Original Article

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Radiology Section

Diagnostic Accuracy of Ultrasonography in Patients with Plantar Fasciitis: A Cross-sectional Study

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ABSTRACT

Introduction: Plantar Fasciitis (PFS) is the most well-known cause of plantar heel pain seen predominantly in middle aged women. Imaging findings of Magnetic Resonance Imaging (MRI) is considered to be the gold standard in the diagnosis of PFS, but MRI is expensive. Hence; there is a need to study the accuracy of Ultrasonography (USG), as USG is inexpensive, free of radiation and readily available.

Aim: To evaluate the diagnostic accuracy, sensitivity, specificity, Positive Predictive Value (PPV) and Negative Predictive Value (NPV) of ultrasound in comparison with MRI for the diagnosis of PFS, in patients with heel pain.

Materials and Methods: The present cross-sectional study was conducted in the Department of Radiodiagnosis, SRM Medical College and Research Centre, Kattankulathur, Tamil Nadu, India, from December 2019 to July 2021. USG and MRI of foot were performed in 40 patients with heel pain. MRI protocol included three plane Proton Density Fat Saturated (PDFS), T1 sagittal, T2 axial and Short inversion Time Inversion Recovery (STIR) sagittal sequences. USG scans were done in prone position with the patient's feet dorsiflexed. The Plantar Fascia (PF) thickness was measured in both USG and MRI and association of the ultrasound and MRI measurements of PF thickness was done using Chi-square test.

Results: Mean age of the cohort was 36.83±10.08 years. Out of this subject population, majority were females 29 (72.5%). Nineteen (47.5%) females were overweight i.e., BMI from 25-29.9 kg/m^2. The accuracy, sensitivity, specificity, PPV and NPV of plantar fascia thickness of USG as compared to MRI was found to be 80%, 60%, 82.9%, 33.3% and 93.5%, respectively.

Conclusion: Despite MRI being the imaging modality of choice in diagnosing PFS, accuracy of ultrasound was comparable to that of MRI and it can be used as the initial investigation and follow-up.

Keywords: Calcaneal spurs, Heel pain, Imaging, Obesity, Plantar fascial rupture

INTRODUCTION

Plantar Fasciitis (PFS) is the most well-known cause for plantar heel pain seen in upto 10% individuals during middle age, predominantly in women [1,2]. Upto 8% of foot pathologies in runners are attributed to PFS [1,3]. The pain in PFS may be aggravated by passive dorsiflexion of the toes. It starts as a low-grade inflammatory process affecting the plantar fascia which may involve the perifascial structures [1,3].

The risk factors include calcaneal spurs, prolonged standing, weight-bearing, obesity, athletics, etc., [4-7]. Radiology allows an early and accurate diagnosis which helps in effective treatment of PFS. The various imaging modalities used commonly are plain radiography (help to detect calcaneal spur, which is associated with PFS), Ultrasonography (USG) and Magnetic Resonance Imaging (MRI). Ultrasound being helpful in the assessment of plantar fascia in real time can be used to improve the success rate of interventions such as steroid injections (thereby reducing the incidence of atrophy of the fat tissue due to accidental injection) and extracorporeal shock wave therapy [8-12]. MRI is considered the gold standard in the assessment of PFS [13,14].

All the imaging modalities have proven that plantar fascia is usually thickened in patients with PFS than in those without PFS [15,16]. The thickness of plantar fascia in patients with PFS can be measured with imaging techniques. In comparison with MRI, USG is a low cost modality, that is non invasive and free of radiation. It is also well tolerated by patients and it is appropriate for serial follow-up. MRI, though highly accurate and considered the gold standard, is costly. As such, many patients undergo X-ray for the detection of calcaneal spurs which is highly inaccurate in diagnosis of PFS as patients who do not have calcaneal spurs may have PFS as well [14,15].

