Evaluation of diabetic foot osteomyelitis using probe to bone test and magnetic resonance imaging and their impact on surgical intervention

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Abstract Objectives: To evaluate the role of probe to bone test (PTB) and magnetic resonance imaging (MRI) in assessing the surgical intervention in diabetic foot.
Study design: 102 diabetic patients were included; 42 males and 60 females, mean age was 52 ± 6, all patients were subjected to PTB test followed by MRI, the presence of osteomyelitis was assessed in relation to histopathological examination.
Results: We had 80 (75.5%) feet of osteomyelitis, PTB test was true positive in 66 (82.5%), false negative in eight and false positive in 6 feet. MRI was true positive in 78, false positive in three and false negative in two feet. Other MRI findings include abscess in 37, tenosynovitis in 69, neuropathic changes in 20 feet, and all cases had cellulitis. Sensitivity, specificity, PPV and NPV were 82.5%, 76.9%, 91.7%, and 58.8% for PTB test and 97.5%, 88.5%, 96.3% and 92% for MRI respectively.
Conclusion: PTB test is a simple, minimally invasive, low cost test and can be done at outpatient clinic. Its sensitivity and specificity are good when compared to those of MRI, but when we need to diagnose associated soft tissue infection and planning the surgical management MRI was the image of choice.

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1. Introduction

Diabetes is a complex disease, it affects various organs resulting in a group of related complications (1), approximately 15% of diabetic patients complain of foot complication, and about one fifth of those patients are being hospitalized (2).

Effective management of diabetic foot disorders is imperative, because delay in diagnosis or inadequate treatment can lead to serious complication such as loss of life or limb. Complications of diabetic foot problems account for from 50% to 60% of all non-traumatic foot or leg amputations, the majority of which are due to infectious complications (3).

The diagnosis of diabetic foot osteomyelitis is usually a challenge to the clinician and radiologist, the major diagnostic difficulty is to differentiate between bone infection and acute neuroarthropathic bone lesion (4).

The probe to bone (PTB) test has been used worldwide since its introduction for evaluating diabetic patients with a foot ulcer. Palpation of bone with a metal probe is a simple bedside technique, the diagnosis of osteomyelitis is based on the idea that if the probe can reach the bone, thus will the infectious bacteria (5).

Imaging plays the key part in the identification of diabetic foot soft tissue, bony, and articular complications, plain films and computed tomography (CT) scan supply helpful bony anatomic information, but their soft tissue detail is lacking, and their sensitivity and specificity for detecting infection are low, particularly within the early stages of infection (6). Bone scintigraphy is also sensitive but lacks specificity (7).

Magnetic resonance imaging is the most sensitive and most specific imaging technique for the diagnosis of osteomyelitis and provides excellent anatomic detail and additional accurate information on the extent of the infectious process and associated soft tissues’ involvement (8).

The aim of this study to evaluate the efficacy of probe to bone test and MRI examination on the early diagnosis of osteomyelitis and its impact on surgical decision in patients with diabetic foot.

2. Research design and methods

This prospective study was performed during the period from September 2011 to October 2013, and included 108 diabetic patients complaining of foot infection, the patients were referred from the vascular surgery department and diabetic outpatient clinic in Zagazig university hospital, the inclusion criterion was the presence of foot ulcers associated with sign of infection in patient with normal plain X-ray (no radiological changes suggesting osteomyelitis), and the patients were scheduled for surgical management.

Exclusion criteria were patients with recurrent or long standing osteomyelitis with evident X-ray changes, ischemic foot ulcers (diagnosed by performing duplex ultrasound for all patients), minor abrasion or laceration, presence of contraindication to surgery (hepatic or renal failure and ischemic heart disease) or MRI examination.

Foot ulcer was defined as a full thickness lesion involving any portion of the foot or ankle (9).

The study was approved by local ethics committee and a written consent was obtained for each patient.

2.1. Study design

The study was carried out on 102 diabetic patients (either type 1 or type 2); who completed the whole research, they were 60 (58.8%) females and 42 (41.2%) males, their age ranged from 21 to 74 (mean 52 ± 6). The included patients were hospitalized and a written consent was obtained from each patients. The demographic data of the patients are shown in (Table 1).

All patients were subjected to full history taking (including treatment for diabetic control and any associated condition) and full clinical examination with routine laboratory investigation (CBC, liver and kidney function tests). The blood glucose level (fasting, 2H. postprandial and HBA1c) was estimated at the time of admission and preoperative diabetic control was done.

The patients were examined first by PTB test at the initial evaluation, followed by MRI examination of the affected foot, and then the patients were subjected to surgical interference according to the obtained finding.

2.2. PTB test

All PTB tests were conducted by an experienced surgeon using a sterile blunt metal probe, which passed gently through the depth of the wound in order to feel the bone. Test was considered positive when the probe palpating a hard or gritty substance that was presumed to be bone or joint space.

