VOLUME 71 | ISSUE 2 | APRIL - JUNE 2020

Treatment of radiocarpal dislocations or fracture-dislocations based on a new classification scheme

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ABSTRACT

Radiocarpal fracture-dislocations are the most debatable of carpal dislocations. The term radiocarpal fracture-dislocations has been used incorrectly for many previously reported cases. Thus, many questions arise concerning their incidence, terminology and classification. In this review, an attempt is made to determine the criteria based on which an injury can be classified as radiocarpal fracture-dislocation. Additionally, the surgical treatment of radiocarpal fracture-dislocations with combined access, allows for a relatively accurate description of osteoligamentous injuries, both on the palmar and on the dorsal side of the wrist. Four types of injuries in the dorsal and two types of injuries in the palmar dislocations are portrayed. Furthermore, a new classification is proposed based on five parameters: those of chronicity, pathoanatomy, direction, associated injuries and complexity.

KEY WORDS: Wrist, Radiocarpal, Dislocation, Classification, Pathological Anatomy

Introduction

Radiocarpal (RC) fracture-dislocations are relatively rare injuries, whose exact frequency is unknown. We will probably never find out the true incidence of these injuries, since there is no consensus as to which injuries should be named radiocarpal fracture-dislocations.

Due to the rarity of the injury most references, describe a relatively small number [1, 2, 3-7]or isolated cases [8-26]. At present, only a few reports involve more than 10 patients: the report by Nyquist and Stern [27] with 10 cases, by Mudgal et al [28] with 12 cases, by Girard et al [29] with 12 cases and by Dumontier et al [30] with 27 cases throughout a 23-year period.

The literature reveals that pure RC dislocations are rare injuries, while the RC fracture-dislocations involving radial styloid fractures are the most frequent. In addition, the dorsal RC fracture- dislocations are much more common than their palmar counterpart [28, 30, 31], although it seems the opposite is true for pure radiocarpal dislocations.

As for more violent traumas, these injuries have been reported mainly in males and usually of young

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VOLUME 71 | ISSUE 2 | APRIL - JUNE 2020

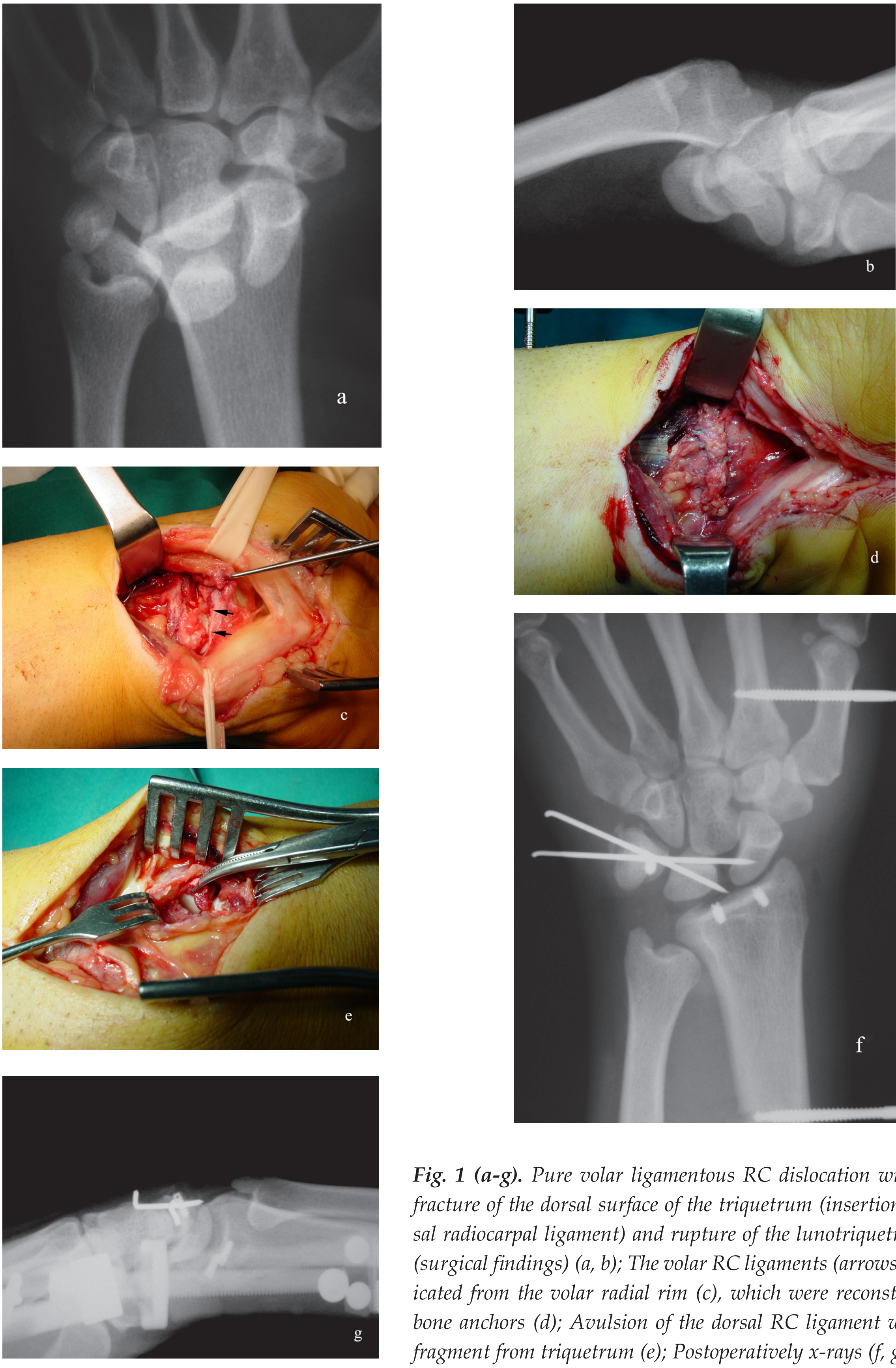


Fig. 1 (a-g). *Pure volar ligamentous RC dislocation with avulsion fracture of the dorsal surface of the triquetrum (insertion of the dorsal radiocarpal ligament) and rupture of the lunotriquetral ligament (surgical findings) (a, b); The volar RC ligaments (arrows) were eradicated from the volar radial rim (c), which were reconstructed with bone anchors (d); Avulsion of the dorsal RC ligament with osseous fragment from triquetrum (e); Postoperatively x-rays (f, g).*

