Radiology

# Association between Extrinsic and Intrinsic Carpal Ligament Injuries at MR Arthrography and Carpal Instability at Radiography: Initial Observations[1]

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**Purpose:** To retrospectively compare the presence or absence of carpal instability on radiographs with the findings of magnetic resonance (MR) arthrographic evaluation of intrinsic and extrinsic ligament tears in patients with chronic wrist pain.

**Materials and Methods:** The institutional review board approved this study and did not require informed consent. Signs of carpal instability were assessed on static and dynamic radiographs of the wrist obtained in 72 patients (24 female, 48 male; mean age, 36 years; age range, 14–59 years) with posttraumatic wrist pain. MR arthrography was subsequently performed. Two musculoskeletal radiologists independently analyzed the radiographs and MR images. Each intrinsic and extrinsic ligament was individually evaluated for the presence of a ligament tear. The extent of the tear also was recorded. Interobserver agreement regarding MR arthrographic findings was tested by calculating κ statistics. Statistical comparison between radiography and MR arthrography was performed by using the Fisher exact test.

**Results:** Twenty-five triangular fibrocartilage complex, 18 (five partial, 13 complete) scapholunate ligament, and 25 (10 partial, 15 complete) lunotriquetral ligament tears were visualized. Twenty-two (all complete) extrinsic ligament tears were detected: two radial collateral ligament, 10 radioscaphocapitate ligament, and 10 radiolunotriquetral ligament tears. Interobserver agreement regarding intrinsic and extrinsic ligament tear detection at MR arthrography was excellent (κ = 0.80). Nineteen patients had evidence of carpal instability on radiographs. Fourteen (52%) of 27 patients with at least one complete intrinsic lesion had no sign of carpal instability. On the other hand, the association of scapholunate ligament and/or lunotriquetral ligament and extrinsic ligament tears was significantly correlated ($P < .001$) with carpal instability at radiography.

**Conclusion:** The presence or absence of carpal instability on radiographs depends on the association between intrinsic and extrinsic ligament tears—even partial ones—rather than on the presence of intrinsic ligament tears alone, even when the tears are complete.



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From a mechanical standpoint, the wrist is a complex joint of the body. Wrist instabilities are caused by ligament and bone abnormalities that result in modification of the normal relationship between carpal bones. Most carpal instabilities result from acute or chronic trauma, synovitis, and/or avascular necrosis of carpal bones (1). The ligaments of the wrist are either intrinsic (ie, between carpal bones alone) or extrinsic (ie, between carpal and metacarpal bones or between carpal bones and the radius and/or ulna) (Fig 1) (2). It is the general belief that the scapholunate ligament (SLL) and lunotriquetral ligament (LTL) are the most important intrinsic ligaments for carpal stability. In terms of the extrinsic ligaments, both palmar ligaments and dorsal ligaments have important roles in maintaining carpal stability (3,4).

Radiography has generally been advocated as the primary diagnostic imaging tool for evaluating wrist ligament injuries (5). The spaces between the carpal bones should always be similar in width: 3 mm or less (6). When normal, the capitolunate space may serve as a guide for normal intercarpal joint width within an individual patient. The three arches seen on the neutral posteroanterior radiographic view where the third metacarpal is coaxial with the long axis of the radius, as described by Totty and Gilula (7), should always be smooth in the neutral frontal position. The first arch corresponds to the convexity formed by proximal articular surfaces of the scaphoid, lunate, and triquetrum; the second arch, to the concavity created by the proximal carpal row along the distal surfaces of the same three carpal bones; and the third arch, to the proximal convexity of the distal carpal row formed by the capitate and hamate. Exceptions to these smooth arches are seen *(a)* at arch 1 at the lunotriquetal joint when the triquetrum is shorter in its proximal distal dimension than the adjacent lunate and *(b)* at arch 2 at the lunotriquetral joint where there is a type 2 lunate (ie, lunate with a large facet that articulates with the hamate).

