ORIGINAL ARTICLE

A Structured Diagnostic Pathway for Diabetic Foot Osteomyelitis: Optimising MRI Use through Clinical and Plain Radiographic Assessment

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ABSTRACT

Background: In current clinical practice, MRI is widely regarded as the preferred non-invasive modality for early detection of osteomyelitis and associated soft-tissue abnormalities. However, due to high costs and limited availability, MRI use is often limited.

Objective: To evaluate the current practice of MRI utilization and to assess its diagnostic yield in patients with suspected diabetic foot osteomyelitis (DFO).

Methods: We conducted a retrospective cross-sectional analysis of 50 patients who underwent foot MRI for suspected DFO at the University Hospitals of Liverpool Group between May and November 2024. Demographic data, clinical documentation, and imaging findings from plain radiographs and MRI were reviewed using the Clinical Radiology Information System (CRIS) and Carestream PACS.

Results: The cohort comprised 80% males and 20% females, with a mean age of 65 years. Foot ulcers were documented in 94% of cases, but the exact site was specified in only 63%. Plain radiographs were performed in 98% of patients, with osteomyelitis reported in 32%, suspected in 4%, and negative in 58%. Among radiographically negative cases, repeat X-ray was advised in 96%, but MRI was recommended in only 12%. MRI confirmed osteomyelitis in 62% of cases, though only 28% of reports described the extent of disease. In total, 52% of MRI-confirmed cases had corresponding findings on plain radiographs, 35% did not, and 13% lacked separate plain film reports.

Conclusion: While MRI offers excellent sensitivity, it may be unnecessary when clinical assessment and plain radiography are concordant.

Keywords: *Diabetic foot osteomyelitis, MRI, radiography, foot ulcers, clinical radiology information system, probe-to-bone test.*

INTRODUCTION

Type 2 diabetes has seen a marked increase in incidence and prevalence globally, along with a rise in associated complications, as highlighted by epidemiological data from the Global Burden of Disease [1-3]. In Pakistan alone, the prevalence of diabetes and its associated complications has reached 26.7% and continues to grow, representing one of the highest national rates worldwide [4]. Of all the complications of diabetes, diabetic foot infections (DFI) [4, 5], predominantly diabetic foot osteomyelitis (DFO) [5], are among the most severe, contributing significantly to patient morbidity, early mortality, and healthcare costs. It is estimated that up to 34% of patients with a diabetic foot ulcer may experience complications during their lifetime, with 20-60% of these cases progressing to infection and potentially osteomyelitis. Diabetic foot osteomyelitis (DFO) is also the most common cause of non-traumatic lower limb amputations [1, 3, 6].

There are multiple factors involved in the pathogenesis of Diabetic foot osteomyelitis, and long-standing diabetes is among the most commonly observed. Peripheral neuropathy, usually seen in long-standing cases, leads to reduced dermal sensation, resulting in skin vulnerable to breakdown and ultimately to ulcer formation. This peripheral neuropathy is further compounded by peripheral artery disease, which results in compromised tissue perfusion and delayed ulcer healing [5, 7]. The immune system is further compromised by hyperglycaemia, and when combined with inadequate offloading, it creates a favourable environment for infection to spread throughout the body. This complex interplay makes the diagnosis of DFO particularly challenging, as it overlaps with other conditions such as Charcot arthropathy [7]. According to local studies from Pakistan, nearly 40% of hospital admissions related to diabetes are due to DFO, and the importance of efficient and accessible diagnostic strategies is underscored by the fact that DFO is a significant predictor of amputation risk [8, 9].

The management of diabetic foot infections requires a multidisciplinary approach encompassing wound care, infection control, revascularization procedures (*e.g.*, angioplasty), and surgical interventions. Several factors can influence treatment decisions, including the severity of infection, the presence of ischaemia, and the extent of tissue involvement [7].

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To improve limb preservation, avoid amputation, and reduce complications related to DFO, timely and accurate diagnosis is essential, as it initiates appropriate medical or surgical management, resulting in fewer complications [5, 6]. Although clinical evaluation is necessary, it is frequently complemented by imaging. Inflammatory markers may be helpful but are generally nonspecific [9]. The probe-to-bone test (PTB), although a valuable diagnostic tool, is frequently underutilised.

