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Imaging of posterior tibial tendon dysfunction—Comparison of high-resolution ultrasound and 3 T MRI

Michael A. Arnoldner[a,*], Michael Gruber[a], Stefanie Syré[b], Karl-Heinz Kristen[c], Hans-Jörg Trnka[c,d], Franz Kainberger[a], Gerd Bodner[a]

[a] Medical University of Vienna, Vienna General Hospital, Department of Biomedical Imaging and Image-guided Therapy, Währinger Gürtel 18-20, 1090 Vienna, Austria
[b] Medical University of Vienna, Vienna General Hospital, Department of Trauma-Surgery, Währinger Gürtel 18-20, 1090 Vienna, Austria
[c] Foot & Ankle Centre Vienna, Alser Straße 43/8, 1080 Vienna, Austria
[d] Orthopaedic Hospital Vienna, Speisinger Straße 109, 1130 Vienna, Austria

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ABSTRACT

Purpose: Posterior tibial tendon dysfunction is the most common cause of acquired asymmetric flatfoot deformity. The purpose of this study was to determine and compare the diagnostic value of MRI and high-resolution ultrasound (HR-US) in posterior tibial tendon dysfunction (PTTD), and assess their correlation with intraoperative findings.
Materials and methods: We reviewed 23 posterior tibial tendons in 23 patients with clinical findings of PTTD (13 females, 10 males; mean age, 50 years) with 18 MHz HR-US and 3 T MRI. Surgical intervention was performed in nine patients.
Results: HR-US findings included 2 complete tears, 6 partial tears, 10 tendons with tendinosis, and 5 unremarkable tendons. MRI demonstrated 2 complete tears, 7 partial tears, 10 tendons with tendinosis, and 4 unremarkable tendons. HR-US and MRI were concordant in 20/23 cases (87%). Image findings for HR-US were confirmed in six of nine patients (66.7%) by intraoperative inspection, whereas imaging findings for MRI were concordant with five of nine cases (55.6%).
Conclusion: Our results indicate that HR-US can be considered slightly more accurate than MRI in the detection of PTTD.

1. Introduction

Posterior tibial tendon dysfunction (PTTD) is the leading cause of asymmetric acquired flatfoot deformity [1].

As the PTT is the main supporter of the medial longitudinal arch of the foot, loss of function results in progressive flattening of the medial aspect of the foot, and, consequently, hind foot valgus deformity occurs [1].

Clinically, individuals suffering from PTTD may complain of posteromedial ankle pain. In cases with significant inflammation, there can be tenderness of the tendon and edema may surround the PTT. This is most likely to be found in the distal portion, as this is the area most commonly involved in PTT lesions [2].

Currently, magnetic resonance imaging (MRI) is considered the gold standard to assess PTTD radiologically [3,4]. MRI at 3 T offers high-resolution image quality and its use in PTTD has recently been described [5].

High-resolution ultrasound (HR-US) is considered a cost-effective, easily available, and – when performed by an experienced investigator – accurate method to evaluate superficial structures of the musculoskeletal system. Its use in the assessment of tendons has been extensively described in the literature. As the PTT is located superficially, ultrasound has been proven to be a highly valuable diagnostic tool with which to visualize the tendon [6–8].

Both MRI and US have been the subject of several studies in order to assess their diagnostic value in the evaluation of PTTD, and comparative studies have also been performed [4–6,9–11]. Nevertheless, considering the ongoing and rapid improvements in technology in radiology, the accuracy of 3 T MRI and high-resolution US, and their concordance in terms of results, needed to

* Corresponding author. Tel.: +43 1 4040076430.
E-mail address: michael.arnoldner@meduniwien.ac.at (M.A. Arnoldner).

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be assessed in order to adapt diagnostic choices to current technical standards.

