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Original Research Article

EVALUATION OF DIABETIC FOOT LESIONS USING MAGNETIC RESONANCE IMAGING

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ABSTRACT

Background: Diabetic foot disease is a major cause of morbidity in patients with diabetes mellitus and frequently leads to infection, osteomyelitis, and lower-limb amputation if not diagnosed early. Accurate assessment of the extent and nature of diabetic foot involvement is essential for optimal management. Magnetic resonance imaging (MRI) has emerged as a key modality for evaluating both soft-tissue and osseous abnormalities in diabetic foot.
Materials and Methods: This hospital-based observational study included 119 patients with diabetes mellitus clinically suspected to have diabetic foot involvement. All patients underwent MRI of the affected foot using a standardized imaging protocol. MRI findings were analyzed for soft-tissue and osseous abnormalities, including osteomyelitis and Charcot neuroarthropathy. Imaging findings were correlated with clinical features, laboratory parameters, surgical findings, microbiological data, and follow-up outcomes where available. Diagnostic performance of MRI for detecting osteomyelitis was assessed.
Results: The mean age of patients was 55.2 ± 7.6 years, with a male predominance (68.9%). Poor glycaemic control (HbA1c ≥8%) was observed in 65.5% of patients. MRI revealed cellulitis in 72.3%, soft-tissue abscess in 40.3%, and osteomyelitis in 47.9% of cases. Osteomyelitis was significantly associated with longer duration of diabetes, poor glycaemic control, deeper and chronic ulcers, sinus tract formation, and elevated inflammatory markers ($p < 0.05$). MRI effectively differentiated osteomyelitis from Charcot neuroarthropathy based on distinct imaging features. MRI demonstrated a sensitivity of 91.2%, specificity of 87.1%, and overall diagnostic accuracy of 89.1% for detecting osteomyelitis, with an area under the ROC curve of 0.89.
Conclusion: MRI is a highly accurate and reliable imaging modality for evaluating diabetic foot disease. Its ability to detect early osteomyelitis, assess disease extent, and differentiate infective from neuropathic pathology makes it indispensable for guiding clinical management and improving limb salvage outcomes.
Keywords: Diabetic foot; Magnetic resonance imaging; Osteomyelitis; Charcot neuroarthropathy; Foot infection.

INTRODUCTION

Diabetes mellitus is a major global public health problem, with a rapidly increasing prevalence, particularly in low- and middle-income countries.[1] One of the most serious and debilitating complications of long-standing diabetes is diabetic foot disease, which encompasses a spectrum of conditions including neuropathy, ischemia, infection, ulceration, osteomyelitis, and Charcot neuroarthropathy.[2] It is estimated that nearly 15–25% of patients with diabetes develop a foot ulcer during their lifetime, and diabetic foot complications account for a significant proportion of diabetes-related hospital admissions and lower-limb amputations worldwide.[3] In India, diabetic foot ulcers contribute to a high morbidity burden due to delayed presentation, poor glycaemic control, and limited access to specialized foot care.[4]

Early and accurate diagnosis of the underlying pathology in diabetic foot is crucial, as management strategies differ substantially between soft-tissue infection, osteomyelitis, ischemic changes, and neuropathic arthropathy.[5] Clinical assessment alone is often insufficient because local signs of infection may be masked by neuropathy or altered inflammatory response, while laboratory markers lack specificity.[6] Imaging therefore plays a pivotal role in the evaluation of diabetic foot, guiding diagnosis, treatment planning, and prognostication.[6]

Conventional radiography is commonly used as the initial imaging modality; however, its sensitivity in early disease is limited, particularly for detecting early osteomyelitis, marrow edema, and subtle joint involvement, which may not be apparent until substantial bone destruction has occurred.[7] Ultrasonography, although useful for identifying superficial collections and guiding drainage, is operator-dependent and has limited ability to assess deep soft tissues and bone marrow involvement.[7] Computed tomography provides good depiction of cortical bone but offers limited soft-tissue contrast and exposes patients to ionizing radiation.[8]

