Review article

Post-traumatic carpal instability

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ABSTRACT

The complexity of the carpus explains the difficulty treating carpal injuries. Lesions are dominated by perilunate dislocation, scapholunate dislocation, and scaphoid fractures. The other injuries are trivial. Symptoms include pain and loss of wrist strength, reversible for an acute and well-treated lesion. Too often, these ligament injuries are diagnosed late. For delays longer than 6 weeks, ligament repair is ineffective. These old, complex lesions are potentially highly arthritic in the radiocarpal and mediocarpal joints. Improvements in wrist surgery have mitigated these chronic lesions. Various surgical techniques can preserve a functional wrist; wrist arthrodesis is no longer the only solution for these arthritic wrists. Over the past decade, arthroscopy has contributed to better understanding the injuries of the carpus as well as to better healing them. For acute or chronic ligament injuries without degenerative osteoarthritis, arthroscopy is the treatment of the future. This technique involves a long learning curve and the various arthroscopic techniques must be validated.

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1. Introduction

Carpal joint and ligament complexity explains the delicate balance of this joint. Many anatomic studies have described the different joints in detail as well as all the intrinsic and extrinsic ligaments of the wrist (Tables 1 and 2). The intrinsic ligaments connect the different bones, whereas the extrinsic ligaments connect the distal extremity of the two bones of the forearm to the carpus or the carpus to the metacarpals. Among the intrinsic ligaments, the scapholunate ligaments (notably its dorsal segment) and ulnotriquetrum (notably its palmar segment) are functionally the most important of the extrinsic ligaments, joining the palmar side of the radius to the carpal side [1,2]. It is difficult to understand the biomechanics of the carpus. A number of publications on the biomechanics of the wrist are available, but they are at times contradictory [3–6].

The main problem of carpal ligament lesions is their high potential for arthritis over the more or less long-term. This arthritis can be first radiocarpal and later intracarpal [7]. Carpal ligament lesions result from high-energy injuries in, for the most part, a young population. Degenerative lesions are related to pathologies such as chondrocaldinosis, rheumatoid polyarthritis, and other rheumatisms. Their management is therefore different because treatment must take into account the underlying chronic pathology [8].

Ligament lesions essentially include scapholunate dissociation and perilunate dislocation from the carpus; other lesions are rarer.

Fracture of the proximal pole of the scaphoid or associated with a ligament lesion has the same potential for arthritis as a ligament lesion.

2. Generalities and classifications of carpal instability [9–11]

Carpal instability signifies the disappearance of the balance between the extrinsic and intrinsic forces that maintains joint cohesion. It results from bone or ligament lesions and its severity is directly correlated with the severity of these lesions.

2.1. Static and dynamic instability

There is instability at rest, called static instability, and instability occurring during movement called dynamic instability.

2.2. Objective and subjective instability

Static or dynamic instability manifests in modifications of the radiographic ratios of the carpal bones themselves and between the carpal and the radius, whether or not there is also subjective instability (as experienced by the patient) or objective instability (anomaly on the clinical exam such as popping or a drawer phenomenon, etc.).

2.3. Dissociative and nondissociative instability

Dissociative instability can also be raised, which manifests as instability of the proximal row of the carpal bones in which the
lunate is considered the intercalated segment. It can be seated between the scaphoid and the lunate or between the lunate and the triquetrum. Scapholunate instability is responsible for dorsal instability of the intercalated segment, or dorsal intercalated segment instability (DISI), whereas lunotriquetral instability is responsible for volar instability of the intercalated segment, or volar intercalated segment instability (VISI).

Non-dissociative instability is characterized by the absence of instability within the proximal row of the carpal bones. It indicates instability between the distal extremity of the radius and the proximal row of the carpus (radiocarpal instability), or between the first and second row (mediocarpal instability).

There are also other complex types of instability that associate dissociative and non-dissociative instability.

2.4. Radial, ulnar, and mixed instability

This axial instability (i.e., in the axis of the wrist) includes radial instability (radial side of the wrist), ulnar instability (ulnar side of the wrist), and mixed instability.

2.5. Adaptive instability

Adaptive instability is characterized by normal intrinsic and extrinsic ligaments. Misalignment of the carpal bones in this case originates in the bones.

