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ORIGINAL ARTICLE

In the Management of Plantar Fasciitis: Is Multi-Detector Computed Tomography a Reliable Imaging Modality?

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ABSTRACT

Background: The aim of this study was to prove the reliability of plantar fascia MDCT thickness measurement in plantar fasciitis diagnosis, using US as an standard. **Methods**: We enrolled 110 participants (80 patients and 30 healthy controls). The patients who had painful heel and admitted to the clinic of the Rheumatology then sent to the Radio-diagnosis department. Adult patients with uni/bilateral heel pain considered as inclusion criteria. Exclusion criteria involved the open wound, foot fracture and infection. All participants underwent the steps: history taking, clinical examination and then examined at the same day by US and 128-MDCT. **Results**: Plantar fasciitis diagnosis by MDCT showed good sensitivity and diagnostic accuracy values. In our study increased plantar fascia thickness was reliable outcome in all patients with the clinical diagnosis of plantar fasciitis. Results revealed that the plantar fascia thickness by US for patients group was 5.65±1.23 mm. We illustrated that the plantar fascia thickness by MDCT for patients group was 5.24±1.20 mm. Our results of small bias and variability measures regarding plantar fascia thickness in plantar fasciitis patients by MDCT considered a good indicator of reliability. **Conclusion:** In previous literatures, US was the first imaging modality as its availability, least cost and lack of radiation. However, US couldn't evaluate the bony lesions, operator dependent, require prone position (uncomfortable). From these weak points, we searched for another imaging modality which had the same accuracy of US in diagnosis and could manage the mentioned weak points. MDCT was a reliable imaging tool for depiction and measurement the plantar fascia thickness.

Keywords: Plantar fascia (PF), plantar fasciitis (PFS), musculoskeletal ultrasound, multi-detector computed tomography (MDCT).

INTRODUCTION

The plantar fascia was a strong connective tissue part that preserved the longitudinal foot arch [1, 2]. The PF composed of three bundles: central, lateral and medial. The thickest of the three was the ***central portion*** which came from the medial calcaneal tubercle and distally, it separated into five digits that ended in the metatarsophalangeal joints. ***The lateral portion*** originated from the lateral border of the medial calcaneal tubercle and inserted into the metatarsal joint capsule of little toe. The thinnest of others was ***the medial portion*** which aroused from the mid portion of the central bundle and ended in the metatarsal joint capsule of big toe [3]. The average maximum thickness of the PF, at its central bundle, was standard to be 4.0 mm [4].

PFS

The most familiar type of PF injury was Plantar fasciitis (PFS) which expected to involve ten percentage of the general population during middle age [5,6]; additionally eight percentage of foot lesions in runners caused by PFS [7].

An excessive physical activity, throbbing pain, toe walking pain, wearing improper footwear, and early pain in the medial heel region, obvious after a long time of immobility (for example, getting up from bed in the morning) were positive history data of PFS [8].

PFS anticipated provoking more than one million patients to request treatment yearly. It had a degenerative rather than inflammatory process [9]. The most typical portion of PF entailed in PFS was the proximal third of the central bundle [10]. The aetiology of plantar fasciitis was multifactorial. The repetitive stress on the PF, such as foot deformities, improper footwear and abnormal high body mass index considered risk factors for PFS. Also, the rough physical exercises that included a long time walking, running or standing entailed in bio-mechanical risk factors of PFS [11].

Radiology performed a chief corner together with patient's history and clinical examination in diagnosing PFS and in assessment of outcome results after treatment [12].

Musculoskeletal ultrasound was the gold standard for discriminating normal PF and PFS. It assessed edema or thickening of PF; thickness of more than 4 mm was a diagnostic item for PFS [13].

PF exhibited a fibrillar feature in US examination due to the hyperechoic nature of type I collagen fibre bundles within a hypoechoic background pattern. Sonographic criteria of PFS involved absent of fibrillar nature, increased thickness over 4 mm, perifascial collections and calcifications within the PF. Hyperaemia was famous criteria of tendinopathy due to neurovascular growth and could be the source of the pain. It picked up by Doppler ultrasound. In the same way, Doppler ultrasound detected hyperaemia in the PF, near its proximal insertion, in PFS cases [9].