On static radiographic views, a broken arch is an indicator of ligament lesions, bone dislocation, or fracture (7). On lateral views, malalignment and/or important variations in the intercarpal angle are also signs of carpal instability (8). Although Peh and Gilula (9) reported that only a true neutral-position radiograph of the wrist is reliable for evaluation of the carpal arches, all posttraumatic carpal instabilities may not be evident on conventional (static) radiographic views, and according to some authors (8), dynamic views are required. Despite reported findings, radiographs provide only indirect information about ligament lesions (10,11). Magnetic resonance (MR) arthrography enables direct visualization of ligament structures and injuries. With MR arthrography, the advantages of conventional arthrography and standard MR imaging are combined. The greater accuracy of MR arthrography in depicting intrinsic and extrinsic ligament injuries compared with the accuracy of radiography has been demonstrated (12).

The reference standard for the detection of intrinsic ligament lesions remains arthroscopy or open surgery. However, arthroscopy cannot be applied as a reference standard for the detection of extrinsic ligaments. According to hand surgeons, even with use of multiportal wrist arthroscopy, the attachments of the palmar and dorsal extrinsic ligaments are not visualized. Therefore, the purpose of our study was to retrospectively compare the presence or absence of carpal instability depicted on radiographs with the findings seen at MR arthrographic evaluation of intrinsic and extrinsic ligament tears in patients with chronic wrist pain.

## Advances in Knowledge

- There is an association between carpal instability patterns seen at radiography and extrinsic wrist ligament tears seen at MR arthrography.
- Extrinsic ligament tears in the wrist can be visualized with MR arthrography.
- MR arthrography is useful for detecting extrinsic carpal ligament abnormalities in association with carpal instability.

## Materials and Methods

### Patients

The data on 72 consecutive patients (24 female, 48 male; mean age, 36 years; age range, 14–59 years) with posttraumatic wrist pain who were examined and treated from August 2001 through December 2002 were assessed in our retrospective study. All of these patients had presented with chronic wrist pain or refractory pain of 2 months or longer duration. Patients with unilateral or bilateral wrist pain were included. Patients who had an alternative explanation for their wrist pain and carpal instability, such as unhealed fractures of the carpal bones or arthritis, were excluded. Twenty-eight patients underwent arthroscopy after MR arthrographic results had been obtained. The institutional review board of Centre Hospitalier Universitaire Vaudois approved this study and did not require informed consent.

### Routine Radiography

Static radiographs of the wrist in neutral posteroanterior and lateral positions had been obtained, as described

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**Abbreviations:**
LTL = lunotriquetral ligament
RLTL = radiolunotriquetral ligament
RSCL = radioscaphocapitate ligament
SLL = scapholunate ligament
TFC = triangular fibrocartilage

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by Peh and Gilula (9). True neutral posteroanterior wrist radiographs were acquired, with the long axes of the third metacarpal bone and the middle radius colinear. Dynamic views had been obtained for a full carpal instability series, as described by Schernberg (11). This series included the acquisition of posteroanterior views with ulnar and radial deviations and translations, supination with fist making, the acquisition of lateral flexion extension views, and dorsal and volar directed capitolunate instability pattern, or CLIP, wrist maneuvers (8).

### Conventional Arthrography

With fluoroscopic guidance, one musculoskeletal radiologist (N.H.T., with 6 years of experience in musculoskeletal radiology) inserted a 22-gauge needle directly through the skin from a dorsal approach and advanced it into the midcarpal joint between the lunate and hamate bones. Satisfactory needle tip position was verified with a test injection of a small amount of iodinated contrast agent. Gadopentetate dimeglumine (Magnevist; Schering, Berlin, Germany) (1/200 mL) diluted in a solution of half saline and half iodinated contrast material (iopentol, Imagopaque 350; Nycomed Amersham, Princeton, NJ) was injected into the midcarpal joint with fluoroscopic guidance. The safety of the mixture injection had been verified previously in the study of Brown et al (13). A maximum volume of 4 mL of the solution was injected.