2.6. Acute, subacute, and chronic instability

Acute and chronic instability were mentioned above. This difference conditions the potential for healing ligament lesions. When the injury dates from less than 1 week, it is considered acute instability. A lesion between 1 and 6 weeks is considered a chronic lesion; its treatment is often difficult and remains poorly codified.

### Table 1

<table>
<thead>
<tr>
<th>Intrinsic carpal ligaments.</th>
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<tbody>
<tr>
<td><strong>Dorsal side</strong></td>
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<tr>
<td>Scapholunate ligament (dorsal segment)</td>
</tr>
<tr>
<td>Lunotriquetral ligament (dorsal segment)</td>
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<tr>
<td>Dorsal scapholunotriquetral ligament</td>
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<tr>
<td>Dorsal scaphotrapeziotrapezoid ligament</td>
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<tr>
<td><strong>Palmar side</strong></td>
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<tr>
<td>Scapholunate ligament (palmar segment)</td>
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<tr>
<td>Lunotriquetral ligament (palmar segment)</td>
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<tr>
<td>Palmar scapholunotriquetral ligament</td>
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<tr>
<td>Radial bundle of the collateral ligament</td>
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<tr>
<td>Ulnar bundle of the collateral ligament</td>
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<tr>
<td>Palmar scaphotrapeziotrapezoid ligament</td>
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<tr>
<td>Interosseous ligament joining trapezium, trapezoid, capitate, and hamate</td>
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</table>

Fig. 1. Mayfield stage 1: scapholunate dissociation caused by intracarpal supination.

### Table 2

<table>
<thead>
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<th>Extrinsic carpal ligaments.</th>
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<tbody>
<tr>
<td><strong>Radial side</strong></td>
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<tr>
<td>Radial collateral ligament</td>
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<tr>
<td><strong>Ulnar side</strong></td>
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<tr>
<td>Ulnar collateral ligament</td>
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<tr>
<td><strong>Dorsal side</strong></td>
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<tr>
<td>Dorsal radiotriquetral ligament</td>
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<tr>
<td>Dorsal ulnotriquetral ligament</td>
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<tr>
<td><strong>Palmar side</strong></td>
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<tr>
<td>Radioscaphocapitate ligament</td>
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<tr>
<td>Radiolunotriquetral ligament</td>
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<tr>
<td>Radioscapholunate ligament</td>
</tr>
<tr>
<td>Short radiolunate ligament</td>
</tr>
<tr>
<td>Ulnolunate ligament</td>
</tr>
<tr>
<td>Palmar ulnotriquetral ligament</td>
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Fig. 2. Mayfield stage 2: capitolunate dislocation caused by lateral disruption.

### 3. Perilunate dislocation of the carpus

Usually posterior, this dislocation associates complex ligament lesions and can compromise vascularization of the lunate. It can be purely ligamental or associated with a fracture of a carpal bone; 30% of these lesions are not diagnosed early.

#### 3.1. Pure ligament lesions

Mayfield describes four stages [12,13]:

- **stage 1**: scapholunate dissociation caused by intracarpal supination (Fig. 1);
- **stage 2**: capitolunate dislocation caused by lateral disruption (Fig. 2);
- **stage 3**: triquetrolunate and radiolunate dislocation resulting in retrolunate dislocation (Fig. 3);
- **stage 4**: radiolunate lesion as severe as enucleation of the lunate caused by rupture of its two constraints with risk of lunate necrosis (Fig. 4).

This perilunate lesion can be associated with a transcapoid fracture, or a transtriquetral or transcapitate fracture. The associated fracture generally ensures preservation of the neighboring scapholunate or lunotriquetral ligament (Herzberg classification [14]).

Frequently, the diagnosis is radiographic with particular importance awarded to the strict lateral view because the AP x-ray is...
misleading. The importance of the need for a CT with no injection of contrast if any doubt persists as to diagnosis should be emphasized.

We exercise caution with pure perilunate dislocations that reduce spontaneously. If this occurs, the x-ray minimalizes the perilunate lesions. Only the scapholunate lesion is visible; the dynamic AP and lateral x-rays (radial and ulnar inclinations and posterior and anterior drawers) demonstrate perilunate instability.

