HHS Public Access

Author manuscript

Foot Ankle Int. Author manuscript; available in PMC 2017 November 01.

Published in final edited form as:

Foot Ankle Int. 2015 September ; 36(9): 1017–1024. doi:10.1177/1071100715586567.

Topically Applied Vancomycin Powder Reduces the Rate of Surgical Site Infection in Diabetic Patients Undergoing Foot and Ankle Surgery

Dane K. Wukich, MD[1,4], **Jeffrey W. Dikis, DPM**[1], **Spencer J. Monaco, DPM**[1], **Kristin Strannigan, DPM**[2], **Natalie C. Suder, MPH**[3], and **Bedda L. Rosario, PhD**[3]

[1]UPMC Mercy Hospital, Pittsburgh, PA, USA

[2]University of Florida College of Medicine–Jacksonville, Jacksonville, FL, USA

[3]Department of Biostatistics and Epidemiology, University of Pittsburgh Graduate School of Public Health, Pittsburgh, PA, USA

[4]Department of Orthopaedic Surgery, Pittsburgh, University of Pittsburgh School of Medicine, PA, USA

Abstract

Background—The purpose of this study was to evaluate the efficacy of topically applied vancomycin powder in reducing the rate of surgical site infections (SSIs) in patients with diabetes mellitus (DM) undergoing foot and ankle surgery.

Methods—Eighty-one patients with DM who underwent reconstructive surgery of a foot and/or ankle deformity and/or trauma and who received topically applied vancomycin were matched to 81 patients with DM who did not receive topically applied vancomycin. The mean age was 60.6 years in the vancomycin group and 59.4 years in the control group ($P < .05$). The 2 groups were similar with regard to gender, body mass index, duration of DM, short-term and longer term glycemic control, and length of surgery.

Results—The overall likelihood of SSI was decreased by 73% in patients who received topically applied vancomycin (odds ratio [OR], 0.267; 95% CI, 0.089–0.803; $P = .0188$). The rate of superficial infection was not significantly different between the 2 groups (OR, 0.400; 95% CI, 0.078–2.062; $P = .2734$); however, deep infections were 80% less likely in patients who received vancomycin powder (OR, 0.200; 95% CI, 0.044–0.913; $P = .0377$).

Conclusion—High-risk diabetic patients undergoing foot and ankle surgery were notably less likely to develop an SSI with the use of topically applied vancomycin powder in the surgical wound, particularly with regard to deep infections. Topically applied vancomycin was associated with a very low rate of complications and was inexpensive ($5 per 1000 mg). Based on this study,

Corresponding Author: Dane K. Wukich, MD, 1515 Locust Street, UPMC Mercy Health Center, Pittsburgh, PA 15219, USA., wukichdk@upmc.edu.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: The senior author, Dane K. Wukich, MD, is a consultant for Stryker and receives royalties from Arthrex.

foot and ankle surgeons may consider applying 500 to 1000 mg of vancomycin powder prior to skin closure in diabetic patients who are not allergic to vancomycin.

Level of Evidence—Level III, retrospective case control series.

Keywords

postoperative; antibiotics; diabetes; neuropathy

Despite systemically administered antibiotic prophylaxis, surgical site infections (SSIs) remain a costly postoperative complication, potentially leading to prolonged hospitalization and adverse outcomes. Surgical site infections are ranked among the 10 leading causes of death in the United States, with more than 20% of hospital-acquired infections attributed to the surgical site.[18] In patients undergoing orthopedic surgery, those who develop an SSI incur more than double the treatment costs of patients without SSI.[6] As a result of the Medicare Modernization Act of 2003 and the Deficit Reduction Act of 2005, the Centers for Medicare and Medicaid Services instituted financial penalties for hospital-acquired infections such as SSIs beginning in 2008.[20]