Adjuvant role of US in PFS was the ability to perform medical injections under US guidance. This modality removed the fault injection into the fat pad. Consequently, we avoided the atrophy of the fat tissue, which sequentially reduced the frequencies of injections [14].

Multi-detector CT didn't routinely be involved in the analysis and measurement of the PF thickness. With the presence of advocated MDCT, the visualization and quantification of soft tissue, such as tendons and plantar fascia were accessible and reliable [15].

The multi-planar reformatting (MPR) enabled to visualize CT images in the sagittal, coronal and axial planes and one volume view to delineate the exact structure in concern. The thickness of the PF at the fifth of the distance measured from the apex of the medial calcaneal process to the most plantar surface of the sesamoids beneath the metatarsal head of big toe or most medial part of the second metatarsal head as illustrated in D'Ambrogi et al. [16]. The MPR sagittal scans were the ideal plane to calculate PF thickness measurements with the thickest portion at the location of interest [17].

METHODS

A prospective cross-sectional study carried out at the Radiology Department from the period December 2016 to February 2018. Approval from the hospital ethics committee and informed consent was obtained from the patient himself. Our study enrolled eighty patients (111 feet) and thirty healthy individuals (30 feet) served as control. The selected patient group picked out from PFS patients who admitted to the outpatient clinic of the Rheumatology and Rehabilitation department then sent to the Radio-diagnosis department. We enrolled adult patients (>18 years old) presenting with unilateral or bilateral inferior heel pain. Our exclusion criteria involved patients with open wound, infection in plantar surface of foot, history of surgery, history of trauma, fracture in the foot or ankle. Also, we added to the exclusion list the neuropathic pain as diabetes mellitus and previous corticosteroid injection of the heel within six months preceding the examination.

All patients and control underwent the subsequent steps: complete history taking, detailed clinical examination and then examined by both musculoskeletal US and 128-MDCT on the same day.

1-Msculoskeletal US examination:

The examination had been done by YD-9000 A (China) and Fukuda denshi (UF-400AX) (Japan). The two ultrasound devices were with: fully digital portable US system, B-mode, M-mode and active convex

and linear probes. All patients had real-time gray-scale US with a 5–8 MHz probe.

Our participants positioned in prone posture with ninety degrees dorsiflexion of the ankle joint. The radiologist scanned from participant's right-hand side, and PF assessed in sagittal profile to evaluate the echogenicity (hypoechoic/ hyperechoic), linearity or plantar fascia fibers (parallel/not parallel). PF thickness was measured in the anterior side of calcaneus bone's inferior border, where PF was inserted into calcaneus bone. Measurements carried out by two radiologists, three times by each examiner, and the average value was recorded, as the examination was extremely operator-dependent. The two radiologists were blinded; they did not know the MDCT outcome and other operator's ultrasound report.

2-MDCT examination:

-Examination Technique:

MDCT examination carried out for all participants enrolled in our work. All MDCT examinations performed with a 128-channel MDCT scanner (Philips ingenuity 128) using the subsequent parameters: detector row configuration, 128 x 1 mm; collimation, 1 mm; slice thickness, 0.90 mm; pitch, 1.375; reconstruction interval, 0.45 mm; 300 mAs; 120 kVp. To obtain direct axial scans, Patients scanned in supine position with flexed knee and plantigrade foot as the participant would tolerate. Patient's feet towards the gantry without gantry tilt. No specific patient preparation required. MDCT protocol consists of volumetric data acquisition starting from above ankle joint and ending when the calcaneus ends.

Our method in the measurement calculated the thickness of PF at the fifth distance between the apex of the medial calcaneal process and the most plantar aspect of the sesamoids under the metatarsal head of big toe or most medial portion of the second metatarsal head.

All measurements plotted at the sagittal scan and cross-referenced in coronal and axial planes to confirm structure measured. Measurements calculated in a maximized scan and confirmed at various levels of magnification between minimized and maximized scans to gain the most precise measurement.

A single, blinded radiologist plotted thickness measurements at the previous mentioned position. After three days, the thickness measurements replicated on these same archived data set. The presentation order of the data set was randomized previous to every measurement session to avoid memory bias.

Statistics

Data were analyzed using SPSS version 20.0 and measurement reliability was analyzed by calculating the difference between the original and repeat measurements. Bias, the tendency for systematic error in the repeat measurements, was analyzed by calculating the mean of the differences. Variability in the repeat measurements was evaluated by calculating SD of the differences. Differences between groups were analyzed by calculating means and standard deviations. Differences between means were tested for statistical significance with using Chi-square test (X^2) ($P < 0.001$).