The probe-to-bone test is a bedside diagnostic test that involves probing a foot ulcer with a sterile blunt instrument to assess for bone contact. The PTB test has a pooled sensitivity of 87% and specificity of 83% according to a systematic review by Lam *et al.* and Hassan *et al.* [10, 11]. A prospective study of 1,666 diabetic patients showed improved sensitivity (87%) and specificity (91%) when used in conjunction with imaging, particularly plain radiographs. The PTB test significantly enhances diagnostic accuracy [12, 13].

Although bone biopsy is considered the gold standard for diagnosis, its invasive nature and limited practicality mean it is not routinely performed [14].

In current clinical practice, magnetic resonance imaging (MRI) is widely regarded as the preferred non-invasive modality due to its high sensitivity (95.6%) and superior soft tissue contrast, allowing for early detection of bone marrow oedema, cortical destruction, periosteal reaction, and associated soft tissue abnormalities such as abscesses, ulcers, or sinus tracts [9, 14]. However, MRI use is often limited by cost and availability [15, 16].

Plain radiography is often the initial modality due to its availability and cost-effectiveness. Cortical erosion, gas in soft tissues, and periosteal reaction can easily be demonstrated on plain radiographs; however, these features are typically absent in early infection [14, 15].

The sensitivity of radiographs was 97% in one study, whereas another reported 93% for SPECT/CT, an almost comparable level; however, SPECT/CT involves higher radiation exposure and is generally reserved for preoperative planning or complex cases [17, 18].

Importantly, it is discouraged to overuse imaging, especially the inappropriate use of multiple modalities, as it can unnecessarily increase healthcare costs and can be clinically ineffective [17]. There is significant variability in clinical practice, despite the availability of evidence-based guidelines and advancements in diagnostic strategies. This highlights the importance of clinicians receiving education, implementing protocol-driven approaches, and collaborating across disciplines when managing diabetic foot infections. Therefore, our study aims to evaluate current MRI utilization and assess its diagnostic yield in patients with clinically suspected Diabetic Foot Osteomyelitis (DFO). We also aim to highlight areas where diagnostic pathways may be optimized.

MATERIALS AND METHODS

We conducted a retrospective audit of the current practice of foot MRI examinations performed for DFO at the University Hospitals of Liverpool Group between May 2024 and November 2024. Inclusion criteria were all adult inpatients or Emergency Department patients who underwent MRI foot with clinical suspicion of diabetic foot osteomyelitis (DFO). Cases referred for alternative indications (*e.g.*, trauma, neoplasm, or non-diabetic foot infections) were excluded.

The records of 98 patients who underwent MRI for suspected DFO from May to November 2024 were reviewed. Of these 98 records, 48 were excluded because they did not meet the inclusion criteria, and 50 were analysed according to the inclusion criteria **(Fig. 1)**.

Demographic and clinical data were extracted from the Clinical Radiology Information System (CRIS) and Carestream Picture Archiving and Communication System (PACS). Information collected included patient age and sex, referral source, clinical details provided (including presence of ulcer, ulcer site, and documentation of a PTB test), imaging performed (radiography and MRI), and radiology report findings. Plain radiographs and MRI reports were reviewed for evidence of osteomyelitis and any documentation of disease extent or complications relevant to surgical planning. To reduce

