Skeletal Radiology (2019) 48:405–411
https://doi.org/10.1007/s00256-018-3045-y

SCIENTIFIC ARTICLE

Added value of MRI to X-ray in guiding the extent of surgical resection in diabetic forefoot osteomyelitis: a review of pathologically proven, surgically treated cases

Micah Cohen [1] · **Brett Cerniglia** [1] · **Tetyana Gorbachova** [1] · **Jay Horrow** [2]

Received: 5 January 2018 / Revised: 30 July 2018 / Accepted: 7 August 2018 / Published online: 22 August 2018

Abstract

Objective This study retrospectively evaluated the added value of MRI over X-ray in guiding the extent of amputation in a cohort of patients with surgically treated, pathologically proven osteomyelitis.

Materials and methods A database search revealed 32 cases of pathology-proven diabetic forefoot osteomyelitis between 2006 and 2016, in which X-ray, MRI, and surgery occurred within 30 days. Data collection included extent of osteomyelitis reported on imaging and extent of subsequent amputation using a point system. Added value of MRI over X-ray in guiding surgical resection was stated if the X-ray was negative, MRI was positive, and there was MRI–surgical concordance; if both modalities were positive, X-ray was discordant whereas the MRI was concordant; or if MRI detected an abscess. Two-tailed Fisher's exact test compared proportions.

Results In 9 cases that were positive on both modalities, MRI identified an average of 1.2 additional bone segments of disease. There was surgical agreement with X-ray in 3 out of 31 cases (9.7%, 95%CI 0–20.1) and with MRI in 17 out of 31 cases (55%, 37.3–72.4; $p < 0.0001$). There was an added value of MRI over X-ray in guiding surgical treatment in 64.5% of cases (95% CI 47.7%–81.4%). MRI added value in 5 out of 9 X-rays positive for osteomyelitis and in 15 out of 22 negative (p value was not significant).

Conclusion Magnetic resonance imaging demonstrated added value over X-ray in guiding surgical management in both X-ray-negative and -positive cases. Although multiple factors are involved in determining the degree of surgical excision, MRI is a clinically useful component of the diagnostic algorithm in patients who undergo surgical treatment.

Keywords MRI · Diabetic infection · Pedal osteomyelitis · Forefoot

Introduction

Multiple studies have established a superior diagnostic accuracy of MRI compared with plain film radiography in the diagnosis of pedal osteomyelitis in diabetic patients [1–5]. Classic studies have examined the usefulness of primary and secondary signs of osteomyelitis on MRI, with emphasis on the diagnostic utility of T1-weighted imaging [6–8], whereas a recent study [9] demonstrated that isolated bone marrow edema-like signal pattern subjacent to a soft-tissue foot ulcer may either represent or herald progression to osteomyelitis. Application of new advanced MRI techniques is also offered for diabetic foot assessment [10]. Still debatable and particularly important in a value-based imaging approach is the cost benefit of MRI in the diagnostic algorithm, in addition to the exact role of the MRI report in clinical management. Previously, large-scale studies utilizing complex cost benefit analysis models have argued both for [1] and against [11] continued utilization of MRI in this clinical setting. Duryea et al. [9] noted the lack of predictive correlation of MRI reports with patient management in a cohort of patients with early osteomyelitis. Before evaluating the cost-effectiveness of MRI, it is imperative to determine its clinical effectiveness, and in surgically treated cases specifically, its precise role in defining the extent of surgical treatment [12, 13].

For surgically treated osteomyelitis, the superior diagnostic accuracy of MRI may lead to more precise surgical resection, decreased morbidity, shorter hospital stay, and fewer subsequent amputations. In clinical practice, concomitant peripheral

✉ Micah Cohen
cohenmic@einstein.edu

[1] Albert Einstein Medical Center, Philadelphia, PA, USA

[2] Drexel College School of Medicine, Philadelphia, PA, USA

vascular disease with associated impaired wound healing may limit these potential gains [14, 15]. Jbara et al. [16] showed no clinical utility of pre-operative MRI with regard to re-amputation rate. Our study examined the surgical utility of MRI by quantitatively evaluating the value added by MRI over plain radiographs (X-ray) to guide the extent of surgical treatment in a cohort of patients with surgically treated, pathologically proven diabetic forefoot osteomyelitis.

