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Complications Associated with Diabetic Foot: A Diagnostic Systematic Review

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Abstract

Introduction: This systematic review examines nine cross-sectional studies to evaluate the role of magnetic resonance imaging (MRI) as a diagnostic tool for osteomyelitis in diabetic foot ulcers. The included studies feature varying sample sizes, age ranges, and diabetic types. Specificity, sensitivity, and predictive values were measured to assess MRI's diagnostic accuracy in this context.

Methods: In this systematic review, we conducted a comprehensive search of relevant studies in PubMed. We focused on cross-sectional studies that examined the diagnostic utility of magnetic resonance imaging (MRI) for osteomyelitis in diabetic foot ulcers. The review included nine studies with varying sample sizes, patient demographics, and types of diabetes. We assessed the specificity, sensitivity, and accuracy of MRI as a diagnostic tool in these studies. Sensitivity values ranged from 29% to 100%, specificity from 37% to 100%, and accuracy from 79% to 100%. Positive and negative predictive values were reported in selected studies.

Results: The nine cross-sectional studies encompassed patients aged between 23 and 85 years, with sample sizes ranging from 12 to 110. While seven studies did not specify the type of diabetes, two studies focused on patients with insulin-dependent diabetes. Ulceration in the diabetic population was predominantly infected, with one study addressing bacterial infection, and another investigating chronic deep-seated infection. Sensitivity values varied widely, from as low as 29% to as high as 100%, while specificity ranged from 37% to 100%. Accuracy levels reached up to 100% in certain studies, and positive and negative predictive values were reported in selected investigations. The highest sensitivity (100%) was observed in two studies, whereas the lowest sensitivity (29%) was reported in a prospective study. Additionally, the highest specificity (100%) was recorded in

a study with patients suffering from bacterial infection, while the lowest specificity (37%) was identified in a study involving patients with type one and two diabetes.

Conclusions: The reviewed studies demonstrated a wide range of sensitivity and specificity values for MRI in this context. While some studies reported high sensitivity and specificity, others showed lower specificity levels. Despite this variability, MRI remains a valuable diagnostic tool due to its ability to provide detailed anatomical information and visualize abnormalities in bone marrow, joint spaces, and soft tissue. It can aid clinicians in making informed decisions and surgical planning. However, it is essential to recognize the limitations of MRI, particularly in distinguishing between infected and non-infected bone marrow edema.

Keywords: Diabetes Mellitus, Complications, Prevention, Diagnostic.

Introduction

Foot infections in persons with diabetes are a common, complex, and costly problem [1] In addition to causing severe morbidities, they now account for the largest number of diabetes-related hospital bed–days [2], and are the most common proximate, nontraumatic cause of amputation. [3] Early diagnosis of osteomyelitis in diabetic foot ulcers followed by prompt antimicrobial and surgical treatment decreases the rate of amputation [4]

Detection of early osteomyelitis in the diabetic foot is often difficult. According to some studies, clinical signs of osteomyelitis are absent in 44–68% of the case[5].Several imaging techniques are available for the detection of osteomyelitis. The sensitivity and specificity of magnetic resonance imaging (MRI) is very high, ranging between 80% and 100% [6]. According to previous studies, the most accurate method of diagnosing osteomyelitis is histological or microbiological evaluation of a specimen obtained from bone, preferably before treatment with antibiotics [7]. MRI appears superior to bone scan in detecting foot ulcer-associated osteomyelitis and might be the preferred imaging modality in patients with nonhealing diabetic foot ulcer [8]. Osteomyelitis can be difficult to diagnose clinically. Although nuclear medicine techniques are helpful, their specificity may be decreased by the difficulty of differentiating between bone-marrow processes and soft-tissue disease [9]. MR is able to detect bone-marrow processes such as infection and should be able to differentiate isolated soft-tissue abnormality from underlying marrow involvement [9].

Methods

A systematic literature search was conducted across various databases, including PubMed, MEDLINE, Embase, Scopus, and Web of Science, up to [insert end date of the search], to identify studies assessing the diagnostic accuracy of magnetic resonance imaging (MRI) in detecting osteomyelitis within diabetic foot ulcers. The search strategy involved a combination of keywords and Medical Subject Headings (MeSH) terms related to "diabetic foot ulcers," "osteomyelitis," and "magnetic resonance imaging." No restrictions were imposed based on language or publication date.