If communication of the midcarpal joint with the radiocarpal joint was present, an additional 3–4 mL was added. If no communication could be seen at fluoroscopy with passive wrist motion, the distal radioulnar and the radiocarpal joints were sequentially injected from a dorsal approach with 1–2 mL and 3–4 mL of the solution, respectively. Fluoroscopic spot views were obtained during the injections to show leakage of contrast agent and opacification of the joints. After each compartment injection, the radiologist performed passive movements of the wrist with videofluoroscopic guidance to visualize passive leakage. Conventional posteroanterior and lateral radiographs were then obtained. The volume of contrast material injected per wrist varied between 4 and 9 mL. Three-compartment arthrography was generally accomplished within 15 minutes.

### MR Arthrography

MR arthrography was performed within 30 minutes after conventional arthrography. No additional contrast agent was administered. The MR images were obtained by using a 1.5-T unit (Symphony; Siemens, Erlangen, Germany) with a dedicated wrist coil. The hand was placed in the prone position, with the wrist in a neutral position in the center of the bore and the center of the wrist pinpointed by the laser mark. Four sequences were performed: sagittal T1-weighted spin echo with fat saturation (516/24 [repetition time msec/echo time msec]), transverse T1-weighted spin echo (537/19), coronal T2-weighted spin echo with fat saturation (4050/64), and three-dimensional dual-echo steady state with a 12-cm field of view and a 0.6–1.0-mm effective section thickness (60/10, 20° flip angle, one acquisition, 256 × 256 matrix).

### Image Evaluation

Retrospective analyses of the radiographs and MR arthrographic images were performed independently by two musculoskeletal radiologists (B.D. and N.H.T., with 13 and 6 years of experience in musculoskeletal radiology, respectively). They were not aware of the clinical or surgical findings. The abnormal carpal alignment (ie, dorsal or ventral intercalated segmental instability, scapholunate diastasis, lunotriquetral offset, ulnar translation, and/or dorsal or volar radiocarpal subluxation) seen on static and dynamic radiographs was assessed. On the conventional arthrographic and MR arthrographic images, each intrinsic and extrinsic wrist ligament was evaluated. Communicating and noncommunicating tears of the triangular fibrocartilage (TFC) were distinguished. The other components of the TFC complex were included in the extrinsic ligament evaluation. The scapholunate and lunotriquetral intrinsic ligaments were evaluated for communicating and noncommunicating tears. A defect extending through a part (palmar, midportion, or dorsal) of a ligament was considered a partial tear. A tear extending through all three parts of a ligament or the absence of the ligament was considered to represent a complete tear. High signal intensity visualized through the entire cross section of an extrinsic ligament was considered to indicate complete tear, whereas high signal intensity in only a part of the

**Figure 1**

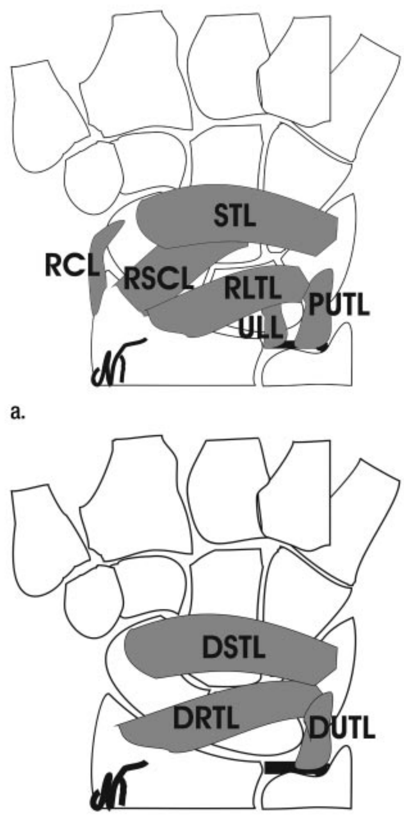



**Figure 1:** Illustrations of extrinsic carpal ligaments. **(a)** Palmar aspect of left wrist and **(b)** dorsal aspect of right wrist are shown. *DRTL* = dorsal radiotriquetral ligament, *DSTL* = dorsal scaphotriquetral ligament, *DUTL* = dorsal ulnotriquetral ligament, *PUTL* = palmar ulnotriquetral ligament, *RCL* = radial collateral ligament, *RLTL* = radiolunotriquetral ligament, *RSCL* = radioscaphocapitate ligament, *STL* = scaphotriquetral ligament, *ULL* = ulnolunate ligament.

cross section of an extrinsic ligament was considered to indicate partial tear.

