Diagnostic performance of high-resolution ultrasound in the evaluation of intrinsic and extrinsic wrist ligaments after trauma

Authors
Salvatore Gitto, Domenico Albano, Francesca Serpi, Pierino Spadafora, Roberta Colombo, Carmelo Messina, Alberto Aliprandi, Luca Maria Sconfienza

Affiliations
1 Department of Biomedical Sciences for Health, University of Milan, Milan, Italy
2 Diagnostic and Interventional Radiology Unit, IRCCS Galeazzi Orthopaedic Institute, Milan, Italy
3 Radiology Unit, Zucchi Clinical Institutes Spa, Monza, Italy

Key words
carpal ligament, magnetic resonance arthrography, magnetic resonance imaging, ultrasound, wrist

ABSTRACT
Purpose To investigate the role of ultrasound (US) in the evaluation of intrinsic and extrinsic ligaments of the wrist with magnetic resonance arthrography (MRA) as the reference standard.

Materials and Methods This prospective study included patients referred for MRA after wrist trauma. US examination was performed just before MRA. On the dorsal and palmar sides of the wrist, the intrinsic interosseus and midcarpal, extrinsic, and collateral ligaments were evaluated. MRA was performed on a 1.5-T unit. In the first 20 patients included, ligament thickness was independently assessed using US and MRA and thickness reproducibility was calculated. Ligament integrity was evaluated in all patients.

Results 38 patients (22 men, 16 women; mean age: 38 years) were included. Ligament thickness reproducibility ranged between 44% for the palmar ulnocapitate ligament and 71% for the palmar scaphotriquetral ligament. US had a sensitivity, specificity, positive and negative predictive values, and accuracy of 100% in the identification of tears of the palmar (n = 8) and dorsal (n = 3) bands of the scapholunate ligament and the ulnar collateral ligament (n = 3). It had a sensitivity of 100%, specificity of 97%, positive predictive value of 50%, negative predictive value of 100%, and accuracy of 97% in the identification of tears of the palmar ulnolunate ligament (n = 1).

Conclusion Compared to MRA, US showed good reproducibility in the assessment of wrist ligament thickness and similar accuracy with respect to identifying tears of the scapholunate, palmar ulnolunate, and ulnar collateral ligaments.

ZUSAMMENFASSUNG
Ziel Es sollte die Rolle des Ultraschalls (US) bei der Beurteilung der intrinsischen und extrinsischen Bänder des Handgelenks untersucht werden, wobei die Magnetresonanz-Arthrografie (MRA) als Referenzstandard diente.


Ergebnisse 38 Patienten (22 Männer, 16 Frauen; Durchschnittsalter: 38 Jahre) wurden eingeschlossen. Die Reproduzierbarkeit der Ligamentdicke lag zwischen 44% beim palmaren Ligamentum ulnolunate und 71% beim palmaren Ligamentum scaphotriquetral. Die US-Untersuchung hatte eine
Introduction

Wrist ligaments stabilize the carpal bones during movement, transmit motion, and act as a guide with respect to the radius, ulna, and metacarpals [1]. Intrinsic ligaments connect the carpal bones to each other within the same carpal row (interossseous) or passing over the midcarpal joint (midcarpal). Extrinsic ligaments connect the carpal bones to the distal radius or ulna [2]. In the setting of wrist trauma, the prevalence of extrinsic and intrinsic ligament injuries has been reported as 75 % and 60 %, respectively [3]. Clinical presentation includes discomfort, grip weakness, and click phenomena, which may progress to restriction of range of motion and finally osteoarthritis [4]. Early diagnosis and prompt treatment are of paramount importance to prevent long-term complications. Imaging, including X-ray assessment of bone structures as first-level and magnetic resonance imaging, computed tomography arthrography, or magnetic resonance arthrography (MRA) as second-level modalities, helps with diagnosis [5, 6, 7]. Particularly, MRA is the best imaging method to visualize wrist ligaments and assess related injuries [6, 7], although it is expensive and often unavailable in the setting of acute trauma. Preliminary results have been published on ultrasound (US) of wrist ligaments, which is cost-effective, noninvasive, and largely available [8, 9, 10, 11, 12, 13]. Additionally, latest-generation US systems allow for the visualization of small superficial structures of the wrist with high resolution [14, 15]. However, most US studies to date have focused on the evaluation of wrist ligaments in normal subjects [8, 9, 10, 11, 12, 13] or cadavers [16].

The aim of this study is to investigate the role of US in the evaluation of intrinsic and extrinsic ligaments of the wrist in patients with history of trauma, using MRA as the reference standard.