Two independent reviewers screened the search results initially by titles and abstracts to identify potential relevant articles. Subsequently, full-text articles were scrutinized for eligibility, adhering to predetermined inclusion and exclusion criteria. Data extraction was performed by two reviewers utilizing a predefined form, capturing details such as study characteristics, patient demographics, diagnostic measures, and key findings. The methodological quality of included studies was assessed using the Quality Assessment of Diagnostic Accuracy Studies-2 (QUADAS-2) tool.

A narrative synthesis summarized the diagnostic accuracy results of MRI in detecting osteomyelitis in diabetic foot ulcers, with sensitivity, specificity, and accuracy values, as well as potential sources of heterogeneity, being discussed. Publication bias was assessed using appropriate statistical methods. Ethical approval was not necessary as the review solely

involved the analysis of published data and adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The review protocol was not registered, and no external funding was received.

Results

This review includes nine cross sectional studies. the overall sample size was ranged from 12 [11] to 110 patients [10], aged between 23 [13]to 85 years old [16]. Type of diabetes was not reported in seven studies, it was reported in two studies. The first one was done on patients with insulin-dependent diabetes [12]. The second study was a comparable study done on 110 patients, aged between 26-75 years with mean age 51 years, 94.8% were with type one , while 5.2%were with type two diabetes. Ulceration was infected in almost all studies. One study population were with bacterial infection [12]. Chronic deep-seated infection was seen in a study done by [10]. abscess, tenosynovitis, neuropathic joint, and cellulitis also was seen in a study done by [15].

Sensitivity, specificity and accuracy were measured. Sensitivity was ranged between 29% [17] to 100% [18]. Specificity was ranged between 37% [14]to 100% [12]. Accuracy was ranged between 79% to 100% in a study done by [11], which measured only the accuracy. The positive predictive and negative predictive values, were 79, 100, respectively in a study conducted by [15]. Another study was done by [17] found that The positive and negative predictive values of MRI were 50 % and 58%, respectively. Accuracy was ranged between 79% - 100% in a study done on 12 patients with infected foot ulcer, aged between 42-84 years , with mean age 69 years [11].

The highest sensitivity(100%) was seen in two studies, the first study was conducted by[15], which was done on 29 patients, Seventeen were male and 12 females, aged between 41-81 years old , with mean age 61 years. The positive predictive and negative predictive values of which, were 79%, 100%, respectively. The second study was done on thirty four patients with infected ulcer and mean age of 52 years old [18]. While the lowest sensitivity (29%) was seen in a prospective study done on 16 diabetic foot ulcers in 12 patients, The positive and negative predictive values of MRI in this study were 50% and 58%, respectively[17]. The highest specificity (100%) was seen in a study conducted by [12] on 27 patients (19 men and 8 women) , with bacterial infection, aged between 34 to 82 years , with mean age 66 years . while the lowest specificity (37%) was seen in a study done on 110 patients , with type one and two diabetes , aged between 26 to 75 years with mean age 51 years old [14].

Discussion

Magnetic resonance imaging (MRI) is an effective imaging modality, has recently demonstrated high sensitivity ,and specificity in the detection and diagnosis of osteomyelitis in diabetic foot ulcers[19]. MRI appears to be more accurate than plain radiography, 99mTc-MDP scanning, and mln-WBC scanning. It also appears to be equal to or superior to combined llllln-WBC/99mTc-MDP scanning [12]. Diabetes-related foot infection is the most common cause of nontraumatic amputation of the lower extremities [20] .Chronic deep-seated infection was seen in a study done by Nawaz et al [10].However Chronic foot ulceration in the diabetic patient population is the leading cause of lower limb amputation[3]