Sensitivity, specificity and diagnostic accuracy of MDCT findings to identify plantar fasciitis were also tested.

RESULTS

Our study enrolled 80 patients (111 feet) and 30 control subjects (30 feet). Patient's group characteristics could be seen in ***(table 1).***

Table (2) represented the PFS diagnosis using PF thickness (> 4 mm) criteria by US measurement and MDCT measurement. ***Table (3)*** showed the sensitivity, specificity and diagnostic accuracy of MDCT in diagnosis of

PFS based on increased thickness of PF above four mm.

Patients group were compared with control group regarding the PF thickness using musculoskeletal ultrasound and MDCT, showed that: there was a highly statistically significant difference between both groups; using Chi-square test (X^2) (P <0.001) as shown in ***Table (4)***.

Regarding the PF thickness measurement by MDCT, bias and variability were small (-0.32 and1.02 mm), respectively ***(Table 5)***.

Table 1. Patients' group characteristics.

Characteristics	n	%
Gender		
Male	20	25 %
Female	60	75 %
Uni/bilateral feet		
Unilateral	49	61.2%
Bilateral	31	38.8%
Age		
35- 40 years old	8	10%
40- 45 years old	12	15%
> 45 years old	60	75%

Table 2. Plantar fasciitis diagnosis using PF thickness (>4 mm) criteria by US measurement and MDCT measurement

PFS based on MDCT	PFS based on US (Gold standard)		
	Positive	Negative	Total
Positive	**99**	**3**	**102**
Negative	6	3	9
Total	105	6	111

PFS=plantar fasciitis

Table 3. Sensitivity, specificity and diagnostic accuracy of 128 MDCT in diagnosing PFS by increased PF thickness compared to musculoskeletal US (gold reference standard)

Sensitivity (%)	Specificity (%)	DA (%)
94.29%	50%	91.89%

DA=Diagnostic accuracy

Table 4. Comparison between patients group and control group regarding the thickness of PF by US and MDCT.

	Patients(n=80)	Control(n=30)	P value
PF thickness by US (mm)	**4.28-8.12(mean range)**	**3.21-3.92(mean range)**	<0.001
	5.65±1.23(mean±SD)	**3.51±0.23(mean±SD)**	
PF thickness by MDCT (mm)	**4.21-7.80(mean range)**	**3.13-3.80(mean range)**	<0.001
	5.24±1.20(mean±SD)	**3.52±0.18(mean±SD)**	

PF=plantar fascia

Table 5. Repeatability study: PF thickness at 1/5 PF length by MDCT

Location	Bias mean Difference (mm)	Variability standard deviation(mm)
PF at 1/5 PF length	**-0.32**	**1.02**

PF= plantar fascia

Figure 1. MDCT sagittal MPR image of healthy control subject (46 years old female) showed normal thickness of PF (white arrow).

Figure 2. MDCT sagittal MPR image of PFS patient (55 years old female) showed PF thickness measurement equal to 5.75 mm (black line) at 1/5th of its length (blue line) with (green line) represented the whole course of PF.

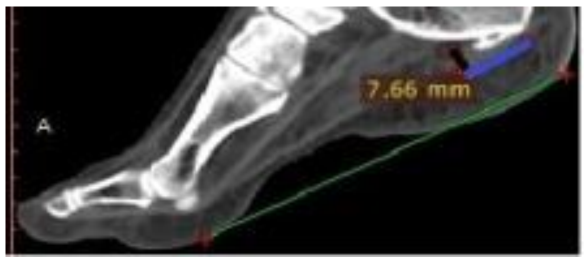

Figure 3. MDCT sagittal MPR image of PFS patient (60 years old male) showed PF thickness measurement equal to 7.66 mm (black line) at 1/5th of its length (blue line) with (green line) represented the whole course of PF.

Figure 4. MDCT 3D image of PFS patient (49 years old female) showed obvious PF thickness (white arrow).

DISCUSSION

Our patient group was sixty females and twenty males, this matched McMillan et al. [18], Kapoor A et al. [19] and Fabrikant J et al. [20] who proved that superior female percentage than male, with entirety 97 males and 186 females, collectively.