More than 29 million people in the United States are estimated to have diabetes mellitus (DM).[4] These high-risk patients are more likely to develop SSI than are patients without DM, leading to an increased economic burden. One study found that rates of SSI in patients with DM undergoing foot and ankle surgery were 3 times higher than in patients without DM.[28] Patients with complications of DM such as neuropathy, nephropathy, and peripheral arterial disease (PAD) have notably higher rates of SSI compared with diabetic patients without such complications.[25,27,28] A prospective study demonstrated that neuropathy and poorly controlled DM (hemoglobin A_{1c} >8%) were associated with increased rates of SSI.[25] Peripheral arterial disease may hinder the ability of systemically administered antibiotics to reach target tissues, since diabetic patients may have both macrovascular and microvascular disease. In this setting, the local application of topically applied antibiotics could deliver high concentrations of antibiotics at the surgical site, potentially leading to a reduction in the rates of SSI, readmission, and patient morbidity. Vancomycin-impregnated cement has been used in revision total joint arthroplasty as a method to reduce prosthetic infections.[3] Topically applied vancomycin has gained popularity in spine surgery and has been the subject of case series, meta-analysis, and systemic reviews.[1,5,8,17] The aim of this study was to evaluate the efficacy of topically applied vancomycin powder in reducing the rate of SSI in patients with DM undergoing foot and ankle surgery and to compare this study group with a cohort of diabetic patients who did not receive topically applied vancomycin.

Methods

Following institutional review board approval, we searched the records of diabetic patients undergoing foot and ankle surgery at our institution. All of the patients were treated by the senior author (D.K.W.), and the study group included diabetic patients who had intraoperative topical application of vancomycin at the surgical site in addition to standard systemic prophylaxis. Patients with preoperative foot ulcers that demonstrated obvious signs of infection such as purulent drainage and/or signs of inflammation such as erythema,

swelling, tenderness, or warmth preoperatively were excluded. Patients with foot ulcers and exposed bone undergoing reconstruction were excluded from analysis if intraoperative cultures were positive for infection or if histopathological evidence of infection was present. The study group was matched to a control group of diabetic patients who underwent foot and ankle surgery and did not receive topically applied vancomycin. The indications for surgery for both groups are recorded in Table 1. In an effort to avoid selection bias, the matching was performed by one of the authors (J.W.D.) who was blinded to whether a patient had experienced an SSI. Patients in both the study and control groups received standard systemic antibiotic prophylaxis, consisting of 1 g of intravenous (IV) cefazolin (or 2 g if the patient's weight was >180 lb) within 1 hour of surgical incision followed by 1 g of IV cefazolin every 8 hours, which was discontinued within the first 24 hours. In patients allergic to penicillin or Ancef (cefazolin), 1 g of parenteral vancomycin was administered over 30 to 60 minutes prior to the procedure, and 1 additional dose was given 12 hours after the conclusion of surgery. Patients who underwent outpatient surgery received 1 preoperative dose of antibiotics. The surgical sites were prepared with chlorhexidine. Prior to closure and application of the topical antibiotic, irrigation with 1 L of normal saline was performed with a bulb syringe. The study group received 500 to 1000 mg of topically applied vancomycin powder, spread evenly throughout the deep and subcutaneous tissues prior to closure. The study group was a consecutive series of patients who underwent surgery between January 21, 2012, and May 23, 2014. The control group consisted of patients who underwent surgery between December 4, 2006, and December 31, 2011. As is typical in foot and ankle surgery, multiple incisions often were used; all incisions were treated with vancomycin powder in the study group. Various demographic data were recorded (Table 2).

Surgical site infection and severity of infection were defined according to previously published reports.[25,27,28] A superficial infection was defined as less than 2 cm of peri-incisional erythema with or without purulent drainage that did not require hospitalization or surgical intervention and was successfully treated with oral antibiotics. For patients who had erythema without drainage, we elevated the lower extremity for 5 minutes. If the erythema resolved with elevation, postoperative wound inflammation was diagnosed and the patient was reevaluated in 1 week and did not receive an antibiotic. Those patients whose erythema failed to resolve with elevation were diagnosed with a superficial SSI. Deep infection was defined by purulent drainage with 2 cm or more of peri-incisional erythema and treatment by inpatient hospitalization and surgical intervention. Pin tract infections associated with external fixation were not included as an SSI since these infections were not at the surgical site and occurred commonly in patients as the duration of external fixation increased.[24]