### Statistical Analyses

Interobserver agreement regarding the MR arthrographic findings was tested by calculating κ statistics (14). According to the procedure of Timins et al (15), TFC lesions were separated from SLL and/or LTL lesions to calculate the association between intrinsic ligament lesions and carpal instability, with knowledge that the SLL and LTL are the most important intrinsic ligaments (especially the dorsal portion of the SLL and the palmar portion of the LTL) for maintaining carpal stability (15,16). Fisher exact tests were performed by using JMP, version 5.0.1a, software (SAS Institute, Cary, NC) to evaluate the correlation between SLL and/or LTL lesions, the radiographic signs of carpal instability, and the correlation between SLL and/or LTL lesions associated with extrinsic ligament injuries and radiographic signs of carpal instability.

**Table 1**

**Carpal Ligament Injuries Diagnosed at MR Arthrography**

| MR Arthrography–based | Intrinsic Ligaments | | | | Extrinsic Ligaments | | |
|---|---|---|---|---|---|---|---|
| Diagnosis | TFC* | SLL | LTL | STTL | RCL | RSCL | RLTL |
| Noncommunicating tear | 10 (7) | 0 | 0 | 0 | 0 | 0 | 0 |
| Partial communicating tear | 15 (12) | 5 (3) | 10 (7) | 1 | 0 | 0 | 0 |
| Complete tear | 0 | 13 (9) | 15 (11) | 0 | 2 | 10 (0) | 10 (0) |
| Total | 25 | 18 | 25 | 1 | 2 | 10 | 10 |

Note.—Data are numbers of ligament tear lesions. The numbers of the given tears confirmed at arthroscopy are in parentheses. RCL = radial collateral ligament, STTL = scaphotrapeziotrapezoidal ligament.

* Only noncommunicating versus communicating tears are reported.

## Results

### Ligament Tear Lesions

Twenty-five TFC, 18 SLL, 25 LTL, one scaphotrapeziotrapezoidal ligament, and 22 extrinsic ligament tear lesions were visualized in 60 patients at MR arthrography (Table 1). All intrinsic ligament tears seen at MR arthrography were confirmed in the 28 patients who underwent arthroscopy, but no extrinsic ligament tears were visualized with arthroscopy (Table 2). The signs of carpal instability are reported in Table 2. In 12 patients, no ligament lesion was seen at MR arthrography. Of the 25 TFC lesions, 10 were noncommunicating and

**Table 2**

**Associations between SLL, LTL, and/or Extrinsic Ligament Tears and Radiographic Signs of Carpal Instability**

| Patient Group | Patients with Signs of Carpal Instability on Radiographs* | Patients with No Sign of Carpal Instability on Radiographs | Total |
|---|---|---|---|
| Partial SLL and/or LTL tears | Three with scapholunate diastasis, one with VISI | 10 | 14 |
| Partial SLL and/or LTL tears with extrinsic ligament tears | 0 | 0 | 0 |
| Complete SLL and/or LTL tears | Two with scapholunate diastasis, one with VISI (with scapholunate diastasis), one with DISI (with scapholunate diastasis) | 12 | 16 |
| Complete SLL and/or LTL tears with extrinsic ligament tears | Three with scapholunate diastasis, two with type 1 ulnar translation, one with type 2 ulnar translation, one with VISI with lunotriquetral offset, one with VISI (with scapholunate diastasis), one with DISI (with scapholunate diastasis) | 2 | 11 |
| Isolated extrinsic ligament tears | 0 | 1 | 1 |
| No intrinsic ligament or isolated TFC lesion | Two with type 1 ulnar translation | 28 | 30 |
| Total | 19 | 53 | 72 |

Note.—Data are numbers of patients.

