relief of neurovascular compression are performed immediately. The final treatment of each lesion (bone fixation, ligament repair) can be undertaken simultaneously or delayed, depending on the patient and the lesions. Cartilage lesions, resulting from the high-energy injury, can be estimated using arthroscopy but cannot be repaired and determine the prognosis. The surgeon’s objective is to restore joint congruence, which does not prevent stiffness, the main complication of these rare injuries, which the surgeon must know how to recognize and treat.

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1. Introduction

We excluded partial and complete devascularization injuries (amputation) or soft tissue defect for which the problem is no longer controlling ostearticular lesions but rather the survival of the hand or the repair of tendons, tendons, or nerves.

High-energy injuries to the wrist gather several lesions that most often occur in patients under 40 years of age who have a high functional demand. Depending on the trauma energy, the position of the wrist at the time of impact, and the change in direction of the trauma forces, the patient presents one or several of the following lesions: a complex fracture of the distal radius, a radiocarpal or perilunate dislocation or another intracarpal dislocation (around the scaphoid, capitate, trapezium, or hamate).

The injury is very often associated with contusion of the median nerve, and it is quite frequently bilateral; one must therefore systematically search for the “other lesion” on the contralateral limb (the same injury or another high-energy lesion) or the same limb (a more proximal lesion at the elbow).

The clinical diagnosis is suggested when there is more or less serious deformity of the wrist; it is confirmed by wrist X-rays (AP, lateral, and oblique) taken immediately. These X-rays are sufficient for the management of radiocarpal and perilunate dislocations. However, in cases of distal radius fracture or intracarpal dislocations, CT is the decisive examination for the analysis and comprehension of the injuries and should always be requested pre-operatively. A precise and recorded clinical exam can request other images (hand, elbow, shoulder).

Depending on the diagnosis, debridement of an open wound, reduction of a dislocation, alignment of the lesions, and release of a neurovascular compression should be handled in the hours following the trauma.

Final treatment can be initiated at the same time or delayed depending on the patient and the injuries in the days following the trauma. Cartilage injuries resulting from high-energy injuries can be estimated using arthroscopy, but no preventive treatment currently exists for secondary cartilage degradation. Nevertheless, the role to be played by therapeutic arthroscopy in these high-energy injuries has not yet been clearly defined.

The surgeon’s objectives should be:

- restoring joint congruence and avoiding any iatrogenic risk;
- carefully informing the patient on the predictable sequelae of the injury.

Even when expertly treated, these lesions require approximately 6 months to recuperate useful wrist function at the expense...
of constant stiffness (30–50% loss of certain joint movements). Over the long term, instability is rare but osteoarthritis is frequent [1].

2. Fracture of the distal radius [2]

2.1. Analysis of the lesions

High-energy complex fractures of the distal radius are a combination of metaphyseal (“M” comminution) and epiphyseal (“E” joint impaction) lesions, sometimes associated with ligament injury at the radiocarpal, mediocarpal, or distal radioulnar level (“U” fracture, dislocation) [3] (Fig. 1) (MEU classification).

They occur in a wrist in hyperextension and variable pronation-supination. The greater the trauma energy the more there will be metaphyseal injuries, then epiphyseal injuries, and then dislocations [4]. Contusion of the median nerve is classic but goes unnoticed and makes the prognosis more severe. In cases of open fracture, it is most often on the ulnar side, resulting from the shortening of the radius.

As in any radial fracture, the exhaustive analysis of the injuries is made possible by the PAF system [5].

2.2. Treatment

If the fracture of the radius occurs in a context of multitrauma, with vital lesions to control, damage control principles must be followed and traction applied to the fracture using external fixation. The median nerve is released at the carpal canal as needed.

New X-rays and a CT are done in the following days, with the fixator in place, to perfectly identify and analyze the lesions and best treat them depending on the patient’s condition: adding pins or ideally internal plate fixation. As a rule, this second phase takes place during the 1st or 2nd week after fracture (Figs. 2–4).

However, if the radial fracture is isolated, with no vital lesions, the definitive treatment can be initiated immediately, but the preoperative CT is always necessary for the same reasons as cited above.

If reduction can be obtained with traction in the frontal and sagittal planes, plate fixation can be proposed.

If reduction with traction is only possible in one plane, external fixation with pins is discussed.