Peripheral neuropathy was diagnosed using the Michigan Neuropathy Screening Index (MNSI) (score ≥2.5).[22] The MNSI has been validated as a method of diagnosing diabetic neuropathy by combining a quantitative neurological examination coupled with nerve conduction studies.[9] Four plantar sites (the first and fifth metatarsal heads, plantar hallux, and heel) were tested with the 5.07 Semmes Weinstein monofilament. One point was given if sensation was absent. Vibratory sensation was evaluated with a 128-Hz tuning fork at the dorsal hallux, and inability to sense the tuning fork received 1 point. Achilles reflexes were evaluated in the standard musculoskeletal manner, and absent reflex received 1 point. The presence of a foot ulcer received 1 point. For the purposes of this study, we defined

neuropathic deformity as multiple claw toes involving both feet and/or the presence of Charcot neuroarthropathy (CN). The presence of a deformity received 1 point. The maximum score per foot was 5, and the combined maximum total score of both feet was 10. If the 4 pedal pulses were palpable and no symptoms of claudication were present, no further vascular evaluation took place. Patients with an abnormal vascular examination were referred for noninvasive arterial studies, and PAD was defined as an ankle brachial index (ABI) less than 0.9 and/or a toe brachial index (TBI) less than 0.7.[21]

The analysis was performed as a matched case-control study. One control subject was matched to each treatment subject by age, gender, and length of surgery. Length of surgery was used as a variable in order to compare the complexity of the procedure. We assumed that procedures of similar length would be of similar complexity. We did not match the patients based on specific types of procedures, nor did we compare the number of surgical incisions between the 2 groups.

Eighty-one diabetic patients who received topically applied vancomycin were identified and matched to 81 diabetic patients, as described earlier (Table 2). The mean age of the vancomycin group was 60.6 ± 10.9 years compared with the control group age of 59.5 ± 10.8 years ($P < .05$). There were no significant differences between the study and control groups with regard to gender, length of surgery, fasting glucose on the day of surgery, hemoglobin A_{1c}, hemoglobin, body mass index, duration of DM, insulin use, or neuropathy scores using the MNSI (Table 2). Patients in the vancomycin group were more likely to have type 2 DM ($P < .0001$), foot ulcers ($P < .0001$), CN ($P < .05$), and history of tobacco use ($P < .01$) than the control group, although patients in the control group had significantly longer follow-up ($P < .0001$), higher prevalence of type 1 DM ($P < .0001$), elevated serum creatinine ($P < .01$), higher prevalence of neuropathy ($P < .001$), and PAD ($P < .0001$) (Table 2). Patients in the vancomycin study group underwent a median of 3 procedures (25%–75% interquartile range, 2–4) during their surgery compared with 3 procedures (25%–75% interquartile range, 2–3) for patients in the control group ($P < .01$).

Descriptive statistics were summarized as frequencies (percentages) for categorical data or as mean ± standard deviation (SD) or median (25th and 75th percentile) for normally or nonnormally distributed continuous data, as appropriate. Examination of normal distribution assumption for continuous data was determined by q-q plots and histograms. McNemar or Bhapkar test was used to compare the frequency distribution of categorical variables between the matched groups. Paired 2-sample *t* test or Wilcoxon sign rank sum test was performed to determine differences between the matched groups for normally or nonnormally distributed continuous data, respectively. Conditional logistic regression was applied to assess the strength of association between the predictor variable (eg, group) and the dichotomous outcome of interest (ie, overall infection, superficial infection, and deep infection). The magnitude of associations between the predictor variable and outcome was quantified using the odds ratio (OR) and the corresponding 95% confidence interval (CI). All tests were 2-sided, and the significance level was set to .05. All analyses were conducted using SAS, version 9.3 statistical software (SAS Institute Inc, Cary, NC). Statistical analysis was performed by 2 of the authors, both experienced in biostatistics.

Results

Two of the 81 patients (2.4%) in the control group ultimately required a transtibial amputation as a result of their deep infection. One patient (1.2%) in the control group required a minor foot amputation. None of the patients in the vancomycin group required a transtibial amputation or minor foot amputation. The overall rate of infection was 11.7% (19 of 162 patients). Patients who received vancomycin powder were 73% less likely to experience an overall infection (OR, 0.267; 95% CI, 0.089–0.803; $P < .05$) and 80% less likely to experience a deep infection (OR, 0.20; 95% CI, 0.044–0.913; $P < .05$). Although the patients who received vancomycin were 60% less likely to experience a superficial infection, this difference did not reach statistical significance (OR, 0.400; 95% CI, 0.078–2.062; $P = .2734$) with the numbers available.