* DISI = dorsal intercalated segment instability, VISI = volar intercalated segment instability.

15 were communicating tears. Thirteen of the 18 SLL tears were complete. Fifteen of the 25 LTL lesions were complete tears. One patient had a partial scaphotrapeziotrapezoidal ligament tear. Combined LTL and TFC tears were observed in 12 patients. Five patients had associated SLL and TFC tears. Two patients had combined SLL and LTL injuries. One patient had partially torn TFC, SLL, and LTL structures.

All extrinsic ligament lesions were complete tears. Extrinsic ligament tears were found within the RSCL, RLTL, and radial collateral ligament. Five patients had associated RSCL, RLTL, and SLL tears; two patients, radial collateral ligament and SLL tears; one patient, RSCL and RLTL tears; three patients, RLTL, RSCL, TFC, and SLL tears; and one patient, RSCL, RLTL, and LTL tears.

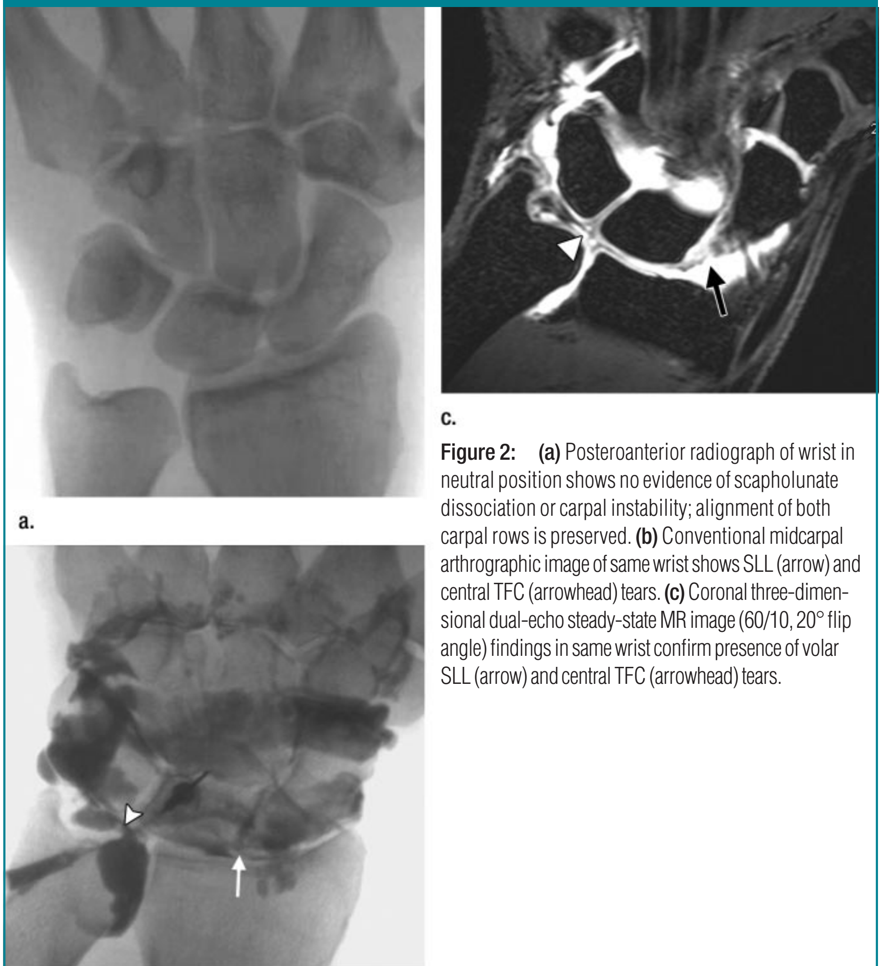
Eleven of 27 patients (37% of the total 72 patients) with complete SLL and LTL tears had associated extrinsic lesions. One patient (1%) had an extrinsic tear without any associated intrinsic tear. Fourteen patients (34%) had partial SLL and/or LTL tears only. Interobserver agreement regarding intrinsic and extrinsic tear detection at MR arthrography was excellent ($\kappa = 0.80$).