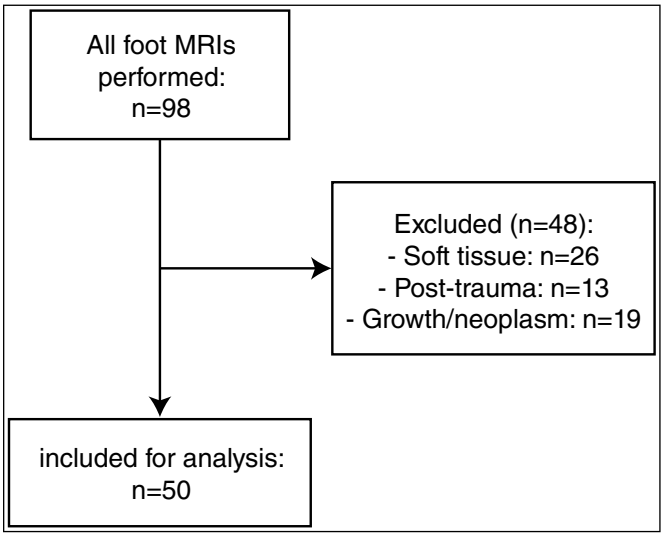

Fig. (1): Flow of participants through the study.

selection bias, all patients referred for foot MRI with suspected DFO during the study period were included regardless of specialty. Two independent reviewers performed data abstraction to minimise interpretation bias.

Diagnostic yield was calculated as the proportion of positive MRIs (that confirmed osteomyelitis). The diagnostic yield is emphasized, as there is increased demand for advanced imaging, and we need to justify its increasing use in health care systems. To analyse the current MRI practice and diagnostic pathways, we look for the frequencies of concordant and discordant findings between MRI and plain films, the documentation quality of clinical referrals, and the utilisation of PTB testing.

The primary outcome was the diagnostic yield (proportion of MRIs that confirmed osteomyelitis). Secondary outcomes included the frequency of concordant findings between MRI and plain film, the quality of documentation for clinical referrals, and the utilisation of PTB testing.

Data was analysed on SPSS version 29. Descriptive statistics were used to summarise demographic characteristics, imaging findings, and the quality of clinical documentation. Categorical variables were presented as frequencies and percentages with corresponding 95% confidence intervals where appropriate. Chi-square test/Fisher's exact test were used to evaluate the association between X-ray and MRI findings, clinical findings, and diagnostic yield. Cohen's kappa statistic was used to assess diagnostic concordance between plain film and MRI. The diagnostic concordance testing approach aligns with recent recommendations in the radiology quality assurance literature (2022-2023).

RESULTS

Of 98 MRIs conducted during the study period, 50 patients were included, with a mix of unilateral and bilateral involvement **(Table 1)**. The cohort comprised 80% males and 20% females, with a mean age of 65 years. Referrals were noted to come from various departments, including Endocrinology (32%), Infectious Diseases (24%), Orthopaedics (24%), and other departments, making up the remaining 20%. A summary of all our results is presented in Table **1**.

Clinical documentation showed that 94% of patients presented with foot ulcers. Ulcer location was clearly specified in 63% of cases, imprecisely described in 29%, and omitted entirely in 8%. The lack of documentation of the ulcer site limits targeted imaging and increases reporting uncertainty, a challenge also documented in Pakistani clinical audits (2022). PTB testing was under-documented: only 14% had a recorded positive PTB result, 2% had a documented negative test, and the remaining 84% made no mention of PTB status.

Table 1: Summary of participant demographics.

Variables	Categories	Frequency (%)
Gender Distribution	Males	40 (80%)
	Females	10 (20%)
Mean Age		65 years
Referrer Specialty	Endocrine	16 (32%)
	Infectious Diseases	12 (24%)
	Orthopaedics	12 (24%)
	Others	10 (20%)
Ulcer Status	Yes	47 (94%)
	No	3 (6%)
Probe-to-Bone Test	Positive	7 (14%)
	Negative	1 (2%)
	Not Provided	42 (84%)
Ulcer Site Clarity	Clearly Provided	32 (64%)
	Not Provided Clearly	12 (28%)
	Not Provided at All	4 (8%)
Recent Plain Radiograph	Yes	49 (98%)
	No	1 (2%)

Nearly all patients (98%) underwent plain radiography before MRI. Among these, 32% of radiographs were reported as positive for osteomyelitis, 4% as suspicious, and 58% as negative. In cases with negative radiographs, 96% recommended a repeat radiograph, while 12% recommended an MRI be obtained **(Table 2)**.

Table 2: Summary of plain X-ray and MRI results.