2. Material and methods

After obtaining institutional review board (IRB) approval, 23 patients (13 females and 10 males) with clinical signs of PTTD were assessed over a period of two years. Patients were referred to our department after clinical examination by three experienced orthopaedic surgeons, who specialized in foot and ankle surgery (20, 19, and 10 years of experience). Clinical inclusion criteria were: pain along the course of the PTT, localized edema, as well as asymmetric acquired flat foot deformity. The mean age at first presentation was 50 years (range: 20–73 years). All patients were assessed at our institution, and written, informed consent was obtained.

In addition to clinical inclusion criteria, general inclusion criteria comprised of no contraindications for MRI and age over 18. Pregnant patients and patients with severe degenerative hindfoot osteoarthritis, as well as rigid valgus deformity, that does not correct to varus position with toe standing, were excluded from our study.

MR imaging was performed on a 3 T MRI scanner (Magnetom Trio 3T, Siemens Medical Solutions, Erlangen, Germany) with a foot and ankle coil (eight-channel foot ankle coil, Siemens Medical Solutions, Erlangen, Germany). The MRI protocol used in this study is shown in Table 1. No contrast media was used, since a recent report by Chhabra et al. showed excellent visualization of the PTT on non-contrast-enhanced 3 T MRI [5].

MRI interpretation was performed on a PACS Workstation (IMPAX, Agfa-Geveart, Mortsel, Belgium), in consensus, by two radiologists with 11 and five years of experience in musculoskeletal radiology. Diagnostic criteria for MRI were as follows: tendinosis was defined as focal or diffuse tendon degeneration with thinning or thickening and an intratendinous signal less than that of fluid on fluid-sensitive sequences.

A partial tear was defined as an intratendinous signal equivalent to that of fluid on fluid-sensitive sequences.

Complete rupture was diagnosed when a complete disruption of the tendon, filled with a fluid gap was noted.

All HR-US examinations were performed by the same radiologist, with 20 years of experience in musculoskeletal sonography. HR-US assessment was standardized, with patients placed in the lateral decubitus position. HR-US was performed with an 18 MHz linear array transducer (Logiq E9, General Electric Medical Systems, Buckinghamshire, United Kingdom). The radiologist performing HR-US was blinded to the MRI results. Longitudinal and transverse sections of the entire course of the PTT were acquired. Images were interpreted during assessment, and subsequently, in consensus with another musculoskeletal radiologist (five years of experience), based on static images. Diagnostic criteria for HR-US were as follows:

(1) *Tendinosis* was defined as heterogenous thickening of the tendon. Color-flow Doppler was also used in sonographic assessment, but was not a diagnostic criteria for tendinosis in our study.
(2) A *partial tear* was diagnosed when the tendon showed hypoechoic disruptions of the fibrillar pattern.
(3) *Complete ruptures* were defined as complete loss of the tendon's continuity.

In addition to image interpretation, surgery was performed in nine cases using the flexor digitorum longus (FDL) tendon to adopt the function of the PTT. As the PTT is exposed in this procedure, the surgeon's opinion of the tendon pathology was noted for comparison.

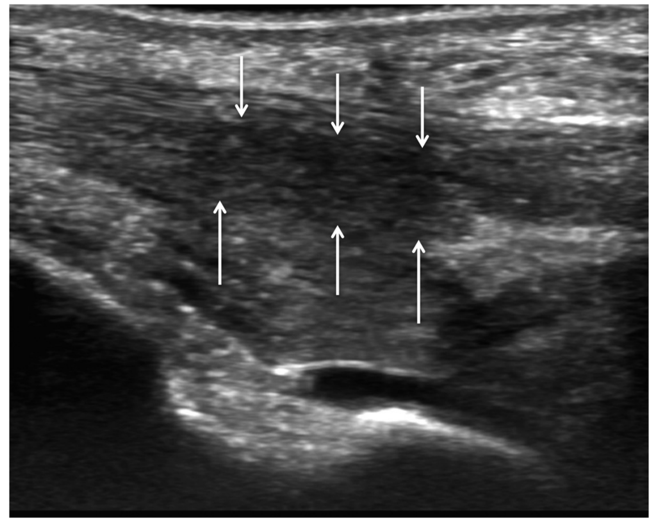

Fig. 1. *Tendinosis*. A 18 MHz longitudinal HR-US of a 39-year-old female shows heterogeneous echostructure and thickening of the PTT (arrows).