Fig. 3. Mayfield stage 3: lunotriquetral and radiolunate dislocation resulting in retrolunate dislocation.

Fig. 4. Mayfield stage 4: radiolunate lesion as severe as enucleation of lunatum caused by rupture of its two constraints with risk of necrosis of the lunate.

Fig. 5. Pinning of a perilunate lesion (locking perilunate joint spaces).

Based on consensus, these lesions should be operated. Only dislocations in patients who are hemodynamically unstable should be reduced and immobilized to later be surgically treated as early as possible.

Orthopaedic treatment is not appropriate here. Initially, the surgical technique consisted in a bloodless reduction and percutaneous pinning of the different joint spaces.

For open surgery, the approach is essentially posterior [15].

- the anterior approach through the flexor retinaculum is possible, however, and presents advantages in two cases: associated pain in the median nerve and anterior enucleation of the lunate, which are not accessible via the posterior approach. The median nerve can be released after reduction and stabilization of the carpus. The anterior approach to the carpus is limited, however, by the blood vessels (superficial palmar arch) and the median nerve; in addition, the criteria for reduction are more difficult to assess;
- the posterior approach is the gold standard. The extensor retinaculum should be lifted from the ulnar edge to the radial edge; all the compartments are open, thus facilitating repositioning during closing. The capsule should be opened in a Z formation, as described by Herzberg, so that supplementary capsulodesis can be performed at closing [16]. It is clear that this wide posterior approach is paradoxical because of the extrinsic ligament lesions made to access the radiocarpal joint. One could even raise the question of aggravation of the ligament lesions, and therefore rigorous closing is necessary.

In all cases, suturing or ligament reinsertions with anchor fixation are recommended [17]. These repairs are protected by scapholunate, scaphocapitate, and lunotriquetral pinning. Scaphocapitate pinning stabilizes the scaphoid in the vertical position, it provides height to the carpus, and reduces the scaphoid opposite the lunate. Lunotriquetral pinning is often multiple to obtain scar tissue that stabilizes the joint, because ligament repair is often insufficient (Fig. 5). Radiolunate pinning to reduce the lunate as recommended by Linscheid was particularly indicated for percutaneous reductions. This pinning was maintained during reduction and stabilized the lunate. Currently, it still seems necessary for lunate enucleations because it increases radiocarpal stability [18].

3.2. Dislocation fractures

Osteosynthesis is recommended for scaphoid, triquetrum, and capitate fractures after reduction of the dislocation. Carrying out
osteosynthesis on carpal bones that are still dislocated increases the risk of malunion. In cases of an avulsion fracture, pinning as described above is logical.

3.2.1. Fracture of the scaphoid

Scaphoid fractures are often complex with anterior comminution. It is easier to use a supplementary anterior approach to reduce the scaphoid and to associate a graft if the comminution is substantial. Osteosynthesis of the scaphoid can be done using screw or pin fixation (Fig. 6). The only disadvantage of screws is excess compression, which can aggravate flexion of the scaphoid resulting in incongruity between the two rows of carpal bones.

3.2.2. Fracture of the capitate

Displacement of the proximal pole of the capitate must be evaluated. For a fracture that is not displaced, classical pinning must be associated with triquetrocaphitate pinning. For a displaced fracture, it must be reduced and screw fixation applied. Fracture of the capitate is rarely isolated and should raise the suspicion of a more complex lesion. Fenton first described the capitate fracture associated with fracture of the scaphoid, but in 1955 Jones understood the association between the perilunate lesion and the capitate fracture [19,20].

3.3. The role of arthroscopy

Arthroscopy is not indicated for complex lesions associating fracture and dislocation [21]. For pure perilunate dislocations, reduction and percutaneous pinning can be done with arthroscopic guidance [22].

3.4. Lesions with delayed treatment

It is not rare for a perilunate lesion to be diagnosed late (30% of cases). Two important problems are added to the complexity of this lesion: increased difficulty reducing the dislocation of the lunate and an increased risk of necrosis of the lunate [23].

It is possible to perform open reduction and stabilize it with classical pinning, but very often at the cost of cartilage lesions and risk of devascularization and residual instability.