If the accuracy of ultrasound is proven to be high, it can be used routinely to diagnose PFS, as well as for serial follow-up of already diagnosed cases. Also, when proven to be accurate, it could also be a valuable therapeutic modality for real time ultrasound guided intrafascial steroid injection for relief of pain.

Although there are previous studies available comparing the role of ultrasound and MRI for diagnosis of PFS [6,17-21], but there are limited data regarding effect of BMI on heel pad thickness, plantar fascia thickness [6]. Hence, the present study was conducted to evaluate the diagnostic accuracy, sensitivity, specificity, Positive Predictive Value (PPV) and Negative Predictive Value (NPV) of ultrasound in comparison with MRI for the diagnosis of PFS. The secondary aim was to evaluate the possible associations between Body Mass Index (BMI) and PF thickness, age and PF thickness.

MATERIALS AND METHODS

The present cross-sectional study was conducted in the Department of Radiodiagnosis, SRM Medical College and Research Centre, Kattankulathur, Tamil Nadu, India, from December 2019 to July 2021. Ethical clearance was obtained from Institutional Ethical Committee (1802/IEC/2019) and written informed consent were obtained to conduct the study.

Inclusion criteria: Patients aged more than 18 years, with heel pain were included in the study. Among the patients with heel pain who were referred for imaging, USG was done and those with increased plantar fascial thickness were diagnosed and recruited for the study and further subjected to MRI.

Exclusion criteria: Patients with heel trauma, prior surgery and paediatric patients were excluded from the study.

Sample size calculation: Sample size was calculated using the formula:

$$n=\frac{(\alpha+\beta)^2 (S_1^2+S_2^2)}{(\mu_1-\mu_2)^2}$$

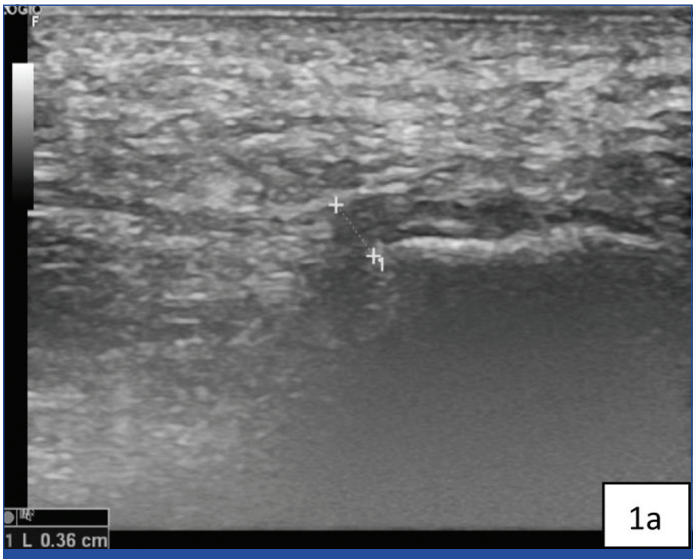
$$n=\frac{(1.96+2.58)^2 (0.13^2+0.13^2)}{(5.143-4.9)^2}$$

$$=11.7\approx12$$

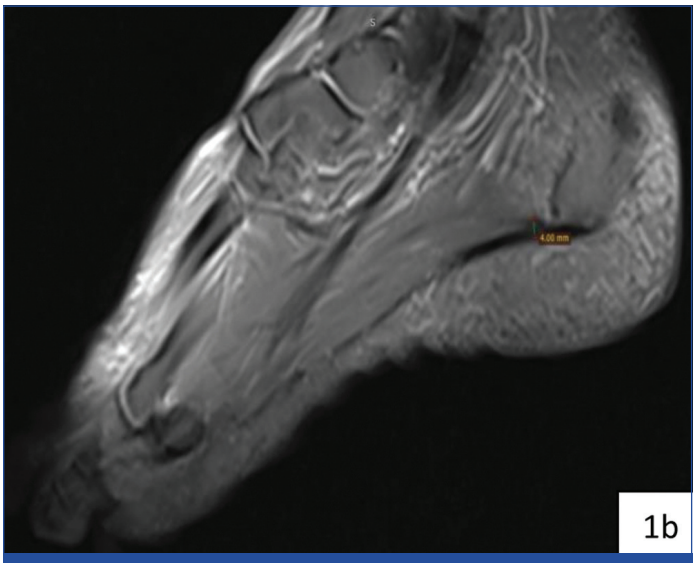
Alpha and Beta are constants. (alpha-1.96; beta-2.58). S1 and S2-standard deviation. μ^1 and μ^2-mean [21]. Calculated sample size was 12. However, 40 cases, who have been referred during the study period were selected by convenient sampling method.

