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Research Article
Characterization of Foot Mycetoma Using Sonography and Color Doppler Imaging

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Abstract

Background and Objective: Mycetoma of the foot, commonly referred to as Madura foot, is a chronic granulomatous infection, which impacts vascularization of the affected region. This study aimed to evaluate foot mycetoma using Doppler and sonography techniques to identify the principle sonographic features and blood flow patterns associated with the condition. **Materials and Methods:** This was a cross-sectional prospective single-center study conducted at the Mycetoma Research Center (MCR) in Khartoum State, Sudan. Sixty patients with Madura foot were examined using a Duplex ultrasound machine with a 7-10 MHZ linear probe. Data was analyzed using SPSS software. The distribution of demographic data was evaluated by simple descriptive statistics. Statistical tests was performed using Student's independent t-tests to compare different forms of mycetoma and Chi-square tests to examine differences in blood flow patterns between fungal (eumycetoma) and bacterial (actinomycetoma) forms of the infection. **Results:** The presence of multiple cavities and aggregated grains were more common in eumycetoma than in actinomycetoma. The echotexture was significantly more heterogeneous in eumycetoma than in actinomycetoma ($p = 0.03$). Eumycetoma had higher vascularity than actinomycetoma. **Conclusion:** Mycetoma has characteristic sonographic features and patterns of vascularity, which are essential to differentiate between the fungal and bacterial forms of mycetoma.

Key words: Mycetoma, eumycetoma, actinomycetoma, sonography, vascularization

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Mycetoma is a local, progressive, chronic granulomatous infection involving invasion of the skin, soft tissues and sometimes bones by both fungi (eumycetomas) and bacteria (actinomycetomas)[1]. A triad of symptoms characterizes the disease-swelling of the affected area, multiple sinuses and a purulent discharge containing grains[2-4]. Mycetoma is an endemic health problem in tropical and subtropical regions, especially Sudan, India and South America[5]. The progression of mycetoma is slow and painless but may involve deep structures such as tendons of joints, muscles, bones and deep fascia. The infected skin manifests wooden fibrotic induration due to sclerosis of the dermis[3]. The prevalence of mycetoma is higher in males than females, with a 3.7:1 gender ratio[6]. Foot mycetoma has severe implications on health as it causes deformity of the limbs and amputation that may lead to severe disability[1].

Mycetoma is characterized by painless local swelling with multiple sinus tracts, abscesses, nodules and production of granules[1,7]. The diagnosis of mycetoma based on clinical presentation and identification of the causative agents. Materials from sinus discharge can be carefully investigated macro and microscopically to confirm visualization the grains[4,7]. Investigation of the grains provides rapid provisional identification of the etiological agent.

Several studies have demonstrated the sonographic appearance of foot mycetoma. The fungal grains of mycetoma appear as hyperechoic foci within hypoechoic lesions[8]. However, previous studies have not described the echotexture of the infected tissue. As such, Doppler assessment of blood flow in mycetoma of the foot could provide useful information on vascularity patterns. Characteristic ultrasonography features and blood flow patterns can lead to early diagnosis. This study investigated the sonographic features and vascular patterns that characterize the different types of mycetoma.
This study aimed to assess mycetoma in the foot using Duplex ultrasonography and to compare the sonographic features and patterns of vascularity between the eumycetoma and actinomycetoma forms of the condition.

MATERIALS AND METHODS

A cross-sectional study was conducted at the Khartoum State Soba Mycetoma Center for Scientific Research, from the period of February-August, 2018. A total of 60 patients with foot mycetoma confirmed by biopsy were recruited in the study. Sample size was calculated using a convenience sampling technique. Patients with a previous history of foot surgery were excluded from the study. The ethical committee of Alzaiem Alazhari University approved the study.