### MR Arthrography

Associations between the SLL and LTL tears depicted at MR arthrography and the signs of carpal instability seen on radiographs are reported in Table 2. Most patients ($n$ = 53) had no radiographic evidence of carpal instability (Fig 2). Thirteen (48%) of the 27 patients with at least one complete intrinsic ligament tear had signs of carpal instability at radiography. Four of these 13 patients presented with isolated complete SLL and/or LTL tears, whereas the remaining nine patients had associated extrinsic ligament tears.

The ligament tears present in cases of carpal instability that was visible on radiographs were partial SLL tears in two cases, partial SLL and LTL tears in two cases, complete SLL tears in two cases, complete SLL and LTL tears in two cases, complete SLL-RSCL-RLTL tears in five cases (Fig 3), complete SLL-RSCL-RLTL tears and a communicating TFC tear in two cases, complete SLL and radial collateral ligament tears in two cases, complete TFC tears in one case, and no ligament lesion in one case.

**Figure 2**



a. b. c.

**Figure 2:** **(a)** Posteroanterior radiograph of wrist in neutral position shows no evidence of scapholunate dissociation or carpal instability; alignment of both carpal rows is preserved. **(b)** Conventional midcarpal arthrographic image of same wrist shows SLL (arrow) and central TFC (arrowhead) tears. **(c)** Coronal three-dimensional dual-echo steady-state MR image (60/10, 20° flip angle) findings in same wrist confirm presence of volar SLL (arrow) and central TFC (arrowhead) tears.

The correlation between isolated intrinsic ligament tears and signs of carpal instability on radiographs was not significantly different from that expected to randomly occur ($P > .99$). Conversely, the correlation between SLL and/or LTL and extrinsic ligament tears and signs of carpal instability was significant ($P < .001$).

## Discussion

Conventional arthrography has been considered the reference standard for wrist imaging to visualize communicating and noncommunicating SLL, LTL, and TFC ligament tears (17). However, Weiss et al (18) in 1996 found that in their practice, conventional arthrography was only 60% accurate for the detection of TFC complex, SLL, and LTL tears. In 1997, two studies, performed by Oneson et al (19) and Potter et al (20), revealed a good association between MR imaging and arthroscopy in the detection of TFC ligament tears, with MR imaging having 96% sensitivity and 100% specificity. However, the sensitivity of MR imaging may be as low as 56% for detection of the SLL and 31%–76% for detection of the LTL (21). In 1999, Scheck et al (12) found MR arthrography to have sensitivity and spec-

