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Sonoelastographic evaluation of plantar fascia in patients with plantar fasciitis: A case–control study

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ABSTRACT

Background: Plantar fascitis causes heel pain and the thickened fascia has specific morphological features that can be utilized for early diagnosis through sonoelastographic evaluation. **Aims and Objectives:** This case–control study was conducted to find out the role of sonoelastography in the diagnosis of plantar fasciitis (PF). **Materials and Methods:** A case–control study was conducted in the department of radiodiagnosis in a teaching medical college. Thirty clinically diagnosed PF patients and thirty controls were recruited based on selection criteria. Shear wave elastography (SWE) was done for all participants and the thickness of plantar fascia and strain ratio was compared between the groups. Plantar fascia thickness (mm) and elasticity (stain ratio) were considered as the primary outcome variable. coGuide software was used for data analysis. **Results:** The mean age of the cases was 46.73±16.92 years and controls was 47.5±16.1 years. There was no statistical difference observed between cases and controls in age, sex, and body mass index. There was a statistically significant difference in thickness of the plantar fascia (P<0.001) between cases (4.18±0.77 mm) and controls (3.33±0.71 mm). The difference in strain ratio between study groups was statistically significant (P<0.001). The strain ratio had excellent predictive validity with the area under the curve of 0.929 (P<0.001). Data were analyzed using co-Guide software, V.1.03. **Conclusion:** Ultrasound elastography can detect the thickening of the plantar fascia and strain ratio has excellent predictive validity in predicting PF.

Key words: Elasticity imaging techniques; Fasciitis; Plantar; Sonoelastography; Ultrasonography

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INTRODUCTION

Plantar fasciitis (PF) is one of the most common causes of heel pain; it occurs due to plantar fascia inflammation and can also affect the perifascial structures.[1] The characteristic symptoms, including pain, are observed when getting out of bed and during initial weight bearing in the morning and are generally aggravated with increased sports activities.[2] Various studies have shown the prevalence of PF ranges from 8 to 10% of the population.[3,4] The diagnosis of PF is made based on the presentation of clinical symptoms. However, magnetic resonance imaging and ultrasonography are sometimes used to aid the diagnosis of this condition.[5-7] Although ultrasound (US) is not crucial for diagnosing PF, it may confirm a diagnosis or be used as imaging guidance for injection procedures and is also suited for serial follow-ups. Typical conventional US findings of PF include thickening of the plantar fascia, loss of normal striation, a hypoechoic area within the fascia, and perifascial fluid.[8] These morphological changes, however, are not always observed with the conventional US in patients with PF.[8,9] US elastography is an ultrasonographic imaging technique that allows the non-invasive estimation of tissue stiffness.[10] Recently, US elastography was used to reveal that the plantar fascia softens in patients with PF. There are reports of improved diagnostic performance of US elastography over the gray-scale US, and it has also been shown to assist in cases with inconclusive gray-scale US findings.[11-13] The treatment

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of PF is primarily non-operative and includes stretching exercises, non-steroidal anti-inflammatory drugs, US diathermy, local injection, shock wave therapy, and so forth.[14] Significant improvements in the plantar fascial thickness and hypoechogenicity were observed after treatments such as local injection and extracorporeal shockwave therapy in the previous studies.[2,14] The previous studies have shown that the US elastography, when used to diagnose PF, has characteristic features of fascial thickening, blurring of fascial borders, and hypoechoic texture.[9,12,15] However, there is a hiatus in the sensitivity and specificity studies on US elastography in predicting PF. Hence, the aim of this present study was to find the role of US in the diagnosis of PF.

Aims and objectives

This case–control study was conducted to find out the role of sonoelastography in the diagnosis of plantar fasciitis (PF).