Materials and methods

After obtaining IRB approval, we searched our institutional database for all cases between 2006 and 2016 calendar years of diabetic pedal osteomyelitis that featured pathologically-proven osteomyelitis at surgical resection, while having undergone X-ray, MRI, and surgery on the same foot within a 30-day period. The 30-day inclusion criterion was based upon the previous assertion that plain film manifestations of osteomyelitis can take up to 4 weeks to develop [17]. Only forefoot osteomyelitis cases were included. A fellowship-trained musculoskeletal radiologist with 1 year's experience and a PGY2 radiology resident retrospectively in consensus reviewed every X-ray, MRI, surgical, and pathology report, recording the presence or absence of osteomyelitis on each imaging modality, the extent of disease when present, the use of intravenous contrast medium, the presence or absence of an abscess on MRI, and the extent of surgical resection. The presence of ulcer and peripheral vascular disease was recorded based on the data from both MRI report and surgical history. Magnet field strength, utilization of T1-weighted and short tau inversion recovery (STIR) sequence and qualifications of the radiologist providing interpretation (general, musculoskeletal fellowship-trained, MRI-trained) were recorded. Reports that stated "concerning for," "suspicious for," and "consistent with osteomyelitis" were counted as positive for osteomyelitis. If a report stated "can't exclude osteomyelitis," it was counted as positive if the description was at a specific anatomical bone segment subjacent to an ulcer, or it was counted as negative if there was not a specific bone segment described or there was not an overlying ulcer. Technical limitations, if stated in the report, were recorded.

A point system quantified the extent of disease as one point for each phalanx and for each one-third of a metatarsal shaft with osteomyelitis (maximum possible score 29; Fig. 1a). An X-ray or MRI negative for osteomyelitis had no point score recorded. The difference in point scores defined agreement between X-ray and MRI. Postoperative radiographs, when available, and the surgical report delineated the extent of actual surgical resection. Agreement between each imaging modality and surgery was defined as surgical resection not exceeding more than one adjacent proximal bone segment (one phalanx or one-third of a metatarsal shaft) of disease reported on imaging (Fig. 1b, c). All bone segments resected distal to