Magnetic Resonance Imaging (MRI) has emerged as the imaging modality of choice for the comprehensive evaluation of diabetic foot due to its excellent soft-tissue contrast, multiplanar capability, and high sensitivity for detecting bone marrow abnormalities.[9] MRI allows early identification of osteomyelitis through detection of marrow edema, delineates the extent of soft-tissue infection, abscesses, sinus tracts, and tendon involvement, and helps in differentiating osteomyelitis from Charcot neuroarthropathy—a distinction that is often challenging but clinically critical.[9,10] Reported sensitivity and specificity of MRI for diagnosing diabetic foot osteomyelitis range from 80–100% and 70–90% respectively, making it superior to other imaging modalities in most clinical settings.[10]

Despite its proven diagnostic utility, the interpretation of MRI in diabetic foot remains complex due to overlapping imaging features between infection and neuropathic changes, particularly in patients with chronic disease. Furthermore, there is variability in the pattern of MRI findings depending on the duration of diabetes, presence of ulcers, vascular status, and glycaemic control. Hence, institution-specific studies are valuable to correlate MRI findings with clinical presentation and to assess its role in real-world tertiary care settings. In this context, the present study aimed to evaluate the role of MRI in the diagnosis and characterization of diabetic foot lesions, emphasizing its utility in identifying the spectrum of soft-tissue and osseous involvement, aiding early diagnosis, and facilitating appropriate management to reduce complications such as limb loss.

MATERIALS AND METHODS

Study Design and Setting

This hospital-based observational cross-sectional study was conducted in the Department of Radiodiagnosis in collaboration with the Departments of General Medicine and General Surgery at a tertiary care teaching hospital. The study was carried out over a defined study period after obtaining approval from the Institutional Ethics Committee. All procedures were performed in accordance with the ethical standards laid down in the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrolment.

Study Population

The study included adult patients with a known diagnosis of diabetes mellitus who were clinically suspected to have diabetic foot involvement and were referred for MRI evaluation. Diabetic foot was defined as the presence of foot ulceration, swelling, pain, discharge, deformity, or suspected infection in a patient with diabetes. Both male and female patients were included. Patients with a history of recent foot trauma, known malignancy of the foot, contraindications to MRI such as pacemakers or ferromagnetic implants, or those unwilling to provide consent were excluded from the study.

Sample Size and Sampling Technique

A consecutive sampling method was used, wherein all eligible patients referred for MRI evaluation of diabetic foot during the study period were included until the desired sample size was achieved. The sample size was determined based on previous studies reporting a high sensitivity of MRI for detecting osteomyelitis in diabetic foot, with an expected sensitivity of approximately 85–90%, allowing for an acceptable margin of error and confidence level.

Clinical Evaluation and Data Collection

Detailed clinical data were collected for each patient using a structured proforma. This included demographic details, duration and type of diabetes, glycaemic control status, presence of peripheral neuropathy or peripheral vascular disease, history of foot ulceration, prior surgical interventions, and current clinical presentation such as ulcer depth, discharge, and signs of infection. Relevant laboratory investigations including blood glucose levels, inflammatory markers, and microbiological culture reports, when available, were documented for correlation with imaging findings.

MRI Equipment and Imaging Protocol

All MRI examinations were performed using a high-field strength MRI scanner (1.5 Tesla) with a dedicated extremity coil. Patients were positioned supine with the affected foot placed comfortably within the coil to minimize motion artefacts. The MRI protocol included multiplanar imaging sequences covering the entire foot. Standard sequences comprised axial, sagittal, and coronal T1-weighted images, T2-weighted images, and fat-suppressed sequences such as short tau inversion recovery (STIR) or T2 fat-suppressed images. Post-contrast T1-weighted fat-suppressed images were acquired in cases where infection was suspected, following intravenous administration of gadolinium-based contrast agent, unless contraindicated. Slice thickness, field of view, and matrix parameters were optimized to achieve high spatial resolution.