MATERIALS AND METHODS

A case–control study was conducted in the department of radiodiagnosis of Sri Devaraj Urs medical college from May 2020 to December 2020. Institutional Human Ethical Committee clearance was obtained and informed written consents were signed by all participants. Patients with a clinical diagnosis of PF were considered cases and controls were patients attending the outpatient department with other ailments. The selection was made based on a simple random sampling method. Patients with rheumatic disease, previous injection therapy in the past 6 months, history of trauma, and a pregnant woman were excluded from the study.

Ultrasonographic examinations were performed for both cases and controls. Patients were in the prone position and ankle in dorsiflexion. An US beam was placed perpendicular to the plantar fascia so that anisotropy could be avoided. The plantar fascia on imaging appears as a "hyperechoic band with linear fibers" on the background of a hypoechoic matrix. The thickness of the fascia was measured within 1 cm of the calcaneal attachment. After the normal thickness, range of plantar fascia was assessed in the control group, the imaging was done on symptomatic patients. Body mass index (BMI) was calculated in both cases and controls. A region of interest of 2-mm-diameter in the most rigid part of the PF in the area of the greatest PF thickness was considered. Elastography was displayed as a color-coded image within a rectangular region of interest, superimposed over B-mode US image obtained simultaneously. The color represented the relative stiffness of the tissues within the ROI and ranged from red (soft) to blue (hard) in a continuous spectrum. For quantitative measurement of strain ratio, using the built-in analysis tool by Philips EPIQ 5G Ultrasound Machine. Ultrasound elastography images chosen for the analysis were those obtained with gray-scale sonography and were of good quality (plantar fascia was horizontal and with clear upper and lower borders). Two ROIs were selected for the strain ratio measurements: the calcaneus (S2) and the plantar fascia (S1). A 1-cm-wide free-form sample line was drawn along the fascial margin, centred within 1 cm of the calcaneal attachment, where the plantar fascial thickness was measured (The relative stiffness in the ROI, scaled between 0 and 6, was measured. The calcaneus bone measured 6 in all the images, which indicates the stiffest structure on the screen. This process was then repeated by another radiologist to obtain a second measurement of the strain ratio. The mean score of the 2 measurements was considered as the fascial elasticity. The patient data was entered in a pre-structured questionnaire and confidentiality was maintained throughout the study.

Sample size calculation

The sample size was calculated assuming the expected proportion/prevalence of plantar fascia as 47.56%, desired sensitivity of the combination of SWE and US as 100% as per Gatz et al.[16] The other parameters considered for sample size calculation were 95% confidence level and 4% precision for sensitivity. The formulae proposed by Buderer.[17] were used to calculate the sample size based on sensitivity and specificity separately. Based on sensitivity, as per the formula mentioned above, the required diseased cases were 24. By considering the 1:1 ratio, controls were calculated to be 24. To account for the non-participation rate of about 20 %, another six subjects were added to the sample size. Hence, the final required sample size was 30 subjects in cases and controls each at the time of recruitment.

Statistical analysis

Plantar fascia thickness (mm) and elasticity (stain ratio) were considered as the primary outcome variable. The study group (cases/control group) was regarded as the primary explanatory variable. Continuous variables were analyzed by Independent-samples t-tests and expressed as the mean and standard deviation. Moreover, the categorical variables were analyzed by the Chi-square expressed as a number. The ability of strain ratio in predicting PF was evaluated by the area under the curve (AUC) of the receiver operating characteristic (ROC) curve. The sensitivity, specificity, predictive values, and diagnostic accuracy of the screening test, along with their 95% CI, were presented. A statistically significant difference was set at $P<0.05$. Data were analyzed using coGuide software, V.1.03.[18]

RESULTS

A total of 60 subjects were included in the final analysis.