X-Ray Reports	Categories	Frequency (%)
OM present on X-ray	Yes	16 (32%)
	No	29 (58%)
	Suspicious	2 (4%)
	Same Report as MRI	3 (6%)
Comment about X-ray insensitivity	Yes	27 (54%)
	No	23 (46%)
If OM-negative, repeat Plain X-rays suggested?	Yes	48 (96%)
	No	2 (4%)
If OM-negative, MRI recommended?	Yes	6 (12%)
	No	44 (88%)
MRI Reports		
OM present on MRI	Yes	31 (62%)
	No	18 (36%)
	Equivocal	2 (4%)
Extent of OM described in MRI report	Yes	14 (28%)
	No	36 (72%)

62% of MRIs were reported as positive for osteomyelitis, 4% equivocal, and 36% negative. Of the MRI-positive cases, only 28% of reports included details on the extent of infection, limiting their utility for surgical planning **(Table 2)**.

Concordance between plain radiography and MRI: 52% of MRI-confirmed osteomyelitis (positive MRI) cases were visible on prior plain radiographs (positive radiograph), whilst 35% of MRI-positive cases were not detectable on plain film (negative radiograph). In the remaining 13% of cases, either no radiograph was available, or the X-ray and MRI were performed and reported concurrently. There was moderate agreement between MRI and plain radiograph ($k=0.46$, $p<0.01$)

Cases with clearly documented ulcers were significantly more likely to have MRI-osteomyelitis than cases with poorly documented ulcers (72% *versus* 44%, $p=0.042$). MRI utilization was higher in cases where PTB test results were not reported ($p=0.03$; Fisher's exact test). The diagnostic yield of MRI is strongly associated with osteomyelitis-positive plain films ($p=0.001$), suggesting plain film radiography as a valid first-line imaging modality when clinical and radiographic features are concordant.

DISCUSSION

The increasing use of MRI for suspected DFO presents a growing challenge to radiology services, particularly in resource-constrained healthcare settings. MRI, while highly sensitive, is a limited and costly resource and may not be necessary for all patients [14]. Our findings highlight several areas where the diagnostic pathway can be streamlined by more effective use of bedside clinical assessment, plain X-rays, and selective MRI. Our findings align with data from low- and middle-income countries (LMICs), where cost-benefit considerations are essential, and MRI availability is limited. This tiered diagnostic approach can help reduce unnecessary imaging, facilitate timely intervention, and improve care delivery for patients with diabetic foot infections, especially in LMICs.

Despite being a cornerstone of bedside evaluation in suspected DFO, the probe-to-bone (PTB) test was documented in only 16% of cases in our cohort. This underuse contrasts sharply with the evidence base supporting its diagnostic accuracy. Lam *et al.* [10] demonstrated that the PTB test, when conducted properly, has a pooled sensitivity of 87% and specificity of 83%, figures comparable to those of MRI. Lam *et al.* [10] further highlighted that in high-risk populations, the positive predictive value of a positive PTB test can approach 98%. Given its rapid, low-cost nature and potential to provide immediate diagnostic direction [10], PTB should be considered a routine component of DFO assessment. Its omission in most of our cases represents a missed opportunity to simplify the diagnostic process and avoid unnecessary imaging.

Plain radiographs were performed in 98% of patients, consistent with current UK guidelines recommending X-ray as the initial imaging modality in suspected DFO [19]. Radiographic findings were positive or suspicious in approximately one-third of cases. Notably, over half (52%) of patients with MRI-confirmed osteomyelitis already exhibited corresponding radiographic changes. This supports the continued value of plain films as a first-line tool, particularly when interpreted alongside clinical findings. Aragón-Sánchez *et al.* [17] demonstrated that combining the PTB test with plain radiography yields diagnostic sensitivity of 97% and specificity of 92%, approaching the accuracy of MRI. This finding supports the diagnostic pathways recommended by Markanday's two-step model and recent Pakistani imaging guidelines (2022), which advocate plain radiographs plus PTB as a reliable combination before escalating to MRI [4, 8]. However, plain radiographs are known to have limited sensitivity in the early stages of osteomyelitis, with bony changes often taking up to two weeks to manifest [4]. Despite this limitation, X-rays offer crucial baseline data, aid in the detection of alternative diagnoses (*e.g.*, Charcot neuroarthropathy, foreign bodies), and are widely accessible and inexpensive. Thus, their use should be maximised before escalating to more advanced imaging.

