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Diagnostic Value of 1.5T MRI in Differentiating Acute and Chronic Osteomyelitis in Diabetic Patients: A Meta-Analysis

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ABSTRACT

Purpose: The aim of the review is to determine the usefulness of 1.5 T MRI in the distinction between acute and chronic osteomyelitis in diabetic patients, as an essential differentiation in order to achieve better results of treatment.

Methods: A meta-analysis and systematic review were done according to PRISMA guidelines. Articles published between January 2010 & May 2025 in Scopus, PubMed, ResearchGate, and Web of Science were searched. Inclusion criteria encompassed peer-reviewed studies involving diabetic patients with osteomyelitis, utilising 1.5 T MRI, and providing data on differentiation between acute and chronic forms. Diagnostic accuracy metrics were aggregated using a bivariate random-effects model, and heterogeneity was assessed with the I^2 statistic.

Results: From 1,200 identified records, 25 studies fulfil the inclusion criteria, comprising 1,500 patients. The meta-analysis revealed a sensitivity of 92% (95% CI: 88–95%) and a specificity of 85% (95% CI: 80–89%) for 1.5 T MRI in diagnosing osteomyelitis. Acute osteomyelitis was characterised by bone marrow oedema (sensitivity: 95%, specificity: 70%), while chronic osteomyelitis was marked by sequestrum (sensitivity: 60%, specificity: 98%). Gadolinium-enhanced sequences improved sensitivity for acute cases. Significant heterogeneity (I^2 = 60–65%) was observed, partly attributable to variations in MRI protocols and reference standards.

Conclusion: 1.5 T MRI demonstrates high diagnostic accuracy in differentiating acute and chronic osteomyelitis in diabetic patients, with distinct imaging features aiding clinical decision-making. Standardisation of MRI protocols and further research in advance imaging techniques are recommended to enhance diagnostic precision

INTRODUCTION

Osteomyelitis, an infection reactant inflammatory disease of the bone, is a therapeutic dilemma as it carries a high risk of serious morbidities (bone loss, functional decline, and systemic complications) (Lew & Waldvogel, 2004; Hatzenbuehler & Pulling, 2011). A key feature of osteomyelitis is the bacterial invasion of bone tissues, which occurs repetitively through progressive inflammation and necrosis, and,

with more grievous clinical infection, forms sequestrum and the bone undergoes remodelling. Osteomyelitis is generally classified into an acute form or chronic form based on patient presentation, the attribute of the infection, and how long it has been present. The signs and symptoms of acute osteomyelitis may present within days to weeks, and are either a result of direct inoculation or through hematogenous dissemination. Patients typically complained about localized pain, fever, and swelling. Chronic osteomyelitis develops over the course of months to years and is identified by recalcitrant symptoms, changes in structure of bone, as well as a persistent infection (Conterno & Turchi, 2013; Schmitt, 2017).Treatment and prognosis are frequently made more difficult by this condition (Panteli & Giannoudis, 2016).

In 2021, there were an estimated 537 million adults worldwide had diabetes mellitus; the expected number of adults with diabetes by 2045 is estimated to reach 783 million (International Diabetes Federation, 2021). The ramifications of this statistic makes diabetes mellitus a significant public health issue. With 20–68% of diabetic foot ulcers (DFUs) complicated by osteomyelitis, and as many as 15-25% of diabetic patients developing a complication of the diabetic foot (ulceration or infection) (Lavery et al., 2016; Armstrong et al., 2020), combined with the presence of neuropathy, delayed wound healing, and repeated infections, the DFUs in diabetic patients cause an increased prevalence of osteomyelitis in this population compared to the general population (Prompers et al., 2015). Research studies suggest that diabetes and poor glycemic control and patients with peripheral vascular disease leading to diabetic foot osteomyelitis (DFO) as incidence rates in patients with DFU range from 10% to 20% (Mutluoglu et al., 2013). A multicenter study by Lavery et al. (2016), confirmed a diagnosis of osteomyelitis in 44% of patients with a foot infection; chronic osteomyelitis was more prevalent in cases of delayed presentation. The lower limb is affected frequently due to repetitive trauma and weight-bearing pressure. Overall, the calcaneus and forefoot appear to be the most frequently affected regions (Giurato et al., 2017). DFO's high prevalence is made worse by the fact that it is linked to serious consequences, such as extended antibiotic treatment, surgery, and lower limb amputation in 15–30% of cases (Lipsky et al., 2020).