The mean age of cases (46.73±16.92 years) and controls (47.5±16.1 years) did not differ significantly (P=0.858). There were 19 (63.33%) males and 11 (36.67%) females in the cases and control group. The difference in gender between the study groups is found to be insignificant, with P=1.000. The mean BMI in the cases group was 25.41±3.16 kg/m^2 and the control group was 23.86±2.09 kg/m^2. The difference in BMI between study groups was statistically significant (P=0.029). The thickness of the plantar fascia is statistically significantly different (P<0.001) in cases (4.18±0.77 mm) and controls (3.33±0.71 mm). Out of 30 participants with cases, the majority, 56.67%, was green color and controls group, the majority 53.33% was a blue color. The mean strain ratio in the cases group was 0.72±0.07 mm^3 and the control group was 0.96±0.14 mm^3. The difference in strain ratio between study groups was statistically significant (P<0.001) (Table 1).

The strain ratio had excellent predictive validity in predicting PF, as indicated by the AUC of 0.929 (P<0.001) (Figure 1).

In cases, 27 (90%) people had low strain ratio (<0.785) and 3 (10%) people had high strain ratio (≥0.785). In controls, 3 (10%) people had low strain ratio (<0.785) and 27 (90%) had high strain ratio (≥0.785). The difference in the proportion of strain ratio between cases and controls was statistically significant (P<0.001) (Table 2).

Strain ratio had sensitivity of 90% (95% CI 73.47% to 97.89%) in predicting PF, Specificity was 90% (95 CI 73.47–97.89%), false positive rate was10% (95 CI 2.11–26.53%), false negative rate was 10% (95 CI 2.11–26.53%), positive predictive value was 90% (95 CI 73.47–97.89%), negative predictive value was 90% (95% CI 73.47–97.89%), and the total diagnostic accuracy was 90% (95 CI 79.49–96.24%) (Table 3).

DISCUSSION

The present study findings show that patients with PF have significantly high plantar fascia thickness in SWE. Furthermore, a significant difference in strain ratio was observed between the cases and controls. The strain ratio had an excellent predictive validity in predicting PF with 90% sensitivity and specificity, respectively. This confirmed that SWE could identify signs of PF. Of all the characters, thickening of fascia and strain ratio is more characteristic of PF.[19]

The present study showed that the sensitivity and specificity of strain ratio in US elastography in predicting PF were 90%, respectively. This was similar to a previous survey of Sconfienza et al.,[12] where they proved that US elastography had a 96% sensitivity and 94% specificity.

The plantar fascia forms a tough connective tissue that supports and maintains the longitudinal arch of the foot. It is the "tendon aponeurosis" for the superficial layer of the intrinsic muscles of the foot. Its function is to absorb and disperse the loading/weight-bearing forces across the mid-foot joints and help during gait.[20]

SWE has been tested previously to evaluate tendons that contain collagen fibers and have elastic properties similar to those of the plantar fasciae.[21,22] The present study findings are identical to Wu et al.,[11] which showed that the plantar fasciae in PF patients are significantly less elastic than healthy control subjects. There is very little literature on the role of US elastography in detecting early changes in plantar fascia thickness before catching findings on routine US are possible.[23] Increased vascularity of plantar fascia is also seen in patients with PF. This hyperemia can be assessed by color Doppler. However, it can be better visualized by power Doppler.[24,25] Overweight and high BMI have been considered as a causative factor in the progress of PF. The present study showed that the mean BMI for cases was more elevated, 25.41±3.16 kg/m^2, compared to 23.86±2.09 kg/m^2 in the control group. This is similar to the study conducted by Sabir et al., where the BMI (≥25 kg/m^2) was significantly higher in the cases group.[26] SWE can also assess the treatment response following post-local steroid injection and can guide the

Table 1: Comparison of baseline parameter between study group (n=60)