If reduction with traction is not possible in any plane, an open approach for reduction must be discussed, with fixation associated as needed.

If internal fixation is used, preliminary reconstruction of the ulnar column of the radius is an important technical point, and like Rikki and Regazzoni [6], we believe that it should be done first. The combination of a dorsal and palmar approach is sometimes required to treat posterior comminution that is inaccessible and uncontrollable despite anterior fixation. One should nonetheless avoid these double approaches that increase the risk of stiffness and choose the best side for a single approach.

2.3. Use of external fixation

An external fixator allows traction and reduction in the plane in which it is positioned (often the frontal plane), but it cannot be considered a means of fixation. It is an interim solution that should always be followed by osteosynthesis: pins associated with the fixator left in place for 4–6 weeks and plates that make it possible to remove or leave the fixator depending on the stability obtained.

The fixator should be easily and rapidly placed. It can be radio-metacarpal or radio-radial. It should be left for 4–6 weeks. It is an unmatched therapeutic tool for the most severe associated metaphyseal and epiphyseal injuries.

It has been erroneously accused of fostering type 1 regional pain syndromes (algodystrophy). After having placed the fixator, one should verify that the patient can make a fist and that the distraction of the radiocarpal and mediocarpal joints is not excessive (not more than 50% of the initial height of the joint space). Proper care of the pins is essential to prevent usually benign but very frequent infections [2].

2.4. Controlling metaphyseal lesions: comminution

In cases of metaphyseal comminution, it is logical to plan for bone grafting and therefore an iliac crest must always be prepared. However, the injectable cements proposed for many years make it possible to:

• forgo general anesthesia (required for iliac crest harvesting);
• fill in the bone loss as for grafting;
• provide stability while adapting perfectly to the situation;
• reduce the duration of surgery [7].

Bone graft or cement nonetheless will not compensate for insufficient fixation.

Pillukat et al. proposed “temporary arthrodesis” (this is in fact a plate bridging the wrist, without avivement or seeking radiocarpal fusion) when there is circumferential comminution and stability cannot be provided with external fixation [8].

2.5. Controlling epiphyseal lesions: impaction and distal fractures of the radius

With very distal fractures or free joint fragments, as well as in cases of joint impaction, an articular approach or arthroscopy is necessary to reduce the fracture with visual guidance and to provide fixation with miniaturized osteosynthesis (finger plates, threaded wires, screws) (Figs. 5–8).

If there is chondral substance loss, some authors have proposed:

• a silicon spacer at the bone loss area, removed after 4–6 months [9].
Fig. 2. A 46-year-old multitrauma patient whose high-energy distal radius fracture with a metaphyseal and epiphyseal component is treated in urgent care with a sole fixator, providing temporary stability.

Fig. 3. The mediocrity of the reduction mandates internal plate fixation, performed at D + 15 in a single procedure.

Fig. 4. Functional results at 6 months.
• costal cartilage grafting, never performed in urgent care and only used as a last resort [9].

2.6. Controlling lesions of the radioulnar joint

In these high-energy fractures, it is imperative to look for an extension of injury to the diaphysis and/or the radioulnar joint.

In cases of fracture with diaphyseal extension and dislocation of the radioulnar joint (Galéazzi injury), which destabilizes the antebrachial region, the length of the radial diaphysis must be restored; direct plate osteosynthesis is preferable to external fixation, which must be avoided. This is where long palmar epiphyseal plates are used to best advantage (Figs. 9–11) [10].

In cases of ulnar styloid fracture, the result is frequently poor, particularly when the fracture is proximal or displaced. Fixation should only be used when it is a proximal fracture with radioulnar instability. The fixation of these small bone fragments nonetheless carries an iatrogenic risk despite the miniaturization of the implants.

In cases of fracture of the ulnar head or neck, three solutions can be proposed after anatomic reduction of the distal radius:

• reduce the head and provide fixation, keeping in mind the highly osteoporotic bone;
• resect the head immediately in patients over 65 years of age;
• or leave the head as is [2].

In cases of radioulnar dislocation, caused by a lesion of the triangular fibrocartilage complex (TFCC) and the extreme distal part of the interosseous membrane, the radioulnar joint must be reduced and a temporary radioulnar wire placed to protect the soft tissue sutures.

Fig. 5. High-energy fracture with very distal epiphyseal component in a racecar driver.

