Pressure ulcers are an extremely common disease process with an estimated 1.3 to 3 million individuals having developed some form of pressure ulcer in 2004. The development of a new pressure ulcer is reported to increase the length of a hospitalization by a factor of 5 associated with an estimated cost of $20 billion per year according to The Agency for Healthcare Policy Research. New pressure ulcers occurring during hospital admission have been categorized as “never events” by the Center for Medicare and Medicaid Services (CMS) and penalized by decreased physician and hospital reimbursement. Thus, in addition to their impact on patient quality of life, pressure ulcers represent a clinically and financially important entity. This unique and challenging patient population is often cared for by plastic and reconstructive surgeons, and a thorough understanding of the diagnosis and surgical management is paramount. This case series of 73 pressure ulcers in 41 individuals who underwent pressure ulcer reconstruction at a single institution provides additional clarity to variation in diagnostic and surgical paradigms, providing further impact into the future care and management of this vexing entity.

Background: Pressure ulcers represent a particularly difficult disease process and remain a financially important entity. The underlying bone in advanced ulcers may harbor osteomyelitis. Radiologic diagnosis of osteomyelitis is confounded by chronic pressure and shear. We sought to determine the test characteristics of preoperative magnetic resonance imaging (MRI) in the diagnosis of osteomyelitis compared to intraoperative bone culture.

Methods: A retrospective review of patients undergoing flap reconstruction who had preoperative MRI and intraoperative bone cultures between 1995 and 2015 was included. Recorded variables included age, sex, level of spinal cord injury and duration, preoperative MRI interpretation, microbiologic bone culture, smoking history, comorbidities, colostomy or urostomy, healing time, complications, length of stay, and discharge facility.

Results: A total of 152 patients (175 flaps) were reconstructed, of which 41 patients (73 flaps) met inclusion criteria. Most patients were male (82.2%) with an average age of 50.4 years. Overall complication rate was 32.4% (n = 23) of which 34.7% (n = 8) were major. Positive and negative predictive MRI values were 84.6% and 16.7%, respectively. There were no significant differences in healing time or complication rate in those with or without osteomyelitis. Intraoperative growth was associated with decreased postoperative complications (hazard ratio = 0.361; P = 0.037).

Conclusion: Test properties of MRI for diagnosis of osteomyelitis in patients with chronic pressure ulcers have limited ability to diagnose osteomyelitis and do not aid in surgical management, but do increase health-care expense. The diagnosis of osteomyelitis by intraoperative bone cultures does not predict inferior outcomes and paradoxically may be associated with fewer postoperative complications.

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Pressure ulcers progress through a predictable continuum culminating in exposure of bone (stage IV), which in some circumstances may lead to osteomyelitis. There remains controversy regarding how to diagnose osteomyelitis in the setting of chronic stage IV pressure ulcers, with some practitioners routinely ordering magnetic resonance imaging (MRI). A variety of tests have been used to confirm the diagnosis of osteomyelitis including “Jamshidi" biopsy, plain radiographs, computed tomogram, and MRI. Although the sensitivity and specificity of MRI in the diagnosis of osteomyelitis have been reported to be 98% and 89%, respectively, and with an accuracy of 97%, this has not been true at our institution, which cares for a relatively high volume of patients requiring pressure ulcer reconstruction. There is little consensus between surgeons and nonsurgeons about the utility of MRI to assess for osteomyelitis in chronic stage IV pressure ulcers. Additionally, the logistics, discomfort, and financial consequence of obtaining an MRI in patients with paraplegia and quadriplegia are significant.

The objective of this retrospective single institution analysis of 41 patients with 73 ulcers who underwent pressure ulcer reconstruction was to (1) investigate the test characteristics of MRI compared to intraoperative bone cultures and to (2) investigate the effect of osteomyelitis on postoperative complications and healing time after debridement and reconstruction.

METHODS

Institutional review board approval was obtained to perform a retrospective chart review of patients who had undergone reconstructive surgery for the following current procedural terminology codes between 1992 and 2013: 15920, 15922, 15931, 15934–37, 15940, 15941, 15944–46, 15950, 15951–53, 15956. Variables of interest were developed before chart review. Inclusion criteria included patients who underwent surgical reconstruction of their pressure ulcer and had preoperative MRI and intraoperative bone cultures. Patients were excluded if they did not have a preoperative MRI, if they did not have intraoperative bone culture data, or if they underwent debridement only without reconstruction. Patient charts were queried for the following variables: reconstruction type (fasciocutaneous flap, mycutaneous flap, or both), age at time of operation, etiology of immobilization, duration of injury, presence of suprapubic catheter, presence of ileostomy or colostomy, smoking status, comorbidities, body mass index (BMI) at the time of operation, preoperative antibiotics, radiology attending interpretation of the preoperative MRI, intraoperative bone culture results, length of stay, postoperative complications, type of discharge facility, and time to definitive wound closure (i.e., healing time) as determined by attending surgeon. Follow-up time was defined as the duration between the initial operation and last-documented patient examination stating a healed wound. Major complications were defined as flap necrosis and need for reoperation. Minor complications were defined as superficial shear, dehiscence not requiring reoperation, superficial infection, or superficial skin necrosis. Statistical analyses were performed by using a Wilcoxon rank sum and Kruskal–Wallis test with α = 0.05.