Certain teams opt for more radical treatment such as resection of the first row of carpal bones or partial or complete arthrodesis [24]. These non-conservative treatments are proposed essentially in the most severe cases associating complex fractures of the carpus and extensive ligament lesions. Similarly, complete enucleation of the lunate should raise the question of immediate resection of the first row or partial arthrodesis of the carpus. In our experience, this type of intervention is easier on an acute lesion than when reduction has failed. It is clear that the decision for a radical solution in an emergency setting is not always easy and should be discussed with the patient.

All in all, pure perilunate ligament lesions or those with fracture are severe lesions that eventually become complicated with arthritis.

3.5. Cases of anterior perilunate dislocations

Anterior perilunate dislocations are rare (5%) and are more frequent in children. The mechanism is palmar hyperflexion; in half the cases an associated scaphoid fracture can be observed. This is a lesion in which the lunate remains in place and it is therefore possible to perform a simple reduction with no incision and no pinning.

4. Scapholunate sprain

The scapholunate sprain is the most frequent lesion of the carpus whose diagnosis is often delayed. The biomechanics of the scapholunate joint is complex. The proximal row of the carpus is endowed with extreme mobility, between the distal extremity of the radius and the distal radioulnar articular disc and the distal row of the carpus. Despite their different morphology and orientation, the scaphoid and the lunate must move together, notably because of the scapholunate ligament that acts as a torsion bar between the two bones. In absence of this interosseous ligament, the scaphoid and the lunate are mobilized differently when they are subjected to axial compression. The first tend to undergo palmar flexion and the second dorsal flexion. The spontaneous palmar flexion of the scaphoid is produced around an axis located in its middle section, corresponding to the radio-scaphocapitate ligament; it may be induced by the scaphotrapezial joint trapezium [25,26]. Dorsal flexion of the lunate may be induced by the triquetrum to which it is joined [25,26].

Two types of scapholunate sprains are distinguished: static and dynamic sprains. A static sprain is visible on simple AP and lateral x-rays (permanent loss of the normal ratios between the carpal bones). The radiographic criteria are scapholunate diastasis, DISI, and flexion of the scaphoid (Fig. 7). A dynamic sprain only appears on dynamic x-rays and one or several of the above-mentioned criteria are found (loss of normal relations between the carpus bones during physiological movements of the wrist).

A scapholunate sprain naturally progresses toward radiocarpal and mediocarpal arthritis [27,28]. This degenerative involvement has been described in detail by Watson, who proposed a classification that today remains a reference (Fig. 8). To analyze this...
unfavorable progression of the scapholunate sprain, one must understand that the scaphoid loses its height, with its proximal pole conflicting with the posterior edge of the radial epiphysis (Fig. 9). This conflict initiates styloidal arthritis, which extends into the mediocarpal area through the DISI effect. The only joint left intact is the radiolunate joint.

4.1. Diagnosis

An acute scapholunate ligament lesion is suspected if hemorrhrosis is found, or pain in the scapholunate joint, with frequent intact mobility and popping sensations [29].

In our experience, the clinical examination is not highly sensitive or specific: the popping sensation can be absent and the Watson sign difficult to reproduce [30]. To look for it, the examiner is positioned facing the patient who is in an arm wrestling position; with one hand, the examiner applies pressure with his or her thumb firmly into the palmar side of the scaphoid tubercle, with the other the index finger on the dorsal side of the proximal pole of the scaphoid. The clinician then moves the patient’s wrist in ulnar deviation (which has the effect of extending the scaphoid) and then radial deviation (but the examiner applies pressure to the scaphoid so that it cannot flex). In case of scapholunate instability, the scaphoid migrates toward the back and comes in contact with the examiner’s index finger. This causes pain and sometimes a popping reaction when the examiner removes his thumb (and the scaphoid returns to its initial position). The only certainty is that a scapholunate sprain must be sought until no doubt of this possibility remains.

The radiographic workup is indispensable, which includes an image with the fist closed. Radiographic criteria on the AP view must be sought: scapholunate diastasis, ring sign (flexion of the scaphoid). On the lateral x-ray, the scapholunate angle must be measured. This is the angle formed between the longitudinal axes of the scaphoid and the lunate, normally usually between 30° and 60° (mean 47°). If the angle is greater than 60°, there is a scapholunate lesion. On the same lateral view, the DISI can be seen.