VOLUME 71 | ISSUE 2 | APRIL - JUNE 2020

age. In our series of 26 patients, the average age was 33.7 (range, 19-60) and only one was a woman, while in Dumontier's [30] series the percentage male/female was 4/1.

Stability of the radiocarpal joint

We know that wrist motion along the transverse plane (pronation-supination) is only possible if the wrist is not loaded. The range of passive rotational motion between radius and carpus varies from 40°-45° [32] and extrinsic tendon loading affects significantly the rotational stability of the wrist: the passive pronosupination laxity of the radiocarpal and midcarpal joint decreases from 45° to 10° by clenching the fist [32].

Many daily manual tasks are performed by rotation of the forearm. To perform these rotational tasks adequately, the relative motion between the radius and the carpus must be constrained within a limited amount of laxity. These constraints to rotation (which at the same time provide stability to the radiocarpal joint) consist of the concavity of the radial fossa, the dorsal and palmar capsuloligamentous structures that link the forearm to the carpus, the extensor compartments and the extrinsic tendons that cross the radiocarpal joint.

Ligamentous structures provide constraints in both rotational (pronosupination between radius and carpus) and translational (dorsopalmar and ulnar) displacement of the wrist.

Mechanism of injury

Radiocarpal dislocations are high energy injuries (fall from a height, traffic or industrial accidents) and therefore the patients rarely remember the exact mechanism of injury. This injury is a product of several factors: the anatomy of the articulating units, the strength and elasticity of the RC ligaments, the strength of the bony structures, the magnitude, rate of loading and position of the RC joint at impact [33, 34].

It is very possible, that independently of their direction, the pivotal separation of the wrist-forearm towards opposite directions is responsible. Specifically, when at the time of injury, the forearm is fixed in pronation and the wrist is violently supinated, a dorsal RC dislocation may develop. Conversely, with the hand being fixed in pronation and the forearm violently supinated, a palmar RC dislocation may develop.

Apart from the rotation and the axial compression which are major components of the mechanism of injury, dorsiflexion and ulnar deviation [21, 23, 33], dorsiflexion and radial deviation [30, 35] or volar flexion and radial deviation [17] of the wrist, have all been implicated in the formation of injury. However, in many cases the mechanism of injury is extremely complex and hard to explain.

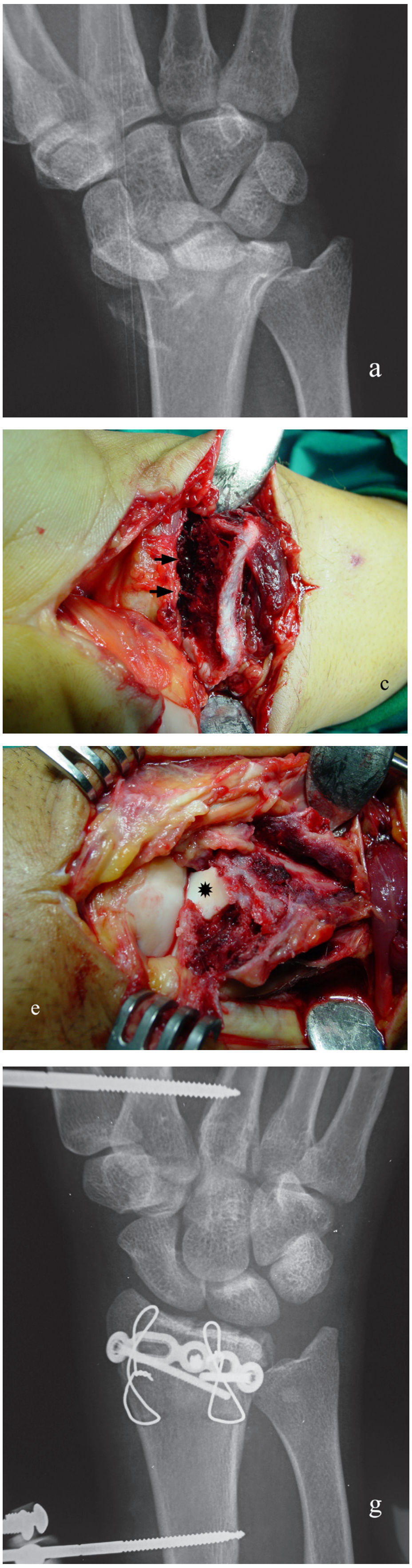
Terminology

Radiocarpal fracture-dislocations are the most debatable of carpal dislocations. The term RC fracture-dislocation has been incorrectly used in a considerable number of cases previously reported [36]. In a strict manner of speaking, dislocations of the RC joint should be either pure ligamentous injuries or dislocations associated with bony avulsions of ligamentous attachments.

There is agreement on terminology, only for pure ligamentous RC dislocations (**Fig. 1 a-g**). Confusion exists concerning the various types of fractures of the distal radius associated with dislocation of the RC joint. Various authors adopted different criteria to include injuries to the RC fracture-dislocation group: Dumontier et al [30] considered as RC fracture-dislocations, patients whose entire carpus had been dislocated volarly or dorsally to the radius, with fractures of the radial styloid more than one third of the width of the scaphoid fossa, provided that the ulnar half of the distal part of the radius was intact; carpal translations associated with a fracture of the volar or dorsal margin of the radius were excluded. On the contrary, others [37, 2, 33, 38, 36, 39], under the term RC fracture-dislocations comprised injuries characterized by dislocation of the RC joint in either dorsal or volar direction, which can be associated with radial and ulnar styloid as well as marginal rim fractures of the distal radius.