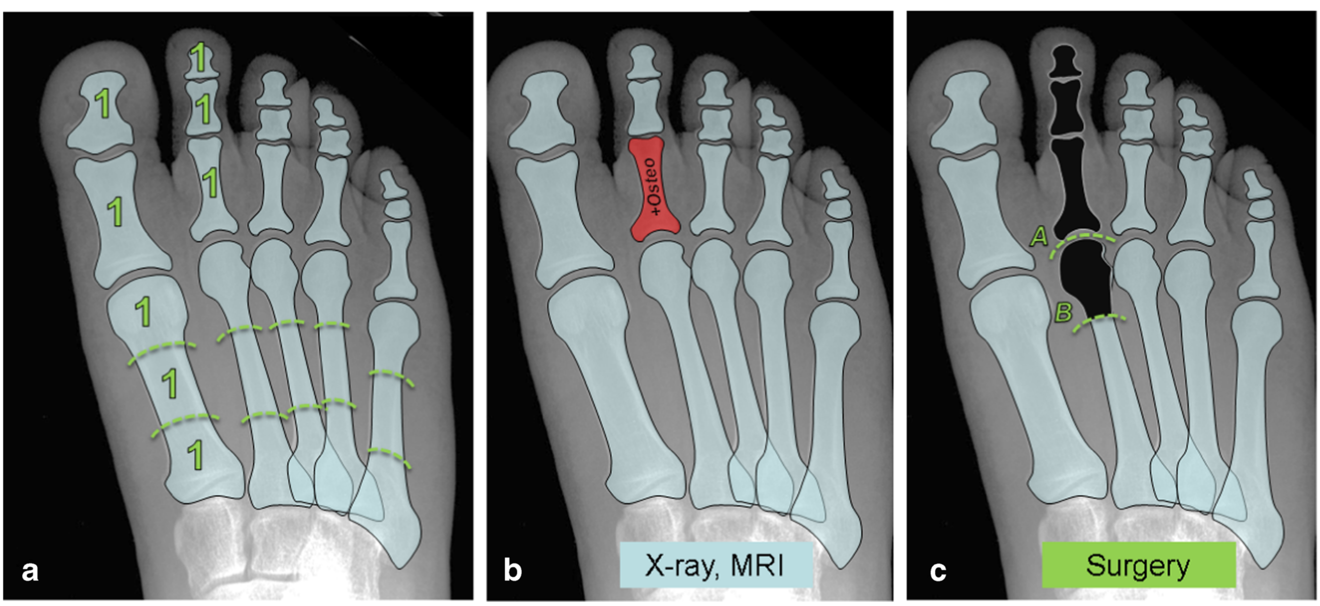

Fig. 1 Scoring system for disease extent and definition of surgical agreement. **a** Point score system to record the extent of disease, one point was allocated for each phalanx and for one-third of a metatarsal shaft where osteomyelitis was reported. Quantitative agreement between X-ray and MRI was determined as a difference in the point score between both modalities when both demonstrated the presence of disease. **b, c** Agreement between each imaging modality and surgery was defined as surgical resection not exceeding more than one adjacent proximal bone segment of disease reported on imaging. Resection of all bone segments distal to the extent of disease was deemed concordant. For example, if osteomyelitis was diagnosed in the second proximal phalanx on X-ray or MRI (*red area*, **b**), surgical resection margins along either *line A* or *line B* were considered concordant with the corresponding imaging modality (**c**)

the extent of disease reported on imaging were deemed concordant because "phalanx sparing" amputations were not universally feasible.

We denoted added value of MRI over X-ray in guiding surgical treatment, if any of the following occurred:

1. The X-ray was negative and the MRI was positive and there was MRI–surgical concordance
2. The X-ray and MRI were both positive; however, the X-ray was discordant with the extent of surgery, whereas the MRI was concordant
3. MRI detected an abscess

We utilized Fisher's exact test to compare proportions of cases.

Results

Thirty-two patients with diabetic forefoot osteomyelitis met the initial inclusion criteria. Twenty-nine patients had ulcers, 2 patients had lacerations, and 1 patient had neither an ulcer nor laceration. Eleven patients had a history of peripheral vascular disease and 21 did not. One case contained an ambiguous description of the extent of surgical resection in the operative report, and there was no postoperative X-ray to help to adjudicate, leading to its removal from the analyses of added value and surgical concordance, although demographic and imaging information remained. The 32 patients comprised 11 women and 21 men, aged 57 ± 13 (SD) years, range 31–77. Eighteen cases involved the right foot and 14 the left. Intravenous contrast medium was utilized in 19 patients. Abscesses were detected in 12 cases, 8 with contrast medium and 4 without contrast medium administration. Of the 20 patients found not to have an abscess, 11 had MRIs performed with contrast medium and 9 without.

Radiographs were interpreted by general radiologists. Thirteen of the MR examinations were interpreted by fellowship trained musculoskeletal radiologists, whereas the other 19 were seen by radiologists with fellowship training in MRI. All MRIs were performed on either 1.5- or 3-Tesla magnets (18 on 1.5-T and 14 on 3-T) utilizing a standard departmental forefoot osteomyelitis protocol with at least one T1-weighted and one STIR sequence, with variable additional T1-weighted and STIR sequences. None of the MRI reports stated technical limitations in assessing for osteomyelitis. The X-ray and MRI were obtained on average 3.2 days apart whereas X-ray and surgery were performed on average 8 days apart and MRI and surgery were performed on average 5 days apart.

The sensitivity for osteomyelitis was 9 out of 32 (28%) for X-ray and 32 out of 32 (100%) for MRI ($p < 0.0001$, Fisher's exact test). In the 9 cases positive on both X-ray and MRI, MRI identified an average of 1.2 additional bone segments of disease. Surgical agreement with X-ray was 3 out of 31 (9.7%, 95%CI 0–20.1) and with MRI it was 17 out of 31 (55%, 37.3–72.4; $p < 0.0001$). Of the 14 cases that were MRI–surgery discordant, 4 were still assigned an "added value" status by virtue of having an abscess. Of the other 10 cases that did not meet "added value" criteria, in 3 cases the two bone segments proximal to disease diagnosed in the same ray on MRI were resected; in 1 case an additional ray was resected; in 3 cases an additional ray and two or more proximal bone segments within the same ray as the disease diagnosed on MRI were resected; and in 3 cases the resection did not extend to the proximal margin of disease described on MRI.