Fig. 6. After a direct approach and reduction of each fragment using pins, a temporary radioulnar arthrodesis wire was put in place for 6 weeks.
2.7. Associated injuries

Any associated injuries, such as a scaphoid fracture or compression of the median nerve must be treated immediately.

3. Radiocarpal dislocations

3.1. Mechanism, diagnosis, and injury types

Dumontier et al. updated the analysis and management of radiocarpal dislocations [11]. These rare injuries are frequently dorsal, five to six times more frequent than palmar injuries, and result from a fall from a height, an industrial accident, or a traffic accident.

Dorsal dislocations may stem from hyperextension, with frontal deviation and rotation of the carpus under the radius, with hyperextension alone probably incapable of generating a radiocarpal dislocation. The rotational component generates radioulnar lesions.

Diagnosis is based on wrist X-rays, which are used to classify dislocations into two broad categories (Fig. 12):

- type 1 with solely ligament lesions. Occasionally, a small cortical fragment is detached or the radial styloid is avulsed. The radioscaphoid ligament and the short radioulnar ligaments are injured on the dorsal side of the wrist, and more often peristomal avulsion in a Bankart lesion than rupture of the dorsal radiocarpal ligaments themselves. These injuries are unstable and expose the patient to multidirectional instability;
- type 2 includes a styloid fragment of at least one-third of the scaphoid surface of the distal radius. The fracture line is always horizontal. The radiocarpal ligaments are joined to the styloid fragment, so its reduction and its fixation can provide stability (Fig. 13);
- Wang et al. proposed adding a third type, which includes an associated radioulnar injury [12].

The median nerve is sometimes compressed or contused, especially if the injuries are open, and it is more frequently involved than the ulnar nerve. These compressions should be released. As a rule, these nerve lesions result from ischemia that resolves after reduction [13]. Nevertheless, recuperation is inconsistent [14].

3.2. Treatment

All irreducible dislocations, whether open or with neurovascular complications, require surgical treatment. Orthopaedic reduction, although anatomic and stable, can give good functional results whatever the direction of the dislocation. However, this reduction is only rarely stable and the latest studies argue in favor...

Dumontier reviewed the three rules of treatment:

- restoration of radiocarpal congruence;
- identification and treatment of any intracarpal lesions;
- stable repair of bone and ligament lesions (fixation of bone fragments and reinsertion with anchoring of ligament avulsions).

Radiocarpal dislocation is reduced using traction through the palmar approach the median nerve at the carpal canal and the ulnar nerve at the Guyon canal can then be decompressed.

Dumontier advised inspecting and cleaning the joint space through the anterior capsular tear, then implanting anchors on the radius, and passing sutures in the capsule and anterior ligaments without tightening the knots [11] in type 2 injuries. In this case, the radiocarpal joint is stabilized by reduction and fixation (with two screws or two wires) of the styloid fragment and sutures passed in front and then knotted.

If there is radioulnar instability, reinsertion of the TFCC and fixation should be implemented to obtain healing of the temporary radioulnar interosseous membrane.

The main complication is stiffness with 30–40% loss of range of motion in flexion–extension. The factors of poor prognosis are open lesions, pure type 1 dislocations, associated nerve damage,
associated intracarpal lesions, and associated injuries on the same limb [11].

4. Intracarpal injuries

4.1. Perilunate dislocations

4.1.1. Lesions

Perilunate dislocation of the carpus is defined as loss of contact between the capitate and the lunate; it accounts for 5–10% of all carpal injuries [15–18].

These dislocations follow multitrauma in 10% of cases and always result from high-energy injuries, when the wrist is more or less locked in hyperextension (motorcycle handlebars) or resulting from falls from a height.

The distal row of the carpus is very solidly attached to the metacarpals and the proximal row is blocked between the radius and the distal row; the lesions therefore occur in the proximal row:

- separation of the two rows as well as of the bones of the first row;
- with diverse ligament lesions (short interosseous ligaments of the first row, scapholunate and lunotriquetral ligaments, ligaments joining the two rows at the mediocarpal joint, and sometimes extrinsic radiocarpal ligaments).

There is a risk of necrosis of the lunate due to intrinsic and extrinsic ligament lesions.