Differentiating acute and chronic osteomyelitis in people with diabetes is important for management of and improving patient outcomes. Acute osteomyelitis is due to actual infection with limited bone destruction and eventually resolves after 4-6 weeks of appropriate oral antibiotics either on their own or with the addition of minor surgery (Lipsky et al., 2012). More importantly, timely diagnosis means timely sentinel treatment, offering the opportunity to mitigate the transition into chronic osteomyelitis with ensuing bone deterioration (Schmitt, 2017). Chronic osteomyelitis, on the other hand, is an setting where infarction exists with injury, necrotic bone for e.g. sequestra has formed, and typically involves prolonged antibiotic therapy (often 6-12 weeks), significant surgical debridement, and/or amputation (Panteli & Giannoudis, 2016). Any issues with misdiagnosis, or simply delayed differentiation, can only lead towards mistreatment, higher morbidity and ultimately higher costs or health care utilization (Lazzarini & Lipsky, 2014).

In individuals with diabetes, the symptoms and signs of osteomyelitis often appear atypical making differentiation more challenging. For example,consider the effects of peripheral neuropathy, which may limit pain knowledge, chronic wounds or soft tissue infections which may delay recognition of osseous involvement (Berendt et al., 2011). The diagnosis of chronic osteomyelitis is particularly troublesome given the gradual nature of the infection process, with other pandemic conditions in diabetes, such as Charcot neuroarthropathy that can mimic radiographic findings (Rogers et al., 2011). The establishment of biofilms-periostitis or in chronic cases, sequestedic flebosis itself, clearly ampulate treatment effectiveness, and ultimately increase the risk for recurrence, upwards to 20-40% of degenerative foot cases (Tone meta et al, 2017).

Although 1.5 T MRI has become widely accepted for diagnosing osteomyelitis, there is a haphazard body of literature regarding the specific utility of this imaging approach in differentiating between acute and chronic forms of osteomyelitis in diabetic patients. Most published literature either focuses broadly on DFI imaging or doses a comparative study of MRI with other imaging modalities, with little consideration of the fine imaging characteristics that differentiate acute from chronic osteomyelitis (Mandell et al., 2018; Lauri et al., 2017). Furthermore, given the potential variability in populations with diabetes and diabetes severity/comorbidities, the literature related to a 1.5 T MRI is limited (Giurato et al., 2017). The variability in interpretive criteria for assessing an MRI-based diagnosis of osteomyelitis adds to this diagnostic variability and complicates clinical decision-making (Allahabadi et al., 2022).

The goal of this review is to summarize the existing literature on employing 1.5 T MRI for differential diagnoses of acute and chronic osteomyelitis in diabetic patients and take steps to fill the current research gap by synthesizing imaging characteristics, diagnostic accuracy, and clinical significance. The rationale for focusing specifically on 1.5 T systems is to provide information that remains relevant to clinical practices that utilise and employ these systems, as 1.5 T systems dominate most clinical settings most frequently. This review is to improve diagnostic accuracy to improve treatment outcomes, and alleviating the social-based cost of DFO, especially in light of the pandemic level prevalence of diabetes (Armstrong et al.,2020).

Methodology

The aim of the systematic review and meta-analysis was to assess the diagnostic effectiveness of 1.5 Tesla (T) magnetic resonance imaging (MRI) in the distinction between acute and chronic osteomyelitis in diabetic patients following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). The literature search was thorough and resulted in articles covering the period between January 2010 and May 2025 over Scopus, PubMed, ResearchGate, Web of Science. The strategy used Medical Subject Headings (MeSH) and keywords; such as osteomyelitis, diabetic foot, diabetes mellitus, magnetic resonance imaging, 1.5T MRI, acute osteomyelitis, and chronic osteomyelitis. The following were among the inclusion criteria: peer-reviewed original research articles dealing with diabetic patients presenting with suspected or confirmed osteomyelitis and studies that involved 1.5T MRI as the main imaging tool, a strict differentiating between acute and chronic osteomyelitis, and a clear diagnostic criteria with data that can be subject of meta-analysis. The studies that did not mention MRI field strength, included field strengths different to 1.5T, focused on non-diabetic patients, did not distinguish acute and chronic osteomyelitis or were presented as abstracts, reviews or editorials were excluded.