Study Procedure

USG scans were done using GE Logic P9 machine with P9 Matrix Linear Probe, 12-15 MHz. In prone position with the patient's feet dorsiflexed and hanging over the edge of the table, sagittal ultrasound was done with slight medial transducer inclination toward the attachment of the plantar fascia to the calcaneum for better visualisation of the long axis of the plantar fascia fibers [Table/Fig-1a]. MRI scans were performed on 1.5T magnet (Siemens, Essenza), with a dedicated extremity coil. MRI foot protocol included three plane Proton Density Fat Saturated (PDFS), T1 sagittal, T2 axial and Short Inversion Time Inversion Recovery (STIR) sagittal sequences. Field of view (120-140) that do not produce aliasing was used. Slice thickness was 3 mm in all planes [Table/Fig-1b].



[Table/Fig-1a]: Plantar fascia measurement on USG.



[Table/Fig-1b]: Plantar fascia measurement on PDFS sequence (MRI).

Images were assessed for essential features of PFS such as plantar fascia thickness, altered signal intensity/altered echo, heel pad oedema and rupture. The patients were categorised according to BMI by World Health Organisation (WHO). BMI criteria using the formula: person's weight in kilograms divided by the square of his height in meters (kg/m^2) [22].

Moreover, possible associations between BMI and PF thickness, age and PF thickness were evaluated in this study.

1. PF thickness of 4 mm was taken as the cut-off for increased PF thickness [23].
2. Rupture of PF was defined as discontinuity in PF fibers [23].

Two experienced radiologists with a minimum of five years of experience reviewed the images. Any interobserver variation was resolved by consensus.

STATISTICAL ANALYSIS

Association between two continuous variables was assessed by Chi-square test of the collected data. The p-value <0.05 was considered statistically significant. RStudio version 1.2.1093 was used for statistical analysis.

RESULTS

Mean age of the cohort was 36.83±10.08 years. Out of 40 subject, majority 29 (72.5%) were females and 19 (47.5%) were overweight with BMI ranged from 25-29.9 kg/m^2 [Table/Fig-2].

Variables	Categories	Frequency	Percentage
Age group (years)	25 to 35	21	52.5%
	36 to 45	11	27.5%
	More than 45	8	20.0%
Gender	Male	11	27.5%
	Female	29	72.5%
BMI (kg/m^2)	18.5 to 24.9 (Normal)	17	42.5%
	25 to 29.9 (Overweight)	19	47.5%
	30 or more (Obese)	4	10.0%

[Table/Fig-2]: Age, gender and BMI distribution.

In MRI technique measurement, 5 (12.5%) of the patients had plantar fascia thickness ≤4 mm whereas in USG technique measurement, 9 (22.5%) had plantar fascia thickness ≤4 mm. The association between plantar fascia thickness, plantar fascia rupture, heel pad oedema and altered echoes/intensity on MRI and USG was found to be statistically significant (p-value <0.001) [Table/Fig-3].

