# Lateral ankle ligaments and tibiofibular syndesmosis

## 13-MHz high-frequency sonography and MRI compared in 20 patients

Petra Milz[1], Stefan Milz[2], Marc Steinborn[1], Thomas Mittlmeier[3], Reinhard Putz[2] and Maximilian Reiser[1]

To test the ability of ultra-high-frequency ultrasound (13 MHz scanner) to distinguish between intact and ruptured ligaments on the lateral side of the ankle, we examined 20 patients with an acute inversion injury with MRI and ultrasound. When judged by the MRI diagnosis, an injured anterior talofibular ligament was correctly diagnosed by ultrasound in 13 of 14 and an intact anterior talofibular ligament in 5 of 6 patients. In the case of the calcaneofibular ligament, 4 ruptured and 16 intact ligaments were diagnosed equally well with both methods. The injured anterior tibiofibular ligament was correctly diagnosed by ultrasound in 6 of 9 patients, while the intact ligament was correctly recognized in 10 of 11 patients.

Our findings indicate that it is possible to distinguish injured from intact ligaments sonographically.

[1]Institut für Radiologische Diagnostik, Marchioninistr. 15, D-81366 München, Germany. Tel +49 89 7095-3620. Fax -8832; [2]Anatomische Anstalt Lehrstuhl I, Pettenkoferstr. 11, D-80336 München, Germany, [3]Virchow Klinikum der Humbold Universität, Unfall- und Wiederherstellungschirurgie, Augustenburger Platz 1, D-13353 Berlin, Germany
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Although ultrasound is now routinely used to evaluate disorders of the musculoskeletal system, it is not yet possible to visualize the fibular collateral ligaments or the anterior tibiofibular ligament directly with scanners of 7.5 MHz. Earlier ultrasonic investigations described parts of the lateral collateral ligament indirectly (Glaser et al. 1989, Ernst et al. 1990, Schnarkowski et al. 1992). Different ways of measuring the instability with ultrasound rather than radiographically have been developed (Schricker et al. 1987, Ernst et al. 1989,1990, Glaser et al. 1989, Kemen et al. 1991, Hoffmann et al. 1993). As with the stress radiographs, active muscular resistance and a reflex increase in muscle tone due to pain can produce a false negative result and the position of the transducer during the stress manipulation is a further source of uncertainty.

Recent advances in ultrasonic equipment have resulted in the development of ultra-high-resolution scanners offering a frequency spectrum above 7.5 MHz. In an earlier investigation, we have shown that one can directly visualize the lateral collateral ligaments of the ankle joint, including the anterior tibiofibular ligament, in dissecting-room specimens (Milz et al. 1996a,b).

In this study, we tested the ability of 13 MHz high-frequency ultrasound to distinguish between intact and ruptured ankle ligaments, even when surrounded by blood and edema. This was achieved by comparing the ultrasonic findings with those obtained by MRI.

## Patients and methods

High-frequency ultrasound and MRI were performed in 20 patients with clinically suspected rupture of the lateral ankle ligaments, following an acute inversion injury. The ultrasound investigation was performed with a commercially available ultrasound unit AU 530 (Esaote Biomedica, Italy), using a mechanical 13-MHz sector scanner (SMA 32, Esaote Biomedica). According to the manufacturer, the 13-MHz scanner offers a 0.118 mm axial and 0.15 mm lateral resolution. A stand-off pad was not necessary, because the variable focus-depth was easily adapted to the thickness of the soft tissue overlying the bone.