MRI Image Analysis

MRI images were independently evaluated by experienced radiologists who were blinded to detailed clinical and laboratory findings to reduce observer bias. The images were systematically assessed for the presence and extent of soft-tissue abnormalities such as cellulitis, abscess formation, sinus tracts, and tendon involvement. Osseous changes including bone marrow edema, cortical disruption, bone destruction, and joint involvement were carefully analyzed. Osteomyelitis was diagnosed based on characteristic MRI findings such as low signal intensity on T1-weighted images and high signal intensity on T2-weighted or STIR images in the bone marrow, with or without post-contrast enhancement. Charcot neuroarthropathy was identified by features such as joint subluxation or dislocation, fragmentation, subchondral marrow edema, and periarticular involvement.

Reference Standard and Diagnostic Correlation

MRI findings were correlated with clinical findings, surgical exploration, histopathology, and microbiological culture results wherever available, which served as the reference standard for final diagnosis. In patients managed conservatively, clinical follow-up and response to treatment were used to support the imaging diagnosis. This correlation helped in assessing the diagnostic role of MRI in various diabetic foot pathologies.

Statistical Analysis

The collected data were entered into a Microsoft Excel spreadsheet and analyzed using SPSS 20.0 statistical software. Descriptive statistics were used to summarize demographic variables, clinical characteristics, and MRI findings. Categorical variables were expressed as frequencies and percentages, while continuous variables were presented as mean and standard deviation. The diagnostic performance of MRI in detecting osteomyelitis and other diabetic foot complications was assessed using sensitivity, specificity, positive predictive value, and negative predictive value wherever applicable. Associations between MRI findings and clinical parameters were evaluated using suitable statistical tests, with a p-value of less than 0.05 considered statistically significant.

RESULTS

The study population comprised 119 patients with diabetic foot, with a mean age of 55.2 ± 7.6 years, and a male predominance (68.9%). The majority of patients were aged ≥50 years (79.8%), reflecting the chronic nature of diabetic foot disease. Long-standing diabetes was common, with 43.7% having a duration of more than 10 years. Poor glycaemic control was evident, as 65.5% of patients had HbA1c levels ≥8%, with a mean HbA1c of 8.9 ± 1.4%. Peripheral neuropathy was present in 59.7% of patients, while peripheral vascular disease was noted in 32.8%. A high burden of comorbidities was observed, including hypertension (57.1%), smoking history (37.0%), and chronic kidney disease (17.6%). Nearly one-third of patients (28.6%) had a history of prior minor foot surgery or debridement, highlighting recurrent disease and delayed presentation. [Table 1]

Table 1: Baseline Demographic, Metabolic, and Clinical Characteristics of the Study Population (n = 119)

Variable	Number (%) / Mean ± SD
Age (years)	55.2 ± 7.6
<40	6 (5.0%)
40–49	18 (15.1%)
50–59	42 (35.3%)
60–69	39 (32.8%)
≥70	14 (11.8%)
Sex	
Male	82 (68.9%)
Female	37 (31.1%)
Duration of diabetes	
<5 years	21 (17.6%)
5–10 years	46 (38.7%)
>10 years	52 (43.7%)
Mean HbA1c (%)	8.9 ± 1.4
HbA1c <7%	19 (16.0%)
HbA1c 7–7.9%	22 (18.5%)
HbA1c ≥8%	78 (65.5%)
Peripheral neuropathy	71 (59.7%)
Peripheral vascular disease	39 (32.8%)
Smoking history	44 (37.0%)
Hypertension	68 (57.1%)
Chronic kidney disease	21 (17.6%)
Previous minor foot surgery / debridement	34 (28.6%)

HbA1c – Glycated hemoglobin; CKD – Chronic kidney disease. Data expressed as mean ± SD or number (%).