Discussion

Surgical site infections are now publicly reported, and third-party payers, patients, advocacy groups, and institutions have access to these data. Surgeons who treat high-risk diabetic patients may appear to have relatively high rates of SSI compared with foot and ankle surgeons who treat low-risk patients. Consequently, addressing risk factors is paramount throughout the entire perioperative period and includes such things as cessation of tobacco use, optimizing glycemic management, and following established intraoperative protocols. The Surgical Care Improvement Project (SCIP) was set forth by the Joint Commission in 2006 as a way to improve surgical care by reducing surgical complications such as SSI. These measures outline multiple perioperative parameters, including use of prophylactic antibiotics within 1 hour prior to surgical incision, adequate selection of antibiotics, and discontinuation of antibiotics 24 hours postoperatively.[2] Our study demonstrated that in addition to the measures recommended by SCIP, the administration of topical vancomycin in diabetic patients led to a notable reduction in the rate of overall SSI and deep SSI compared with a cohort of diabetic patients who did not receive topically administered vancomycin. Topically applied vancomycin did not have a notable impact on the rate of superficial infections with the numbers available.

The diabetic patients in this study represented a high-risk population who underwent surgical procedures that lasted an average of 2.5 hours. Several studies have identified diabetic patients, especially those with complications such as neuropathy, to be at high risk for SSI after foot and ankle surgery.[25,27,28] Comorbidities and risk factors for SSI present in our vancomycin study group and control group, respectively, included CN (38% vs 34%), foot ulcers (26% vs 20%), neuropathy (75% vs 80%), active tobacco use (17% vs 18%), and PAD (11% vs 20%). To the best of our knowledge, the use of topical vancomycin powder has not been described in foot and ankle surgery. The 73% reduction in the rate of SSI in our series of foot and ankle patients (from 18.5% to 4.9%; Table 2) was remarkably similar to the 71% reduction reported in a combined spine series (from 3.39% to 0.97%).[1,5,8,17] A recent systematic review of topically applied vancomycin in spine surgery identified 8 retrospective studies and reported a 78% reduction in the rate of SSI in the vancomycin group (from 3.7% to 0.82%).[8]

Three recent studies have reported on a combined series of 834 diabetic patients who underwent foot and ankle surgery, citing an SSI rate of 17%, which is similar to the rate observed in our control group.[16,25,27] The most commonly identified microbe in an SSI is *Staphylococcus aureus*, which includes both methicillin-susceptible (MSSA) and methicillin-resistant (MRSA) strains. Approximately half of all SSIs following orthopedic procedures are caused by *S aureus*, and vancomycin has been shown to be effective against these microbes.[14] Vancomycin powder has been used in bone cement for revision joint arthroplasty, and its use has been described in the spine and total joint surgery literature.[3] Chiang et al[5] reviewed 10 studies and concluded that local vancomycin powder was protective against superficial and deep SSIs in spine surgery, although the authors felt that publication bias may have been present.[5] In a separate meta-analysis, Kanj et al[17] reported similar results and recommended the use of topical vancomycin in clean orthopedic surgery. Another recent systematic review/meta-analysis identified 8 observational studies that addressed the use of topical vancomycin in spine surgery, reporting that the odds of infection with intrawound vancomycin was 0.19 times the odds of infection without intrawound vancomycin (95% CI, 0.08–0.47; $P = .0003$).[8] No adverse events were attributed to intrawound vancomycin, although the authors stated that the quality of the evidence was low.[8] The safety of topical vancomycin has also been evaluated in pediatric patients undergoing spine surgery. The postoperative systemic vancomycin levels remained undetectable, and none of the patients experienced known complications such as nephrotoxicity or red man syndrome. In this pediatric cohort, there were no clinically important changes in creatinine level or systemic vancomycin level caused by intraoperative use.[10]

Not all studies have been supportive of topically applied vancomycin in spine surgery. In a randomized study of 907 patients with various spinal pathologies, controls received standard systemic prophylaxis only whereas the treatment group received vancomycin powder in the surgical wound as well.[23] There were 8 infections (1.68%) in the control group and 7 infections (1.61%) in the study group (OR, 0.96; 95% CI, 0.34–2.66; $P = .93$). No adverse effects were observed from the use of vancomycin powder.[23] A retrospective study of 981 consecutive patients who underwent spine surgery and received topically applied vancomycin reported an SSI rate of 6.7%.[11] A number of gram-negative infections were encountered, and the authors cautioned that topically applied vancomycin after spine surgery could increase the incidence of gram-negative or polymicrobial spinal infections and postoperative seromas.[11]

Although the overwhelming majority of patients who have had topically applied vancomycin did not experience any complications, a recent report identified a case of circulatory collapse.[19] During closure of the subcutaneous layer, hypotension and tachycardia occurred, and it was thought that the rapid absorption of vancomycin powder resulted in anaphylaxis. With an increase in the use of topical vancomycin in surgical wounds, communication and awareness among all intraoperative team members are important for rapid diagnosis of an adverse reaction and for appropriate management.[19] All of the topical applications of vancomycin in our study occurred after deflation of the tourniquet, and we did not experience any intraoperative or perioperative complications (ie, prolonged drainage).