MRI and HR-US findings were compared, and statistical analysis was performed using Microsoft Excel 2008 (Microsoft Corporation, Redmont, WA, USA) and IBM SPSS Statistics (IBM Corporation, Amonk, NY, USA). Descriptive statistics were derived and Cohen's kappa coefficient was calculated in order to describe the inter-rater agreement for MRI and HR-US.

If applicable, surgical findings were used for comparison to both MRI and HR-US results. The mean time interval between imaging and surgery was 77 days (min. 4; max. 351).

3. Results

MRI at 3 T and HR-US were consistent in 20/23 cases (87%). Concordances and inconsistencies are shown in Table 2. In 18/23 cases (78.3%), both MRI and HR-US showed pathological findings of the PTT.

In 10 cases (mean age, 49.9 years; range, 26–67 years; four males and six females), HR-US findings were interpreted as tendinosis (Fig. 1). MRI also showed tendinosis (Fig. 2) in 10 cases (mean age, 50.7 years; range, 26–67 years; four males and six females). MRI and HR-US were consistent in 9/10 patients. For partial tears, MRI (Fig. 3A) and HR-US (Fig. 3B) were concordant in 5/7 cases (71.4%). HR-US showed partial tears in six patients (mean age, 41.6 years; range, 46–67; two males and four females). Partial tears were diagnosed on MRI in seven cases (mean age, 38.7 years; range, 46-65; two males and five females). Complete rupture was diagnosed in two cases (a 46-year-old male and a 73-year-old female). HR-US and MRI were concordant in both cases (Fig. 4).

Ultrasound and MRI were inconsistent in three cases, one of which showed a partial tear on MRI, while HR-US diagnosed tendinosis. In another case, the MRI findings were read as tendinosis and HR-US revealed a partial tear. One case showed an unremarkable tendon on HR-US examination, but MRI findings were interpreted as a partial tear.

In five patients with clinical symptoms of PTTD, HR-US did not show pathological alterations of the PTT. Four of these PTTs were interpreted as unremarkable on MRI as well. However, in three of these cases, MRI revealed other pathologies of the ankle structures. These findings comprised of a diffuse bone marrow edema of the calcaneus and talus in a 20-year-old male, an osteochondral lesion of the talar dome in a 31-year-old male (Fig. 5), and thickening