MRI demonstrated a wide spectrum of soft-tissue and osseous abnormalities in patients with diabetic foot. Soft-tissue involvement was common, with cellulitis seen in 72.3% and diffuse subcutaneous edema in 62.2% of cases. Localized soft-tissue abscesses were identified in 40.3%, while intermuscular abscesses were present in 16.0%. Sinus tracts were visualized in 26.1% of patients. Tendon and fascial involvement, including tenosynovitis and plantar fasciitis, was observed in 24.4% and 17.6% respectively. Osseous abnormalities were frequent, with bone marrow edema detected in 70.6% and osteomyelitis in 47.9% of patients. Septic arthritis and Charcot neuroarthropathy were seen in 18.5% and 15.1% respectively. The metatarsals and phalanges were the most commonly involved bones, and more than half of the patients (58.0%) demonstrated involvement of multiple anatomical compartments. [Table 2 and Figure 1]

Table 2: Spectrum and Anatomical Distribution of MRI Findings in Diabetic Foot (n = 119)

MRI Finding	Number (%)
Soft-tissue abnormalities	
Cellulitis	86 (72.3%)
Diffuse subcutaneous edema	74 (62.2%)
Localized soft-tissue abscess	48 (40.3%)
Intermuscular abscess	19 (16.0%)
Sinus tract	31 (26.1%)
Tendon and fascial involvement	
Tenosynovitis	29 (24.4%)
Plantar fasciitis	21 (17.6%)
Osseous involvement	
Bone marrow edema	84 (70.6%)
Osteomyelitis	57 (47.9%)
Septic arthritis	22 (18.5%)
Charcot neuroarthropathy	18 (15.1%)
Most commonly involved bones	
Metatarsals	41 (34.5%)
Phalanges	36 (30.3%)
Calcaneum	18 (15.1%)
Midfoot bones	24 (20.2%)
Multiple compartment involvement	69 (58.0%)

MRI – Magnetic Resonance Imaging. Multiple findings may be present in the same patient.

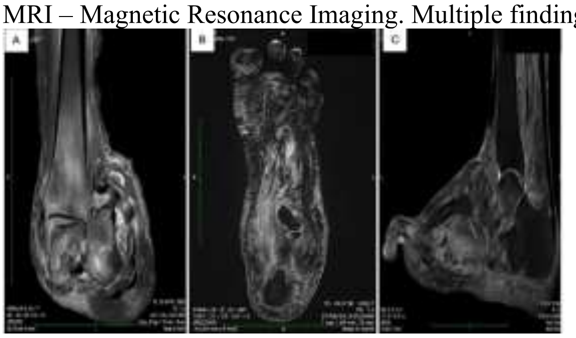

Figure 1: MRI Spectrum of Soft-Tissue Infection in Diabetic Foot. A: Coronal PD fat-suppressed MRI of the foot showing dislocation of subtalar and talo-calcaneal joint. B: Axial T2-weighted GRE/STIR MRI demonstrating plantar soft-tissue oedematous changes. C: Sagittal PD fat-suppressed MRI showing sinus tract extending from plantar ulcer into deep soft tissues.

Patients with osteomyelitis on MRI had a significantly longer duration of diabetes compared to those without osteomyelitis (11.2 ± 4.1 vs 7.8 ± 3.9 years; $p < 0.001$). Poor glycaemic control (HbA1c ≥8%) was more prevalent among patients with osteomyelitis (78.9%) than those without (53.2%) ($p = 0.004$). Advanced ulcer characteristics were strongly associated with osteomyelitis, including ulcer depth greater than grade 2 (68.4% vs 33.9%; $p < 0.001$) and ulcer duration exceeding six weeks (73.7% vs 38.7%; $p < 0.001$). The presence of a clinically detectable sinus tract and elevated inflammatory markers such as C-reactive protein were significantly higher in the osteomyelitis group ($p < 0.001$). Leukocytosis was also significantly associated with osteomyelitis ($p = 0.01$) (Table 3 and Figure 2).