Magnetic resonance imaging provided added value to X-ray in 20 out of 31 patients (64.5%; 95%CI 47.7–81.4; Table 1). These 20 cases comprise 5 of the 9 X-ray-positive cases (56%) and 15 of the 22 X-ray-negative cases (68%; $p = 0.68$). Of the 20 added value cases, 12 were in category 1 (X-ray negative, MRI positive, with MRI–surgical concordance); 2 were in category 2 (X-ray and MRI both positive, X-ray was discordant but MRI concordant with the extent of surgery, Fig. 2); and 6 in category 3 (abscess detected on MRI, and not in categories 1 or 2). Of the 11 patients without added value by MRI, 7 had a negative X-ray, but their positive MRI was discordant with the extent of surgery; 3 were both X-ray- and MRI-positive and both were surgically discordant; and 1 patient was X-ray- and MRI-positive and both were surgically concordant (Fig. 3).

Table 1 Summary of the results of the added value of MRI over X-ray in guiding the extent of surgery

	X-ray	MRI	X-ray/surgical concordance	MR/surgical concordance	Abscess	Patients (*n*)	Total (*N*)
Added value	Negative	Positive	Discordant	Concordant	±	12	20
	Positive	Positive	Discordant	Concordant	±	2	
	Otherwise "no added value"				Present	6	
No added value	Negative	Positive	Discordant	Discordant	Absent	7	11
	Positive	Positive	Discordant	Discordant	Absent	3	
	Positive	Positive	Concordant	Concordant	Absent	1	

± indicates that the abscess could be either present or absent in these cases to be categorized in the added value group