2.3. MRI examination

MRI was performed using 1.5-T superconductive magnet (Intera Achiva Nova Dual system, Philips Medical System, Best, the Netherlands), all patients were scanned by dedicated extremity coil, the patient is placed in supine position with feet first. The examined foot was positioned in the midline of the table, which corresponding to the center of the magnet.

Examination time was ranged from 20–30 min with the mean time being 20 ± 4 min. The protocol included: fast spin-echo T1-weighted (FSE T1); 700/12 ms (repetition time/echo time); field of view, 15–20 cm; and matrix, 256 × 256 and T2-weighted images with f at-saturation were obtained with the following parameters: fast spin-echo sequence with

<table>
<thead>
<tr>
<th>Table 1 Demographic data and symptoms at presentation of the patients.</th>
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<tbody>
<tr>
<td>Characteristics</td>
</tr>
<tr>
<td>Sex (F:M)</td>
</tr>
<tr>
<td>Mean age (years)</td>
</tr>
<tr>
<td>Mean duration of diabetes (years)</td>
</tr>
<tr>
<td>Diabetes type</td>
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<tr>
<td>Type 1</td>
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<tr>
<td>Type 2</td>
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<tr>
<td>Diabetic control medication</td>
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<tr>
<td>Insulin</td>
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<tr>
<td>Oral medication</td>
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<tr>
<td>Duration of foot symptoms (days)</td>
</tr>
<tr>
<td>Pain</td>
</tr>
<tr>
<td>Erythema</td>
</tr>
<tr>
<td>Purulent discharge</td>
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<tr>
<td>Fetal odor</td>
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</table>
(a–e) MRI examination of the foot sagittal (a–d) and axial (e) T1 WI post contrast shows extensive soft tissue inflammatory process involving the soft tissue of the dorsal and plantar aspect of the foot encircling the tarsal and metatarsal bones, a soft tissue defect noted at the dorsum of the foot. There are multiple marginal enhanced lesions distributed near the lateral malleolus, supracalcaneous, above the cuboid and cuneiform bones as well as at the plantar aspect of the foot mainly above the flexor tendons, there are abnormal bone marrow signal intensity enhanced lesions seen involving all metatarsal bones, inferior part of the talus. Abnormal enhancement of the flexor tendon sheath. Picture of metatarsal bone and talus osteomyelitis with multiple soft tissue abscesses and tenosynovitis in patient with ulcer on the dorsal aspect of the foot.
two signals acquired; 5600/70–95 ms (repetition time/effective echo time); echo train length, eight; field of view, 15–20 cm; and matrix, 256 × 192 with a section thickness of 4–5 mm and a 1-mm gap. Fat-suppressed T1-weighted images were obtained with a fast multiplanar spoiled gradient-recalled-echo (GRE) sequence at the following settings: 200–350/1.8–2.2 ms (repetition time/echo time); flip angle, 90°; field of view, 15–20 cm; matrix, 256 × 192; and section thickness, 3–4 mm with a 1-mm gap.

The image was obtained at least in two orthogonal planes. Post contrast images were acquired after intravenous administration of gadolinium, at the dose of 0.1 ml/kg in 96 cases (the other 6 cases did not tolerate the examination length).

2.4. Image interpretation

All images were reviewed by two radiologists on separate session, cases that had diagnostic disagreement were excluded from the study. The MRI images were reviewed for the presence of bone marrow, soft tissue or joint infection. Signs of bone marrow infection in MRI were area of low T1 signal intensity, high T2 signal intensity, with post contrast enhancement, however sign of soft tissue infection on MRI was edema, fluid collection with post contrast rim enhancement (abscess), presence of ulcer (diagnosed as area of discontinuity of the cutaneous signal intensity line), or sinus tract (abnormal linear tract with fluid signal intensity inside and shows wall enhancement after contrast). The MRI signs of joint infection were effusion, post contrast enhancement of the synovial lining of the joint or the contained fluid, articular surface erosion or fragmentation.

2.5. Surgical management

All patients were surgically managed by the same surgeon. Surgical debridement of all infected and devitalized tissues included infected bones. During surgical intervention, bone specimens were obtained from all patients for culture and for histopathological examinations.

2.6. Histopathological examination

All specimens obtained during surgical management were examined and the diagnosis of osteomyelitis depends on the
presence of necrosis, aggregation of inflammatory cells, erosion of the cortical bone, and loss of normal bone marrow fat.

2.7. Statistical analysis

The results obtained from each patient in PTB test and MRI were collected and compared with the surgical finding and bone culture, sensitivity, specificity, positive and negative predictive value as well as the P value, were measured for each test. Statistical values were calculated using SPSS version 11.0 for Macintosh (SPSS, Chicago, IL).