CT-arthrography is indispensable in assessing the lesion to confirm rupture, assess the trophicity of the remaining ligament, and look for other associated lesions. Its diagnostic performance is slightly better than MRI in detecting perforations of the intermediary segment and in ruptures of the palmar segment [31]. Moreover, CT arthrography provides information on the condition of the cartilage.

4.2. Treatment

4.2.1. Recent sprains

Recent sprains present the same features as a perilunate lesion. The direct approach allows ligament repair and isolated scapholunate pinning. This technique provides perfect reduction and reliable repair of the ligament. Certain authors systematically associate capsulodesis to lock the scapholunate in place [32].

With the development of wrist arthroscopy over the past few years, reliable joint assessment, debridement of the ligament, and pinning has been possible with visual guidance. This technique is less invasive, keeps the extrinsic ligaments intact, and provides perfect reduction of the scapholunate joint. Nevertheless, arthroscopy does not allow direct suturing of the scapholunate ligament. A recent publication has shown that the arthroscopic repair technique can only be performed if the ligament stumps are preserved throughout the joint [33]. With ligament avulsion on one of the joint surfaces, open repair must be performed with ligament reinsertion. The ideal presence of two stumps is only found in 40% of lesions according to Anderson and Garcia-Elias [33].

4.2.2. Old sprains

For a lesion more than 6 weeks old, treatment is conditioned by the presence of secondary arthritis, by the seat of the rupture, the position of the scaphoid, and the reducibility of the scapholunate pair.

4.2.2.1. Lesion without arthritis. For a lesion without arthritis, the means of stability for this joint must be reconstructed:

- the ligament stump can be reinserted if the quality of the remaining ligament is satisfactory;
- other techniques, often complex, can be proposed such as capsulodesis, ligament repair, or tenodesis [34]. There is currently no consensus on how to treat the soft tissues to ensure scapholunate joint stability, and it has not been scientifically proven whether one technique is superior to any other. The soft tissues always tend to slacken over time if there is not true ligament reconstruction; moreover, there is no technique that re-establishes the physiology of the scapholunate ligament complex;

![Fig. 8. Classification of SLAC wrist in three stages according to Watson.](image)

![Fig. 9. This sagittal view of an arthrography CT of the wrist shows impingement between the radius and the proximal pole of the scaphoid directly resulting from a scapholunate sprain.](image)
• other authors have proposed scapholunate arthrodesis; this technique seems logical to stabilize this joint permanently, but the various series, all retrospective, have shown a high rate of non-union [35]. The difficulty of achieving union of this joint space is related to the complexity of this joint, whose movements are complex, and the extent of the joint restrictions;

• other partial arthrodoses have been proposed with the idea of avoiding radioscapohoid impingement. The two main techniques are scaphotrapeziotrapezoidal and scaphocapitate arthrodesis (Fig. 10). Their non-union rate is lower than the scapholunate non-union rate, but their clinical results are highly variable from one series to another [36].

4.2.2.2. Treatment of an old lesion. Treatment of an old lesion complicated by arthritis is totally different. Decomposition of an old lesion is often difficult to understand and its tolerance can be surprising. This can even be the case in highly advanced arthritis of the wrist.

In our experience, there is no correlation between functional discomfort and the extent of the arthritis. There is, however, relative tolerance in cases of progressive and accepted stiffening.

Treatment depends directly on the symptoms as well as the patient’s activities. These two considerations should take into account the degenerative carpal lesion (Watson classification: Fig. 8). There are different interventions possible, depending on the type of degenerative lesion.

4.2.2.2.1. Denervation of the wrist with styloectomy. This is the least aggressive therapeutic option, with no real contraindication. It allows other more radical therapeutic solutions if the analgic effect is not obtained. Denervation achieves painlessness in 80% of cases while preserving mobility. We recommend total denervation because partial denervation often gives a mediocre result [37,38].