During the sonographic examination, the patient lay on the side of the unaffected leg with the knee joint flexed to 90°, while the affected leg was only slightly flexed. A supporting roll was put under the ankle joint of the affected leg and the joint itself was placed in moderate inversion and plantar flexion to achieve a comfortable position for the patient. In this position, the talofibular and calcaneofibular ligaments are slightly stretched, so that the intact ligaments are more easily depicted as full-length parallel-

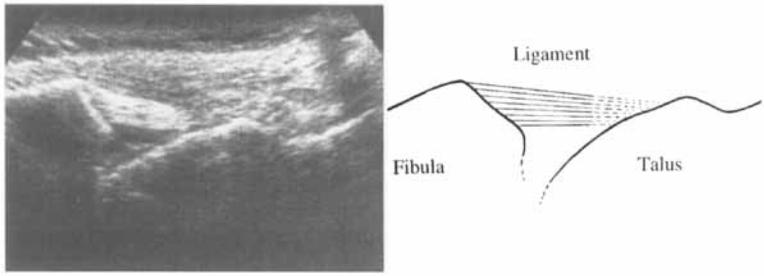


Figure 1. Sonographic appearance and schematic drawing of an intact anterior talofibular ligament. The talar insertion appears less echoic because the direction of the ultrasound beam is not orthogonal to this part of the ligament.

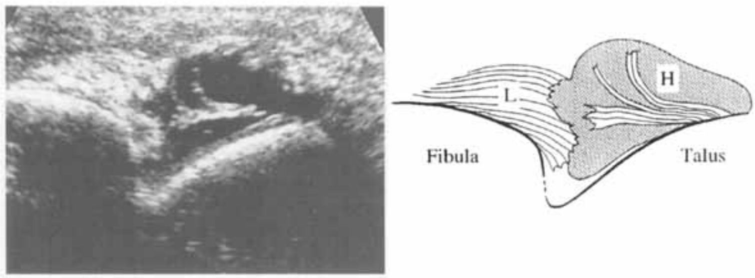


Figure 2. Ruptured anterior talofibular ligament and schematic drawing. The dehiscence at the ends of the torn ligament is clearly seen with fibers floating in the anechoic hematoma. H hematoma, L parts of the torn ligament.

layered echogenic structures (longitudinal scans in the direction of each ligament), with the bony insertions as reference structures (Figure 1). In the case of a ruptured ligament, the site of the lesion is seen more clearly in this position, because the torn ends are separated from each other. This position also offers good skin contact for the scanner membrane and diminishes disturbing artefacts.

A rupture was diagnosed sonographically if a dehiscence of the ligamentous ends or interruption of the parallel fibers in combination with a hypoechogenic zone (edema, hematoma) could be visualized (Figure 2). If some straight, parallel fibers could still be seen, a diagnosis of incomplete rupture was made.

The MRI was performed with a 0.2 Tesla unit (Artoscan, Esaote Biomedica, Italy). T1-weighted spin-echo sequences (TR 580 ms, TE 24 ms) and T2-weighted spin-echo sequences (TR 3000 ms, TE 80 ms) were obtained in different oblique axial imaging planes. A 192 × 160 matrix was used with a 160 mm × 160 mm field of view. The slice thickness was 4 mm. A fixed extremity coil was employed.

The anterior talofibular ligament was visualized in 15° ventrally tilted imaging planes, the anterior tibiofibular and the calcaneofibular ligaments with a dorsal tilt of 10°, while the foot was always fixed in plantarflexion at about 10–20° according to the layout of the equipment. These values of the oblique imaging planes had been found to be the most suitable in healthy volunteers before the clinical investigation was begun (Steinborn et al. 1995).

Using MRI, the diagnosis of a complete rupture of a ligament was made, if a dislocation of the ends of the ligamentous fragments without any unruptured fibers could be seen. A rupture was also diagnosed if a hematoma or effusion in the joint space was seen, but no ligamentous structure could be detected. An incomplete rupture was assumed if thickening and signal increase in the ligament were found.