3. Results

Out of 108 patients met the eligibility to participate in this study only 102 completed the study, six patients were excluded (two had severe toxaemia and needed urgent amputation and four had impaired renal function preventing contrast administration during MRI examination). The included 102 patients had 106 involved foot (4 cases had bilateral affection).

The ulcer was located in the fore foot in 54 (60.4%) feet, mid foot in 30 (33.9%) feet and hind foot in 22 (20.7%) feet, the most common location of the ulcer was the plantar aspect of the distal head of the first metatarsal bone (43 patients, 41%) followed by plantar side of the head of fifth metatarsal bone (26 patients, 24.5%), lateral side of the fifth metatarsal bone (14 patients, 13%), at the head of the second, third or fourth metatarsal bone (8 patients, 7.5%) and heel ulcers (15 patients, 14%).

Surgical debridement of the ulcers was done in 81 patients (76.4%), toes amputation was done in 14 patients (13.2%) and forefoot amputation was done in 11 patients (10.4%).

Osteomyelitis was diagnosed in 80 (75.5%) examined foot depending on histopathological examination of the surgical specimen, PTB test give true positive results in 66 (62.2%) feet, in the other 14 (13.3%) feet the PTB test was false negative in eight feet (probing of the ulcer cannot reach the bone however infection was detected by histopathological examination) and false positive in 6 feet (no osteomyelitis in the examined bone specimen, inspite of positive culture, this may be due to contamination during per-coetaneous biopsy).

The MRI finding in the examined 106 feet revealed osteomyelitis in 81 (76.4%) feet, abscess in 37(32%) feet, tenosynovitis in 69 (65%) feet, neuropathic changes in 20 (18.9%) feet, and in all cases cellulites was present (see Figs. 1–3).

From the 81 (76.4%) osteomyelitis cases diagnosed by MRI, 78 (73.6%) feet were confirmed histopathologically, in the other three cases histopathological examination reveals one case of reactive marrow edema and two cases of acute neuropathic joints.
Of the twenty cases diagnosed by MRI as neuropathic joints, 18 were confirmed histopathologically and in the other 2 cases osteomyelitis and neuropathic changes were coexisting.

The extent and site of infection as diagnosed by MRI were proved by histopathological examination of the surgical specimen.

All cases diagnosed by PTB test as having osteomyelitis give positive results in MRI examination, Table 2 shows comparison of PTB test and MRI in diagnosing osteomyelitis in referral to histopathological results.

The P value for PTB test and MRI in detecting osteomyelitis was highly significant measuring 0.000 for both.

Diagnostic accuracy in detecting osteomyelitis and the values for sensitivity, specificity, and positive and negative predictive values of the PTB test and MRI are shown in Table 3.

4. Discussion

Foot infection in the diabetic population continues to be a significant clinical problem (3), with higher morbidity and healthcare costs, the lifetime risk for development of foot ulcers among diabetic patients is approximately 25% (10,11). The diagnosis and management of diabetes-related pedal osteomyelitis, especially when acute, are challenging requiring a multidisciplinary and team approach (12,13).

The incidence of osteomyelitis in diabetic patients ranged in the literature from 20–66% of cases (12,14–16).

In our study we record a higher incidence of osteomyelitis measuring about 78.4%, also in a study of Aragon-Sánchez et al. (17) they described an incidence of 74% of osteomyelitis in their patients, they attributed this to high prevalence of osteomyelitis in their referral population, in our study the high osteomyelitis incidence may be due to the higher prevalence of diabetic foot in our institution, also to the method of patients’ selection we include only those having ulcer with evident foot infection.

Most of our patients had ulcer in the forefoot 60.4% and on the plantar aspect 65%. Most of the literature reported that foot ulcer in diabetic patients are more at pressure point due to callus formation (18).

Early diagnosis of osteomyelitis is of critical importance, unfortunately it is difficult, the clinical and laboratory signs and symptoms are mostly unhelpful (5). The sensitivity of clinical assessment for diagnosing osteomyelitis ranges from 0 to 54% (7,19,20). So the clinicians have to look for an effective noninvasive means of studying the diabetic foot for occult infectious to help determine which patients should undergo more extensive evaluations (3,5).

The probe-to-bone test is widely used for diagnosing osteomyelitis in patients with diabetes with a foot infection (17).

