Does obtaining an initial magnetic resonance imaging decrease the reamputation rates in the diabetic foot?

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Objective: Diabetes mellitus (DM) through its over glycosylation of neurovascular structures and resultant peripheral neuropathy continues to be the major risk factor for pedal amputation. Repetitive trauma to the insensate foot results in diabetic foot ulcers, which are at high risk to develop osteomyelitis. Many patients who present with diabetic foot complications will undergo one or more pedal amputations during the course of their disease. The purpose of this study was to determine if obtaining an initial magnetic resonance imaging (MRI), prior to the first amputation, is associated with a decreased rate of reamputation in the diabetic foot. Our hypothesis was that the rate of reamputation may be associated with underutilization of obtaining an initial MRI, useful in presurgical planning. This study was designed to determine whether there was an association between the reamputation rate in diabetic patients and utilization of MRI in the presurgical planning and prior to initial forefoot amputations.

Methods: Following approval by our institutional review board, our study design consisted of a retrospective cohort analysis of 413 patients at Staten Island University Hospital, a 700-bed tertiary referral center between 2008 and 2013 who underwent an initial great toe (hallux) amputation. Of the 413 patients with a hallux amputation, there were 368 eligible patients who had a history of DM with documented hemoglobin A1c (HbA1c) within 3 months of the initial first ray (hallux and first metatarsal) amputation and available radiographic data. Statistical analysis compared the incidence rates of reamputation between patients who underwent initial MRI and those who did not obtain an initial MRI prior to their first amputation. The reamputation rate was compared after adjustment for age, gender, ethnicity, HbA1c, cardiovascular disease, hypoalbuminemia, smoking, body mass index, and prior antibiotic treatment.

Results: The results of our statistical analysis failed to reveal a significant association between obtaining an initial MRI and the reamputation rate. We did, however, find a statistical association between obtaining an early MRI and decreased mortality rates.

Discussion: Obtaining an early MRI was not associated with the reamputation rate incidence in the treatment of the diabetic foot. It did, however, have a statistically significant association with the mortality rate as demonstrated by the increased survival rate in patients undergoing MRI prior to initial amputation.

Keywords: diabetic foot; osteomyelitis; diabetic foot infections; foot ulcer; amputations; magnetic resonance imaging

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continues to be the major risk factor resulting in osteomyelitis and often amputation.

Accurate and early diagnosis of osteomyelitis affecting the diabetic foot remains a clinical challenge. Traditional tools used by clinicians to diagnose osteomyelitis including the probe-to-bone test have shown to be unreliable having a relatively low positive predictive value (1). Furthermore, bone biopsy, often considered the gold standard, has been shown to have suboptimal interobserver agreement (2). In addition, bone biopsy is an invasive procedure and generally not performed in the initial assessment to determine the presence of osteomyelitis. The unreliability and invasive nature of these tests renders making the diagnosis of osteomyelitis difficult when based on clinical factors alone, and magnetic resonance imaging (MRI) has emerged as the modality of choice for the assessment of pedal osteomyelitis (3). Therefore, the American College of Radiology (ACR) appropriateness criteria recommend MRI in conjunction with conventional radiography in diabetic patients presenting with symptoms of the diabetic foot and provide guidelines on how to choose the appropriate imaging based on common clinical scenarios of cellulitis, ulceration, neuropathy, and many others (4). MRI has proven to be a reliable preoperative standard examination in diabetic patients exhibiting poor wound healing and is used to identify the extent of infection and mapping the devitalized areas. In these ways, imaging helps to delineate appropriate levels for amputation.

Materials and methods
Following approval by our institutional review board, a retrospective chart review for all patients at Staten Island University Hospital from 2008 to 2013 who underwent an initial great toe (hallux) amputation and a reamputation within 6 months was performed. Four hundred and thirteen chart reviews resulted in 368 eligible patients stratified into two groups according to whether or not they received an MRI within 3 months prior to their first amputation and had a documented hemoglobin A1c (HbA1c).