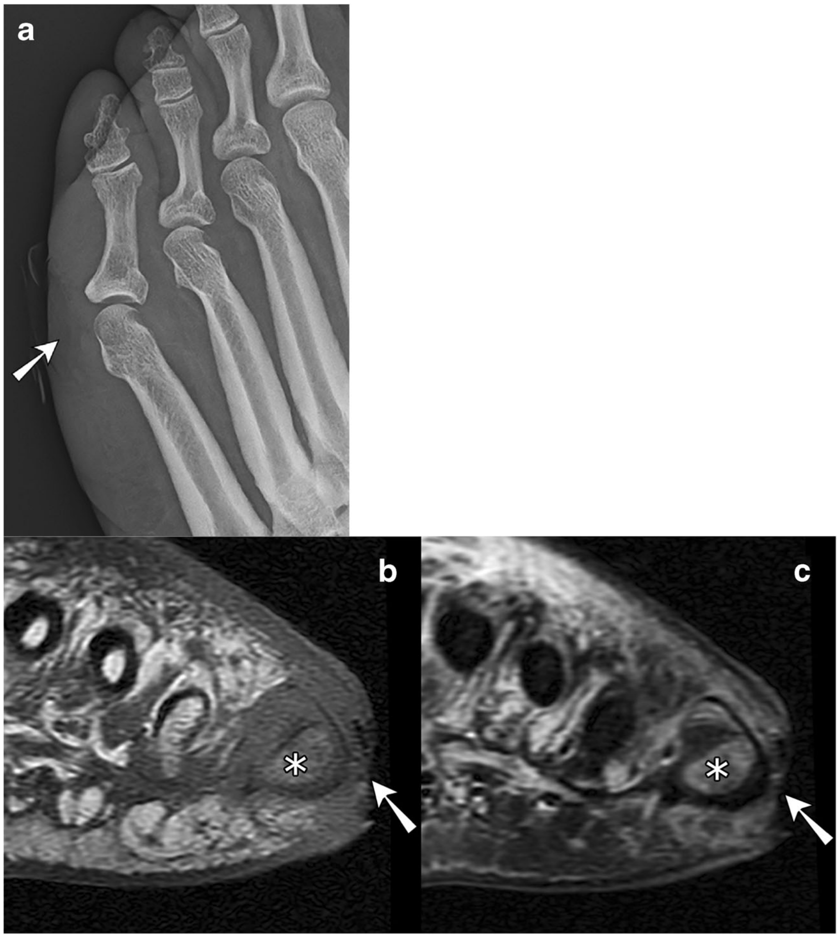

Fig. 2 Example of an "MRI added value" case. A 62-year-old diabetic man with a nonhealing ulcer over the head of the fifth metatarsal. **a** Oblique radiographic projection of the foot demonstrated a soft-tissue ulcer (*arrow*), whereas the X-ray was reported as being negative for osteomyelitis. **b** Coronal T1-weighted and **c** short tau inversion recovery (STIR) sequences from MRI obtained 2 days later demonstrated bone marrow replacement and edema of the head of the fifth metatarsal (*asterisks*) deep to the ulcer (*arrow*). The MRI was reported to be positive for osteomyelitis involving the head of the 5th metatarsal and also 5th proximal phalanx (not shown here). Surgery was performed 19 days after the X-ray; a transmetatarsal amputation at the level of the distal fifth metatarsal was described in the surgical report. This case was categorized as X-ray/surgical discordance and MRI/surgical concordance, and classified as demonstrating an added value of MRI over X-ray in guiding surgical treatment

Discussion

Numerous studies have established the diagnostic accuracy of MRI in detecting soft-tissue and marrow abnormalities, including infection in the diabetic foot [1, 2, 4, 5, 12, 13, 18, 19]. Clinical practice guidelines state the diagnostic utility of MRI in these patients [20–23]. Usefulness of various MRI sequences, primary and secondary MRI signs, and utilization of advanced MRI techniques have been delineated in the radiology literature [6–8, 10]. With current emphasis on value-based imaging, the cost-effectiveness of MRI in the management of diabetic foot ulcer and infection in addition to the exact role of the MRI report in clinical management are still under debate [1, 9, 11, 24]. A need to demonstrate the clinical utility of MRI before evaluating its cost-effectiveness engendered the current study. Previous studies examining the cost benefit of MRI for osteomyelitis by Morrison et al. [1] and Eckman et al. [11] compared diagnostic performance and costs of MRI, X-ray, and scintigraphy. Morrison et al. [1] evaluated the surgical utility of MRI as a correlation between the extent of disease diagnosed on MRI and the general scope of surgical excision. However, that study provided no quantitative comparisons among X-ray, MRI, and extent of surgery. In a study of outcomes in diabetic foot ulcer patients with isolated T2 marrow signal abnormality in the underlying bone, Duryea et al. [9] acknowledged the lack of predictive correlation of MRI reports with patient management in a cohort of patients with early osteomyelitis. A recent study seeking to determine the clinical utility of MRI with respect to forefoot re-amputation rates in diabetic patients by Jbara et al. [16] found no association between the utilization of preoperative MRI and re-amputation rates; however, it did reveal a decreased mortality in the group undergoing preoperative MRI. The study did not include data on radiographs. To our