Sixty patients enrolled in our research, their age above forty five years old. This agreed with McMillan et al. [18], Kapoor A et al. [19] and Fabrikant J et al. [20] who stated that the age of their cases ranged from forty two years old to fifty eight years old with a mean age of fifty years. Also, Ozdemir et al. [21] who reported that PFS frequently noticed in the age of forty to sixty years old.

Our statistical analysis illustrated good sensitivity (94.29%) and diagnostic accuracy (91.89%) values, for PFS diagnosis by MDCT.

The associated fat tissue edema could cause unreal thick PF measure than it really was when measured by MDCT. Therefore, normal PF thickness (<4 mm) seemed abnormal, and false positive could occur more frequently (lower specificity = 50%) in MDCT. On the contrary, a real abnormal PF thickness (>4 mm) would be moreover diagnosed by the adjacent edema. Consequently, the false negative results were hardly detected (higher sensitivity = 94.29%).

Sabir et al. [22] and Abdel Wahab et al. [23] stated that musculoskeletal US in PFS diagnosis had 80.9% sensitivity and 69.5% DA values. So, MDCT in PFS diagnosis according to our results had better sensitivity and DA values.

In our study increased PF thickness was reliable outcome in all patients with the clinical diagnosis of PFS. Our results revealed that the PF thickness by US for patients group (80 patients with 111 feet examined) was 5.65±1.23 mm. This approved by Abdel-wahab et al. [23] who declared that; the PF thickness in PFS feet was (3.0–7.0 mm; 4.9 ± 1.3) measured by US which was significantly thicker than in the control group (1.1–2.4 mm; 1.7 ± 0.06); P < 0.05. Also, our results parallel to Wearing et al., 1n 2007 study (10 patients with 10 feet examined) the PF thickness was 6.1 ± 1.43mm.

Yet our outcome were higher than Akfirat et al. [24] study (25 patients with 29 feet examined) and the study by Ozdemir et al. [21] (39 patients with 41feet examined), which was 2.9± 0.6 mm. This might apparently due to number of included subjects of these studies.

Radwan A. et al. [8] concluded that any PF thickness above 4 mm considered a positive result for PFS diagnosis by US.

Our data revealed that the PF thickness by US for control group (30 control with 30 feet examined) was 3.51±0.23 mm. This matched with Wearing et al. [25] study (10 controls with 10 feet examined) the PF thickness was 3.5±1.43mm and Akfirat et al. [24] study (15 control with 30 feet examined) which was 3.62±0.68 and the study by Genic et al. [26] (30 control with 60 feet examined) the PF thickness was 3.5±0.3.

Our work illustrated that the PF thickness by MDCT for patients group was 5.24±1.20 mm and PF thickness for control group was 3.52±0.18 mm. This approved with preceding MR and US researches that diagnosed PFS, where control groups were shown to have PF thickness between 3.22 mm and 3.8 mm at the same sites to our measures [27]. **Fig. (1, 2, 3, 4)**

A high statistically significant difference (p<0.001) between patients group and the control group regarding PF thickness measurement by US and MDCT, proved by our result analysis. Our results agreed with the studies by Wearing et al. [25], Akfirat et al. [24], Genic et al. [26] and by Sabir et al. [22].

Our specific results of small bias and variability measures regarding PF thickness in PFS patients by MDCT considered a good indicator of reliability. So, we demonstrated that reliable measurements of PF can be made using MDCT images. This agreed with Bolton N. et al. [17].

CONCLUSION

The frequent reason of painful heel in the general population was PFS. Imaging modalities were necessary to prove the diagnosis and any coexistent lesions.

MDCT was a reliable imaging tool for depiction and measurement the PF thickness. It would also be more comfortable for patients because in US examination, patients had to be in prone position, which was uneasy mainly for obese participants. Furthermore, MDCT assessed bony portions of the heel, which could not be estimated in US. So, not only MDCT could diagnose PFS, but it could also assess or rule out other reasons of painful heel, such as micro-fracture and heel spur.

As an inexpensive, quick, easy availability, free radiation and dynamic imaging modality that also offered high-resolution illustration of the PF and comparison with the contra-lateral side, ultrasound believed to be the first choice modality for assessing PF disorders and following up the degree of improvement along the management plane.

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