In our institution, for the diagnosis of osteomyelitis, we routinely performed non-contrast axial, sagittal, and coronal non-fat suppressed T1-weighted (T1W) imaging, axial and coronal short tau inversion recovery (STIR) as well as axial T2-weighted (T2W) fat suppressed sequences through the forefoot. Diagnosis of osteomyelitis was based strictly on T1W marrow infiltration (5).

Statistical analysis
A multiple logistical regression analysis was performed to compare the incidence rate of reamputation between early MRI and no early MRI groups after adjustment for age, gender, ethnicity, HbA1c, cardiovascular disease (CVD), hypoalbuminemia, smoking, body mass index (BMI), and prior antibiotic treatment.

The two groups (early MRI and no early MRI) were compared with respect to presurgical (baseline) demographic and clinical factors using the chi-squared or Fisher’s exact test for categorical data and the Wilcoxon rank-sum test for continuous data. The two outcomes were time to a second amputation (no, yes) and time to death. The Kaplan–Meier method and the Cox proportional hazards regression model (adjusted for observed confounders) were used to estimate and compare these time-to-event distributions, respectively. Results were considered statistically significant if \( p < 0.05 \).

Results
Our study sample of diabetic patients included 262 males and 106 females, with over 65% being poorly controlled

| Table 1. Demographics and clinical characteristics of the study sample stratified into whether or not they obtained an early magnetic resonance imaging |
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| Gender | No (%) | Yes (%) | p |
| Female | 91 (28.09) | 15 (34.09) | 0.48 |
| Male | 233 (71.91) | 29 (65.91) | 0.48 |
| Ethnicity | | | |
| African American | 40 (14.13) | 5 (13.16) | 0.87 |
| Caucasian | 243 (85.78) | 33 (86.84) | 0.87 |
| CVD | No | 80 (24.69) | 21 (48.84) | <0.0009 |
| Yes | 244 (75.31) | 22 (51.16) | 0.38 |
| Smoking | No | 253 (78.09) | 31 (72.09) | 0.38 |
| Yes | 71 (21.91) | 12 (27.91) | 0.38 |
| Obese (BMI > 29) | No | 156 (48.15) | 23 (53.49) | 0.51 |
| Yes | 168 (51.85) | 20 (46.51) | 0.51 |
| Controlled DM | No | 171 (68.13) | 29 (76.32) | 0.31 |
| Yes | 80 (31.87) | 9 (23.68) | 0.31 |
| Hypoalbumin | No | 125 (40.45) | 29 (70.73) | <0.0002 |
| Yes | 184 (59.55) | 12 (29.27) | <0.0002 |
| Age | Mean | 61.87 | 60.23 | 0.47 |
| SD | 14.52 | 12.1 | 0.47 |
| HbA1c | Mean | 8.66 | 8.16 | 0.24 |
| SD | 2.42 | 1.75 | 0.24 |
| Extent of Amp#1 | Distal | 313 (98.12) | 42 (100.00) | 0.37 |
| Proximal | 6 (1.88) | 0 (0) | 0.37 |

MRI, magnetic resonance imaging; CVD, cardiovascular disease; BMI, body mass index; DM, diabetes mellitus; SD, standard deviation; HbA1c, hemoglobin A1c.
diabetics and more than 50% afflicted with CVD. The two
groups were comparable with respect to gender, ethnicity,
smoking history, BMI, controlled diabetes mellitus (DM), age, and HgA1c (Table 1). The groups differed
significantly with respect to history of CVD ($p < 0.0017$)
and hypoalbumin ($p < 0.0004$). The early MRI group had a
lower prevalence rate of both CVD and hypoalbumin.
Also, there was no association between obtaining an early
MRI and the extent of the initial amputation.
In addition, there was no association between obtaining
an early MRI and the incidence of a second amputation (Fig. 1). This lack of association persisted, even
after adjusting for CVD and hypoalbumin using the Cox
regression technique. There was, however, a significant
reduction in mortality ($p < 0.0172$) associated with an early
MRI (Fig. 2). The estimated 4-year survival rates
were 100% for early MRI and 73% for no early MRI.
Unfortunately, due to the 100% survival rate in the early
MRI group, it could not be determined (using Cox
regression) whether CVD and/or hypoalbumin played a
role in this finding. There was no association between
survival and extent of the initial amputation (Fig. 2).