4.2.2.2.2. Resection of the first row of the carpal. This is a simpler procedure; once the three bones of the first row are resected, the joint is made between the head of the capitale and the radius. The only imperative is the absence of osteoarthritis on the head of the capitale. The results are simple: a short period of immobilization and no risk of non-union. Mobility is often preserved and the result remains stable over time [39]. The head of the capitale adapts to the new constraints. In fact, joint pressure is greater (25% increase) and the contact surface is less (60% reduction) than after four-bone arthrodesis. Partisans of four-bone arthrodesis criticize this procedure for the risk of premature wear of the “capitoralial” joint space caused by this excess of stress on a small surface [40].

4.2.2.2.3. Arthrodesis of the four “internal” bones. This is intracarpal arthrodesis between the lunate, the triquetrum, the capitale, and the hamate. The main objectives of this intervention are preservation of carpal height and preservation of sufficient contact surface with the radius. Initially, a scaphoidectomy was associated, but this instigated complete disorganization of the carpus with aggravation of the arthritis process.

The advantage of preserving the carpal height is most particularly the preservation of strength. This concept remains theoretical, because strength is above all the absence of pain. There is a risk of non-union of the different joint spaces, whose rate varies depending on the series reported in the literature [41]. Mobility is reduced by half compared to the healthy side, but it remains stable over time. The surgical technique must be rigorous because the height of the carpus must be reestablished. One of the main difficulties is reducing the lunate, which is tilted in DISI. Its mobilization is a source of devascularization and cartilage lesions. Avivement of the different joint spaces if often difficult. New osteosynthesis material improves the fixation.

4.2.2.2.4. Three-bone arthrodesis. This is an intervention halfway between resection of the first row and arthrodesis of four bones. This arthrodesis involves the lunate, the capitale, and the hamate. It makes it possible to keep a certain height of the carpus (shortening is minimal), thus allowing theoretical preservation of strength. Moreover, it is simpler to perform than four-bone arthrodesis. It provides a contact surface with the radius greater than that obtained with resection of the proximal row. Its indications are the same as above, but it is particularly advantageous in Watson type III arthritis (when there is capitale head arthritis, simple resection of the first row is not possible).

4.2.2.2.5. Radiocarpal arthrodesis. This intervention has been used the longest. At one time it was the only intervention proposed. It has the advantage of being radical, but patients have changed. We have fewer laborers and more patients who absolutely wish to retain mobility and refuse arthrodesis, particularly if the lesion is on their dominant side. It should be proposed for lesions following occupational accidents. It has been observed that patient satisfaction with total arthrodesis is correlated with the existence of an occupational accident [42]. The intervention is difficult, whether it involves avivement of the different joint spaces or fixation. There is no one technique that is better than the others. With proper perspective, we have observed that the distal radioulnar joint could not be preserved: without distal resection of the ulna, the onset of ulnacarpal impingement is rapidly observed, probably due to the loss in radiocarpal height and the absence of lunate sliding under the radius during ulnar deviation.
4.2.2.6. *Total wrist arthroplasty.* Until now, total wrist arthroplasty has only been indicated in rheumatoid arthritis of the wrist. The results were inconsistent, the series small, and the follow-up periods insufficient. Currently, series of total wrist arthroplasty for degenerative diseases can be found [43,44]. These are most often sequelae of scapholunate sprains or scaphoid non-union. The prosthesis preserves functional mobility. Only short-term loosening remains the pitfall of this technique. It should be reserved for female patients, older than 60 years of age, for the non-dominant side, and exclude laborers. The place of total wrist arthroplasty remains to be specified alongside that of the classical techniques, which are reliable and benefit from the longest experience (Fig. 11).

4.2.2.7. *Arthroplastic resection with interposition of an implant or tissue.* This technique is very old. At the beginning of this technique, soft tissues were interposed, as in Ollier’s princeps technique. In the 1980s, silicone was widely used with the problems that are now known. Currently, pyrocarbon is available, which responds to biomechanical expectations with its biocompatibility, resistance, and sliding qualities.

Other teams use costal cartilage for interposition in different joints of the hand [45]. The technique consists in performing minimal joint resection and interposing an implant to preserve joint congruence. It is important to preserve the carpus height. The implantation technique is less rigorous than the classical joint implantation technique, positioning is not particularly precise, but the literature reports good tolerance. The major risk is joint instability. Multicenter studies are indispensable to assess the results of these implants with longer follow-up [46].