The main injury, from which RC fracture-dislocation must be differentiated, is the shearing marginal articular fractures of the distal radius (Type B according to AO classification or type II according to

VOLUME 71 | ISSUE 2 | APRIL - JUNE 2020



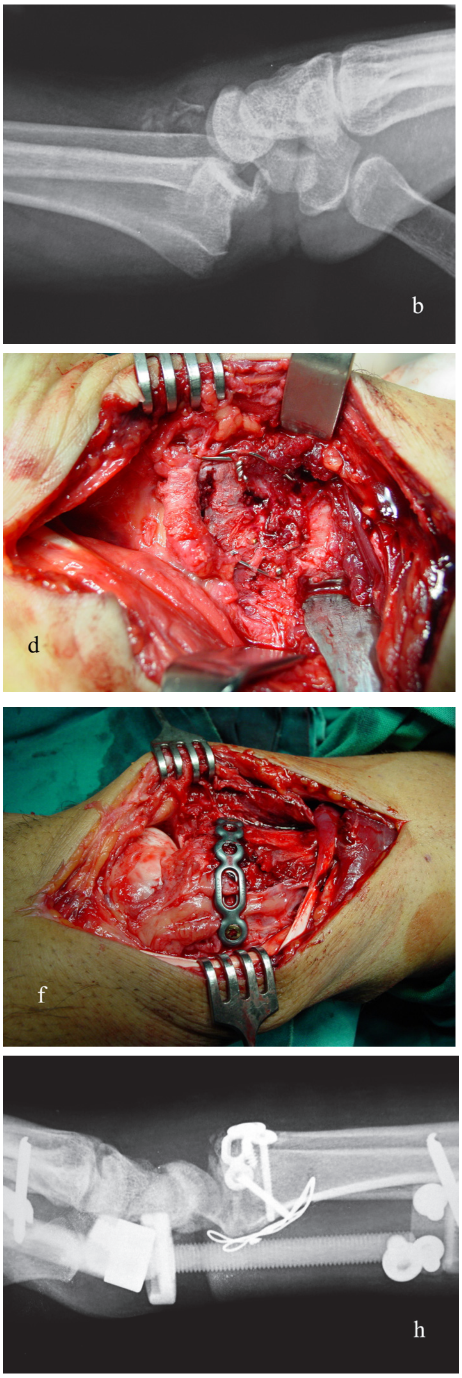


Fig. 2 (a-h). *Dorsal RC fracture-dislocation (a, b). The volar radial rim (containing the insertions of the volar RC ligaments) was fractured throughout its width in two parts (arrows) (c); Two figures of eight wire frames were used for the fixation (d); The dorsal approach reveals a comminuted fracture of the dorsal radial rim while a significant part of chondral bone was wedged and rotated 90o into the subchondral bone (asterisk) (e); After the reduction, fixation was achieved with a contoured horizontal low profile plate using only the two extremes screws (f); Postoperative radiographs (g, h).*

TABLE 1 *Differences between RC fracture-dislocations and shearing fractures with wrist subluxation*

	RC fracture-dislocation	Shearing fractures + wrist subluxation
Mechanism	Mainly rotational injury	Mainly compressive or axial load injury
Pathoanatomy	Injury at both sides of the RC joint (ligamentous or osseoligamentous)	One side injury (osseous)
Relation of osseous fragments with PCR	Fragments with no or only partial contact with PCR	Fragment in contact with PCR contains stabilizing ligaments
Reduction	Ease of reduction insecure maintenance	Reduction and fixation of the sizeable osseous fragment ensure joint stability

**RC = Radio-Carpal, PCR= Proximal carpal row*

Fernandez classification) (**Table 1**). These injuries should not be confused with true RC fracture-dislocations, since, the fractured fragment containing significant ligamentous attachments, remains in contact with the proximal carpal row and its fixation restores the stability of the RC joint. However, most importantly they constitute one-sided injuries by definition, since the opposite cortex and the extrinsic RC ligaments must be intact [34, 40-42]. Thus, the distinction should not be based on the size of the osseous fragment alone, which either way is a subjective criterion, but whether there is an associated injury opposite the osseous fragment side. On the contrary, fractures of the dorsal radial rim associated with dorsal RC subluxation (frequently referred to as dorsal Barton) merit particular attention, as they are more related to RC fracture-dislocations. Lozano-Calderon et al [43] examined 20 such patients and found that 18 of them also had a wide spectrum of opposite volar injuries.

RC fracture-dislocations must also be differentiated from patterns of perilunate ligamentous injuries that have a radial styloid component [33], since they have a different mechanism of injury, pathoanatomy, treatment and prognosis.

Therefore, we believe that the prerequisite to consider these injuries as ***radiocarpal dislocations*** is the dislocation of the entire carpus volar or dorsal to the distal radius without fracture or with avulsion fractures at the insertion site of the ligaments (e.g. tip of the radial styloid, small ulnovolar fragment). Under the term ***radiocarpal fracture-dislocations*** we should include patients: a) with dislocation of the RC joint associated with fractures which involve: the marginal cortical radial rims (volar and/or dorsal), the radial styloid or both, while there must be injuries (osseous and/or ligamentous) to both sides of the RC joint (dorsal and volar), b) whose radius metaphysis and the main portion of articular surface of the distal radius are intact, and c) with no associated intercarpal dislocations (the head of the capitate retains normal alignment with the distal lunate).