Variable	Categories	MRI n (%)	USG n (%)	p-value (Chi-square test)
Plantar fascia thickness (mm)	≤4	5 (12.5%)	9 (22.5%)	**0.001**
	4.01 to 4.5	13 (13.5%)	15 (37.5%)	
	>4.5	22 (55.0%)	16 (40.0%)	
Plantar fascia rupture	Yes	8 (20.0%)	6 (15.0%)	**0.001**
	No	32 (80.0%)	34 (85.0%)	
Heel pad oedema	Yes	28 (70.0%)	27 (67.5%)	**0.001**
	No	12 (30.0%)	13 (32.5%)	
Altered echoes/ intensity	Yes	36 (90.0%)	37 (92.5%)	**0.001**
	No	4 (10.0%)	3 (7.5%)	

[Table/Fig-3]: Showing plantar fascia thickness, plantar fascia rupture, heel pad oedema and altered echoes/intensity on MRI and USG.
p-value in bold font indicates statistically significant value

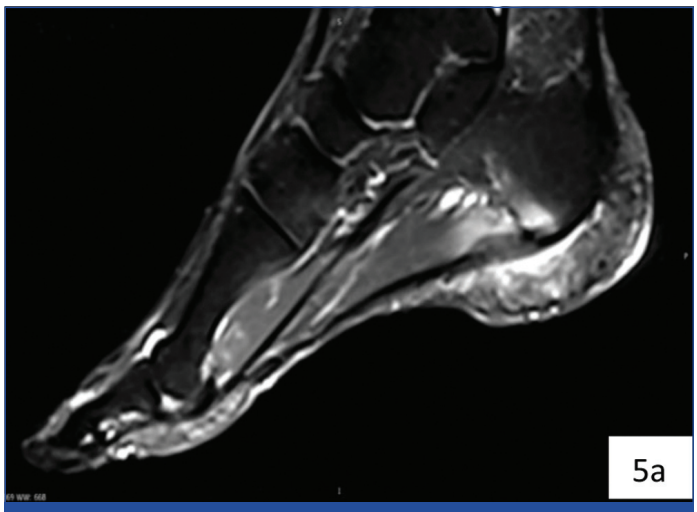
[Table/Fig-4a,b] demonstrating thickened plantar fascia in two different patients. As shown, the thickness was 5.5 mm in a patient measured by USG and was 8.2 mm in another patient measured on MRI.

[Table/Fig-4a]: Demonstrates plantar fascia thickening measurement on USG.

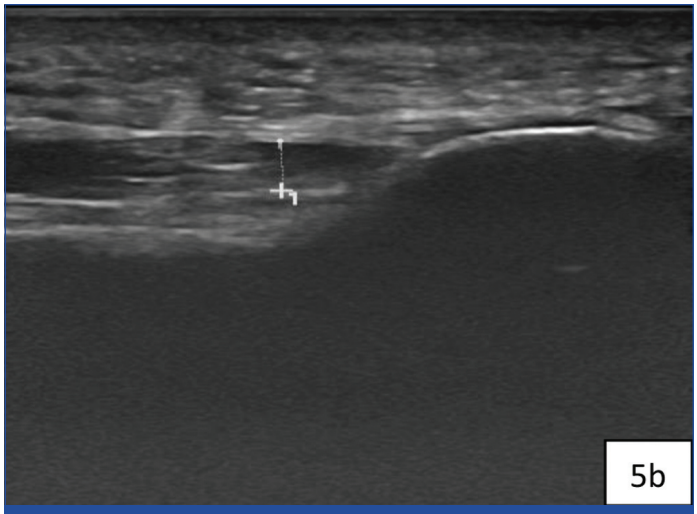
[Table/Fig-4b]: Shows the thickened plantar fascial measurement on sagittal MRI PDFS s sequence.

The ruptured plantar fascial fibres showed PDFS hyperintensity on MRI as showed in [Table/Fig-5a] and focal discontinuity and increased echogenicity on USG as shown in [Table/Fig-5b].