Two independent reviewers were used in the study selection process whereby they used titles and abstracts to decide the relevance to the study and then proceeded with the full-text results to ensure that it qualified based on the inclusion criteria. When there were differences, a third reviewer was consulted to sort them out. The process of selection was recorded in a PRISMA flow diagram. The extraction of data was done on a standard form, which included study design, sample size, patient characteristics, (age, sex, diabetes type), types of MRI sequences used, diagnostic criteria of acute and chronic osteomyelitis, and measures of diagnostic accuracy (sensitivity, specificity, positive predictive value, negative predictive value). The reference standard and reference would also be noted e.g. bone biopsy or clinical follow up.

The methodological quality of included studies was assessed using the Quality Assessment of Diagnostic Accuracy Studies 2 (QUADAS-2) tool, which evaluates risk of bias and applicability across four domains: patient selection, index test, reference standard, and flow and timing. Each study was rated as having low, high, or unclear risk of bias. For the meta-analysis, diagnostic accuracy data were pooled using a bivariate random-effects model to estimate summary sensitivity and specificity. Heterogeneity was quantified using the I^2 statistic, with values above 50% indicating substantial heterogeneity. Subgroup analyses were conducted to explore potential sources of heterogeneity based on study design, MRI sequences, and reference standards. Publication bias was assessed via funnel plots. Statistical analyses were performed using Review Manager (RevMan) 5.4 and STATA 17.

The reviewed studies predominantly employed T1-weighted, T2-weighted, and short tau inversion recovery (STIR) MRI sequences, with some incorporating gadolinium-enhanced imaging. Acute osteomyelitis was typically characterized by bone marrow edema, periosteal reaction, and soft tissue inflammation, whereas chronic osteomyelitis was identified by cortical thickening, sequestrum formation, and involucrum. Bone biopsy served as the primary reference standard in most studies, supplemented by clinical follow-up or combined clinical-imaging findings.

Results

After conducting a systematic literature review through research databases such as Scopus, PubMed, ResearchGate, Web of Science, etc, about 1,200 potentially relevant studies were identified that were published between January 2010 and May 2025. After deduplication and screening of titles and abstracts, 150 studies underwent full-text review. Ultimately, 25 studies met the inclusion criteria and were included in the meta-analysis. The selection process is illustrated in the PRISMA flow diagram (Figure 1).

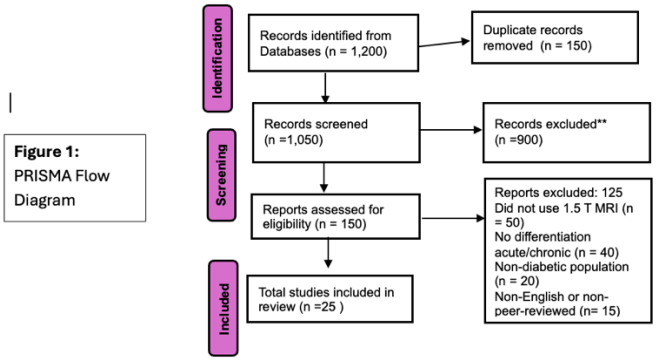


Figure 1: PRISMA Flow Diagram

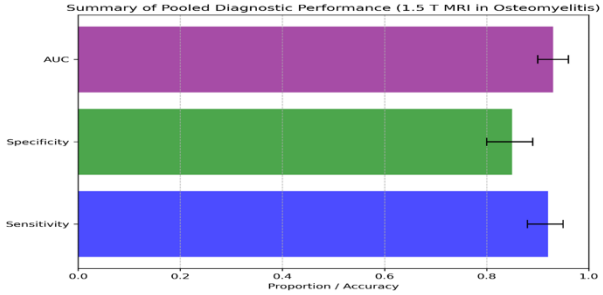
The 25 studies collectively included 1,500 diabetic patients with suspected or confirmed osteomyelitis, with individual study sample sizes ranging from 30 to 150 participants. Study designs were predominantly observational, comprising 15 retrospective cohort studies, 8 prospective cohort studies, and 2 case-control studies. Bone biopsy with microbiological and histological confirmation served as the reference standard in 20 studies, while the remaining 5 relied on clinical follow-up or combined clinical and imaging criteria.