Table 3: Association of Clinical and Laboratory Parameters with Osteomyelitis on MRI

Variable	Osteomyelitis Present (n=57)	Osteomyelitis Absent (n=62)	p-value
	Number (%) / Mean ± SD		
Mean diabetes duration (years)	11.2 ± 4.1	7.8 ± 3.9	<0.001
HbA1c ≥8%	45 (78.9%)	33 (53.2%)	0.004
Ulcer depth >Grade 2	39 (68.4%)	21 (33.9%)	<0.001
Ulcer duration >6 weeks	42 (73.7%)	24 (38.7%)	<0.001
Sinus tract on exam	29 (50.9%)	8 (12.9%)	<0.001
Raised CRP (>10 mg/L)	41 (71.9%)	19 (30.6%)	<0.001
Leukocytosis	34 (59.6%)	22 (35.5%)	0.01

CRP – C-reactive protein. p-value <0.05 considered statistically significant.

Figure 2: MRI Features of Osteomyelitis in Diabetic Foot. A: Sagittal T1-weighted post contrast MRI showing enhancing plantar soft tissues and subcutaneous fat region. B: Coronal PD/T2 fat-suppressed MRI showing plantar myoedema with adjacent soft-tissue inflammation.

Distinct MRI features were observed between osteomyelitis and Charcot neuroarthropathy. Focal bone marrow edema and cortical erosion were significantly more common in osteomyelitis (86.0% and 64.9% respectively), whereas Charcot neuroarthropathy predominantly showed diffuse periarticular edema (88.9%) and subchondral marrow edema (88.9%) ($p < 0.001$). Soft-tissue abscesses and post-contrast rim enhancement were significantly associated with osteomyelitis, while joint subluxation or dislocation was markedly more frequent in Charcot neuroarthropathy (83.3%; $p < 0.001$). These imaging characteristics enabled reliable differentiation between infective and neuropathic pathology (Table 4 and Figure 3).

Table 4: MRI Features Differentiating Osteomyelitis and Charcot Neuroarthropathy

MRI Feature	Osteomyelitis (n=57)	Charcot (n=18)	p-value
	Number (%)		
Focal marrow edema	49 (86.0%)	6 (33.3%)	<0.001
Diffuse periarticular edema	21 (36.8%)	16 (88.9%)	<0.001
Cortical erosion/breach	37 (64.9%)	3 (16.7%)	0.002
Subchondral marrow edema	14 (24.6%)	16 (88.9%)	<0.001
Soft-tissue abscess	31 (54.4%)	2 (11.1%)	0.004
Joint subluxation/dislocation	9 (15.8%)	15 (83.3%)	<0.001
Post-contrast rim enhancement	33 (57.9%)	4 (22.2%)	0.01

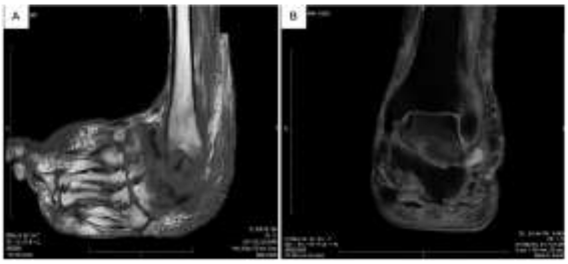

Figure 3: MRI Differentiation of Osteomyelitis and Charcot Neuroarthropathy. A: Saggital T1 weighted MRI showing osseous destruction with surrounding soft tissue edema involving tarsal bones. B: Coronal PDFS MRI showing joint subluxation, subchondral marrow edema, and midfoot collapse consistent with Charcot neuroarthropathy.