Sonographic procedure: Participants were evaluated in both sitting and supine positions. Three certified sonologists performed the sonography using a 7-10 MHZ linear probe and a Duplex ultrasound machine EUB-5500 (Hitachi, Japan). The sonography began by scanning the anterior part of the foot, at the ankle region, from the forefoot to the heel. The tissue echotexture and findings were assessed. Cavitation was classified as single and multiple. They appeared as thick-walled hypoechoic foci without acoustic enhancement in the infected bone. Three patterns of vascularity were identified: a) hyper-vascularity, defined as multiple vessels, which appeared as increased Doppler signals, (b) Moderate vascularity, in which the vascularity was lesser than that in the hyper-vascularity pattern and (c) Normal vascularity, defined by normal perfusion.

Statistical analysis: Data was analyzed using Statistical Package for Social Sciences (SPSS) (version 22, IBM Corp., Armonk, N.Y., USA). Descriptive statistics are summarized as means with standard deviation (SD) for quantitative variables. Nominal and categorical variables are summarized using frequencies and percentages. For normally distributed data, means were compared using Student's independent t-tests. Chi-square tests were used to evaluate differences in blood flow patterns between the two types of mycetoma. P-value less than 0.05 was considered to be statistically significant.

RESULTS

Sixty patients infected with foot mycetoma were enrolled in this study. The mean age was 27.23±3.25 years (Table 1). The incidence of foot mycetoma was significantly higher in males than females (46 vs. 14). Swelling and discharge with swelling were the most frequent clinical findings (present in 60 and 3 0 %, respectively, Table 2). Table 3 summarizes the comparison between Doppler and sonographic features of eumycetoma and actinomycetoma. Tissue echotexture was more frequently heterogeneous in cases of eumycetoma compared to that in actinomycetoma (in 44 vs. 9 cases, $p = 0.03$). Half of cases of foot mycetoma showed normal vascularity (30 out of 60 cases). Eumycetoma cases showed increased vascularity more frequently than

actinomycetoma (in 14 vs. 6 cases, p = 0.06). Sonography revealed that multiple cavities and aggregated grains were found in fungal mycetoma more often than in the bacterial form.

Figure 1 demonstrated the duration of fungal and bacterial types of mycetoma. It was noted that the chronicity of the infection was higher eumycetoma than actinomycetoma. The triad features of foot mycetoma was demonstrated in Fig. 2, which is a photograph of a 25 years old man with left foot mycetoma presenting multiple discharging sinuses, black grains and soft-tissue swelling. The pattern of blood flow was demonstrated in Fig.3a, b which demonstrated

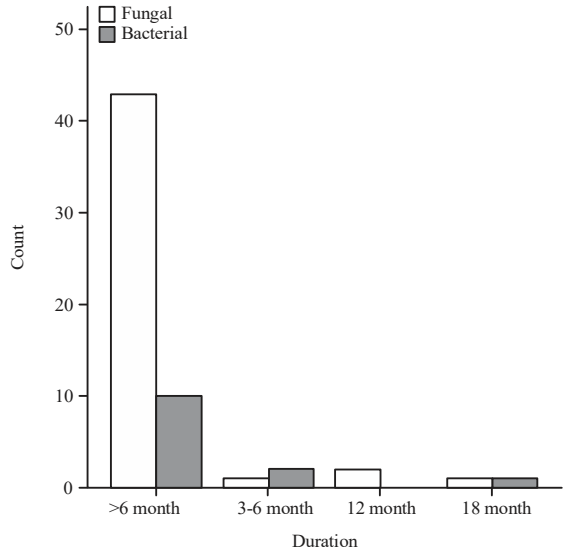

Fig. 1: Duration of mycetoma infection and types of mycetoma

Fig. 2: A photograph of a 25-years-old man with left foot mycetoma showing the triad features of mycetoma, multiple discharging sinuses and black grains and soft-tissue swelling

Table 1: Characteristics of the patients with foot-mycetoma and duration of the disease

Variables	Frequency	Percentage
Gender		
Female	14	23.3
Male	46	76.7
Age		
<18 years	7	11.7
19-25 years	13	21.7
26-30 years	16	26.7
31-35 years	24	40.0
Mean age = 27.23±3.25 years		
Duration of disease		
<6 months	53	88.3
3-6 months	3	5.0
12 months	2	3.3
18 months	2	1.7