Our standard surgical practice for pressure ulcer reconstruction includes resection of the epithelialized sinus tract to the underlying bone (e.g., sacrum or ischium), debridement of the fibrotic tissue around the ulcer and involved bone with an osteotome, followed by a larger contouring ostectomy to remove any bony prominence. At least one sterile sample of cancellous bone is routinely sent for culture. Reconstruction is then performed in the same setting using either a myocutaneous or fasciocutaneous flap, or occasionally both. Flap selection is based on ulcer location, prior surgical incisions, and defect dimensions. Large (#19 Blake) closed suction catheters are placed in the base of the wound and at the flap donor site. The incision is closed using a combination heavy (0-Vicryl) deep sutures followed by 2-0 nylon and staples. Postoperatively, patients are placed on an active pressure relief air mattress bed for 1 week (e.g., Clinitron or equivalent) and then a semisolid mattress (e.g., first step or equivalent) with a progressive wedging protocol for 1 month.

RESULTS

During the 20-year study period, there were 152 patients who had one or more of the previously listed current procedural terminology codes leading to 175 pressure ulcers, of which 111 patients (122 flaps) were excluded because of lack of both preoperative MRI and intraoperative bone cultures. The resultant cohort included 41 patients who required 73 flap reconstructions. Because many patients had multiple surgical reconstructions, this analysis is presented as reconstructed pressure ulcers and not by patient number.

The majority of our patients were male (82.2%), with an average age of 50.4 years and BMI of 27 kg/m² (Table 1). The most common reason for immobilization was thoracic spinal injuries (61.6%) followed by cervical spine injuries (17.8%), with an average duration of immobilization of 20.1 years. Ischial pressure ulcers were the most common (62%), followed by sacral (25%) and trochanteric (7%).

### Table 1. Study Cohort Demographics

| Demographic                        | Osteomyelitis (n = 61) | Nonostomyelitis (n = 12) | P       |
|-----------------------------------|------------------------|--------------------------|---------|
| Age (y)                           | 51.1                   | 44.2                     | 0.97    |
| Duration of immobility (y)        | 23                     | 19.7                     | 0.767   |
| Spinal cord injury (%)            | 25                     | 21.3                     | 0.399   |
| Osteomyelitis on MRI (%)          | 0.75                   | 0.689                    | 0.401   |
| Length of stay (d)                | 24.6                   | 30.8                     | 0.077   |
| Colostomy/ileostomy (%)           | 16.7                   | 39.3                     | 0.522   |
| Suprapubic catheter (%)           | 23.1                   | 17.5                     | 0.578   |
| Recurrent pressure ulcer (%)      | 61.5                   | 58.8                     | 0.832   |
| Skilled nursing facility at discharge (%) | 41.7                   | 36.3                     | 0.725   |
| Flap type                         |                        |                          |         |
| Fasciocutaneous (%)              | 25                     | 29.5                     | 0.431   |
| Myocutaneous (%)                 | 58.3                   | 62.3                     | 0.795   |
| Muscle (%)                        | 16.7                   | 8.2                      | 0.364   |
trochanteric (13%) ulcers. Recurrent ulcers were common (56.2%). Nearly 23.1% of the patients had urinary diversion, and 35.6% had stool diversion by colostomy. Hospital length of stay after surgery averaged 30.9 days, with 34% of patients discharged to a skilled nursing facility. Myocutaneous flaps were the most common type of reconstruction (n = 45; 61.6%), followed by fasciocutaneous flaps (n = 21; 28.8%) and muscle flaps (n = 7; 9.5%).

There were a total of 23 (32.4%) complications observed during the 31.8 mean months of follow-up. Of these complications, 15 were minor and 8 were major. Most pressure ulcers demonstrated growth from intraoperative cultures (n = 61; 83.5%), of which 39 positive cultures (63.9%) were polymicrobial.

Nearly all of the preoperative MRI readings were definitive (i.e., osteomyelitis present or not) and 6 (8.45%) pressure ulcers had indeterminate MRI readings. Of those pressure ulcers with a definitive preoperative radiologic reading, the positive predictive value was 84.6%, negative predictive value was 16.7%, sensitivity was 91.7%, and specificity was 9.1%.

**DISCUSSION**

**Preoperative Imaging**

Although appropriate for the diagnosis of osteomyelitis in long bones that are not subject to chronic pressure or acute hematogenous osteomyelitis of the axial skeleton, the utility of MRI in the diagnosis of pelvic osteomyelitis in chronic pressure ulcer remains unclear. A handful of prior studies have attempted to correlate preoperative MRI readings with tissue diagnosis of osteomyelitis in patients with stage IV pressure ulcers.