At our institution, 1 g of vancomycin costs approximately $5. Consequently, the addition of topically applied vancomycin did not add appreciable cost to the procedure. Although we did not evaluate the economics of SSI in this study, this topic has been reported in spine surgery.[7,13] Substantial savings have been demonstrated in patients who received vancomycin powder compared with those who did not receive vancomycin. We recognize that translating economic data from spine surgery to foot and ankle surgery may not be ideal; however, it does illustrate the potential impact of postoperative infection on healthcare costs. Postoperative infections in foot and ankle surgery can be catastrophic, ultimately leading to major amputation. A recent report demonstrated that the average 12-month cost for a diabetic patient undergoing transtibial amputation was $49 000.[12] If 1 major amputation could be avoided by the use of intrawound vancomycin, the additional cost savings in foot and ankle surgery could be considerable. Our control group experienced 2 major amputations and 1 minor amputation. If we use the economic impact from the above study,[12] the 2 major amputations in our control group would have cost $98 000; the vancomycin powder in our study group cost $405. Foot and ankle surgeons who treat patients with complicated DM recognize the potential for major amputation, as illustrated by a major amputation rate of 8.7% in a cohort of diabetic patients with ankle fractures.[26]

This study has several limitations that should be acknowledged. First, the retrospective analysis was conducted with data from electronic medical records, so our results rely on the accuracy of the documentation. Second, measurement bias between study and control groups was a possibility, although this likelihood was minimized by the fact that a single foot and ankle surgeon performed all of the operations in both patient groups. We attempted to minimize measurement bias between study and control groups by providing patients with equivalent perioperative antibiotic prophylaxis and similar perioperative care, with the exception of the use of topically applied vancomycin powder. We recognize that due to patient allergies, and whether surgery was performed as an inpatient or outpatient, differences in the perioperative antibiotic regimen may be present in our study and control groups. We did not account for this in our matching, and the reader should view as a potential weakness of this study. Third, selection bias is also a possibility because of the matching of a control group. We attempted to minimize this by having a blinded author match the patients based on age, gender, and length of surgery. The fact that we did not match our patients based on the number of incisions or specific procedure is also a potential weakness of this study. Our 2 groups were remarkably similar with regard to various comorbidities and demographic data. Although the mean age difference between the 2 groups was only 1 year, this difference was statistically significant and the reader should interpret this accordingly. Our control group had a relatively high rate of infection (18%); however, this SSI rate is similar to the 17% reported in a retrospective study of complicated diabetic patients[27] and the 10.4% rate in a prospective study.[25] The rate of SSI in our control group is lower than that recently reported in a cohort of diabetic patients.[15,16] This retrospective study identified 322 diabetic patients from a series of 3795 patients who underwent ankle and/or foot surgery. The overall rate of postoperative infection was 28.9% in patients with DM, and the average surgical time was 75 minutes. Diabetic patients without comorbidities had an infection rate of 21%, and diabetic patients with comorbidities had an infection rate of 36% ($P = .003$). Another limitation of this study is that interviewer

bias was potentially present as the senior author determined the outcome of SSI. Finally, different risk factors may play a role in postoperative infection, and we attempted to address these issues and confounders through proper matching of study and control groups based on sex, age, and length of foot and ankle surgery. As illustrated in Table 2, there were some differences between the 2 groups, and the reader should be cognizant of these differences when interpreting our results. Our control group also had longer follow-up than our study group, and it is possible that more infections may manifest with longer follow-up. The most likely explanation for the longer follow-up is that we began to use vancomycin powder in 2012; however, the overwhelming majority of control patients were obtained from 2008 to 2011, which was prior to the use of vancomycin powder. We also acknowledge that the relatively small size of our study is a potential weakness, although this study is adequately powered to detect a significant difference in the rate of overall and deep SSI. It is conceivable that a larger study might identify a significant difference in the rate of superficial infections. A prospective, randomized study is the optimal method to evaluate the efficacy of topically applied vancomycin powder. This study does not address the usefulness of topically applied vancomycin in reducing the rate of SSI in nondiabetic patients.