The PTB test is an easy bed side test that can be done at outpatient clinic without special preparation, also few studies were done to evaluate the efficacy of the test in diagnosing osteomyelitis and the reported sensitivity, specificity, PPV and NPV of these studies were widely variable. In the first study of Grayson et al. (21) done at 1995 he used PTB test and described a sensitivity of 66%, specificity of 85%, positive predicative value of 89%, and a negative predictive value of 56% (the high positive predictive values leading them to conclude that a positive test usually made imaging studies for diagnosing osteomyelitis unnecessary), in the following studies Shone et al. (15) and LAVERY et al. (5), reported much lower PPV in their studies (53% and 62% respectively) and in a more recent study (validating) using bone histopathology as the criterion standard had sensitivity of 98%, specificity of 78%, positive predicative value of 95%, and a negative predictive value of 91%. In the present study we compared the results of PTB test with those of histopathological examination of the obtained bone specimen at surgery, we had sensitivity of 85.5%, specificity of 84.6%, PPV of 94.2% and NPV of 66.7%, which was comparable to the results of the last study (validating), the difference between the studies were attributed to the low prevalence of osteomyelitis in the studies of (5,15) (23% and 20%) also to the different method to confirm the presence of osteomyelitis only a study done by Lozano and associates and the present study used histopathological examination as a gold standard reference (22).

The most prevalent diagnostic imaging modality for osteomyelitis was plain X-ray of the foot (4).

However plain X-ray has low sensitivity as radiological changes take more than two weeks to become evident (22,23), after bone mineral density reduced up to 35–50% of normal adjacent bone (24). Bone scanning using Tc 99 m or gallium was also used for diagnosing osteomyelitis, with higher sensitivity than plain X-ray giving positive results within 24–48 h (25). The draw back with bone scan is that it is not specific and positive results were obtained as well with diabetic neuroarthropathy (4).

Most studies proved that MRI is the modality of choice and is the most sensitive imaging technique in detecting early osteomyelitis as early as 3–5 days after the onset of infection. 21 with sensitivity and specificity reaching up to 100% (4,26–30).

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### Table 2 Comparison of PTB test and MRI in diagnosing osteomyelitis with referral to histopathological results.

<table>
<thead>
<tr>
<th></th>
<th>PTB</th>
<th>MRI</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Osteomyelitis</td>
<td>No osteomyelitis</td>
<td></td>
</tr>
<tr>
<td>Osteomyelitis by histopathology</td>
<td>66(62.2%)</td>
<td>14(13.2%)</td>
<td>78(73.6%)</td>
</tr>
<tr>
<td>No osteomyelitis by histopathology</td>
<td>6(5.7%)</td>
<td>20(18.9%)</td>
<td>3(2.8%)</td>
</tr>
<tr>
<td>Total</td>
<td>72(67.9)</td>
<td>34(32.1%)</td>
<td></td>
</tr>
</tbody>
</table>

### Table 3 Sensitivity, specificity, positive and negative predictive values of PTB and MRI in diagnosing osteomyelitis.

<table>
<thead>
<tr>
<th>Variable</th>
<th>PTB</th>
<th>MRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>82.5%</td>
<td>97.5%</td>
</tr>
<tr>
<td>Specificity</td>
<td>76.9%</td>
<td>88.5%</td>
</tr>
<tr>
<td>PPV</td>
<td>91.7%</td>
<td>96.3%</td>
</tr>
<tr>
<td>NPV</td>
<td>58.8%</td>
<td>92%</td>
</tr>
<tr>
<td>Accuracy</td>
<td>81%</td>
<td>95%</td>
</tr>
<tr>
<td>P value</td>
<td>0.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>
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We recorded a sensitivity of 98%, specificity of 96%, PPV of 99% and NPV of 91% and this is in agreement with values described in most of the literatures.

MRI provides more accurate information about the extent of involvement of bony and soft tissue infectious process (31), also the differentiation between osteomyelitis and neuroarthropathy is difficult. MRI finding can favor osteomyelitis when there is associated ulcer, the location of the ulcer in the forefoot not mid foot, presence of single bone involvement not multiple that usually occurs with osteomyelitis, and lastly the presence of other signs of infection as cellulitis and abscess of surrounding tissue involvement (13,26,28,32).

The value of using MRI is not only for the diagnosis of osteomyelitis but also helping the surgeon in planning the surgical management (8).

In the present study MRI can diagnose the presence of associated pathology as abscess in 37 feet, tenosynovitis in 69 feet, neuropathic changes in 20 feet, and in all cases there was cellulitis.

The limitation in our study was that all of our patients were referred from a single diabetic foot center and were not population based, some patients cannot tolerate the relatively long time of MRI examination, and gadolinium not used in all cases. On the other hand the strengths of this study are; it was a prospective research, we included relatively large number of patients, the bias was restricted on bases that the agreement between the two radiologists in diagnosing osteomyelitis was 100%, all PTB tests were performed by a same experienced surgeon and we have a histopathological confirmation in all cases.

In conclusion: the probe to bone test is a simple, minimally invasive, low cost test and can be done at outpatient clinic. The sensitivity, specificity and positive predictive values are good when compared to those of MRI, but when we need more specific and accurate diagnosis especially for diagnosing associated soft tissue infection and planning the surgical management MRI was the image of choice.

Conflict of interest

None.

References