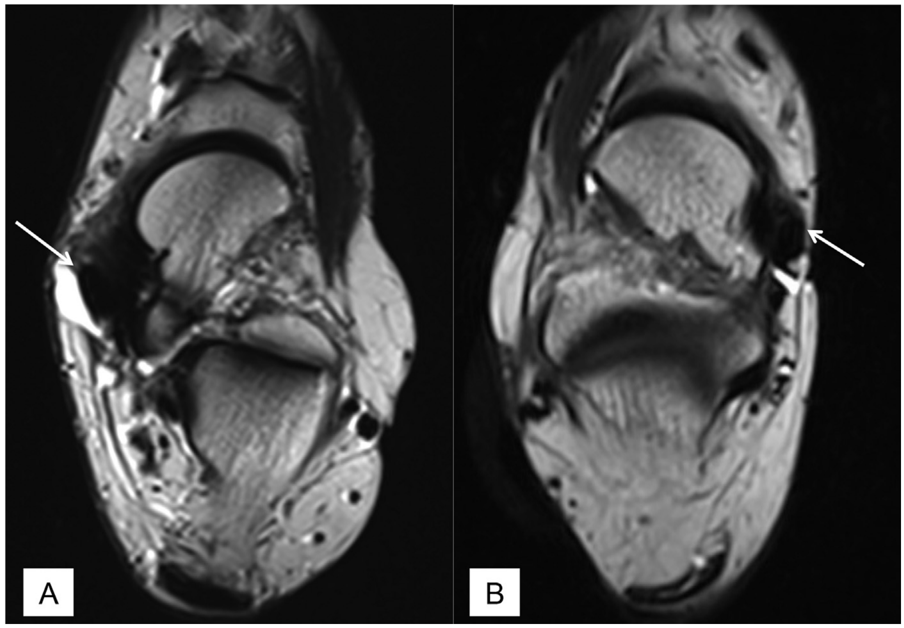

Fig. 2. *Tendinosis*. Axial T2-weighted TSE MR image at the level of the left talonavicular joint of a 49-year-old female reveals a thickened PTT with subtle intratendinous signal hyperintensities (arrow) and peritendinous fluid (A). Axial T2-weighted TSE MR image of a 39-year-old female also shows thickening of the right PTT (arrow) consistent with tendinosis (B).

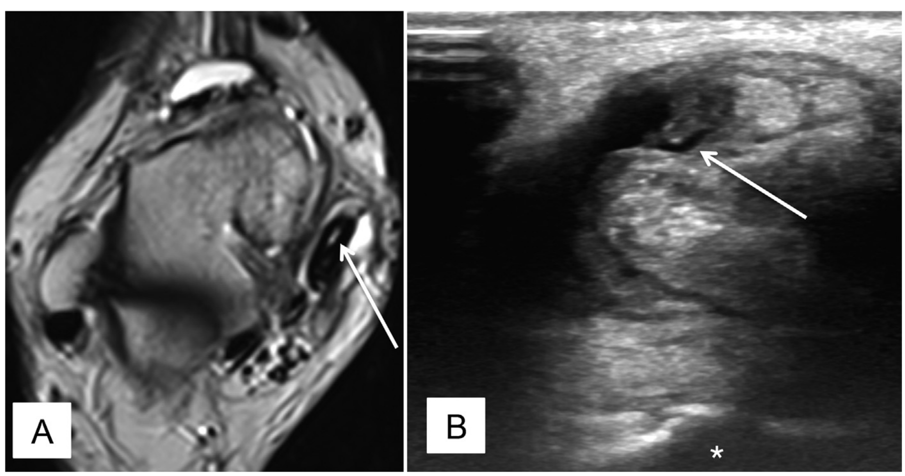

Fig. 3. *Partial tear*. Axial T2-weighted MR image and HR-US image of a 46-year-old female. The right PTT shows intratendinous signal equivalent to that of fluid (arrow) and consistent with a partial tear (A). 18 MHz transverse HR-US reveals a partial tear (arrow) (B). Talus (asterisk).

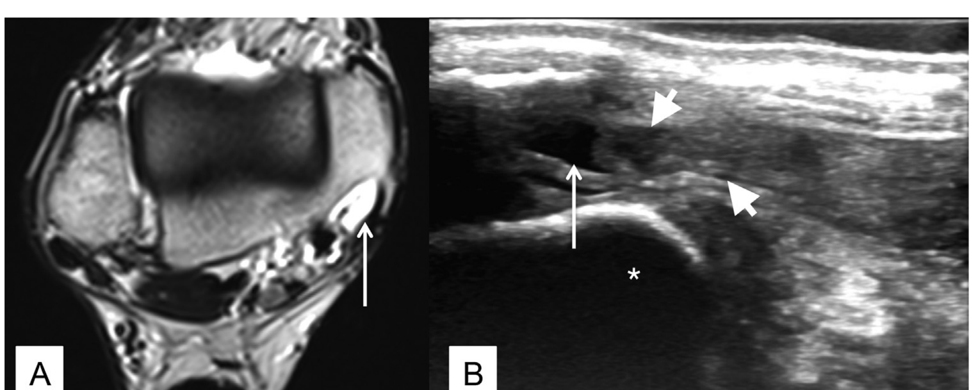

Fig. 4. *Complete rupture*. Axial T2-weighted MR image and longitudinal 18 MHz HR-US image of a 46-year-old male. Both MRI (A) and HR-US (B) show complete discontinuity of the right PTT (arrowheads) with a fluid-filled gap (arrows) proximal to the flexor retinaculum. Further, MRI reveals an exostosis of the tibia, which could have caused chronic friction and weakening of the PTT. Medial malleolus (asterisk).