Idler [44] defined RC dislocation "as loss of articular contact between the proximal carpal row and distal radius not in association with a biomechanically significant fracture of the distal radius". Although the expression "biomechanically significant" raises much debate, we believe that the definition would be more accurate if the phrase: "and which also requires injury of at least both sides of the RC joint" is also added at the end.

However, there will always be cases in the grey area or questionable cases as to where they belong.

Pathologic anatomy of the injury

Understanding the pathologic anatomy of RC dislocations or fracture-dislocations is dependent on findings at surgical exposure. Since only few cases have been treated operatively with detailed description of their osseoligamentous injuries, the magnitude and spectrum of injuries are not exactly known. As a result, the extent of tissue compromise is often underestimated, leading to under-treatment and inferior results.

VOLUME 71 | ISSUE 2 | APRIL - JUNE 2020

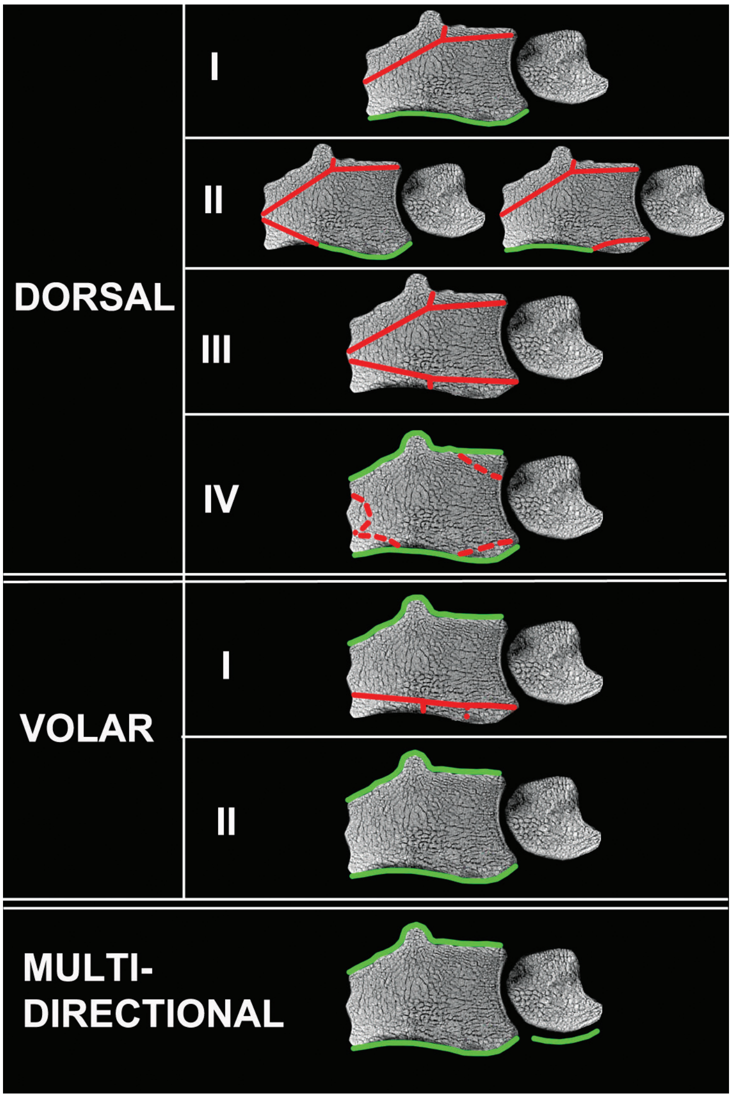


Fig. 3. *The pattern of osseous (red lines) and ligamentous (green lines) disruption that was found in different types of dorsal, volar and multi-directional dislocations (see text for details).*

RC fracture-dislocations are frequently associated with ulnar–sided injuries and only a few cases have been reported in the literature, where this injury was associated with dislocation of the distal radioulnar joint [1, 14, 30, 45, 46]. Rarely the dislocation is irreducible due to interposition of the flexor digitorum profundus of the small finger [30], or the extensor carpi ulnaris [46], or the dorsal part of the sigmoid notch where the dorsal radioulnar ligament is attached [45], or the flexor profundus tendons and the ulnar nerve and artery [14].

Wide displacement of any type of ulnar styloid fracture was also recognized as a significant risk for development of DRUJ instability [47, 48].However, it is believed that the presence of an ulnar styloid fracture is no longer considered an absolute indicator of DRUJ instability regardless of the fragment size and displacement [49,50], but only as a risk factor [51].

By excluding patients treated with methods that preclude the ability to describe the pathoanatomy of the injury, i.e. conservative treatment (5 patients) or closed reduction, percutaneous wires and/or external fixation (4 patients), twenty six patients were treated operatively, mostly with combined approach and their surgical findings were recorded. A single approach (1 volar and 1 dorsal) was used in 2 patients, a double approach (dorsal and volar) in 18, and a triple approach (dorsal, volar, ulnar) in 6 patients.

VOLUME 71 | ISSUE 2 | APRIL - JUNE 2020

Four patients presented RC dislocations and 22 patients were of RC fracture-dislocation type. According to the direction of the dislocation, there were 19 dorsal (12 pure dorsal, 4 dorsoradial, 3 dorsoulnar), 5 volar and 2 multidirectional dislocations. All were closed injuries.