Conclusion

Patients with complications of DM are at high risk for SSI after foot and ankle surgery, and some variables (ie, neuropathy and deformity) are not modifiable. Optimizing glycemic control (hemoglobin A_{1c} <8%), stopping tobacco use, and establishing adequate perfusion are important modifiable factors in these high-risk patients. Topically applied vancomycin powder was inexpensive, was associated with a very low complication rate, and notably reduced the rate of deep SSIs in high-risk diabetic patients. Based on this retrospective controlled study, foot and ankle surgeons may consider topically applying 500 to 1000 mg of vancomycin powder prior to skin closure in patients who are not allergic to vancomycin. Our approach to elective surgical reconstruction in high-risk diabetic patients has evolved over the past decade and continues to evolve as we have incorporated the above changes into our surgical protocol.

Acknowledgments

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: The Clinical and Translational Science Institute (CTSI) at the University of Pittsburgh provided statistical assistance for this manuscript. The CTSI statistical consultation was supported by the National Institutes of Health through Grant Number UL1-TR-000005.

References

1. Alcala-Cerra G, Paternina-Caicedo AJ, Moscote-Salazar LR, Gutierrez-Paternina JJ, Nino-Hernandez LM. Application of vancomycin powder into the wound during spine surgery: systematic review and meta-analysis. Rev Esp Cir Ortop Traumatol. 2014; 58(3):182–191. [PubMed: 24703108]
2. Bratzler DW, Hunt DR. The surgical infection prevention and surgical care improvement projects: national initiatives to improve outcomes for patients having surgery. Clin Infect Dis. 2006; 43(3): 322–330. [PubMed: 16804848]

3. Buttaro MA, Guala AJ, Comba F, Suarez F, Piccaluga F. Incidence of deep infection in aseptic revision THA using vancomycin-impregnated impacted bone allograft. Hip Int. 2010; 20(4):535–541. [PubMed: 21157761]

4. Centers for Disease Control and Prevention. National Diabetes Statistics Report: Estimates of Diabetes and Its Burden in the United States, 2014. Atlanta, GA: US Department of Health and Human Services; 2014.

5. Chiang HY, Herwaldt LA, Blevins AE, Cho E, Schweizer ML. Effectiveness of local vancomycin powder to decrease surgical site infections: a meta-analysis. Spine J. 2014; 14(3):397–407. [PubMed: 24373682]

6. de Lissovoy G, Fraeman K, Hutchins V, et al. Surgical site infection: incidence and impact on hospital utilization and treatment costs. Am J Infect Control. 2009; 37(5):387–397. [PubMed: 19398246]

7. Emohare O, Ledonio CG, Hill BW, et al. Cost savings analysis of intrawound vancomycin powder in posterior spinal surgery. Spine J. 2014; 14(11):2710–2715. [PubMed: 24650851]

8. Evaniew N, Khan M, Drew B, et al. Intrawound vancomycin to prevent infections after spine surgery: a systematic review and meta-analysis. Eur Spine J. 2015; 24(3):533–542. [PubMed: 24838506]

9. Feldman EL, Stevens MJ, Thomas PK, et al. A practical two-step quantitative clinical and electrophysiological assessment for the diagnosis and staging of diabetic neuropathy. Diabetes Care. 1994; 17(11):1281–1289. [PubMed: 7821168]

10. Gans I, Dormans JP, Spiegel DA, et al. Adjunctive vancomycin powder in pediatric spine surgery is safe. Spine. 2013; 38(19):1703–1707. [PubMed: 23759805]

11. Ghobrial GM, Thakkar V, Andrews E, et al. Intraoperative vancomycin use in spinal surgery: single institution experience and microbial trends. Spine. 2014; 39(7):550–555. [PubMed: 24480966]

12. Gil J, Schiff AP, Pinzur MS. Cost comparison: limb salvage versus amputation in diabetic patients with Charcot foot. Foot Ankle Int. 2013; 34(8):1097–1099. [PubMed: 23493775]

13. Godil SS, Parker SL, O'Neill KR, Devin CJ, McGirt MJ. Comparative effectiveness and cost-benefit analysis of local application of vancomycin powder in posterior spinal fusion for spine trauma: clinical article. J Neurosurg Spine. 2013; 19(3):331–335. [PubMed: 23848350]