Table 1
MRI protocol.

Sequence	FS	FOV	Slice thickness (mm)	Number of slices	TR	TE	A	C
Sagittal turbo spin echo TSE proton-density weighted	Yes	285	3	30	3650	36	1	1
Coronoal proton-density-weighted TSE wire spectral selection attenuated inversion recovery (SPAIR)	Yes	160	3,5	32	5000	40	1	2
Axial T2-weighted TSE	No	260	2,5	35	3990	125	3	2
Sagittal T1-weighted TSE	No	260	3	26	830	19	3	2

Fat saturation (FS); field of view (FOV); time of repetition (TR); time of echo (TE); averages (A) and concatenations (C).

Table 2
Concordances and inconsistencies between MRI and HR-US.

		Ultrasound				Total
		Normal PTT	Tendinosis	Partial tear	CR	
MRI	Normal PTT	4	0	0	0	4
	Tendinosis	0	9	1	0	10
	Partial tear	1	1	5	0	7
	CR	0	0	0	2	2
Total		5	10	6	2	23

CR—complete rupture.

of the flexor retinaculum, as well as tenosynovitis, of the FDL in a 45-year-old male.

3.1. Surgical correlation

Surgical exposure of the PTT revealed tendinosis in three patients. In those cases surgery was performed to prevent progressive collapse of the arch due to a clinically significantly impaired PTT. Further surgical findings included three partial tears and two complete ruptures. In one case, the PTT showed thinning, but no tendinosis or partial tear was noted by the surgeon. However, due to the patient's clinical appearance, a flexor digitorum longus tendon transfer was performed in combination with a calcaneus osteotomy.

Fig. 5. Coronal proton-density-weighted MR image of a 31-year-old male shows an osteochondral lesion of the medial talar dome.

HR-US and surgical findings were concordant in 6/9 cases (66.7%). The three inconsistencies were as follows: two tendons showed tendinosis on HR-US, but were interpreted as partial tears when surgically exposed. In the remaining case, HR-US revealed a partial tear, and tendinosis was diagnosed intraoperatively.

MRI and surgical findings were inconsistent in the same three cases as well, in addition to another patient, where, upon surgical exposure, a healthy tendon was seen and MRI diagnosed a partial tear. Therefore the MRI–surgical findings concordance was 5/9 cases (55.6%).

3.2. Statistical analysis

Table 1 shows the calculation of Cohen's kappa coefficient for inter-rater agreement, which was 0.81 for MRI and HR-US, indicating very good agreement.

4. Discussion

PTTD is most commonly found in middle-aged obese women [12,13], and, as traumatic injury is rare, primarily occurs due to chronic intrinsic changes of the tendon [14]. It has been hypothesized that the acute angulation of the PTT at the medial malleolus affects the structure and poses a risk for degeneration and trauma [15]. In addition, a zone of relative hypovascularity in this area is likely to compromise regeneration [16]. Furthermore, an association with seronegative inflammatory diseases has been reported [17].

Imaging of asymmetric acquired flatfoot deformity due to PTTD requires accuracy to ensure optimal therapeutic management, because with misleading and/or delayed diagnosis, the deformity will progress. We compared 18 MHz HR-US and 3 T MRI in order to correlate their diagnostic value in PTT pathologies, and our findings showed a very high inter-rater agreement using Cohen's Kappa value. Our results indicate that 18 MHz HR-US is as accurate as 3 T MRI when assessing the PTT. Furthermore, when comparing imaging findings to surgical findings, a slightly higher accuracy for HR-US than for MRI was observed.