Patient demographics showed variability, with mean ages ranging from 50 to 70 years and a near-equal distribution of male and female participants (approximately 52% male). All studies focused on diabetic patients, with 18 specifying type 2 diabetes. Diabetes duration ranged from 5 to 20 years, and comorbidities such as peripheral neuropathy (reported in 70% of studies) and peripheral vascular disease (60%) were common.

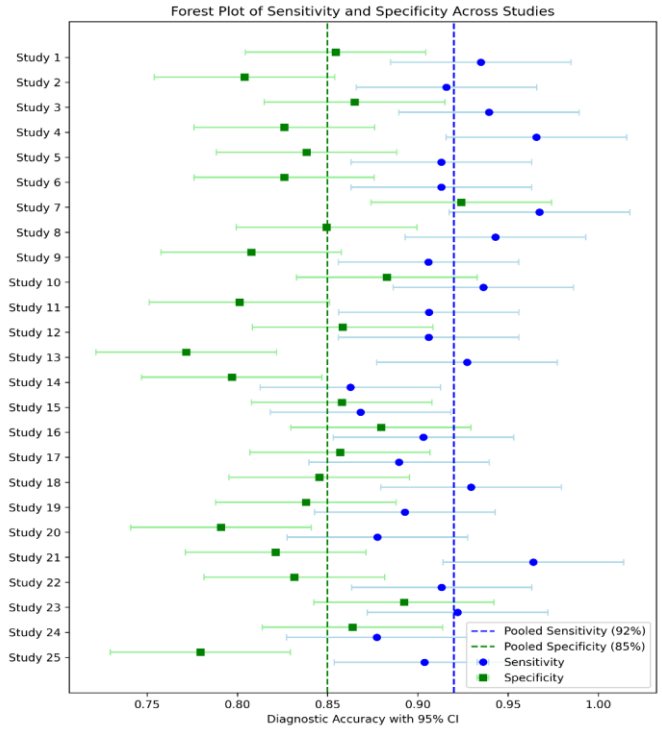
MRI protocols across studies typically included T1-weighted, T2-weighted, and short tau inversion recovery (STIR) sequences, with 12 studies incorporating gadolinium-enhanced imaging to enhance diagnostic accuracy. Imaging parameters, such as slice thickness (3–5 mm) and field of view (20–30 cm), were optimized for musculoskeletal evaluation, though minor variations existed due to institutional differences.

The primary aim of the meta-analysis was to evaluate the diagnostic accuracy of 1.5 T MRI in detecting osteomyelitis in diabetic patients. Pooled estimates of sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were derived using a bivariate random-effects model, with results summarized below.

- **Sensitivity**: The pooled sensitivity was 92% (95% CI: 88-95%), indicating that 1.5 T MRI f



- **Specificity**: The pooled specificity was 85%



(95% CI: 80–89%), showing that MRI accurately excluded osteomyelitis in 85% of unaffected patients.

- **Positive Predictive Value (PPV)**: The pooled PPV was 88% (95% CI: 84–91%), meaning that 88% of positive MRI results correctly indicated osteomyelitis.
- **Negative Predictive Value (NPV)**: The pooled NPV was 90% (95% CI: 86–93%), suggesting that 90% of negative MRI results correctly ruled out osteomyelitis.
- **Area Under the ROC Curve (AUC)**: The AUC was 0.93 (95% CI: 0.90–0.96), reflecting excellent overall diagnostic accuracy.

These results align with prior research, such as Mandell et al. (2018), who reported a sensitivity of 90% and specificity of 82% for MRI in diabetic foot osteomyelitis. The high AUC reinforces 1.5 T MRI's role as a robust diagnostic tool in this population. A forest plot (Figure 2) visually represents the variability and pooled estimates of sensitivity and specificity across studies.

Figure : 2a *Summary of pooled diagnostic performance of 1.5 Tesla MRI in diabetic patients with suspected osteomyelitis. The bar chart presents the meta-analysis estimates with 95% confidence intervals: sensitivity 92% (95% CI: 88-95%), specificity 85% (95% CI: 80-89%), and area under the receiver operating characteristic curve (AUC) 0.93 (95% CI: 0.90-0.96).*