Parameter	Study group (Mean±SD)		P-value
	Cases (n=30) (%)	Controls (n=30) (%)	
Age (in years)	46.73±16.92	47.5±16.1	0.858
Gender			
Male	19 (63.33)	19 (63.33)	1.000
Female	11 (36.67)	11 (36.67)	
BMI (in kg/m^2)	25.41±3.16	23.86±2.09	0.029
Plantar fascia thickness (mm)	4.18±0.77	3.33±0.71	<0.001
Color Code			
Blue	0 (0)	16 (53.33)	*
Green	17 (56.67)	0 (0)	
Red	13 (43.33)	14 (46.67)	
Strain ratio (mm^3)	0.72±0.07	0.96±0.14	<0.001

*No statistical test was applied- due to o subjects in the cells

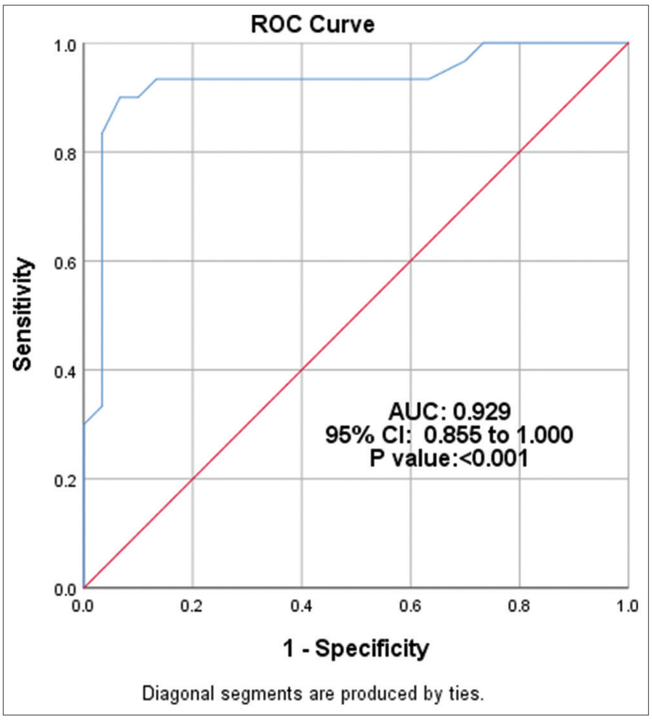

Figure 1: Predictive validity of strain ratio in predicting plantar fasciitis (receiver operating characteristic analysis)

Table 2: Comparison of study group with strain ratio (n=60)

Strain Ratio	Study Group		Chi-square	P-value
	Cases (n=30)	Controls (n=30)		
Low (<0.785)	27 (90)	3 (10)	38.400	<0.001
High (≥0.785)	3 (10)	27 (90)		

Table 3: Predictive validity of strain ratio in predicting plantar fasciitis (n=60)

Parameter	Value (%)	95% CI	
		Lower	Upper
Sensitivity	90.00	73.47	97.89
Specificity	90.00	73.47	97.89
False positive rate	10.00	2.11	26.53
False negative rate	10.00	2.11	26.53
Positive predictive value	90.00	73.47	97.89
Negative predictive value	90.00	73.47	97.89
Diagnostic accuracy	90.00	79.49	96.24

clinician in choosing the management regimens and follow-up. However, the major limitation of ultrasonography is that it is operator-dependent. The burden of the present study is that a follow-up of the patients was not done.

CONCLUSION

Sonoelastography can be used for the diagnosis of PF. Thickening of fascia, blurred margins, and hypoechogenicity are the diagnostic features. The strain ratio has 90% sensitivity and specificity in predicting PF. Sonoelastography can guide the physician in primary diagnosis and follow-up.

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R- Conceptualized the study and played primary role in compiling, analysis, and interpretation of the data. **RRB, DN, YUL, SHS, and AVSNR-** All the drafts were prepared, reviewed, and final draft was approved; **RRB, DN, YULA, SHS, and AVSNR**- Contributed in fine tuning of the proposal and contributed in data collection and entry. Reviewed the results and contributed to preparation and review of drafts. All the authors have read and approved final version of the manuscript. All the authors take complete responsibility for the content of the manuscript.

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