14. Hidron AI, Edwards JR, Patel J, et al. NHSN annual update: antimicrobial-resistant pathogens associated with healthcare-associated infections: annual summary of data reported to the National Healthcare Safety Network at the Centers for Disease Control and Prevention, 2006–2007. Infect Control Hosp Epidemiol. 2008; 29(11):996–1011. [PubMed: 18947320]

15. Humphers JM, Shibuya N, Fluhman BL, Jupiter D. The impact of glycosylated hemoglobin and diabetes mellitus on wound-healing complications and infection after foot and ankle surgery. J Am Podiatr Med Assoc. 2014; 104(4):320–329. [PubMed: 25076074]

16. Jupiter DC, Humphers JM, Shibuya N. Trends in postoperative infection rates and their relationship to glycosylated hemoglobin levels in diabetic patients undergoing foot and ankle surgery. Foot Ankle Surg. 2014; 53(3):307–311.

17. Kanj WW, Flynn JM, Spiegel DA, Dormans JP, Baldwin KD. Vancomycin prophylaxis of surgical site infection in clean orthopedic surgery. Orthopedics. 2013; 36(2):138–146. [PubMed: 23379827]

18. Klevens RM, Edwards JR, Richards CL Jr, et al. Estimating health care-associated infections and deaths in U.S. hospitals, 2002. Public Health Rep. 2007; 122(2):160–166. [PubMed: 17357358]

19. Mariappan R, Manninen P, Massicotte EM, Bhatia A. Circulatory collapse after topical application of vancomycin powder during spine surgery. J Neurosurg Spine. 2013; 19(3):381–383. [PubMed: 23829290]

20. Peasah SK, McKay NL, Harman JS, Al-Amin M, Cook RL. Medicare non-payment of hospital-acquired infections: infection rates three years post implementation. Medicare Medicaid Res Rev. 2013; 3(3)

21. Rooke TW, Hirsch AT, Misra S, et al. 2011 ACCF/AHA focused update of the guideline for the management of patients with peripheral artery disease (updating the 2005 guideline): a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines: developed in collaboration with the Society for Cardiovascular Angiography

and Interventions, Society of Interventional Radiology, Society for Vascular Medicine, and Society for Vascular Surgery. J Vasc Surg. 2011; 54(5):e32–e58. [PubMed: 21958560]

22. Suder NC, Wukich DK. Prevalence of diabetic neuropathy in patients undergoing foot and ankle surgery. Foot Ankle Spec. 2012; 5(2):97–101. [PubMed: 22322102]
23. Tubaki VR, Rajasekaran S, Shetty AP. Effects of using intravenous antibiotic only versus local intrawound vancomycin antibiotic powder application in addition to intravenous antibiotics on postoperative infection in spine surgery in 907 patients. Spine. 2013; 38(25):2149–2155. [PubMed: 24048091]
24. Wukich DK, Belczyk RJ, Burns PR, Frykberg RG. Complications encountered with circular ring fixation in persons with diabetes mellitus. Foot Ankle Int. 2008; 29(10):994–1000. [PubMed: 18851815]
25. Wukich DK, Crim BE, Frykberg RG, Rosario BL. Neuropathy and poorly controlled diabetes increase the rate of surgical site infection after foot and ankle surgery. J Bone Joint Surg Am. 2014; 96(10):832–839. [PubMed: 24875024]
26. Wukich DK, Joseph A, Ryan M, Ramirez C, Irrgang JJ. Outcomes of ankle fractures in patients with uncomplicated versus complicated diabetes. Foot Ankle Int. 2011; 32(2):120–130. [PubMed: 21288410]
27. Wukich DK, Lowery NJ, McMillen RL, Frykberg RG. Postoperative infection rates in foot and ankle surgery: a comparison of patients with and without diabetes mellitus. J Bone Joint Surg Am. 2010; 92(2):287–295. [PubMed: 20124054]
28. Wukich DK, McMillen RL, Lowery NJ, Frykberg RG. Surgical site infections after foot and ankle surgery: a comparison of patients with and without diabetes. Diabetes Care. 2011; 34(10):2211–2213. [PubMed: 21816974]

Table 1

Indications for Surgery.