Surgical findings

1. In all cases, the ligamentous or osseo-ligamentous injuries involved both the dorsal and volar sides of the RC joint.
2. Of 22 patients with RC fracture-dislocations, 19 had fractures of the radial styloid, two patients had an osseous avulsion of the dorsoulnar corner of the distal radius and one patient had a combination of the above injuries.
3. Of 20 patients with fractures of the radial styloid, no one had fractured the entire radial styloid in dorsovolar dimension, independently of its width. The dorsal styloid segment was involved in 6 patients, the volar styloid segment in 3 patients and a combination of both segments was found in 11 patients. It was difficult to detect radiographically the combined segments of the fractured radial styloid; it was feasible only operatively.
4. Fractures of radial rims were either of compression or avulsion type depending on the direction of the dislocation. The direction of the dislocation coincided with the compression side of the radial rim, while the opposite radial rim had an avulsion type of fracture. Usually the osseous injury of the dorsal radial rim was double: there was a larger-sized fragment from the dorsal half of the radial styloid and a smaller-sized simple or comminuted fracture of the radial rim, ulnar to the Lister's tubercle, which involves the attachment of the DRC ligament (**Fig. 2 a-h**). The osseous fragments from the volar radial rim were sometimes rotated by 90^o-180^o, since the volar are shorter than the dorsal RC ligaments. There were 10 dorsal rim fractures, 4 volar and 4 combined dorsal and volar rim fractures.
5. A wide range of injuries of the proximal carpal row was noticed in 11 patients (42%), all of which were discovered intraoperatively: a) Osteochondral defects of adjacent bones of the proximal carpal row comprising the interosseous ligaments (3 patients; two at scapholunate junction and one at lunotriquetral junction), b) isolated rupture of the interosseous ligaments (4 patients; two of scapholunate and two of lunotriquetral ligament), c) chondral defects of isolated bones (2 patients; at proximal scaphoid and at proximal lunate respectively), d) fractured bones (2 patients; lunate and triquetrum respectively).
6. In six patients, free osteochondral fragments were found intra- or extra-articularly, originating either from carpal bones or from the distal radius.
7. The RC ligaments were usually avulsed from the volar or dorsal radial rims, but in 7 patients they were avulsed from carpal bones with or without small osseous fragments. Specifically, the short radiolunate ligament was avulsed from the lunate (5 patients) and the dorsal RC ligament, was avulsed from the triquetrum (2 patients).
8. In 3 patients (2 with volar and 1 with multidirectional dislocation) there was an extensive rupture of the floor of the dorsal retinaculum, while in the patient with the multidirectional dislocation, the extensor and abductor pollicis longus were ripped-off from their musculotendinous junction, a finding indicative of the rotational component of the mechanism of injury.
9. Seventeen patients (65.3%) had associated injury of DRU joint (fracture through the base of the ulnar styloid in 14 patients, an osseous avulsion from the dorsal sigmoid notch of the dorsal radioulnar ligament in 3 patients and a Type IV rupture of the TFC in 1 patient).
10. The two multidirectional and one volar dislocation had in addition a complete rupture of the volar ulnocarpal ligaments.

Based on our surgical findings, we could define the pattern of osseo-ligamentous disruption as follows (**Fig. 3**):

In dorsal dislocations, there were roughly 4 types of injuries:

Type I (4 cases): Dorsally, a double osseous injury (separate fragments, radially and ulnarly to Lister's tubercle) and volarly a purely ligamentous injury.

Type II (7 cases): Dorsally a double osseous injury

VOLUME 71 | ISSUE 2 | APRIL - JUNE 2020

TABLE 2 *Classification of RC dislocations or fracture-dislocations*

Chronicity	Pathoanatomy	Direction	Associated injuries	Complexity
a. Acute b. Gradually developed	**RC dislocations** a. Pure ligamentous b. Equivalent: Tip of radial styloid Ulnovolar fragment **RC fracture-dislocations** a. Radial styloid: Dorsal part Volar part Combination b. Radial rim: Dorsal rim Volar rim Both rims c. Dorsoulnar fragment	a. Dorsal b. Volar c. Ulnar d. Combinations e. Multidirectional	a. DRUJ b. UC ligaments c. Interosseous lig. of PCR d Osteochondral fragment e Carpal bone fractures f Tendons -muscles g Neural or vascular h Retinaculum	a. Reducibility b. Open or closed

**RC = Radio-Carpal, DRUJ= Distal radioulnar joint, PCR=Proximal carpal row, UC=Ulnocarpal ligaments*

and volarly a double osseoligamentous injury. Usually the RC ligaments were detached from the ulnar side of the volar radial rim, while the radial side showed an avulsion fracture fragment. Less often, the reverse was true.

Type III (3 cases): Double osseous or comminution on both dorsal and volar sides.

Type IV (5 cases): Dorsal and volar, mainly ligamentous injuries, which were sometimes associated with small osseous fragments of avulsion type, originating from the radial styloid (either side) or from the dorsoulnar side of the radius.

In volar dislocations we found 2 types of injuries:

Type I (4 cases): Dorsally, purely ligamentous and volarly a double or comminuted osseous injury.

Type II (1 case): Purely ligamentous injuries on both sides.

In the two cases with **multidirectional dislocations**, we found a purely ligamentous injury on both sides with rupture of the ulnocarpal ligaments. One of those cases exhibited fracture of the tip of the radial styloid.

Classification

Two classification schemes have been discussed extensively in the literature: Dumontier et al [30] classified RC dislocations into two types: type 1 included pure dislocations with or without fracture of only the tip of the radial styloid, a fracture involving less than one-third of the width of the scaphoid fossa, postulating that the RC ligaments were torn off the radius; type 2 included dislocations with associated fracture of the radial styloid involving more than one-third of the scaphoid fossa, postulating that most of the RC ligaments were still intact and attached to the radial styloid fragment.

Moneim et al [2] classified these injuries into type 1 and type 2 according to the integrity of the intracarpal ligaments. In type I dislocation, the carpus moves as one unit on the distal radius whereas in type II, an associated intercarpal dislocation is also present. He presented 7 cases and 3 of them were characterized as type II dislocations. According to the author, type II dislocations represent a more complex pattern, with a graver prognosis. It should however be noted, that all 3 cases characterized as type II RC dislocations were in fact trans-styloid perilunate injuries with volar dislocation of the lunate, from which RC fracture dislocations must be differentiated.