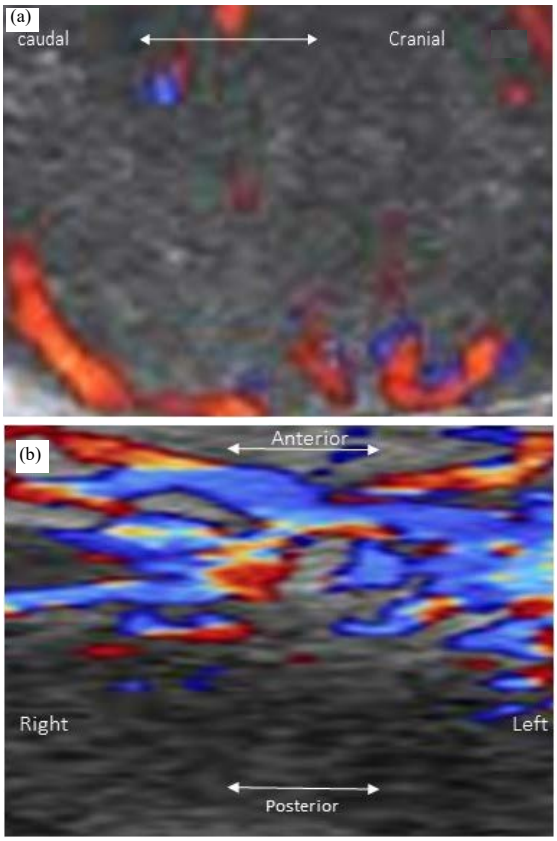

Fig. 3(a-b): (a) A color Doppler sonogram of a 28-year-old man presented with foot mycetoma confirmed as eumycetoma. The color Doppler sonogram was a longitudinal section of infected area with eumycetoma at the dorsum of the right foot reveals hypervascularity and (b) A color Doppler sonogram of a 30-year-old man presented with foot mycetoma confirmed as actinomycetoma. The Doppler sonogram was a transverse section taken at infected area with actinomycetoma at the dorsum of the right foot reveals moderate vascularity

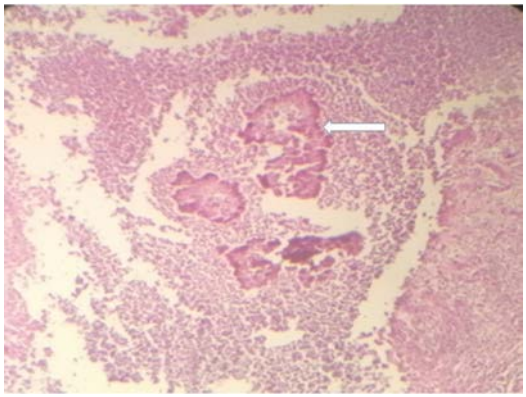

Fig. 4: Suppurative granuloma of black mycetoma (eumycetoma)
Arrow point to the fungus

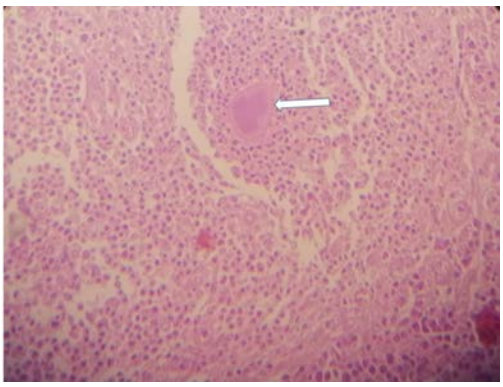

Fig. 5: Granuloma of yellow Madura (actinomycetoma)

Table 2: Frequency of clinical findings of foot-mycetoma

Clinical findings	Frequency	Percentage
Swelling	36	60.0
Discharge, swelling	18	30.0
Itching, swelling	4	6.7
Discharge	1	1.7
Discharge, itching, swelling	1	1.7
Total	60	100.0

Table 3: Comparison of doppler ultrasound findings between eumycetoma and actinomycetoma in patients with foot-mycetoma

Sonographic and doppler findings	Types		p-values
	Fungal	Bacterial	
Cavity			
Multiple	40	8	0.073
Single	7	5	
Grains			
Aggregated	15	3	0.40
Separated	32	10	
Echotexture			
heterogeneous	44	9	0.03
Homogeneous hypoechoic	3	4	
Vascularity			
hyper vascularity	14	6	0.06
moderate vascularity	3	3	
Normal vascularity	30	4	

patterns of flow in fungal and bacterial types of mycetoma. Eumycetoma revealed higher vascularity than actinomycetoma. The histopathological findings of eumycetomic and actinomycetoma were shown in Fig. 4 and Fig. 5 respectively.