The accuracy, sensitivity, specificity, PPV and NPV of USG as compared to MRI regarding plantar fascia thickness in diagnosis of PFS was found to be 80%, 60%, 82.9%, 33.3% and 93.5%, respectively. The accuracy, sensitivity, specificity, PPV and NPV of plantar fascia rupture between USG and MRI was found to be 95%, 75%, 100%, 100% and 94.1%, respectively [Table/Fig-6].



[Table/Fig-5a]: Sagittal PDFS MRI image shows ruptured plantar fascia.



[Table/Fig-5b]: Shows the increased echoes in a patient with ruptured plantar fascia on USG.

Parameters	Accuracy	Sensitivity	Specificity	PPV	NPV
Plantar fascia thickness	80%	60%	82.9%	33.3%	93.5%
Plantar fascia fiber rupture	95%	75%	100%	100%	94.1%
Altered echoes/ intensity	82.5%	91.7%	0%	89.2%	0%
Adjacent heel pad oedema	92.5%	92.9%	91.7%	96.3%	84.6%

[Table/Fig-6]: Accuracy, sensitivity, specificity, PPV and NPV of ultrasound for the various parameters assessed.

The mean plantar fascia thickness was found higher in overweight BMI group i.e., 25-29.9 kg/m^2 when measured from MRI technique whereas mean plantar fascia thickness was found higher in obese BMI group i.e., ≥30 kg/m^2 when measured from USG technique. There was no statistical significance between the normal, overweight and obese group for plantar fascia thickness measured by ultrasound and MRI [Table/Fig-7]. The association of age group with plantar fascia thickness was not found significant in both MRI and USG technique (p-value >0.05) [Table/Fig-8].

DISCUSSION

Plantar fasciitis is degenerative disease caused due to overuse trauma leading to microtears [19]. The proximal third of the PF is classically involved; however, distal PFS has recently been recognised as a cause of heel pain [24]. Plain radiography, ultrasound and MRI all provide valuable information regarding the PFS diagnosis. Doppler ultrasound is often normal in PFS, but it may demonstrate various degrees of hyperaemia [25,26].

In comparison with a study by Sabir N et al., which aimed to investigate the utility of USG in diagnosing PFS, the PPV is significantly higher (83.3%) than that of the present study (33.3%) and NPV is lower (83.5%) than the present study (93.5%). The predominantly included subjects in this study were females (66 out of 77) as the present study (29 females out of 40). Also, as compared to the present study, diagnostic accuracy was lesser (42.7% for PF thickening and 1.3% for PF rupture). They concluded that USG can also serve as an effective tool and may substitute MRI in the diagnosis of PFS [18].

Abdel-Wahab N et al., found that the diagnostic accuracy was 69.5% for abnormal focal echogenicity within the fibers, 60.8% for PF thickening, 78.2% for perifascial oedema, 69.5% for PF rupture and the lowest diagnostic accuracy of ultrasound was in detection of associated calcaneal spur (56.5%).The accuracy values of the ultrasound found in this study was lower that the values of the present study in general [19].

BMI (kg/m²)	Plantar fascia thickness (mm) MRI				Plantar fascia thickness (mm) USG				p-value
	Mean±SD	95% CI for mean	Median	Minimum, Maximum	Mean±SD	95% CI for mean	Median	Minimum, Maximum	
18.5 to 24.9	4.66±0.61	(4.35,4.97)	4.5	4.0,6.3	4.42±0.66	(4.08,4.76)	4.5	3,5.8.0	0.563
25 to 29.9	5.30±1.32	(4.66,5.94)	5.1	4.0,8.5	4.58±0.64	(4.27,4.89)	4.3	3.6,6.0	0.669
30 or more	4.88±1.00	(3.28,6.47)	4.6	4.0,6.3	4.70±0.89	(3.28,6.12)	4.4	4.0,6.0	0.881

[Table/Fig-7]: Mean plantar fascia thickness according to BMI in both MRI and USG technique.
Chi-square test was used to measure statistical significance