Discussion
DM is at the forefront of a healthcare crisis, affecting the
US population in increasing numbers with significant
consequences to quality of life and our national economy.
In 2014, 245 billion US dollars were spent on the care
of the diabetic patient (6, 7). Despite all of the dollars
that have been spent on care of the diabetic foot, poor
outcomes measured in decreased quality of life are still a reality in 2015 (8). DM is a complex, multifactorial,
multisystem disease affecting the neurovascular integrity
of the hands and feet in a stocking and glove distribution.
Through complex pathophysiologic cascades, over glyco-
sylation of vascular structures results in a vascular occlu-
sive state. When peripheral vascular disease is coupled
with altered nerve function, intrinsic muscular atrophy
leads to biomechanical imbalances. Chronic repetitive
biomechanical stress on the insensate foot creates a state
of abnormal pressure loading, particularly deep to the first
and fifth metatarsal joints. Improper footwear
and abnormal biomechanics are cited as major factors in
the development of a soft tissue ulcer (9). Up to 15% of
diabetic patients will have the presence of a diabetic foot
ulcer in their lifetime, creating a large number of people
who are at risk for the development of osteomyelitis and
amputation (10).
The purpose of this paper was to examine the role of
MRI and its association with the amputation rate in the
forefoot. Our hypothesis was that patients, who obtained
a diagnostic MRI early in their disease, prior to an
amputation, would result in better outcomes. We hypothe-
sized that the knowledge of the extent of osteomyelitis and
localization of abscess would result in prompter treat-
ments that were adequate to decrease the volume of
infection. We purported that if a specific and sensitive
diagnosis could be made, that is, osteomyelitis, septic
arthritis, abscess, or cellulitis, the treating physician
would be armed with appropriate information necessary to the
cure of the diabetic foot. In addition, the MRI would
help to locate pressure points of impending ulceration for
which this information could be used to properly offload
the pressure point and avoid the ulceration. Though
we recognize that MRI cannot prevent the need for an amputation, it may be beneficial in that it raises the physician awareness of the extent of disease. In addition, perhaps by performing the test, patient awareness may be elevated in the need for careful foot inspection and adequate gate-keeper care. The information gleaned from MRI is likely to direct the course, duration, and type of therapy offered to the patient including the important decision of medical versus surgical therapies.

Study limitations
Limitations of the study are intrinsic to the variability between the two groups. Patients who obtained a preoperative MRI had statistically significant less CVD and hypoalbuminemia. This may have been because the patients with more severe illnesses and medical comorbidities were not diagnostic dilemmas. These discrepancies likely played a role with medical management, increasing the likelihood of more conservative surgical approaches with the relatively healthier group of patients (the MRI cohort) and thereby possibly increasing the risk of reamputation. Ideally, a larger group of patients with similar risks and medical comorbidities would be analyzed with and without preoperative MRI. In addition, by nature of chart review, some information was unavailable or incomplete limiting assessment of their effect, namely recording of patient percentage with renal failure, antibiotic course, and other confounding variables.

Conclusion
Obtaining an early MRI was not associated with the incidence of reamputation in the treatment of the diabetic foot. Though the use of MRI in the accurate diagnosis of pedal osteomyelitis has shown utility for the clinician in terms of treatment of the diabetic foot, obtaining an MRI prior to initial amputation had no effect on the predisposition for subsequent amputations. It did, however, have a statistically significant association with the mortality rate as demonstrated by the increased survival rate in patients undergoing MRI prior to initial amputation. This decreased death rate persisted even after adjusting for confounding variables, most notably CVD and hypoalbuminemia.

Despite the limitations of the study, this is one of the first studies to assess an association between obtaining early advanced cross-sectional MRI and incidence of reamputation utilizing a large sample size with statistical adjustment for confounding variables.

Conflict of interest and funding
The authors have no conflict of interest to declare in relation to the content of this article.

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