DISCUSSION

This study describes the sonographic appearance and blood flow patterns in foot mycetoma. Demographic characteristics of the study revealed that the incidence of foot mycetoma is more common in males than females (76.7% of cases). This result is consistent with the findings of Relhan *et al.*[7] who reported that mycetoma infection of the foot was more prevalent in males. The high incidence was attributed to increased activity of males in agricultural fields compared to females. Further, that study reported that eumycetoma was more prevalent than actinomycetoma and this finding agreed with reports that eumycetoma is the most common form of the condition (70%)[9,10]. Mycetoma can affect any age group. In this study, it was observed to be common over the age of 30. This finding agrees with previous studies that report the incidence of mycetoma most common in patients between 20 and 40 years of age[1,3,10].

In the current study, ultrasonography revealed that numerous cavities and separated grains were more evident in cases of eumycetoma compared to actinomycetoma. In previous studies, the grains were reported to be thicker in eumycetoma than actinomycetoma and were found in compact aggregates[2,11,12]. The presence of grains was attributed to microcolonies of the causative agent. Similarly, cavities were attributed to bone destruction caused by the causative agent. Previous studies reported that bone cavities were frequent radiological findings in mycetoma[13,14]. Therefore, ultrasonographic features can be used to characterize the type of mycetoma in the foot, leading to early diagnosis.

Tissue echotexture was significantly more frequently heterogeneous in cases of eumycetoma compared to cases of actinomycetoma, a feature that has not been previously described. The sonographic appearance of eumycetoma and actinomycetoma cases in terms of hyper-reflective echoes that characterized the foci in the fungal type are without characterizing tissue echotexture[11]. The heterogeneity of echotexture in the fungal type of mycetoma might be attributed to more numerous, thicker grains and multiple thick-walled cavities that were more evident in the fungal

form than the bacterial one. Therefore, identifying the features of tissue echotexture with ultrasound can facilitate characterization of the type of mycetoma in the foot.

Analysis of blood flow patterns revealed that the majority of the infected foot demonstrated normal blood flow. Nonetheless, eumycetoma cases had higher vascularity than actinomycetoma cases. Consistent with these Doppler findings, previous studies have demonstrated the same phenomenon[11]. The difference in vascularity patterns between the two forms of infection may be attributed to the increased presence of a capsule and dense fibrosis in cases of fungal mycetoma compared with that observed in bacterial type[11]. The presence of adequate vascularity in mycetoma in general was attributed to a pathological circulation which associates with neo-vessel formation. As such, doppler assessment of blood flow patterns can facilitate the characterization of infection into one of the two types of mycetoma. This study will be beneficial for clinicians and radiologists who are responsible for diagnosis and management of mycetoma.

CONCLUSION

Ultrasonographic evaluation of foot mycetoma revealed features including multiple cavities, separated grains and heterogeneous echotexture, which were more notable in eumycetoma than actinomycetoma. Further, Doppler assessment revealed significantly increased vascularity in eumycetoma cases compared to than actinomycetoma cases.

Doppler ultrasound features can be used to characterize types of mycetoma, which is a beneficial for early diagnosis and preventing spread of the damage and infection. Further studies are recommended to the study the vascularity of infected foot specifically the doppler indices of arterial supply.

SIGNIFICANCE STATEMENT

This study explored the doppler and sonographic features of foot mycetoma. Studying the doppler ultrasound features of foot mycetoma can be beneficial for characterizing types of mycetoma, which help in early diagnosis and management. This study will help the surgeons and clinicians to study suspected extension of the infection in bones and vessels, which may lead to foot amputation.

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