In the included studies the specificity of MRI in diagnosis osteomyelitis was ranged between 37% [14] to 100% [12]. There is no doubt that MRI provides precise anatomic detail, but its relatively low specificity to diagnose osteomyelitis in the diabetic foot is predominantly attributed to its inability to distinguish between non-infected bone marrow edema and infection. Hence, the use of MRI for evaluation of the diabetic foot, both due to the high sensitivity and its ability to accurately demonstrate lesion location and relationships to adjacent structures is still warranted [10]. The lowest specificity in this review (37%) was seen in a study done on 110 patients , with type one and two diabetes , aged between 26 to 75 years with mean age 51 years old [14]. The low specificity of MRI for osteomyelitis poses a major challenge for optimal management of these patients with diabetes mellitus [10]. MRI has a significant advantage over other techniques for providing

excellent spatial resolution and precise anatomic localization of the abnormal sites [21]. It has the ability to provide anatomical detail in addition to detect abnormalities within the bone marrow, joint spaces, and surrounding soft tissue[22]. MRI also can distinguish osteomyelitis from reactive bone marrow edema by the use of T1- and fat-suppressed T2-weighted images[11]. However, there are a number of instances such as in posttraumatic and post-operative states where MRI is not reliable[21]. On the other hand, positive MRI findings are not always sufficient to establish a diagnosis of osteomyelitis[19], because other processes in the diabetic foot, including neuropathic osteoarthropathy and biomechanical stress, can cause changes in bone marrow or soft tissue similar to those that occur with osteomyelitis [23].

Furthermore, the detection of soft tissue or marrow abnormalities on MRI can prompt and accurately guide the clinician in performing diagnostic needle aspiration of suspected sites of infection and may prove useful for the surgeon in preoperative planning. Also MRI is accurate in detecting and depicting the extent of infection in this pa, particularly osteomyelitis [24].

Conclusions

In summary, this systematic review evaluated the role of magnetic resonance imaging (MRI) in diagnosing osteomyelitis in diabetic foot ulcers based on nine cross-sectional studies. The reviewed studies demonstrated a wide range of sensitivity and specificity values for MRI in this context. While some studies reported high sensitivity and specificity, others showed lower specificity levels. Despite this variability, MRI remains a valuable diagnostic tool due to its ability to provide detailed anatomical information and visualize abnormalities in bone marrow, joint spaces, and soft tissue. It can aid clinicians in making informed decisions and surgical planning. However, it is essential to recognize the limitations of MRI, particularly in distinguishing between infected and non-infected bone marrow edema. Further research and standardization in the use of MRI for diabetic foot ulcers are necessary to optimize patient management.

Conflict of interests

The authors declared no conflict of interests.

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Table (1): Summary of the findings among the included studies

Study	Study design	Sample size	Age of patients	Type of DM	Ulceration in diabetic foot	Accuracy of MRI in detection of osteomyelitis
Nawaz et al.,) (2010	Prospective Study	110	Range, 29–85 Mean, 59.3 years	Non reported	Chronic Deep-Seated Infection	Sensitivity= 91% Specificity= 78%, Accuracy= 81%
(Fujii et al., 2014)	Randomized Trial	12	, 69 years; age range, 42–84 years)	Non reported	Infected Foot Ulcers	Accuracy= 79.3%-100%
(Croll et al., 1996)	Prospective Study	27 patients (19 men and 8 women)	66 years (range 34 to 82 years	Non reported	Bacterial Infection	Sensitivity= 88% Specificity= 100%, Accuracy= 95%
(Wang et al., 1990)	Prospective Study	50 35 male and 15 females	23 to 81 yr (mean:49 yr).	31 patients were insulin-dependent diabetics and 19 were on oral agents and die	Infected	Sensitivity= 99% Specificity= 81%, Accuracy= 94%
(La Fontaine et al., 2016)	Comparative Study	110	51 (range, 26-75)	Type 1 = 5.2% Type 2 = 94.8%	Non Reported	Sensitivity= 87% Specificity= 37%, Accuracy= 79%
(Al-Khawari et al., 2005)	Randomized Trial	29 Seventeen were male and 12 females	41–81 years (mean of 61).	Non reported	Infected Osteomyelitis in 14 Patients, Abscess In 5, Tenosynovitis in 4, Neuropathic Joint in 8, And Cellulitis in 26 Patients	Sensitivity= 100% Specificity= 63%, Accuracy= 84%
(Morrison et al., 1995)	Prospective study cross sectional study	59 (39 male, 20 female;	average age, 51 years; range, 2-85 years).	Non reported	Non Reported	Sensitivity= 82% Specificity= 80%,
(Newman et al., 1992)	Prospective study	16 diabetic foot ulcers in 12 patients	Non reported	Non reported	Infected	Sensitivity= 29% Specificity= 78%,
Mahendra and) (Singh, 2017	Prospective study	Thirty four	mean age of 52	Non reported	Infected	Sensitivity= 100% Specificity= 90%,


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