5. *Lunotriquetral sprain*

This lesion is rarely isolated and often associated with another carpal ligament lesion or a distal radioulnar disc joint lesion.

In a normal condition, the lunate and the triquetrum are mobilized synchronously when they are subjected to axial compression (sometimes called lunotriquetral block). This is not the case if the lunotriquetral ligament is ruptured and the secondary stabilizer elements are injured (notably the dorsal radiotriquetral ligament). In this case, the lunate tends to undergo spontaneous palmar flexion (resulting from the action of the scaphoid which it is joined by the scapholunate ligament). The triquetrum tends to undergo:

- spontaneous dorsal flexion (resulting from the action of the hamate, because the latter slides along the distal joint surface of the triquetrum, deviated toward the dorsal side of the carpus);
- proximal migration resulting from the action of the distal row of the carpus and the annex ligaments, notably the hamate and capitate ligaments [47].

5.1. *Diagnosis*

Diagnosis is often delayed. The patient is usually a young adult and manual laborer. Different clinical tests with variable sensitivity and specificity can be done: the Reagan lunotriquetral ballottement test, the Kleiman shear test, the Linscheid compression test, the Deby test, and Sennwald’s triquetrum ascension test [48].

The stage of this lunotriquetral instability can be determined in terms of the lesion encountered, the clinical examination, and the imaging results (Table 3). The static radiographic workup of lunotriquetral instability demonstrates a rupture of the Gilula arcs, upper lunotriquetral diastasis at 3 mm, flexion of the scaphoid, and flexion of the lunate (VISI: volar intercalated segment instability). The lateral x-ray of the wrist demonstrates loss of colinear alignment of the radius, the lunate, and the third metacarpal. Completing the workup with the arthrography to examine all lesions as well as the associated lesions and any cartilage lesions is recommended.

5.2. *Treatment*

In acute sprains, pinning is the reference treatment. It should be combined with any associated lesions (scapholunate lesion or others). When there is a fresh joint disk lesion, one can choose between spontaneous healing and reininsertion of the joint disk [49]. The only certainty is that first-line conservative treatment can avoid abusive resections.

Arthroscopy can be associated with pinning to control reduction, assess the associated lesions, and repair the triangular fibrocartilage complex if necessary.

| Table 3 |
| Different stages of lunotriquetral instability. |

<table>
<thead>
<tr>
<th>Stage</th>
<th>Lesions encountered</th>
<th>Clinical</th>
<th>Imaging</th>
</tr>
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<tbody>
<tr>
<td>I Predynamic</td>
<td>Partial lesion of LT ligament</td>
<td>Normal exam</td>
<td>Normal</td>
</tr>
<tr>
<td>II Dynamic</td>
<td>Isolated complete rupture of LT ligament</td>
<td>Abnormal exam</td>
<td>Normal static x-rays</td>
</tr>
<tr>
<td></td>
<td>Complete rupture of LT ligament with secondary stabilizer lesion</td>
<td>Abnormal exam</td>
<td>Abnormal dynamic x-rays</td>
</tr>
<tr>
<td>III Static</td>
<td>LT ligament rupture with secondary stabilizer and arthritis</td>
<td>Abnormal exam</td>
<td>Abnormal static x-rays</td>
</tr>
<tr>
<td>IV Mediocarpal arthritis</td>
<td>LT ligament rupture, Rupture of secondary stabilizers and arthritis</td>
<td>Abnormal exam</td>
<td>Abnormal static x-rays: arthritis</td>
</tr>
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</table>
In chronic lesions, the other associated lesions, such as joint disk lesions, must be assessed. Treatment consists in lunotriquetral arthrodesis or multiple pinning of the lunotriquetral joint so as to obtain formation of fibrous tissue maintaining the joint. This arthrodesis requires keeping the lunotriquetral joint space height intact to prevent an imbalance between the first and second carpal rows. Too much pressure between the lunate and triquetrum causes painful impingement with the hamate. To prevent this, a “sandwich” graft between the two bones is recommended as well as stabilization with pinning to avoid excessive compression.