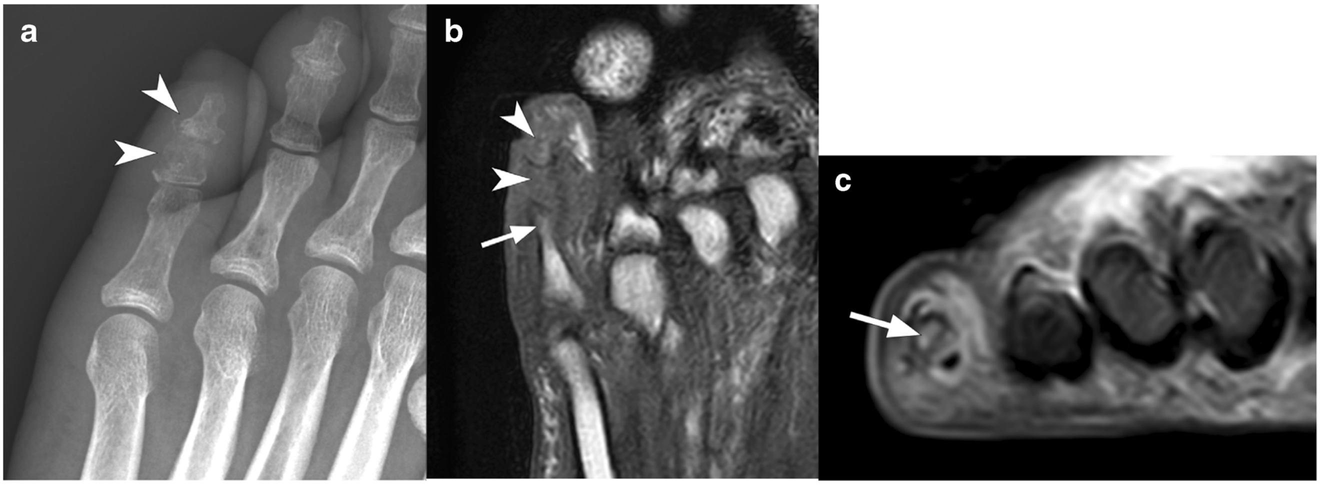

Fig. 3 Example of an "MRI no-added value" case. A 69-year-old diabetic man with a nonhealing ulcer overlying the fifth distal interphalangeal joint. **a** Frontal radiographic projection demonstrated cortical erosion and rarefication at the lateral aspect of the middle and distal phalanges of the fifth toe (*arrowheads*), with the radiological report stating osteomyelitis in these two bone segments. **b** Axial T1-weighted and **c** coronal STIR sequences from MRI obtained the next day show marrow replacement and edema in the distal and middle phalanges, but also involving the head of the proximal phalanx (*arrows*), with the MRI report stating osteomyelitis in these three bone segments. No abscess was reported on MRI. Surgery performed the same day as the MRI consisted of resection of the entire fifth toe. In this case, X-ray and MRI reports were both categorized as surgically concordant, with resection performed within one bone segment of the proximal extent of disease reported on X-ray and corresponding exactly to the extent of disease reported on MRI. Because MRI and X-ray were both surgically concordant, this case was classified as no added value of MRI over X-ray in guiding surgical treatment

knowledge, no previous studies have specifically assessed the added value of MRI over X-ray in guiding the extent of surgical excision as a primary outcome in pathologically proven, surgically treated cases of diabetic pedal osteomyelitis.

In our cohort of patients with pathology-proven osteomyelitis undergoing X-ray, MRI, and surgery within a 30-day period, in cases that were positive for osteomyelitis on both modalities, MRI detected a larger extent of disease involvement. This improved diagnostic performance did not uniformly translate to a more precise surgical management, with the additional information provided by MRI affecting surgical management in approximately 65% of cases. This benefit did not differ between the X-ray-positive and X-ray-negative cases, although the cohort was small. We hypothesize that although MRI does provide a clinically significant added value, additional factors might affect the scope of surgical intervention in patients with diabetic forefoot osteomyelitis, such as peripheral vascular disease with associated poor wound healing, surgeon preference, and patient compliance.

Our data address the added value of MRI only in pathologically proven cases in which the patient underwent surgery. This study did not evaluate a potential added value of MRI in cases of suspected diabetic pedal osteomyelitis when negative MRI spares patients unnecessary treatment, both conservative and surgical.

These data may underreport the true added value of MRI over X-ray, even in this cohort. First, within the strict definition of added value adopted in this study, patients with a negative X-ray, positive MRI, and no abscess were categorized as having no added value if the surgical resection did not mirror the exact extent of disease based on the MRI. In these cases, resection typically involved more than one additional segment set by our criteria. Although MRI may not be guiding the precise extent of surgery in these instances, MRI demonstrated disease when X-ray did not, arguably providing some value. Second, our study did not examine if a toe-sparing procedure or a procedure that included removal of the toe was performed when feasible based on imaging. It could be argued that a significant added value of MRI in surgical planning lies in its ability to determine the absence of disease in the toes, which would allow toe preservation during metatarsal head resection. Analysis of toe-sparing was not included in our study, in part because of a limited sample size and in part because of the complexity of clinical, biomechanical, and cosmetic factors that determine the feasibility of such surgery in addition to defining the extent of disease on imaging [14, 15, 21, 25].

Another limitation is the retrospective study design. Thus, diagnostic reports by radiologists with varying levels of experience and musculoskeletal subspecialty training, and not actual images, were used for analysis. The level of certainty in the diagnostic imaging reports could not be entirely controlled; however, a standardized methodology was applied to address various terminology encountered in the reports. Despite these limitations, a retrospective review of images would be irrelevant in this study of value added to clinical decisions, because clinical decision-making was based upon the contemporaneous diagnostic reports. We assumed that the surgeons utilized the information from preoperative imaging performed at the same institution in surgical planning.