Although PTTD is clinically classified into four stages [2,17], and therapeutic decisions are made by the orthopedic surgeon, imaging plays an important role in visualizing the tendon and other ankle structures.

Both MRI and US have advantages and disadvantages. Sonopalpation offers the possibility to directly visualize areas of tenderness and the tissue beneath. However, orthopaedic surgeons may tend to prefer MR images, especially when patients require surgery. MRI is able to visualize the entire area of the ankle joint, and other pathologies that may or may not be secondary to PTTD can be revealed. Bone marrow edema, in particular, may be present and cannot be seen on HR-US images.

As expected, the majority of our patients who showed pathologies of the PTT were middle-aged women. Tendinosis was the most common finding in our study, followed by partial tears and complete ruptures. Complete tears could easily be seen on both MRI and HR-US. However, the distinction between partial tear and tendinosis can be difficult, as described in the literature [18]. In all but one case, where HR-US was interpreted as normal and MRI showed a partial tear, the inconsistencies in our study were in the tendinosis and partial tear group.

While most of the PTT pathologies occurred in the distal portion of the tendon, one case showed a complete supramalleolar rupture proximal to the flexor retinaculum. Jain et al. reported that supramalleolar pathologies are likely to be severe and more often occur in women [19]. They also concluded that those patients have an increased prevalence of coexisting findings, such as tenosynovitis [19]. Hence, complete assessment of the entire course of the tendon is crucial.

As the PTT angulates around the medial malleolus, it requires the flexor retinaculum to keep it in position. When there is too much friction at this level, e.g., due to thickening of the retinaculum, PTT pathology can occur. In one case from our study, MRI and HR-US showed a hypertrophic retinaculum and tenosynovitis of the FDL, but the PTT did not show abnormalities. The inflammation of the FDL might have simulated a possible PTT pathology to the referring clinician. Furthermore, lesions of the retinaculum may cause subluxations.

Several studies on the comparison of MRI and US in PTTD have been published [4,9,10,20–22]. Rocket et al. surgically explored the tendons of the ankle and compared the findings with MRI and US [20]. They reported a higher accuracy for US, at 94.4%, compared to 65.75% for MRI. However, this study did not exclusively consider the PTT [20]. In contrast to that, Conti et al. concluded that MRI should be considered the gold standard when assessing PTTD, as, according to their findings, MRI is even more accurate than surgical exploration [23]. They reported that this might be due to intramural lesions that can be shown with MRI, but are not visible to the surgeon when assessing the tendon macroscopically [23]. Our results support this conclusion, as one patient, who underwent surgery, showed an intramural partial tear on both MRI and HR-US, but surgical findings were only consistent with tendinosis. However, our findings suggest strongly that high-resolution HR-US is able to detect those changes as accurately as MRI, and might have the potential to replace MRI as the current gold standard for PTTD imaging.

Our study had several limitations. Only 23 patients participated in this study. In some cases, there were long intervals between imaging and surgery. However, one patient, who underwent surgery almost one year after imaging, had a complete rupture, and we believe that, in this case, there was no change during this time, as the tendon was completely torn. In addition, the surgeons had not been blinded to the results of MRI and HR-US, because the radiological findings of the PTTD and other ankle structures were critical information for them.

5. Conclusion

Our results indicate that 18 MHz high-resolution HR-US is slightly more accurate than 3 T MRI in the diagnosis of PTTD. We recommend the use of HR-US as an initial diagnostic tool, since it properly visualizes PTT pathologies, is easily available, and saves time as well as costs. In patients with long-lasting discomfort and an inconclusive HR-US exam, MRI appears favorable, as it might detect bone marrow edema or other secondary signs of PTTD.

Conflict of interest statement

The authors state that they have no financial or conflicts of interests to disclose.

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