Materials and methods

Study design and population

This prospective study included a consecutive series of patients with a history of wrist trauma, who were referred for MRA between 2018 and 2021 at a tertiary orthopedic institution. All patients were older than 18 years of age and provided written consent to undergo MRA and preliminary US, which served as a guide for intra-articular injection of contrast medium, as per routine protocol. All patients also provided written consent for anonymized data use for research purposes, which is accepted by Institutional Review Board as informed consent for data publication. Exclusion criteria were: (i) prior wrist surgery and (ii) chronic arthritides, such as rheumatoid arthritis, in which a decrease in ligament detectability has previously been reported [17].

US examination

US examination of the symptomatic wrist was performed on the same day as MRA, just before injecting intra-articular contrast medium, by one of two musculoskeletal radiologists with respectively 10 and 5 years of experience in musculoskeletal US. A commercially available US system (HI VISION Preirus, Hitachi Medical Systems, Tokyo, Japan; or MyLab Alpha, Esaote, Genoa, Italy) equipped with a high-resolution linear probe (14–6 MHz or 13–3 MHz, respectively) was used. The patient sat opposite the radiologist with the hand and forearm lying on the examination table. A large amount of gel was used. Either a rolled towel or a cylindrical US gel tube allowed proper wrist positioning, namely mild palmar flexion and mild dorsal flexion for dorsal and palmar ligaments, respectively. Wrist ligaments were imaged along their longitudinal axis using the distal radius, distal ulna, and carpal bones as anatomical landmarks [13, 18], according to a previously described imaging protocol which also included dynamic evaluation and comparison with the contralateral healthy side (Table 1) [19]. Schematic drawings of intrinsic and extrinsic wrist ligaments are shown in Fig. 1.

In the first 20 patients included in the study, a preliminary analysis was conducted to evaluate thickness reproducibility between US and MRA. Maximum ligament thickness was measured on US. Healthy ligaments appeared as fibrillar echogenic structures in the expected anatomic location, according to their origin and insertion sites, deeper than the wrist tendons [20, 21]. In all patients included in the study, the US criteria for ligament tears were: (i) ligament disruption or fiber discontinuity and (ii) loss of normal echogenic appearance of the ligament, which was not visualized in contiguity with its attachment site.

MRA examination

MRA of the symptomatic wrist was performed immediately after US examination. The radiocarpal joint was injected in a standard sterile fashion, under US guidance, using a dorsal approach between the radius and scaphoid [22]. A 23-gauge needle was used to inject gadopentetate dimeglumine 1.88 mg/ml (Magnevist, Bayer Healthcare Pharmaceuticals, Wayne, NJ) until joint distension was achieved. MRA studies were performed on a 1.5-T unit (Magnetom Espree or Magnetom Avanto, Siemens Medical Sys-
tems, Erlangen, Germany) equipped with a dedicated wrist coil. The imaging protocol included coronal and sagittal T1-weighted, coronal and axial fat-suppressed T1-weighted, coronal and axial fat-suppressed proton density-weighted, and sagittal T2-weighted sequences.

MRA evaluation of wrist ligaments for the purpose of this study was performed beyond our clinical schedule. After a delay of 2–3 months aimed at minimizing the recall of specific cases, the musculoskeletal radiologist with 5 years of experience reviewed all MRA scans and assessed the maximum thickness and integrity of the same ligaments that were previously evaluated by means of US. MRA criteria for ligament tears were: (i) ligament disruption or fiber discontinuity and, (ii) in case of scapholunate or lunotriquetral ligament tear, leak of radiocarpal joint contrast into the midcarpal joint.

Data analysis
Anonymous data were analyzed using SPSS 26.0 (SPSS Inc., Armonk, NY, USA). Ligament thickness reproducibility between MRA and US was assessed using the Bland-Altman method. The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy were calculated for each ligament. A two-sided p-value < 0.05 was defined as statistically significant. Continuous variables were reported as mean value ± standard deviation (SD), and categorical variables were reported as absolute value and percentage.

Results
Forty patients with a history of wrist trauma were referred for MRA of the wrist between 2018 and 2021. Two of them underwent prior wrist surgery and were excluded. None of them had chronic arthritis. A total of 38 patients (22 men, 16 women; 38 ± 18 years of age) were included in this study. Trauma occurred between 1 and 12 months before MRA examination. All patients were referred to rule out injuries to the scapholunate and lunotriquetral ligaments or triangular fibrocartilage complex.

Ligament thickness reproducibility between US and MRA ranged between 44 % of the palmar ulnocapitate ligament and 71 % of the palmar band of the scaphotriquetral ligament. ▶ Table 2 details ligament thickness assessed using both MRA and US, as well as thickness reproducibility for each ligament. ▶ Table 3. A false-positive palmar ulnolunate ligament tear was detected.
Discussion

The main finding of our study was that US showed good performance in the assessment of intrinsic and extrinsic ligaments of the wrist, including good reproducibility rates in thickness evaluation and high accuracy in tear detection, compared to MRA. Although a limited number of tears was found, our results are encouraging and support the use of US in patients with a history of trauma.