A third classification was that of Graham [38] who considered RC dislocations as “inferior arc” injuries, in addition to the existing injury patterns the “greater” and “lesser arc” injuries. He stated that

VOLUME 71 | ISSUE 2 | APRIL - JUNE 2020

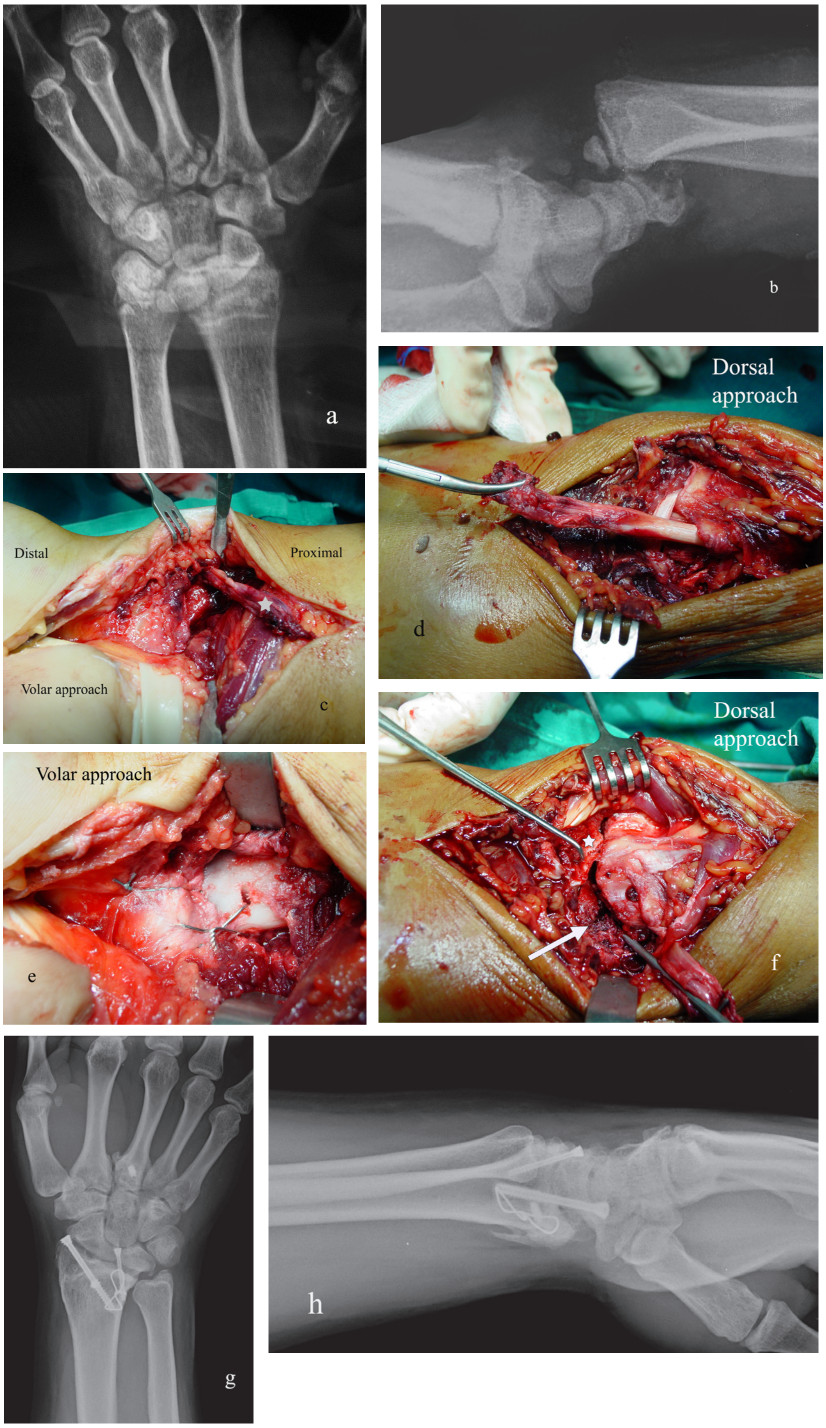


Fig. 4 (a-h). *Volar RC fracture-dislocation associated with comminuted fracture of third metacarpal base (a, b); With volar approach, over pronator quadratus, a tendon stump was found (asterisk) (c); With dorsal approach it appeared to be the avulsed insertion of the ECRB from the base of the third metacarpal, a finding indicative of the magnitude of rotational force applied (d); The volar radial rim was divided into two parts, a smaller radial bone fragment containing RC ligaments and a larger one concerning the ulnovolar fragment which were fixated with a bone anchor and a figure-of-eight wire frame respectively (e);Despite volar direction of the dislocation the dorsal radial rim was separated in 2 fragments: a dorsoulnar (asterisk) and a dorsoradial fragment (arrow) which were fixed with 2 cannulated screws (f); Final x-rays 5 years post-injury (g, h)*

RC dislocations could be classified as: a) purely ligamentous disruptions, b) dislocations with a "large fragment" styloid fracture, starting in the area of the previous physeal scar and entering the joint near the crista separating the scaphoid and lunate fossae and c) dislocations with a "small fragment" fracture, which represents avulsion or impaction injuries of the volar or dorsal margins of the distal radius.

Bilos et al [1] classified these injuries into four general types: dorsal, volar, radial, and ulnar, depending on the direction in which the carpus is displaced.

Bozentka and Beredjiklian [52] commented on the need to include in the classification schemes other important factors, such as the direction, the presence of associated neurovascular injury and the presence of associated intercarpal ligamentous injuries.