4.1.2. Understanding the mechanism to predict lesions (Fig. 17)

The experimental work conducted by Mayfield et al. [16] demonstrated an intracarpal supination mechanism after an impact on the thenar eminence with progression of lesions on the lateral side toward the medial side.

However, Laulan reported the proof of another mechanism that has practical consequences: the opposite mechanism to Mayfield’s, by intracarpal pronation following injury to the ulnar side of the carpus, with a hypothenar impact (with fracture of the associated pisiform) [17,18]. In fact, the majority of perilunate dislocations result from this mechanism [17,18].

In ulnar extension and inclination, the lunate is embedded under the radial joint surface. The triquetrum is in the low position, at the anterior side of the hamate, and the two bones are therefore very congruent [17,18]. In this position, a hypothenar injury first calls on the triquetrolunate region and the intracarpal “unlocking” can occur between the lunate and the triquetrum (stage 1). The triquetrum pushes the hamate back and with it the second row. Since the lunate is protected by the posterior edge of the radius,

Fig. 11. Bone union and functional recuperation at 6 months.

Fig. 12. Diagram showing where the energy passes in cases of radiocarpal dislocation: type 1 dislocation (solid line); type 2 dislocation (radial styloid fracture) or extension in the radioulnar area (dotted line).
Fig. 13. Pre- and postoperative aspect type 2 radiocarpal dislocation.

Fig. 14. A 22-year-old patient presenting type 1 radiocarpal dislocation, open with associated tendon lesions.

Fig. 15. Fixation of fracture–dislocation of the ulna and stabilization of the carpus.
the solution providing continuity passes between the lunate and the capitate.

The capitate can dislocate backward, whereas the scaphoid is always in place under the radius (stage 2). In this case, the risk of misjudging the diagnosis is the greatest, as shown by the examples reported by Sochard and Birdsall [19].

If the causative force continues, the scaphoid runs up against the posterior edge of the radius and, depending on the degree of extension and compression, either a scaphoid fracture or a fracture of the radial styloid occurs, or both (stage 3).

This knowledge of the possible lesional mechanisms clarifies that, depending on the center of the impact, the energy of the trauma, as well as the position of the carpus under the radius, dislocations and fractures of the structures between the rows or in the same row can occur.

Therefore, hidden injuries must be sought, for the most part to the ligaments is:

- a scapholunate dissociation isolated? Or is there the first stage of a perilunate dislocation with triquetrolunate lesions that may dominate the later progression with misalignment of the carpus and secondary mediocarpal osteoarthritis?

- a scaphoid fracture isolated? Or is there the first stage of a perilunate dislocation associated with extensive ligament injury: scapholunate, triquetrolunate, etc.?

4.2. Diagnosis

In one quarter of cases, posterior perilunate dislocation is not detected because of a lack of diagnostic rigor and/or a poorly interpreted or a poorly produced or absent lateral X-ray.

Edema and thickening of the wrist are different from what is observed in fractures of the distal radius. If the patient is conscious, there is pain on both sides of the wrist, sometimes with paresthesia of the median nerve, but the clinical picture is poor, with slight cracking noises upon examination of the wrist that has only slightly increased in volume. There is nonetheless an important sign: it is difficult to extend the fingers.

The diagnosis can be made based on AP X-rays (the lunate has a pyramid-like aspect, the Gilula lines are disturbed) and lateral X-rays [the lunate has lost its normal ratios with the radius and the capitale, it is dislocated forward or backward from the radius (Fig. 18)].

However, in the context of a patient that needs to be resuscitated, an AP X-ray alone can be misleading and the absence of a lateral image can lead to misjudging the lesions.

Two-thirds of perilunate dislocations are dorsal and associated with scaphoid fractures. In dorsal perilunate dislocations:

- the injury forces are applied to the scaphoid rather than to the scapholunate ligament
- the capitate is displace backward from the radius and the lunate can remain under the radius (stages I and II) or be dislocated forward (stage III).

Two-thirds of the perilunate dislocations are dorsal and associated with scaphoid fractures; in this case, the trauma forces were applied to the scaphoid rather than to the scapholunate ligament.