Theoretically, the surgeons involved in these cases viewed the MRI images in addition to the reports; however, this cannot be confirmed in a retrospective review. Establishing the extent of resection was limited to operative reports and postoperative radiographs, the latter of which was not universally performed. Multiple surgeons performed the resections analyzed in our cohort, and personal surgical technical preference could not be examined as a potential source of bias introduced into our assessment of surgical concordance with imaging. Sample size was limited based on the exclusion of patients who did not undergo both imaging studies and surgery within a 30-day period and those with mid- or hindfoot disease. The latter criterion was chosen because of the often-confounding presence of Charcot arthropathy and the tendency to go onto larger, less precise amputations in these patients.

The dynamic nature of disease evolution limits our ability to say with confidence whether differences in the extent of disease seen at X-ray, MRI, and surgery performed within a 30-day period represent true differences in disease detection rather than temporal differences in disease progression. Given the variability of disease, in certain cases changes in imaging may occur in 2–3 weeks, as opposed to the 4-week time period that was utilized in this study based on previously published data [17]. It is worth noting that in this study, all X-rays were obtained either contemporaneously or before the MRIs within the 30-day period with a 3.2-day average between the X-ray and MRI, an 8-day average between the X-ray and surgery, and a 5-day average between MRI and surgery. Sensitivity calculations for X-ray and MRI were biased because all selected patients had pathologically proven disease; therefore, they do not represent the general population. Additionally, not all patients with positive disease on imaging go on to surgery, further limiting evaluation for true sensitivity and specificity. Last, the point scheme we used to compare the extent of disease between X-ray and MRI and between the two modalities and surgical resection, although logical in our opinion, was arbitrary and has not been validated. However, in a recent study by Bernstein et al. [26], a significant reduction in residual disease at metatarsal osteotomy margins was found using a margin of 1 cm proximal to the disease called on MRI, a result that we believe lends credence to our valuation of resections extending up to one bone segment proximal to disease diagnosed on MRI as "surgically concordant."

In conclusion, our study demonstrated an added value of MRI over X-ray in guiding the extent of surgical treatment in 64.5% of cases of diabetic forefoot osteomyelitis in our cohort. Added value occurred not only in cases that were X-ray-negative, but also in those that were X-ray-positive for osteomyelitis. Although multiple factors determine the degree of surgical excision, MRI represents a clinically useful component of the diagnostic algorithm in patients who ultimately undergo surgical treatment. Future prospective, larger population studies are necessary to verify a continued, more selective use of MRI in the diagnostic algorithm.

Compliance with ethical standards

Conflicts of interest The authors declare that they have no conflicts of interest.