When the initial radiograph is negative or inconclusive, repeat imaging after 7-10 days may improve diagnostic accuracy. This is particularly relevant given the delayed radiographic appearance of early osteomyelitis. Our data indicate that while 96% of negative radiographs included a recommendation for follow-up imaging, there was no consistent evidence that such follow-up occurred. This disconnect between radiologic recommendations and clinical action underscores the need for integrated follow-up protocols within care pathways. Pineda *et al.* [7] also support repeat imaging as a valuable intermediate step, especially in patients with moderate risk or equivocal presentations. Introducing structured follow-up would reduce unnecessary MRI referrals and enhance diagnostic certainty using widely available tools. In our cohort, 62% of MRIs confirmed osteomyelitis. However, only 28% of these reports included details on the extent of the infection, which is essential for surgical planning.

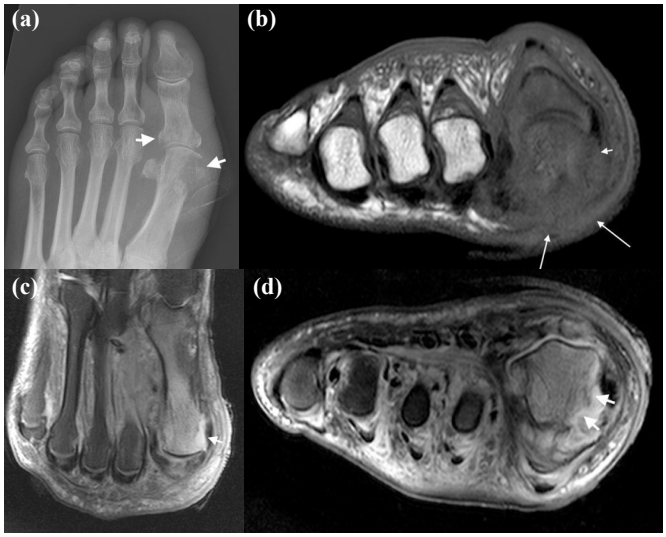

Fig. (2): (a) Plain x-ray showing erosion of medial margin of first metatarsal head and lateral margin of base of first proximal phalanx (short arrows) representing osteomyelitis. **(b)** MRI Short axis T1 showing a large ulcer (long arrows) on the plantar aspect of the first MTP joint with erosion of the first metatarsal head (short arrow). **(c)** MRI Long axis T2 FS (fat-suppressed) showing an ulcer of the first metatarsal head (short arrows) along with marrow oedema of the metatarsal shaft. **(d)** MRI Short axis T2 FS showing an ulcer of the first metatarsal head (short arrows) along with marrow oedema of the metatarsal shaft. MRI did not change management of this patient.

Moreover, 35% of MRI-confirmed osteomyelitis cases lacked corresponding findings on plain radiographs, supporting the use of MRI when prior investigations are inconclusive. Yet, the fact that 52% were positive for osteomyelitis on both prior plain films and MRI raises concerns about overutilisation, particularly when earlier diagnostic steps could have avoided the need for advanced imaging. **(Fig. 2a-d)**. MRI should be used selectively, for example, in cases of diagnostic uncertainty after PTB and radiography, or when detailed anatomical mapping is required for surgical decision-making [4] **(Fig. 3a-d)**.

Practical imaging depends heavily on the quality of clinical information provided. Nearly 40% of referrals in our study lacked a precise ulcer location, and 84% omitted PTB findings. Such omissions hinder diagnostic accuracy by preventing radiologists from focusing on the most clinically relevant areas. NICE guidelines [16] emphasise that comprehensive clinical data, including ulcer site, duration, depth, and the presence of exposed bone, enhance the diagnostic performance of imaging. Inadequate documentation not only delays care but can also lead to misinterpretation of imaging or the need for repeat studies. Embedding clinical requirements intov referral templates and electronic medical records may help address this systemic issue [20, 21].