MRI demonstrated high diagnostic accuracy in detecting osteomyelitis in diabetic foot. Using surgical findings, microbiological culture, and clinical follow-up as reference standards, MRI showed a sensitivity of 91.2% and specificity of 87.1%. The positive predictive value was 86.7%, while the negative predictive value was 91.5%. Overall diagnostic accuracy was 89.1%. Receiver operating characteristic analysis revealed an area under the curve of 0.89, indicating excellent diagnostic performance (Table 5 and Figure 4).

Table 5: Diagnostic Performance of MRI for Detection of Osteomyelitis

Diagnostic Parameter	Value
True positives	52
False positives	8
True negatives	54
False negatives	5
Sensitivity	91.20%
Specificity	87.10%
Positive Predictive Value (PPV)	86.70%
Negative Predictive Value (NPV)	91.50%
Overall diagnostic accuracy	89.10%
Area under ROC curve (AUC)	0.89

PPV – Positive predictive value; NPV – Negative predictive value; AUC – Area under the curve.

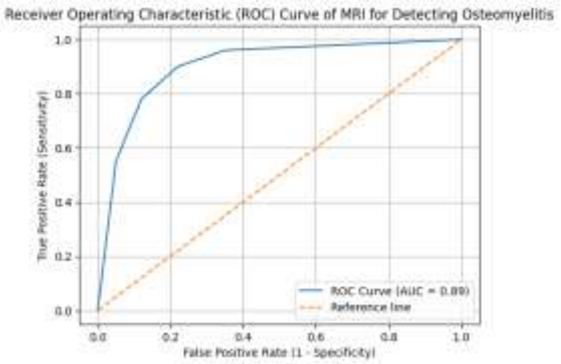

Figure 4: Receiver Operating Characteristic (ROC) Curve of MRI for Detection of Osteomyelitis in Diabetic Foot

DISCUSSION

Diabetic foot disease represents a complex interplay of neuropathy, ischemia, infection, and impaired wound healing, making early and accurate diagnosis essential for limb salvage. In the present study, the mean age of patients was 55.2 ± 7.6 years with a clear male predominance (68.9%), a pattern consistently reported in Indian studies by Mankar et al., Krishna et al., and Tholiya et al., reflecting higher outdoor activity, occupational exposure, and delayed health-seeking behavior among men.[11,12,13] A substantial proportion of patients had long-standing diabetes (>10 years in 43.7%) and poor glycaemic control (HbA1c ≥8% in 65.5%), emphasizing the cumulative microvascular and neuropathic burden that predisposes to foot complications. Similar demographic and metabolic profiles have been described in previous Indian studies by Roy et al., and Upadhyay et al., where prolonged diabetes duration and uncontrolled glycaemia were identified as major risk factors for severe diabetic foot disease.[14,15]

MRI in the present study demonstrated a broad spectrum of soft-tissue and osseous abnormalities, underscoring its role as a comprehensive imaging modality. Soft-tissue involvement predominated, with cellulitis (72.3%) and diffuse subcutaneous edema (62.2%) being the most frequent findings, consistent with the pathophysiological progression of infection from superficial tissues to deeper planes.[16] The relatively high prevalence of soft-tissue abscesses (40.3%) and sinus tracts (26.1%) highlights delayed presentation and inadequate early intervention, a recurring theme in resource-limited settings. Tendon and fascial involvement, seen in nearly one-quarter of patients, is clinically significant as it often necessitates prolonged antibiotic therapy or surgical intervention. These findings mirror prior studies by Kumar et al., and Mahendra et al., where MRI detected occult deep soft-tissue disease not appreciated clinically or on conventional imaging, thereby altering management decisions.[17,18]

Osseous involvement was a major component of disease severity in the present cohort. Bone marrow edema was detected in 70.6% of patients, while osteomyelitis was confirmed in 47.9%, aligning with previously reported in studies by Truong et al., and Alkhalfan et al., with prevalence ranging from 40% to 60% in tertiary care populations.[19,20] The metatarsals and phalanges were the most commonly involved bones, reflecting their proximity to plantar ulcers and repetitive microtrauma in neuropathic feet. The high rate of multi-compartment involvement (58.0%) further reinforces the ability of MRI to delineate disease extent, which is critical for surgical planning and prognostication.[21]