Huang et al. found a 97% accuracy, 98% sensitivity, and 89% specificity in 44 patients with 59 preoperative MRIs. The tissue samples used for diagnosis were histological/microbiologic results in 32 patients and clinical course in 10 patients. Exactly how specimens were obtained is not always detailed (e.g., intraoperative bone sample, soft tissue sample, or clinical examination). Sending the excised pressure ulcer sinus tract would likely lead to different and less-reliable results compared to sterile bone cultures. Haupfleistch et al., using a chart review for the diagnosis of osteomyelitis, detailed the interobserver agreement for diagnosis of osteomyelitis in 41 preoperative MRI scans in patients with pressure ulcers, noting a 90% sensitivity and specificity in patients with a high pretest probability of osteomyelitis (i.e., cortical erosion). Again, whether or not the diagnosis was made on a tissue or bone sample is unclear. Lastly, Erdman et al. sought to develop radiologic diagnostic criteria for acute or chronic osteomyelitis in patients suspected of having osteomyelitis throughout the entire body (diabetic feet, hematogenous osteomyelitis, etc.). Radiologists were blinded to the patient’s chart, provided a radiologic diagnosis, which was then correlated to a tissue sample. Similar to the aforementioned studies, the type of tissue sample used as the gold standard for diagnosis was not reported. Of the 54 patients diagnosed as having osteomyelitis on MRI, only 6 were correlated to an adjacent pressure ulcer. Overall, they report a sensitivity of 98% and specificity of 82%. Unfortunately, the narrow number of pressure ulcer patients in the study and lack of de-
tail regarding tissue source limit the article’s comparison to the patient population in question.

Using a similar study design to this current manuscript, Mathes et al. performed a retrospective analysis of paralyzed patients with spinal cord injuries who were diagnosed with osteomyelitis by MRI and intraoperative bone culture to determine whether preoperative MRI impacted the surgical management (e.g., area of bony resection) of patients undergoing reconstruction for stage IV pressure ulcers. Of the 26 patients with preoperative MRI showing osteomyelitis, 18 patients (69%) had an intraoperative bone specimen sent for culture, of which 12 patients (66.7%) had positive bone cultures. Similar to this experience, the MRI reading had no impact on the site of bony resection as the site of ostectomy correlated with the preoperative site of osteomyelitis only 42% of the time. These data suggest that given the 86% prevalence of osteomyelitis in these patients, negative predictive value of 16.7%, and lack of bearing on the perioperative course, the routine use of MRI is not indicated for the diagnosis or management of osteomyelitis in patients with chronic stage IV ulcers.

Impact of Osteomyelitis on Outcomes

From a surgical perspective, the extent of the radiographic involvement has never been used in isolation to guide bony resection. Instead, bony resection is determined by the amount of unhealthy bone identified during the surgical/operative examination, as well as the degree of bony prominence that would lead to persistent focal pressure if not removed. In 2012, Larson et al.9 published one of the largest series to date on late-stage pressure ulcers using a retrospective design to determine the effect of using a standardized protocol on postoperative outcomes in 101 patients comprising 179 pressure ulcers. The protocol used in the Larson study is similar to this study, with the exceptions that pressure ulcers in close proximity to the anus of the patients in this study were reconstructed only after colostomy, we did not perform primary closure (compared to 48%), and all of our patients were stage IV (compared to 87%). In concert with this study, Larson did not find bone harboring osteomyelitis to have obvious changes in architecture during resection in areas where osteomyelitis was diagnosed preoperatively by preoperative x-ray. Although Larson did not analyze healing time between those with and without osteomyelitis, they found no correlation between positive microbial growth from the intraoperative bone culture and recurrence or postoperative complication of pressure ulcer, P = 0.97 and 0.93, respectively. This relationship between intraoperative growth and outcomes is further corroborated by the work by Mathes et al., who also found no difference in postoperative outcomes (including recurrence, dehiscence, or operative revision) in those diagnosed with osteomyelitis by preoperative MRI or by intraoperative bone culture.10 Our results suggest that patients with positive bone cultures may, paradoxically, have fewer postoperative complications. We do not put forth a causal relationship. Rather, this highlights an association such that patients with osteomyelitis who require 6 weeks of IV antibiotics have more clinical evaluations by physicians, visiting nurses, and other care team members than patients who do not require prolonged IV antibiotics. They also require frequent blood work (e.g., CRP, ESR, CBC) to monitor their progress, which are likely harbingers to early pathologies. In a high-risk patient population for ulcer recurrence, more aggressive follow-up and frequent examination may deter complications.

CONCLUSIONS

Based on these findings, the use of preoperative imaging for the diagnosis of osteomyelitis is not routinely warranted given its test properties, significant expense, and lack of impact on operative technique selection or patient outcomes. The choice of reconstruction (with or without muscle flaps) should be based on the specific wound requirements. Growth from intraoperative bone cultures is not associated with inferior outcomes when compared to those without growth.

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