In two-thirds of cases, there is another associated fracture caused by the severity of the injuring forces. These can be lesions in the antebrachial area (distal radioulnar dislocation, Galéazzi fracture) or in the elbow, as well as intracarpal lesions with osteochondral fractures of the top of the capitale, the tip of the styloid, and avulsions of the anterior pole of the triquetrum.
4.3. Treatment

There are several forms of injury possible depending on the time since injury [15,20]:

- forms seen in urgent care that should be reduced and stabilized in the hours and days following the trauma depending on the patient’s condition;
- perilunate dislocations seen before the 6th week, where reduction may still be possible;
- chronic dislocations, beyond 6 weeks, paradoxically well tolerated, where reduction is nearly always impossible, even when resecting the interposed ligament structures;
- finally, rare cases seen several years after the trauma, following rupture of the flexors of the index and third finger.

The objectives of emergency management are:

- first making the diagnosis;
- then analyzing the X-rays to identify the direction of the displacement and its severity, and to identify the associated lesions;
- immediately reducing the dislocation and stabilizing it to allow ligament and bone healing;
- reducing as much as possible the complication rate (stiffness of the wrist, necrosis of the lunate [15,20,21]). Post-traumatic osteoarthritis due to cartilage lesions is, however, unavoidable.

The best results come from surgical treatment during the 1st week. Emergency treatment consists of reduction, stabilization, and immobilization. Treating only the associated carpal fractures is insufficient.

4.3.1. Emergency reduction and fixation

The fracture is reduced under general anesthesia in the operating room, with 5–7 kg of traction, possibly using a digital traction system. With the wrist flexed, the thumb pushes forward on the semilunate, whereas the index exerts a posterior counterpressure. The lunate is reduced gently with the thumb and the wrist is moved in dorsiflexion. This manoeuvre should be easy, but traction is long (10–15 min).

Surgical stabilization is ideally performed at the same time or in the following days, depending on the patient’s condition. Even if 40% of perilunate dislocations remain reduced, surgical stabilization is imperative in all cases.

The approach should be posterior, longitudinal on the skin. Arthrotomy can be performed in different ways: we prefer the
Herzberg Z approach. Continuous breaches in capsules and extrinsic ligaments as well as all other injuries are identified (Fig. 19). The posterior interosseous nerve can be resected. After checking that the reduction will be as anatomic as possible, visually and with radioscopic guidance, temporary pin fixation of the scapholunate, lunocapitate, and scaphocapitate joint spaces is placed when there is perilunate dislocation with no fracture (Figs. 20 and 21).

In cases where associated scaphoid fracture is present, first placing osteosynthesis of the scaphoid makes it possible to proceed to scapholunate pinning if the scapholunate ligament is intact. The pins are left in place for 2–3 months. Herzberg et al. described rotation arthroplasty to reconstruct the compartment of the extensors if a direct suture is impossible [15,20].

Kremer et al. demonstrated that a dorsal rather than a combined approach, denervation, and the patient's profession before trauma (not involving heavy physical work) were the prognostic factors associated with a good result [22]; 70–90% of patients were able to resume their professional activities.

Herzberg and Forissier reported that at 6 years more than half the patients presented post-traumatic osteoarthritis [21].

4.4. Fractures–dislocations other than perilunate

These are rare high-energy injuries that directly involve the capitate (scaphocapitate syndrome) or that occur around the capitate (axial dislocations of the carpus).

4.4.1. Scaphocapitate syndrome [23]

Combined fractures of the scaphoid and the capitate are improperly called scaphocapitate syndrome. In these lesions, there is rotation of the capitate head from 90 to 180°. Hamdi updated the analysis of this lesion, better known as Fenton syndrome, a particular form of perilunate dislocation in which the scaphoid and the capitate are fractured [24,25].

Several presentations exist and several classifications have been described depending on the displacement of the capitate fracture or...
Reduction of dislocations and relieving the compression of the median nerve, as is usual, should be done in the hours following the trauma.

Stable fixation of the bone and ligament injuries is indispensable, immediately or in the following days depending on the patient's condition.

One should systematically search for associated lesions on the same limb or identical contralateral lesions, caused by high-energy trauma.

It is necessary to explain to those young patients that despite chirurgical (reduction and temporary fixation of the joint spaces concerned, bone fixation, and ligament repair), they will never recover normal amplitude of the wrist.

Disclosure of interest

Laurent Obert declares having no conflict of interest in relation with this article, but has relations with the following firms: FX Solutions, Zimmer, Medartis, Evolutis, Biotech Wright, Argol.

The other declare that they have no competing interest.

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