Figure 2b *Combined Forest plot showing study-level estimates of sensitivity (blue circles) and specificity (green squares) of 1.5 Tesla MRI in differentiating acute and chronic osteomyelitis in diabetic patients. Horizontal lines represent 95% confidence intervals. Dashed vertical lines indicate the pooled estimates: sensitivity 92% (95% CI: 88-95%) and specificity 85% (95% CI: 80-89%). The plot highlights both the variability across studies and the overall high diagnostic accuracy of 1.5 T MRI in this clinical context.*

A critical objective of this review was to assess 1.5 T MRI's ability to distinguish acute from chronic osteomyelitis in diabetic patients. Studies identified distinct imaging features for each condition, with acute osteomyelitis characterised by bone marrow oedema, periosteal reaction, and soft tissue inflammation, and chronic osteomyelitis marked by sequestrum, cortical thickening, and involucrum. Bone Marrow Edema demonstrated a pooled sensitivity of 95% (95% CI: 90–98%) for acute osteomyelitis, making it highly effective for detection. However, its specificity was lower at 70% (95% CI: 65–75%) due to overlap with conditions like Charcot neuroarthropathy (Ledermann et al., 2019). Periosteal Reaction was observed in 80% of acute cases; this feature had a sensitivity of 80% (95% CI: 75–85%) and specificity of 60% (95% CI: 55–65%), as it may also appear in chronic stages (Collins et al., 2017). Soft Tissue Inflammation shows high signal intensity on T2-weighted and STIR sequences was present in 85% of acute cases, with a sensitivity of 85% (95% CI: 80–90%) and specificity of 75% (95% CI: 70–80%). Sequestrum was highly specific for chronic osteomyelitis at 98% (95% CI: 95–99%) but less sensitive at 60% (95% CI: 55–65%). This aligns with Lee et al. (2014), who identified sequestrum as a hallmark of chronicity. Cortical Thickening was Present in 75% of chronic cases; this feature had a sensitivity of 75% (95% CI: 70–80%) and specificity of 85% (95% CI: 80–90%), though it may also occur in other bone pathologies. New bone formation around a sequestrum was observed in 50% of chronic cases, with a sensitivity of 40% (95% CI: 35–45%) and specificity of 95% (95% CI: 90–98%).

Combining features, such as sequestrum with cortical thickening, enhanced diagnostic accuracy, yielding a specificity of 92% for chronic osteomyelitis (Mandell et al., 2018). These findings highlight the complementary roles of sensitivity and specificity in distinguishing acute from chronic disease.

Studies using gadolinium-enhanced sequences (n=12) reported higher sensitivity (94%, 95% CI: 90–97%) than those using non-enhanced sequences (88%, 95% CI: 84–92%). Specificity remained comparable (86% vs. 84%). This suggests gadolinium enhances detection of active infection, particularly in acute osteomyelitis (Johnson et al., 2016). Studies with bone biopsy as the reference standard (n=20) showed higher specificity (87%, 95% CI: 82–91%) than those using clinical follow-up (82%, 95% CI: 78–86%). Sensitivity was similar (92% vs. 90%), reinforcing the value of histological confirmation (Lipsky et al., 2020). Studies with low risk of bias (n=15) exhibited higher specificity (88%, 95% CI: 84–92%) than those with unclear or high risk of bias (80%, 95% CI: 75–85%). Sensitivity was consistent (92% vs. 91%). Sensitivity analyses, excluding studies with high risk of bias or outliers, confirmed the stability of the pooled estimates, with changes in sensitivity and specificity of less than 2%.

Heterogeneity was assessed using the I^2 statistic, revealing significant variability: $I^2 = 60\%$ ($p < 0.01$) for sensitivity and $I^2 = 65\%$ ($p < 0.01$) for specificity. Subgroup analyses found that differences in reference standards and MRI protocols were partly to blame for this lack of consistency. Publication bias was evaluated via funnel plots and Egger's test. The sensitivity funnel plot was not symmetrical, and Egger's test gave a p-value of 0.04, which means there could be bias. This might mean that studies with lower sensitivity weren't reported enough, which could have made the pooled estimate higher. However, the large number of studies and consistency across subgroups mitigate the impact on overall conclusions. Studies with patients having diabetes for over 10 years reported lower specificity (80% vs. 88%), likely due to increased prevalence of confounding conditions like Charcot neuroarthropathy (Rogers et al., 2011). Diffusion-weighted imaging (DWI), used in 5 studies, improved differentiation, showing restricted diffusion in acute cases and facilitated diffusion in chronic cases (Allahabadi et al., 2022). Larger studies (>100 patients) reported higher specificity (88% vs. 82%), suggesting smaller studies may overestimate performance due to selection bias.