References

1. Morrison WB, Schweitzer ME, Wapner KL, Hecht PJ, Gannon FH, Behm WR. Osteomyelitis in feet of diabetics: clinical accuracy, surgical utility, and cost-effectiveness of MR imaging. Radiology. 1995;196(2):557–64.
2. Dinh MT, Abad CL, Safdar N. Diagnostic accuracy of the physical examination and imaging tests for osteomyelitis underlying diabetic foot ulcers: meta-analysis. Clin Infect Dis. 2008;47(4):519–27.
3. Gold RH, Tong DJ, Crim JR, Seeger LL. Imaging the diabetic foot. Skeletal Radiol. 1995;24(8):563–71.
4. Kapoor A, Page S, Lavalley M, Gale DR, Felson DT. Magnetic resonance imaging for diagnosing foot osteomyelitis: a meta-analysis. Arch Intern Med. 2007;167:125–32.
5. Termaat MF, Raijmakers PG, Scholten HJ, Bakker FC, Patka P, Haarman HJ. The accuracy of diagnostic imaging for the assessment of chronic osteomyelitis: a systematic review and meta-analysis. J Bone Joint Surg Am. 2005;87:2464–71.
6. Morrison WB, Schweitzer ME, Batte WG, Radack DP, Russel KM. Osteomyelitis of the foot: relative importance of primary and secondary MR imaging signs. Radiology. 1998;207:625–32.
7. Collins MS, Schaar MM, Wenger DE, Mandrekar JN. T1-weighted MRI characteristics of pedal osteomyelitis. AJR Am J Roentgenol. 2005;185(2):386–93.
8. Johnson PW, Collins MS, Wenger DE. Diagnostic utility of T1-weighted MRI characteristics in evaluation of osteomyelitis of the foot. AJR Am J Roentgenol. 2009;192(1):96–100.
9. Duryea D, Bernard S, Flemming D, Walker E, French C. Outcomes in diabetic foot ulcer patients with isolated T2 marrow signal abnormality in the underlying bone: should the diagnosis of "osteitis" be changed to "early osteomyelitis"? Skeletal Radiol. 2017;46(10):1327–33.
10. Martín Noguerol T, Luna Alcalá A, Beltrán LS, Gómez Cabrera M, Broncano Cabrero J, Vilanova JC. Advanced MR imaging techniques for differentiation of neuropathic Arthropathy and osteomyelitis in the diabetic foot. Radiographics. 2017;37(4):1161–80.
11. Eckman MH, Greenfield S, Mackey WC, Wong JB, Kaplan S, Sullivan L, et al. Foot infections in diabetic patients. Decision and cost-effectiveness analyses. JAMA. 1995;273(9):712–20.
12. Nigro ND, Bartynski WS, Grossman SJ, Kruljac S. Clinical impact of magnetic resonance imaging in foot osteomyelitis. J Am Podiatr Med Assoc. 1992;82(12):603–15.
13. Durham JR, Lukens ML, Campanini DS, Wright JG, Smead WL. Impact of magnetic resonance imaging on the management of diabetic foot infections. Am J Surg. 1991;162:150–3.
14. Aragon-Sanchez J, Lazaro-Martinez JL, Alvaro-Afonso FJ, Molines-Barroso R. Conservative surgery of diabetic forefoot osteomyelitis: how can I operate on this patient without amputation? Int J Low Extrem Wounds. 2015;14(2):108–31.
15. Tamir E, Finestone AS, Avisar E, Agar G. Toe-sparing surgery for neuropathic toe ulcers with exposed bone or joint in an outpatient setting: a retrospective study. Int J Low Extrem Wounds. 2016;15(2):142–7.

16. Jbara M, Gokli A, Beshai S, et al. Does obtaining an initial magnetic resonance imaging decrease the reamputation rates in the diabetic foot? Diabet Foot Ankle. 2016;7:31240.
17. Vartanians VM, Karchmer AW, Giurini JM, Rosenthal DI. Is there a role for imaging in the management of patients with diabetic foot? Skeletal Radiol. 2009;38(7):633–6.
18. Beltran J, Campanini DS, Knight C, McCalla M. The diabetic foot: magnetic resonance imaging evaluation. Skeletal Radiol. 1990;19(1):37–41.
19. Croll SD, Nicholas GG, Osborne MA, Wasser TE, Jones S. Role of magnetic resonance imaging in the diagnosis of osteomyelitis in diabetic foot infections. J Vasc Surg. 1996;24(2):266–70.
20. Lipsky BA, Berendt AR, Cornia PB, et al. 2012 Infectious Diseases Society of America clinical practice guideline for the diagnosis and treatment of diabetic foot infections. Clin Infect Dis. 2012;54(12): e132–73.
21. Cavanagh PR, Lipsky BA, Bradbury AW, Botek G. Treatment for diabetic foot ulcers. Lancet. 2005;366(9498):1725–35.
22. Hingorani A, LaMuraglia GM, Henke P, et al. The management of diabetic foot: a clinical practice guideline by the Society for Vascular Surgery in collaboration with the American Podiatric Medical Association and the Society for Vascular Medicine. J Vasc Surg. 2016;63;(2 Suppl):3S–21S..
23. Schweitzer ME, Daffner RH, Weissman BN, et al. ACR appropriateness criteria on suspected osteomyelitis in patients with diabetes mellitus. J Am Coll Radiol. 2008;5(8):881–6.
24. Chow I, Lemos EV, Einarson TR. Management and prevention of diabetic foot ulcers and infections: a health economic review. Pharmacoeconomics. 2008;26(12):1019–35.
25. Van Damme H, Rorive M, Martens De Noorthout BM, Quaniers J, Scheen A, Limet R. Amputations in diabetic patients: a plea for footsparing surgery. Acta Chir Belg. 2001;101(3):123–9.
26. Bernstein B, Stouder M, Bronfenbrenner E, Chen S, Anderson D. Correlating pre-operative MRI measurements of metatarsal osteomyelitis with surgical clean margins reveals the need for a one centimeter resection margin. J Foot Ankle Res. 2017;10:40.