## Results

When judged in terms of the MRI diagnosis, an injured anterior talofibular ligament (Figure 2) was correctly diagnosed by ultrasound in 13 of 14 cases (sensitivity 92%, specificity 83%, positive predictive value 93%, negative predictive value 82%; Table). In 1

**Comparison of the results between MRI and 13-MHz sonography**

| | Anterior tibiofibular (n 20) | | Anterior talofibular (n 20) | | Calcaneofibular ligament (n 20) | |
|---|---|---|---|---|---|---|
| | intact | ruptured | intact | ruptured | intact | ruptured |
| MRI | 11 | 9 | 6 | 14 | 16 | 4 |
| Sonography correct | 10 | 6 | 5 | 13 | 16 | 4 |
| Sonography incorrect | 1 | 3 | 1 | 1 | 0 | 0 |

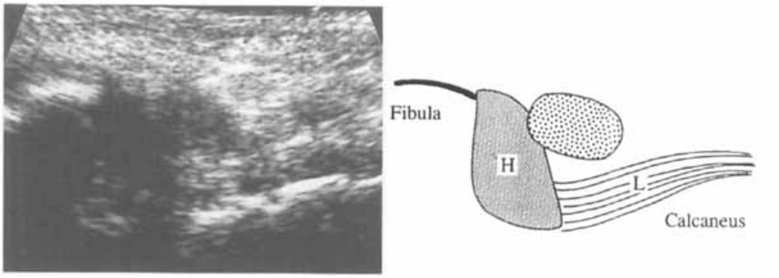


Figure 3. Rupture of the calcaneofibular ligament and schematic drawing. The peroneal tendons appear as oval, hypoechoic structures next to the hematoma. The calcaneal part of the ligament is represented by parallel hyperechoic layers.
H hematoma, L calcaneal part of the injured ligament.

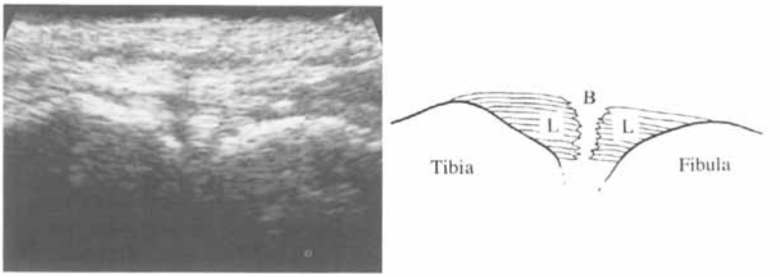


Figure 4. Ruptured anterior tibiofibular ligament and schematic drawing.The hypoechoic zone starts next to the ventral border of the ligament and crosses the ligament itself, involving the dorsal connective tissue between fibula and tibia.
L parts of the torn ligament, B hypoechoic discontinuation of the ligament.

case, the ligament showed an incomplete rupture sonographically, which could not be seen with MRI. In 5 cases, the anterior talofibular ligament appeared to be intact with both methods (Figure 1).

In all of the 4 cases where MRI showed an injured calcaneofibular ligament, sonography identified the rupture correctly (Figure 3). In the remaining cases, an intact ligament could be demonstrated by both methods.

The anterior tibiofibular ligament was injured in 9 patients according to MRI, and correctly diagnosed by ultrasound in 6 cases (Figure 4), whereas in the remaining 3 cases ultrasound revealed no injury (sensitivity 66%, specificity 91%, positive predictive value 86%, negative predictive value 77%). In 1 case, the ultrasound showed an incomplete rupture which could not be confirmed by MRI. In 10 cases with no injury to the ligament, the findings of the 2 methods were identical.

## Discussion

In previous investigations of the ankle joint, the lateral collateral ligaments and the anterior tibiofibular ligament could not be visualized directly with sufficient clarity by 7.5 MHz ultrasound-probes (Friedrich et al. 1990,1993, Striepling et al. 1991). This is attributable to an inadequate axial resolution of about 0.4 mm in relation to the 1 or 2 mm thickness of the ligament. With recent progress in equipment technology, however, a much higher axial resolution of 0.12 mm is obtained by 13-MHz scanners, which now makes it possible to analyze the structure of small musculoskeletal elements (Milz et al. 1996a,b). On the other hand, the higher ultrasound frequencies are always associated with a decrease in the depth of penetration. This is probably the reason why in our previous anatomical investigation the dorsal ligaments (posterior talofibular and posterior tibiofibular ligament) could not be demonstrated since the soft tissue covering is significantly thicker in this region than that overlying the anterolateral ligaments (Milz et al. 1996a,b). Therefore, we did not examine the posterior ligaments in this investigation.