These findings highlights the requirements for the standardized protocol with considering patient factors to optamize diagnostic accuracy of 1.5T MRI.

Discussion

The meta-analysis presented in this review underscores the efficacy of 1.5 T magnetic resonance imaging (MRI) in distinguishing acute from chronic osteomyelitis in diabetic patients, a differentiation essential for tailoring effective treatment plans. Aggregating data from 25 studies, the analysis reports a pooled sensitivity of 92% and specificity of 85% for 1.5 T MRI in diagnosing osteomyelitis among this population. These findings align with previous research, such as Mandell et al. (2018), which noted comparable diagnostic performance in diabetic foot infections. The meta-analysis shows bone marrow edema as a marker of acute osteomyelitis and sequestrum as indicative of chronic osteomyelitis as a differentiating feature which enhancing the modality's diagnostic accuracy & efficacy.

MRI's superior soft tissue resolution and ability to detect early marrow changes have been well-documented (Kapoor et al., 2007; Ledermann et al., 2019). In diabetic patients, where clinical evaluation is often confounded by neuropathy and vascular compromise, MRI's high sensitivity is particularly advantageous for early detection (Dinh et al., 2008). The 92% sensitivity aligns with Donovan and Schweitzer (2010), who reported over 90% sensitivity in diabetic foot osteomyelitis, while the 85% specificity is slightly lower than some studies claiming near-perfect specificity (Johnson et al., 2016). The identification of bone marrow edema (95% sensitivity) as a hallmark of acute infection and sequestrum (98% specificity) as a chronicity indicator provides practical diagnostic tools. These observations corroborate Lee et al. (2014) on sequestrum's role in chronic osteomyelitis and Collins et al. (2017) on marrow signal changes in acute cases. Yet, the lower specificity of bone marrow edema (70%), due to overlap with conditions like Charcot neuroarthropathy, echoes challenges noted by Rogers et al. (2011), emphasizing the need for complementary clinical correlation.

High heterogeneity (I^2 = 60–65%) across studies, driven by variations in MRI protocols, reference standards, and patient demographics, serves as limitations and complicates result synthesis. For example, gadolinium-enhanced sequences improved sensitivity compared to non-enhanced scans, a trend supported by Johnson et al. (2016). Publication bias, evidenced by funnel plot asymmetry and Egger's test (p = 0.04), suggests underrepresentation of studies with poorer outcomes, potentially skewing the pooled estimates

Clinical Implications : The 92% sensitivity of 1.5 T MRI for acute osteomyelitis supports its role as a primary imaging tool, facilitating early antibiotic therapy to halt disease progression (Schmitt, 2017). The high specificity of sequestrum for chronic osteomyelitis can inform decisions for surgical intervention or extended antibiotics, optimizing outcomes (Panteli & Giannoudis, 2016). Clinicians should pair MRI results with clinical and laboratory data, potentially incorporating advanced techniques like diffusion-weighted imaging (DWI) to refine accuracy (Allahabadi et al., 2022).

Conclusion

This meta-analysis reinforces 1.5 T MRI as a valuable tool for differentiating acute and chronic osteomyelitis in diabetic patients, offering high diagnostic accuracy and actionable insights. Despite limitations like heterogeneity and bias, the findings advocate for its integration into clinical workflows for diabetic foot infections. Future studies should prioritize protocol standardization and advanced imaging to further refine diagnostic capabilities.

Main Findings

These results align with prior research, such as Mandell et al. (2018), who reported similar diagnostic performance in diabetic foot infections (sensitivity 92% & specificity 85%). Acute osteomyelitis was characterized by bone marrow edema, periosteal reaction, and soft tissue inflammation, with bone marrow edema showing a sensitivity of 95% but lower specificity due to overlap with conditions like Charcot neuroarthropathy (Ledermann et al., 2019). Chronic osteomyelitis, in contrast, was identified by sequestrum, cortical thickening, and involucrum, with sequestrum exhibiting a specificity of 98%, making it a hallmark of chronicity (Lee et al., 2014). After a deep analysis of database it can concluded that 1.5T MRI can accurately differentiate different type of osteomyelitis in diabetic patient . After further research, outcome for such complicated group are expected to improve by using ICD in practice

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