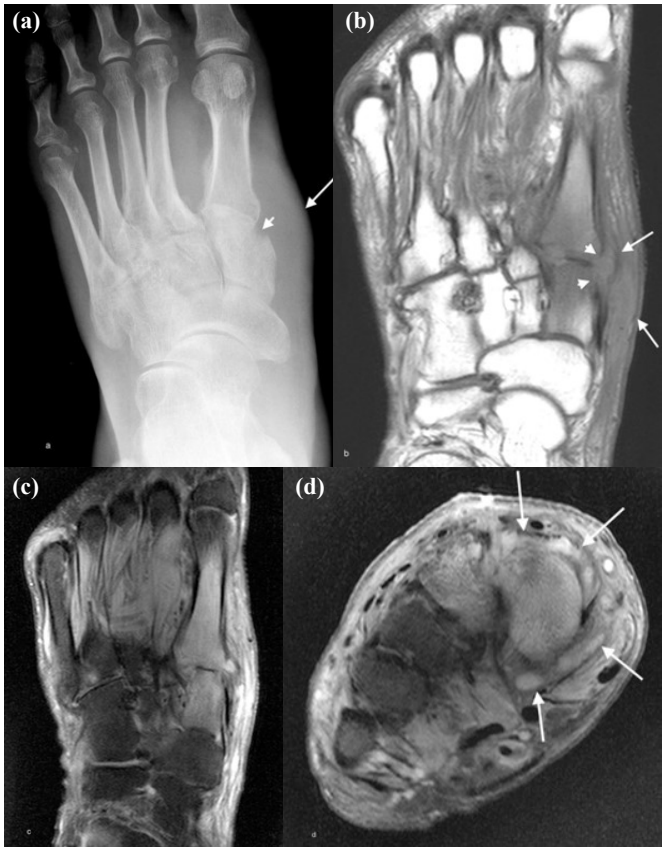

Fig. (3): (a) Plain X-ray showing erosion of the middle margin of the medial cuneiform (short arrow) along with associated soft tissue swelling (long arrows). **(b)** MRI Long axis T1. **(c)** MRI Long axis T2 FS. **(d)** MRI Short axis T2 FS MRI confirms erosion of adjacent surfaces of the medial cuneiform and base of 1st metatarsal in keeping with osteomyelitis (short arrows). Images **(c)** and **(d)** show extensive marrow oedema around the along with a collection around 1st TMT joint (long arrows). MRI clearly shows the abscess and aided surgical management in this case.

Referrals for suspected DFO originated from a range of specialities, including Endocrinology, Infectious Diseases, Orthopaedics, and General Medicine [6]. This diversity reflects real-world practice but also introduces variability in referral quality and imaging utilisation. A standardised diagnostic protocol can mitigate this variation, ensuring that all patients receive a consistent

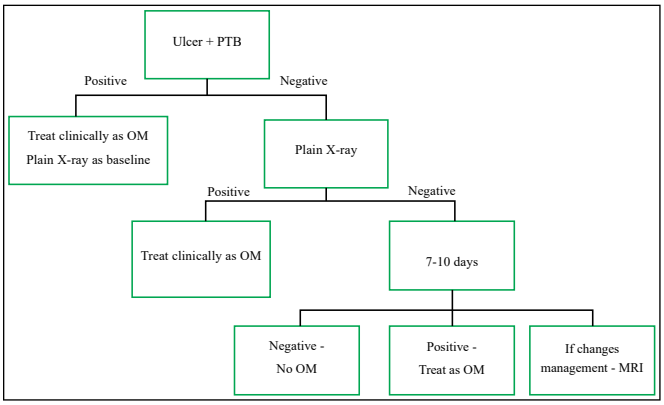

Fig. (4): Proposed diagnostic pathway.

and evidence-based approach. A recent meta-analysis by Calvo-Wright *et al.* [9] reinforced these findings, supporting a tiered diagnostic model that first uses simple tools. Adoption of such a model could streamline workflows, reduce diagnostic delays, and alleviate pressure on imaging services.