Mainly relying on surgical findings, we propose a new classification based on five parameters (chronicity, pathoanatomy, direction, associated wrist injuries and complexity). Using this classification, a RC dislocation or fracture-dislocation should be presented with information on all five parameters (**Table 2**):

1. **Chronicity**: RC dislocations or fracture-dislocations are differentiated into acute and gradually developed. The latter group includes ulnar translation as sequelae of an already treated RC dislocation or a remote consequence after a subtle RC ligament rupture. Special mention deserve those cases presented in the literature, where the RC subluxation or dislocation was associated with a small fragment from the ulnovolar articular surface of the distal radius [3, 8, 15, 22, 25, 53, 54]. Since all these cases were closely reduced and after a period of time the subluxation recurred, they could belong to the gradually developed group.
2. **Pathoanatomy**: RC dislocations are differentiated into purely ligamentous or equivalent, which include the tip of the radial styloid or a small ulnovolar fragment. RC fracture-dislocations are differentiated according to the location of the fracture into: radial styloid (dorsal or volar part or combinations), radial rim (dorsal or volar or combined rims) and dorsoulnar fragment.
3. **Direction**: The direction of the dislocation allows us to assume in a great extent the underlying lesions. Thus, these injuries are divided into dorsal, volar, ulnar, combinations (dorsoradial, dorsoulnar, radiovolar or ulnovolar) and multidirectional.
4. **Associated injuries**: These are related to concomitant injuries located in the vicinity of the dislocated wrist. They may concern DRUJ, ulnocarpal or interosseous ligaments, osteochondral fragments, fractured carpal bones, ruptured tendons or muscles (**Fig. 4 a-h**), neurovascular injuries and the dorsal retinaculum.
5. **Complexity**: This parameter clarifies if the dislocation is reducible or not and if the dislocation is open or closed.

Treatment

There have been reports of successful treatment with: closed reduction and casting [3, 12, 21, 30, 55], closed or open reduction and percutaneous pinning [56, 2, 7, 13, 23, 30], open reduction and casting [26, 57], open reduction and internal fixation with ligamentous repair [1, 2, 4, 8, 30, 58, 45, 36,59]. Due to the rarity of these injuries, there is no unanimously accepted method for their management.

Most of these dislocations are relatively easy to reduce, there are therefore cases that, being spontaneously reduced, escape diagnosis. The reported cases of a non-reducible dislocation are rare. In one case there was tendon interference [14], whereas in two other cases there was bone fragment interference [24, 45].

In several reports, mostly of isolated cases, closed reduction and cast immobilization are advised [2, 3, 12, 21, 25], in dorsiflexion for the dorsal and in palmarflexion for the palmar dislocations [25, 31]. However, RC dislocations treated non-surgically have been reported to develop palmar subluxation, ulnar translation DISI or VISI instabilities [3, 6, 9, 12, 13, 18, 21, 22, 36]. Certainly, everyone agrees that open, non-reducible dislocations and those accompanied by neurovascular injury must be managed with open reduction [60, 7]. Many reports [27, 28, 30, 33, 61-63], plead for open reduction since, if the RC ligamentous mechanism is not repaired, wrist function will be severely compromised with instability and/or subluxation later [59].

There are many cases in the literature that were initially managed with closed reduction and casting, but the wrist was subluxated early or late [2, 7, 13, 30]. In our series 7 out of 26 patients lost their reduction and were treated operatively with a delay of 4-20 days

If, for any reason, closed reduction is chosen, a basic requirement is to ensure that during the healing period, the anatomical alignment of the bones and joints will be preserved, in order for intraarticular fractures to be united without articular incongruity and most importantly, the RC joint to be axially aligned so that the ruptured ligaments can heal with proper tensioning. Alternatively, following closed reduction and once we have ensured that the RC joint has been anatomically reduced, we can immobilize the joint using K wire or external fixation.

There is no consensus as to which is the most appropriate approach for open reduction. The approach should be dictated by the direction of the dislocation, the fracture pattern, the associated carpal bone injuries, the presence of neurovascular injury and if we are dealing with an open or closed injury. Moneim et al [2] for cases necessitating open reduction proposed combined approaches. Mudgal et al [28] advised the use of palmar approach in the presence of a neurological defect, dorsal approach if the dorsal radial rim is involved and ulnar approach when the ulnar styloid requires fixation. Dumontier et al [30] believed that group 1 patients should be treated with reattachment of the ligaments through a volar approach. In group 2 patients, the ligaments are still attached to the radial fragment and in this group of patients, exact articular reduction should be performed through a dorsal approach. The Mayo clinic group, as quoted by Idler [44], has recommended palmar and dorsal approaches for ligament repair of the radiocapitate, long radiolunate, ulnocarpal, and dorsal radiotriquetral ligaments.

Considering that by definition, RC dislocations or fracture-dislocations constitute double-sided injuries and that structures important for wrist stability are located both dorsally and volarly, we regard the combined approach as the most appropriate. In any case, of an acute dislocation or fracture dislocation, regardless of its direction, we consider the palmar approach most important in order to repair the volar RC and ulnocarpal ligaments as well as any fractures of the volar radial rim, since these structures are crucial for wrist stability. In the majority of cases, dorsal approach is also required, especially in cases of compressive fractures of the dorsal radial rim, for the fixation of a potential dorsal part of a fracture of the radial styloid or to evaluate the integrity of proximal carpal row bones. Sometimes, when dorsally the injuries are purely ligamentous or are associated with small avulsed fragments or with subperiosteal detachment of the dorsal extensor compartments, then dorsal approach may be avoided, on the premise that the volar structures have been restored and the RC joint is maintained reduced and properly aligned for 6-8 weeks.

In cases of DRUJ instability or of a displaced fracture at the base of the ulnar styloid, a separate ulnar approach is frequently necessary.