A key strength of this study is the detailed correlation between clinical parameters and osteomyelitis on MRI. Patients with osteomyelitis had a significantly longer duration of diabetes ($p < 0.001$) and poorer glycaemic control ($p = 0.004$), supporting the hypothesis that chronic hyperglycaemia impairs host immune response and promotes deep infection.[22] Advanced ulcer characteristics, including greater ulcer depth and prolonged ulcer duration, showed a strong statistical association with osteomyelitis ($p < 0.001$). The presence of a sinus tract and elevated inflammatory markers were also highly predictive of underlying bone infection.[23] These findings are in concordance with earlier studies by Mergenhagen et al., and La Fontaine et al., that identified deep ulcers and chronicity as the most reliable clinical predictors of osteomyelitis, yet emphasized that clinical assessment alone lacks sufficient specificity thereby reinforcing the indispensability of MRI.[24,25]

Differentiating osteomyelitis from Charcot neuroarthropathy remains one of the most challenging aspects of diabetic foot imaging.[8] In the present study, distinct MRI features enabled reliable differentiation between these two entities.[6] Osteomyelitis was characterized by focal marrow edema, cortical breach, soft-tissue abscesses, and rim enhancement, whereas Charcot neuroarthropathy showed predominant periarticular and subchondral marrow edema, joint subluxation, and disorganization (all $p < 0.001$).[9] These imaging patterns reflect underlying pathophysiology infective marrow infiltration in osteomyelitis versus neuro-traumatic joint destruction in Charcot arthropathy.[26] Similar MRI criteria have been validated in previous studies by Diez et al., and Lauri et al., which emphasized that recognition of these distinguishing features is crucial, as misdiagnosis may lead to inappropriate antibiotic therapy or delayed immobilization.[27,28]

The diagnostic performance of MRI in detecting osteomyelitis in the present study was excellent, with a sensitivity of 91.2%, specificity of 87.1%, and overall accuracy of 89.1%. The area under the ROC curve of 0.89 further confirms MRI as a highly reliable modality for diagnosing osteomyelitis in diabetic foot. These values are comparable to, and in some instances exceed, those reported in earlier studies by Wudhikulprapan et al., and Jin et al., where MRI sensitivity ranged from 80% to 100% and specificity from 70% to 90%.[29,30] The high negative predictive value (91.5%) observed in this study is particularly important, as it allows confident exclusion of osteomyelitis and helps avoid unnecessary prolonged antibiotic therapy or surgical intervention.[30]

Limitations

The present study has certain limitations that should be acknowledged. Being a single-center hospital-based study, the findings may not be fully generalizable to all patient populations, particularly those in primary care or community settings. Histopathological confirmation or microbiological culture was not available for all cases, and in some patients, clinical follow-up served as the reference standard, which may introduce verification bias. Interobserver variability in MRI interpretation was not formally assessed, which could have further strengthened the reliability of imaging findings. Additionally, vascular assessment using dedicated MR angiography was not routinely performed, limiting detailed evaluation of ischemic contributions to disease severity. Despite these limitations, the study provides robust and clinically relevant data reflecting real-world tertiary care practice.

CONCLUSION

Magnetic resonance imaging plays a pivotal role in the comprehensive evaluation of diabetic foot disease. MRI accurately delineates the extent of soft-tissue and osseous involvement, enables early detection of osteomyelitis, and reliably differentiates infective pathology from Charcot neuroarthropathy. The high sensitivity, specificity, and overall diagnostic accuracy observed in this study underscore MRI as the imaging modality of choice in patients with suspected diabetic foot complications. Early and appropriate use of MRI can facilitate timely intervention, guide surgical planning, and contribute significantly to limb salvage and improved patient outcomes, particularly in settings where advanced disease at presentation is common.

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