These findings open the possibility for US to be implemented in clinical practice, for instance as a first-level imaging modality, which is ideally suited for the assessment of superficial structures such as the carpal ligaments.

In our study, good reproducibility rates were found between MRA and US in the evaluation of ligament thickness, ranging between 44% and 71% for the palmar ulnocapitate and palmar scaphotriquetral ligaments, respectively. Additionally, US showed similar diagnostic performance to MRA in the assessment of tears of dorsal and palmar bands of the scapholunate ligament, ulnar collateral ligament, and palmar ulnolunate ligament. Our results agreed with preliminary studies dealing with US of intrinsic interosseous ligaments of the proximal carpal row [23, 24]. Particularly, in our study, US achieved a sensitivity, specificity, accuracy, PPV and NPV of 100% in identifying scapholunate ligament tears, as also shown by Finlay et al. [23]. In the same paper, the specificity was 100% and the sensitivity was low (25%) when evaluating the lunotriquetral ligament [23]. As we did not find any lunotriquetral ligament injuries, the latter result could not be compared with our findings. Regarding extrinsic ligaments, in our study, US had an accuracy of 97–100% when assessing tears of unocarpal ligaments, namely the palmar ulnolunate and ulnar collateral ligaments. We found no case of radiocarpal ligament tear using both US and MRA. This seems surprising, as high rates of palmar long radiolunate (referred to as palmar radiolunotriquetral ligament), palmar radioscaphocapitate, and dorsal radiolunotriquetral (referred to as dorsal radiotriquetral ligament) ligament tears were previously reported in the setting of wrist trauma [3]. However, in
In this previous study, ligament injuries were evaluated on magnetic resonance imaging and most of them were sprains [3] rather than tears resulting in fiber disruption, which was our US criterion for diagnosis.

Some limitations of our study need to be addressed. First, our study population was relatively small and included only patients with tears of the scapholunate, palmar ulnolunate, and ulnar collateral ligaments. This, however, reflects our study population’s characteristics, as all patients were referred to rule out injuries to the proximal interosseous ligaments or the triangular fibrocartilage complex, which also consists of the palmar ulnolunate and ulnar collateral ligaments [25]. Second, MRA was considered as the reference standard, and surgical inspection was not performed. Third, ligament thickness was evaluated on US and compared to MRA, although a certain degree of variability exists when performing these measurements using different imaging modalities [26, 27, 28, 29]. Fourth, all examinations were performed by one of two musculoskeletal radiologists without evaluating interob-

**Table 3** Accuracy, sensitivity, specificity, positive (PPV) and negative (NPV) predictive values in US detection of ligament tears.

<table>
<thead>
<tr>
<th>Ligament</th>
<th>Tears (n)</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Accuracy</th>
<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>SL (palmar band)</td>
<td>8</td>
<td>100 %</td>
<td>100 %</td>
<td>100 %</td>
<td>100 %</td>
<td>100 %</td>
</tr>
<tr>
<td>SL (dorsal band)</td>
<td>3</td>
<td>100 %</td>
<td>100 %</td>
<td>100 %</td>
<td>100 %</td>
<td>100 %</td>
</tr>
<tr>
<td>PUL</td>
<td>1</td>
<td>100 %</td>
<td>97 %</td>
<td>97 %</td>
<td>50 %</td>
<td>100 %</td>
</tr>
<tr>
<td>UC</td>
<td>3</td>
<td>100 %</td>
<td>100 %</td>
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PUL = palmar ulnolunate; SL = scapholunate; UC = ulnar collateral
server agreement. However, both radiologists were experienced in musculoskeletal US, and good interobserver agreement has already been shown when evaluating wrist ligaments on US [30]. Fifth, although a standardized protocol was used [19], learning curves of US assessment of wrist ligaments remain unknown and deserve investigation in less experienced operators.

In conclusion, US is a noninvasive, cost-effective, and largely available imaging method that enables evaluation of the intrinsic and extrinsic wrist ligaments. Tears of the scapholunate, lunocapitate, and palmar ulnocarpal ligaments can be detected using US with similar diagnostic performance compared to MRA, which is expensive and less easily available. Future larger studies are warranted to investigate US performance in the assessment of other ligamentous injuries and involve operators with different levels of expertise and experience.

Acknowledgement

S. Gitto was supported by Fondazione Umberto Veronesi (Post-doctoral Fellowship 2022)

Conflict of Interest

The authors declare that they have no conflict of interest.

References


Gitto S et al. Diagnostic performance of... Ultraschall in Med 2024; 45: 54–60 | © 2023. Thieme. All rights reserved.