	Vancomycin (n = 81)	Control Group (n = 81)
Achilles tendon disorders	3	2
Ankle synovitis	1	1
Arthritis of the ankle, hindfoot, or midfoot requiring primary or revision arthrodesis	15	11
Charcot neuroarthropathy reconstruction	31	29
Exostectomy/ostectomy for bone spurs or exostosis	2	4
Equinovarus deformity (acquired from traumatic brain injury or cerebrovascular accident)	5	3
Flatfoot reconstruction (tendon transfers, osteotomies, and fusions)	13	10
Hallux disorders (bunions and arthritis)	4	5
Hammertoe disorders	5	5
Open reduction internal fixation of ankle or foot fractures	3	9
Removal of hardware (isolated procedure)	0	1
Tendon disorder (peroneal)	0	1

Table 2

Comparison of Patients Receiving Vancomycin and Patients Who Did Not Receive Vancomycin.

	Overall Results (N = 162)	Topically Applied Vancomycin (n = 81)	No Vancomycin (n = 81)	*P* Value
Age, mean (SD), y	60.1 (10.8)	60.6 (10.9)	59.5 (10.8)	<.05
Gender, % males (n)	59.3 (96)	59.3 (48)	59.3 (48)	.1193
BMI, mean (SD)	34.8 (7.7)	34.5 (7.2)	35.1 (8.2)	.5859
Duration of DM, median (25%, 75% interquartile range), y	10.0 (5.0, 20.0)	10.0 (5.0, 19.0)	10.0 (4.0, 24.0)	.3602
Type of DM, % type 2 (n)	87.7 (142)	93.8 (76)	81.5 (66)	<.0001
Insulin use, % (n)	49.4 (80)	49.4 (40)	49.4 (40)	1.000
Serum glucose mg/dl, median (25%, 75% interquartile range)	131.5 (105.0, 160.0)	131.0 (106.0, 171.0)	132.0 (103.0, 156.0)	.3363
Hemoglobin A_{1c}%, median (25%, 75% interquartile range)	7.0 (6.3, 8.2)	7.0 (6.4, 8.2)	8.0 (6.2, 8.1)	.5906
Serum creatinine mg/dl, median (25%, 75% interquartile range)	1.0 (0.8, 1.2)	0.9 (0.8, 1.2)	1.1 (0.9, 1.3)	<0.01
Hemoglobin gr/dl, mean (SD)	12.9 (1.8)	13.0 (1.8)	12.8 (1.6)	.2459
ASA classification, % (n)				.5629
2	9.9 (16)	8.6 (7)	11.1 (9)	
3	84.0 (136)	87.7 (71)	80.3 (65)	
4	6.2 (10)	3.7 (3)	8.6 (7)	
Presence or absence of ulcer, % (n)	22.8 (37)	25.9 (21)	19.8 (16)	<.0001
Active or former smoker, % (n)	29.6 (48)	33.3 (27)	25.9 (21)	<.001
Active smoker current, % (n)	17.9 (29)	17.3 (14)	18.5 (15)	<.0001
Presence of Charcot neuropathy, % (n)	36.4 (59)	38.3 (31)	34.6 (28)	<.05
Peripheral artery disease, % (n)	15.4 (25)	11.1 (9)	19.8 (16)	<.0001
Neuropathy, % (n)	77.8 (126)	75.3 (61)	80.3 (65)	<.001
Michigan Neuropathy Screening Index, median (25%, 75% interquartile range)	6.0 (3.0, 7.0)	6.0 (2.0, 8.0)	5.5 (3.0, 7.0)	.8307
Follow-up duration, median (25%, 75% interquartile range), wk	52.0 (26.0, 100.0)	44.0 (24.0, 78.0)	60.0 (27.0, 104.0)	<.05
Length of surgery, mean (SD), min	147.5 (64.3)	147.8 (66.6)	147.2 (62.3)	.9137
No. of procedures performed during surgery, median (25%, 75% interquartile range)	3.0 (2.0, 4.0)	3.0 (2.0, 4.0)	3.0 (2.0, 3.0)	<.01
Overall infection, % (n)	11.7 (19)	4.9 (4)	18.5 (15)	<.05 (OR, 0.267; 95% CI, 0.089–0.803)
Superficial infection, % (n)	4.3 (7)	2.5 (2)	6.2 (5)	.2734 (OR, 0.400; 95% CI, 0.078–2.062)
Deep infection, % (n)	7.4 (12)	2.5 (2)	12.4 (10)	<.05 (OR, 0.200; 95% CI, 0.044–0.913)

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; DM, diabetes mellitus; OR, odds ratio.