Based on the literature and on personal experience, we consider the following steps as necessary for open reduction:

1. The patient is positioned supine on the operating table. An arm table is positioned beneath the affected extremity and the procedure is performed under tourniquet control. During anaesthesia, useful information concerning the magnitude and direction of dislocation can be acquired under image intensifier, through manipulation of the wrist (longitudinal traction and dorsal, volar, radial and ulnar displacement) with the forearm stabilized. In addition, PA and L radiographs with the RC fracture dislocation reduced are recommended.
2. Depending on the nature and the time elapsed from injury, an external fixator may be applied from the initial stages of operation, so that the wrist is kept in gross alignment and mild distraction, as it facilitates the exposure of the capsuloligamentous structures. The more delayed the injury's treatment is, the greater the need for the application of the external fixator at the initial stages of the operation. Its placement on the radial side of the wrist does not obstruct the impending approach.
3. The extended carpal tunnel approach is used to decompress both the carpal tunnel and

VOLUME 71 | ISSUE 2 | APRIL - JUNE 2020

Guyon canal if needed and to fully evaluate the radio-volar injuries by displacing the FPL and the median nerve radially and the remaining flexor tendons ulnarly. The ulno-volar injuries are assessed by displacing the flexor tendons radially. Less often and depending on the extent of injuries, Henry's approach is sufficed. The joint is irrigated and the osseoligamentous lesions are recorded in detail. The palmar RC ligaments are either detached from their insertions to the volar radial rim or from carpal bones (usually the lunate) or avulsed with a small osseous fragment from their insertions. The reattachment of ligaments is achieved using non-absorbable sutures through transosseous holes or bone anchors that are inserted at the sites where the ligaments were detached. Depending on the size of the fractured fragments of the volar rim, their fixation is achieved using K-wires, small plates, or a wire-loop [64].

4. In cases where the healing capacity of the volar RC ligaments is questionable, especially in delayed cases, augmentation using tendon grafts is an option. Originally Rayhack et al [58] and more recently Maschke et al [65] described a cadaveric model for reconstructing the radioscaphocapitate using the brachioradialis tendon, while Obafemi and Pensy [66] applied the same technique in a patient with palmar RC dislocation, in order to reconstruct the radioscaphocapitate ligament and to reinforce the dorsal capsular repair.

5. The dorsal approach is longitudinal over Lister's tubercle, the third compartment is exposed if intact and the EPL tendon is displaced radially. The integrity of the dorsal retinaculum is recorded; if it is intact, subperiosteal elevation of the second and fourth compartments allow for a full evaluation of the dorsal injuries, since the dorsal capsule is already ruptured. At this stage and after joint irrigation, the injuries of the dorsal surface of the radius (from radial to ulnar) and the integrity of the chondral surfaces and the interosseous ligaments of the proximal carpal row bones are evaluated. Any entrapped chondral or osteochondral fragments are debrided or preserved for later transfixation. The integrity of the dorsal RC ligament must be checked throughout its course. In cases of compressive fractures of the dorsal radial rim, the insertion of cancellous bone grafting is necessary to support the articular surface, using small buttress plates for fixation [28, 59, 67]. In cases with purely ligamentous injuries, small osseous fragments or subperiosteal detachment of the dorsal cortex, there are many alternative stabilizing methods including K-wires, bone anchors, screws or tension band wiring. Any injury of the proximal carpal row bones is treated accordingly and stabilized with K wires.

6. At the end of a stable reconstruction of the RC joint, the stability of the DRUJ is assessed. This information will be provided with passive anteroposterior glide of the distal ulna relative to the distal radius in positions of neutral rotation, full pronation and full supination, and whether the ballottement test demonstrates or not a hard end point. Thus, in cases of DRUJ instability or displaced fracture of the base of the ulnar styloid, tension band wiring or TFCC suturing are recommended [28, 59].

7. It is necessary, using the external fixator, to maintain the RC joint in a reduced position throughout the healing process for 6-8 weeks and to protect the reconstructed RC ligaments from slackening. In highly unstable injuries or when the reconstruction is suboptimal, an additional RC pinning is essential and is usually inserted percutaneously or through a small incision (protecting the sensory branches of the radial nerve), from the radial aspect of the radius and through the lunate towards the wrist.

8. The immobilization of the RC joint is maintained for 6-8 weeks and physiotherapy consisting of active and passive wrist mobilization must be initiated.

Complications

Limitations in the range of motion and reduction in grip strength are common occurrences regardless of the treatment method applied for these injuries. In addition, post-traumatic arthritis, instability findings and residual volar, dorsal or ulnar subluxation of the wrist, have been reported as possible complications after the management of these injuries [37, 7, 30, 44].

Ulnar translation [68] or ulnar translocation [31] is observed in cases of serious and generalized lig-

VOLUME 71 | ISSUE 2 | APRIL - JUNE 2020

amentous injuries of both the palmar and dorsal sides of the wrist. It could be manifested as either pure ulnar translocation [9, 58, 69, 70, 71] or as sequelae of reduced palmar [15, 18, 22] or dorsal [19] RC dislocations, which were treated with closed or open reduction and inadequate reconstruction of the volar RC and ulnocarpal ligaments. Ulnar translocation of the wrist is more common with purely ligamentous injury patterns [13, 18, 22, 25, 30], while excessive minus variance of the ulna with deficient ulnar buttressing by the TFCC, may be a predisposing factor [58, 72].

Palmar translation of the wrist was found with less ligament disruption than that required for ulnar translation, whereas in all cases of ulnar translation, there was a component of palmar wrist displacement [73].

Different methods of assessing ulnar translation have been reported. The methods using the center of the capitate head [74-76] as a carpal reference should not be used in type II injuries, because only the lunate-triquetrum complex is significantly displaced in these cases. In contrast, when using the lunate as a reference [77-79], if the wrist is slightly radially or ulnarly deviated, the measurements may be unreliable [73].

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