The arthroscopic technique allows debridement of the joint space and verification of the reduction. With arthroscopic guidance, the multiple pinning procedure is then performed. The procedure to follow with a triangular ligament lesion should be discussed: reinsertion or complete resection [50]. The patient’s age and activity, the type of disinsertion (radial or ulnar), and the size of the perforation must all be considered.

6. Other sprains

There are as many types of carpal ligament lesion as there are joint spaces. They are rarely pure but are most often associated with bone fractures or avulsions. Descriptions of new wrist ligament lesions are frequently found in the literature [51], but often these supposedly new lesions refer to older studies in the literature or to neighboring lesions that have been described earlier. These are not multicenter collections of case studies reported in the literature, the only means to provide useful information on these rare lesions.

7. Fracture of the proximal pole of the scaphoid

The complexity of the carpus is illustrated by scaphoid fractures, which, if unhealed, can create intracarpal imbalance: 30% of scaphoid fractures evolve toward symptomatic or asymptomatic malunion. This imbalance can evolve toward radiocarpal arthritis called SNAC wrist (scaphoid non-union advanced collapse). It is very frequent that the distal fragment of the scaphoid turns horizontal, resulting in loss of height and carpal destabilization.

Contrary to scapholunate instability (SLAC), SNAC is responsible for arthrogenic impingement between the radius and the distal pole of the scaphoid. Similarly, in SLAC wrist, more or less diffuse arthritis, as defined by Watson, can be found.

Fracture of the proximal pole, which remains joined to the lunate, can be compared to scapholunate ligament rupture. The distal fragment turns horizontal, showing up as a ring sign, which corresponds to the AP view of the scaphoid neck lying horizontal. This results in dorsal instability of the intermediate segment (DISI). Malunion can exist without DISI, not a source of substantial problems, other than consolidation of the scaphoid. In cases of malunion associated with DISI, one must first reduce the DISI using the Linscheid technique and then graft the scaphoid [52]. Necrosis of the proximal pole of the scaphoid can lead to intracarpal imbalance resulting directly in SNAC wrist.

Once arthritis has set in, the same situation is found as in a chronic scapholunate lesion with arthritis. One of the following interventions must be chosen:

- denervation of the wrist with styloidectomy;
- resection of the first carpal row;
- four-bone arthrodesis;
- three-bone arthrodesis;
- radiocarpal arthrodesis;
- total wrist arthroplasty;
- resection of the distal pole of the scaphoid with or without interposition: this can be a pyrocarbon or biological implant; it seems more logical in SLAC, because it provides compensation for the loss of scaphoid height [53,54].

8. Conclusion

For an acute ligament lesion, open surgery with pin fixation for stability is recommended. If the surgeon is familiar with wrist arthroscopy, this can be performed to assess the lesions and verify reduction.

For a chronic ligament lesion with no arthritis, different techniques can be used without one being superior to the others. This can be done arthroscopically when there is a ligament stump on each of the two joint surfaces. Avulsion of the ligament on one of the sides of the ligament is a contraindication for arthroscopic procedures.

For type II SLAC and SNAC, three interventions can be discussed: total denervation of the wrist, four-bone arthrodesis, and resection of the first carpal row. The choice will be made based on the patient’s age, activity level, and functional request. Theoretically, if the patient requests only absence of pain and if the functional needs are not significant, denervation or resection of the first row can be used to stop the arthritis. For a manual laborer who requests strength and mobility, four-bone arthrodesis should be proposed.

For type III SLAC and SNAC, the only certainty is that resection of the first row is not appropriate. Denervation can be proposed only to relieve pain, if the patient has no functional requirement. In other cases, the indication is for three- or four-bone arthrodesis. The only condition for the latter procedures is preservation of the radioulnar joint. Four-bone arthrodesis can be preferred to preserve strength in young patients and manual laborers.

For diffuse radiocarpal and intracarpal arthritis, simple denervation can be proposed for a sedentary patient. If on the other hand the patient requires strength and painlessness, only radiocarpal arthrodesis is appropriate. Total wrist arthroplasty is reserved for sedentary patients refusing arthrodesis. It is important to remember that total arthrodesis should be the last-resort therapeutic solution. All of the other interventions (excluding total wrist arthroplasty) do not close the door on total wrist arthrodesis.

Disclosure of interest

The author declares that he has no conflicts of interest concerning this article.

References

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