Variables	Categories	Age group			Chi-square	p-value
		25-35 years	36-45 years	>45 years		
Plantar fascia thickness (mm) (MRI)	≤4	2 (9.5%)	2 (18.2%)	1 (12.5%)	3.284	0.543
	4.01 to 4.5	7 (33.3%)	5 (45.5%)	1 (12.5%)		
	>4.5	12 (57.1%)	4 (36.4%)	6 (75.0%)		
Plantar fascia thickness (mm) (USG)	≤4	6 (28.6%)	3 (27.3%)	0 (0.0%)	3.543	0.516
	4.01 to 4.5	8 (38.1%)	4 (36.4%)	3 (37.5%)		
	>4.5	7 (33.3%)	4 (36.4%)	5 (62.5%)		

[Table/Fig-8]: Association of age group with plantar fascia thickness (MRI and USG).
Note: Simulated p-value was calculated when one or more expected cell count was 0

Kapoor A et al., found that USG had a sensitivity of 65.8% and specificity of 75%, which were lower than the values obtained in the present study. It was concluded that the combination of elastography with ultrasound improved the accuracy from 68% to 96% and also stages the extent of disease, with the results being comparable to MRI [20]. In a study by Fabrikant JM and Park TS, PF thickness was found to be significantly increased in patients with PFS which is consistent with the present study [23].

In a study by Darwish M et al., USG was found to be 85.71% accurate for abnormal focal thickening and abnormal echogenicity within the plantar fascia, and 76.19% accurate for soft tissue oedema and 38.1% accurate for calcaneal spur. The present study did not measure the accuracy levels for calcaneal spurs. The accuracy for plantar fascial thickening and soft tissue oedema was higher than the present study. The author concluded that USG has a similar accuracy level as MRI and it can be effective in diagnosing clinically suspected PFS [21]. Comparison of accuracy of ultrasound for PF thickening and PF rupture with different studies is shown in [Table/Fig-9] [18,19,21].

Author	Place and year of the study	Title	Plantar fascia thickening	Plantar fascia rupture
Sabir N et al., [18]	Department of Radiology, Faculty of Medicine, Pamukkale University, Denizli, Turkey 2005	Clinical Utility of Sonography in Diagnosing Plantar Fasciitis (PFS)	42.7%	1.3%
Abdel-Wahab N et al., [19]	General Hospital, Radiology Department, Doha, Qatar2008	High-resolution ultrasonographic diagnosis of Plantar Fasciitis (PFS): a correlation of ultrasound and MRI	60.8%	69.5%
Darwish M et al., [21]	Department of Radiodiagnosis, Faculty of Medicine, Alexandria University, Egypt 2019	Evaluation of the Diagnostic Role of Ultrasonography (USG) Compared to MRI in Plantar Fasciitis (PFS)	85.7%	NA
Present study	Department of Radiodiagnosis, SRM Medical College and Research Centre, Tamil Nadu, India	Diagnostic Accuracy of USG with Magnetic Resonance Imaging (MRI) in patients with Plantar Fasciitis (PFS)	80%	95%

[Table/Fig-9]: Comparison of accuracy of ultrasound for PF thickening and PF rupture with different studies [18,19,21].

Limitation(s)

Calcaneal spurs, which is commonly associated with PFS could not be visualised optimally on USG images. Hence, its association could not be adequately assessed. MRI and USG images were only taken on sagittal plane. There is a possibility that images taken in coronal/axial sections will have a higher chance of detecting PFS. This will alter the sensitivity and specificity of USG compared to MRI.

CONCLUSION(S)

In spite of the fact that MRI is the imaging methodology of choice in the diagnosis of PFS, accuracy of ultrasound was comparable to that of MRI and it can very well be used as the initial investigation for clinically suspected PFS patients and follow-up of diagnosed cases. In patients with increased BMI, plantar fascia thickness was found to be increased, proving that obesity is a risk factor for PFS. Hence, USG is recommended as the screening modality of choice for PFS in patients with heel pain.

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