**Figure 3**

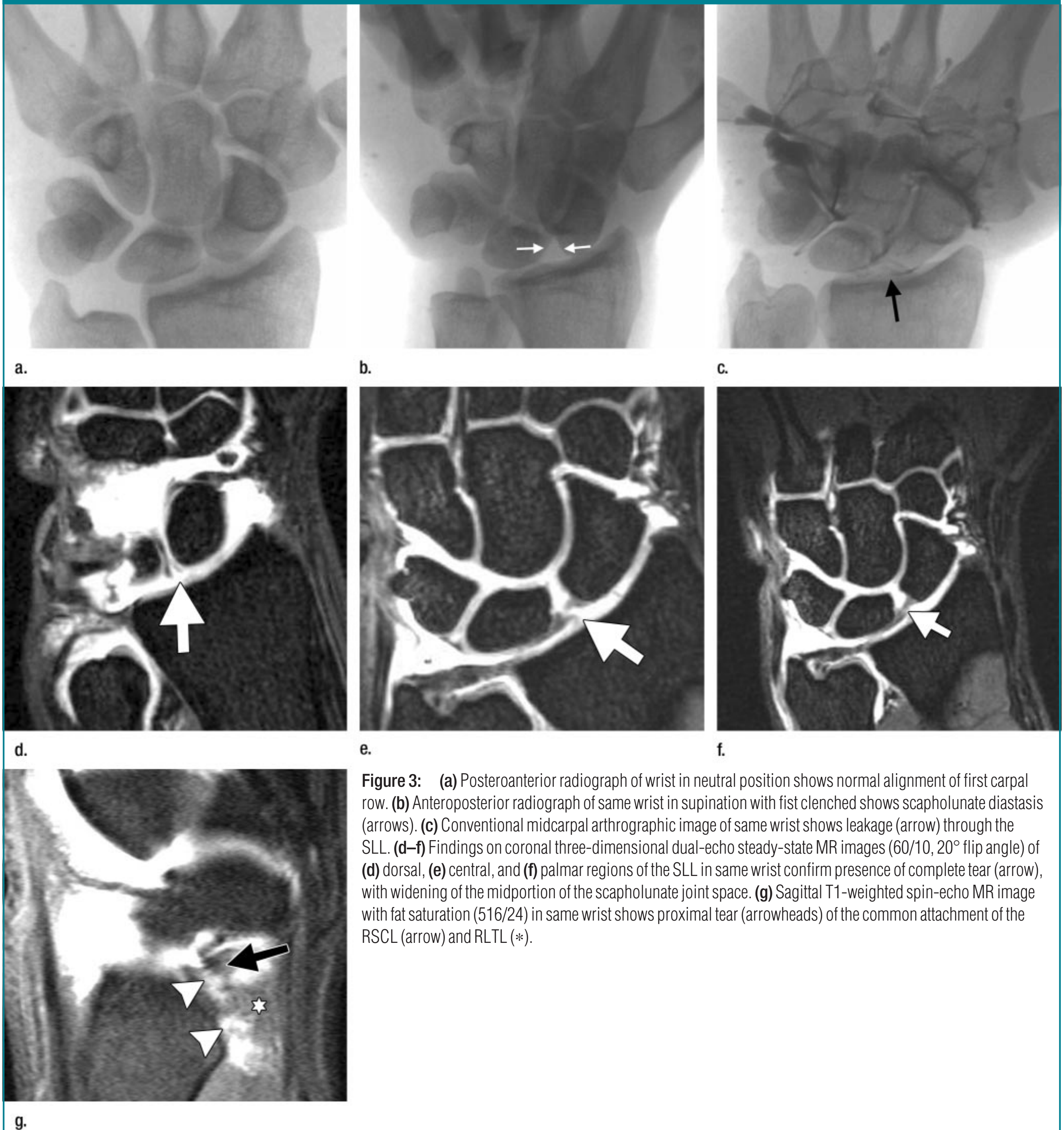



**Figure 3:** **(a)** Posteroanterior radiograph of wrist in neutral position shows normal alignment of first carpal row. **(b)** Anteroposterior radiograph of same wrist in supination with fist clenched shows scapholunate diastasis (arrows). **(c)** Conventional midcarpal arthrographic image of same wrist shows leakage (arrow) through the SLL. **(d–f)** Findings on coronal three-dimensional dual-echo steady-state MR images (60/10, 20° flip angle) of **(d)** dorsal, **(e)** central, and **(f)** palmar regions of the SLL in same wrist confirm presence of complete tear (arrow), with widening of the midportion of the scapholunate joint space. **(g)** Sagittal T1-weighted spin-echo MR image with fat saturation (516/24) in same wrist shows proximal tear (arrowheads) of the common attachment of the RSCL (arrow) and RLTL (*).

ificity values ranging between 90% and 100% for the diagnosis of tears of the TFC, SLL, and LTL. In 2003, Theumann et al (2) found that MR arthrography enabled accurate visualization of the carpal ligaments and their bone attachments, with good association with findings on anatomic sections. In the present study, MR arthrography yielded excellent interobserver agreement in the assessment of ligament tears.