Based on our findings and the existing evidence base, we propose a stepwise diagnostic pathway for suspected diabetic foot osteomyelitis **(Fig. 4)**. The initial assessment should include a thorough clinical evaluation, with routine documentation of the ulcer's anatomical location and a PTB test. A positive PTB test should be considered sufficient to initiate treatment for osteomyelitis, unless an MRI is required explicitly for surgical planning or to assess complications. All patients should also undergo plain radiography as the first-line imaging modality. If radiographic findings are positive, treatment can proceed without further imaging. In cases where the initial radiograph is negative or equivocal, a repeat radiograph should be performed after 7-10 days, allowing for the temporal progression of radiographic changes. MRI should be reserved for cases in which diagnostic uncertainty persists after clinical and plain film assessment, or when detailed anatomical information is required for operative planning or the identification of deep collections. Standardising this pathway across specialities, with clear documentation and referral templates, may improve diagnostic efficiency, reduce imaging burden, and support timely intervention.

LIMITATIONS

There are several limitations of our study. Firstly, the potential for selection bias is introduced by its retrospective design, as we include completed MRI requests and available documentation, which may not be representative of the larger number of patients with suspected DFO.

Secondly, osteomyelitis was diagnosed based on imaging findings and clinical interpretation, with no microbiological or histopathological (bone biopsy) confirmation; therefore, the diagnosis cannot be definitively confirmed or refuted in every case due to this limitation.

Thirdly, clinical documentation was often incomplete, with crucial details such as probe-to-bone test results and ulcer location usually absent, so the accuracy of imaging interpretation may be compromised, and we won't be able to measure adherence to diagnostic protocols.

Additionally, the inconsistent implementation of radiographic follow-up recommendations hindered the evaluation of the actual utility of serial imaging in practice. Also, this study was conducted at a single centre, so the generalizability of the findings to other institutions may be limited, especially those institutions with different referral patterns, documentation practices, or access to imaging resources.

Finally, our sample size was inadequate to estimate the primary outcome—the proportion of MRI-confirmed DFO—with sufficient accuracy. As a result, the statistical certainty and generalisability are limited by the wide 95% confidence interval around our observed yield of 61% (47-74%). To validate these findings with greater precision, future studies should use larger cohorts.

CONCLUSION

When applied consistently and supported by clear clinical documentation, simple, low-cost tools can often be used to establish the diagnosis of DFO. According to our findings, the PTB test and plain radiography, when used appropriately, can provide sufficient diagnostic certainty in many cases, possibly eliminating the requirement for an MRI. However, current practice indicates inconsistent documentation, underutilization of the PTB test, and overreliance on advanced imaging. In resource-limited settings such as Pakistan, these findings are particularly relevant, as diagnostic efficiency is crucial for optimal care. By adopting a stepwise diagnostic pathway that prioritises bedside examination and first-line imaging, and reserving MRI for cases in which it meaningfully alters management, healthcare providers can optimise resource use, reduce delays in care, and maintain diagnostic accuracy. Standardising referral practices and embedding structured clinical information into imaging requests will be key to improving interdisciplinary communication and diagnostic stewardship in the management of suspected DFO.

ETHICS APPROVAL

This study was registered as a retrospective audit of diagnostic practice at the University Hospitals of Liverpool Group. According to UK Health Research Authority guidelines, ethical approval was not required. All data were anonymised before analysis, and the study was conducted in accordance with the principles of the Declaration of Helsinki.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA

The data that support the findings of this study are available from the corresponding author upon reasonable request.

FUNDING

None.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Declared none.

AUTHORS' CONTRIBUTION

HA and ST: Data collection and interpretation of results.

MUF, RK, SA, MIA: Drafting and writing of the manuscript.

HA: Overall supervision and final approval of the manuscript.

GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this work the author(s) limitedly used ChatGPT (GPT-4, OpenAI) to get language suggestions and do minor proofreading in some parts of the manuscript. After using this tool/ service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

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