Since closed treatment is appropriate for most acute ankle injuries, we could not confirm the sonographic findings surgically. We therefore had to rely on MRI as regards the status of the ligaments. Since only a few studies have surgically confirmed the MRI findings, these must also be regarded as tentative. Nevertheless, MRI visualization of the ligaments around the ankle is comparable to that of the injured ligaments in the knee, which has been surgically confirmed (Lee et al. 1988, Grover et al. 1990). Hence, it seems reasonable to use MRI as a diagnostic standard for comparison with sonography.

To evaluate the integrity of ligaments accurately, the MR imaging plane has to be parallel to them. In this way, each ligament is visualized throughout its full extent from origin to insertion (Erickson et al. 1991, Schneck et al. 1992a,b). Because of the fixed foot position necessitated by the technical equipment, the axial imaging planes are tilted according to the anatomical requirements of this position. The degree of tilting appropriate to clinical use was calculated from the data previously obtained from healthy volunteers (Steinborn et al. 1995).

Rather than following the advice given in the literature, according to which the foot has first to be taped in maximum dorsal flexion and then in plantar extension, so that different axial and coronal sections can be scanned along the course of the ligaments, our way of placing the foot and then tilting the imaging plane instead is much less painful for the acutely injured patient.

A previous investigation on healthy volunteers, in which the same low-field system used in the current study was compared to a 1.5 T high-field system, revealed that the intact ligaments can be visualized sufficiently clearly with both systems (Steinborn et al. 1995).

Among the 60 ligaments we investigated, we found a disagreement between the ultrasonic diagnosis and MRI picture in only 6. In the 2 cases where a talofibular ligament was diagnosed as injured by only one of the two methods, a divided ligament with only one of its parts ruptured may have been the explanation. The confusion of accessory fibers with the ligament itself is another possible cause of diagnostic discrepancy.

It should also be remembered that an increase in fluid in the ligament itself is more easily identified by MRI than by ultrasound. It is therefore quite likely that minor injuries with a posttraumatic increase in the fluid inside the ligament will alter the MRI signal characteristics, although the ligament may still appear normal on sonographic examination. This could explain why the tibiofibular ligament produced altered MRI signal characteristics in 9 cases, which were mostly interpreted as a partial rupture at the distal end of this broad structure, while 3 of these appeared ultrasonically normal. Such minor injuries might also be missed on ultrasonic examination, because the ruptured ends of an anterior tibiofibular ligament are much less likely to dislocate obviously than those of the talofibular or calcaneofibular ligaments. The anterior tibiofibular ligament is surrounded by dense fibrous connective tissue, which also fills the cleft between the leg bones in the deeper layers dorsal to the anterior tibiofibular ligament. For this reason, one should not expect obvious dehiscence of the ruptured ends of the anterior tibiofibular ligament, but rather more subtle sonographic changes.

In the 6 tibiofibular ligaments which, according to MRI diagnosis, were correctly classified by ultrasound as injured, we could, indeed, see an interruption of the parallel-layered appearance by a small hypoechoic zone. This started at the ventral border of the ligament or in the adjacent superficial soft tissue structures and ran through the ligament itself, frequently also involving the dorsal connective tissue between the fibula and tibia. This was probably caused by bleeding into the rupture, the cleft of which also involves the dorsal connective tissue. One false ultrasonic diagnosis of a partially ruptured tibiofibular ligament was probably due to a diffraction artefact behind the anterior tibial artery, which, in many cases, crosses the tibiofibular ligament. This artefact might mimic a rupture, but can be recognized starting in a pulsating hypoechoic round structure.

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