Standard interpretation of wrist ligament instabilities seen on radiographs is complex and reveals only indirect information about ligament lesions. Furthermore, some dynamic radiography–depicted instabilities, such as those involving injuries to the ligaments at the distal radioulnar joint, cannot be depicted with radiography alone (22). Manton et al (21) found arch disruption in the neutral position to have low sensitivity in the evaluation of partial SLL and LTL tears. With most dynamic instabilities, alignment of carpal rows is normal on neutral posteroanterior and lateral views, whereas stress radiographs may show malalignment (23). Our study results confirmed these findings: Carpal signs of instability on static views were noted for only seven of the 27 patients with complete ligament tears.

The SLL and LTL are arguably the most important intrinsic carpal ligaments for maintaining carpal stability (15). Furthermore, the dorsal portions of the SLL ligament and the volar part of the LTL are essential to stabilization of the wrist because they are the intrinsic ligaments most often injured in cases of instability (3,15,24). By distributing forces across the proximal row, the SLL and LTL balance out the palmar flexion tendency of the scaphoid and the dorsiflexion tendencies of the triquetrum on the lunate. The anatomic relationships between the distal radius, distal ulna, and carpal bones are precise, and even minor modifications in these relationships can lead to major changes in load, with resulting increases in pain (25).

Among the extrinsic ligaments, the palmar radiocarpal ligaments are the most important for carpal stability (26); the dorsal radiocarpal and intercarpal ligaments remain important for stabilization of the scapholunate joint (3). The dorsal radiocarpal ligament prevents the perilunate instability that can lead to volar intercalated segment instability, and the dorsal intercarpal ligament prevents dorsal intercalated segment instability (3). The RLTL is more important clinically for load transference and preventing ulnar translation, whereas the RSCL mainly keeps the scaphoid in position (26). These findings regarding the palmar radiocarpal ligaments were confirmed by our current study results, which show that carpal instability associated with extrinsic carpal ligament lesions involved RSCL and RLTL tears. In our series, no dorsal extrinsic ligament injuries were noted in any cases, either with or without signs of carpal instability at radiography.

Depending on the nature of the wrist injury, partial tears of intrinsic or extrinsic ligaments may not affect the integrity of the joint support structures and thus are associated with a decreased probability of the development of carpal instability. Consequently, many authors have postulated that carpal instability results from complete tears (3,27,28). This theory was challenged in our study, in which 14 (52%) of the patients with at least one complete intrinsic lesion had no sign of carpal instability. In our study, the carpal instability depicted on radiographs seemed to be related to the association between intrinsic and extrinsic ligaments tears— even partial ones—rather than to the presence of intrinsic ligament tears alone, even when the tears were complete. This conclusion is supported by other work in the literature, which indicates that extrinsic as well as intrinsic ligaments need to be abnormal to lead to intercarpal instability (3,28).

Several limitations to our study can be identified. First, this was a retrospective study; no systematic comparison between the MR arthrographic and wrist arthroscopic findings was performed. Only 28 arthroscopic procedures were performed, but the results of each one—with the exception of the extrinsic ligament findings— confirmed the MR arthrography–based diagnosis. This limitation applied specifically to the intrinsic and extrinsic ligament evaluations. According to some hand surgeons (29), the proximal attachments of some palmar and dorsal extrinsic and intrinsic ligaments cannot be visualized with arthroscopy, even with use of multiportal wrist arthroscopy (30). In our study, all of the extrinsic ligament tears were located at their attachment sites.

Second, the small number of extrinsic ligament tears might have been due to a delay between the trauma event and the MR arthrographic examination, given the rapid healing of these capsular ligaments (31). Therefore, persistence of carpal ligament tears should be additional proof of carpal instability. Third, given the small number of cases, the findings of this study have to be considered preliminary results.

In conclusion, our study results support the theory that carpal instability patterns seen on radiographs depend on the presence of both intrinsic and extrinsic ligament tears— even partial ones—rather than on the presence of intrinsic ligament tears alone, even when the tears are complete.

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