Orthopedic Surgical Site Infections: Analysis of Causative Bacteria and Implications for Antibiotic Stewardship

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Abstract

Data that can be used to guide perioperative antibiotic prophylaxis in our era of emerging antibiotic resistance are limited.

We reviewed orthopedic surgeries complicated by surgical site infections (SSIs). Eighty percent of 69 arthroplasty and 80 spine fusion SSIs were infected with Gram-positive bacteria; most were staphylococcal species; and more than 25% of *Staphylococcus aureus* and more than 65% of coagulase-negative staphylococci were methicillin-resistant. Gram-negative bacteria were isolated from 30% of arthroplasty SSIs and 25% of spine fusion SSIs. Resistance to cefazolin was higher than 40%. A significant proportion of SSIs were caused by resistant organisms, and antibiotic guidelines were altered to provide more adequate surgical prophylaxis.

Surgical site infections (SSIs) are preventable complications often associated with increased morbidity and prolonged hospitalization.[1] Over the past 50 years, numerous strategies to reduce SSI risk have been used, including preoperative bacterial decolonization, use of incision site antiseptics, and antimicrobial prophylaxis. Perioperative antimicrobial prophylaxis is recommended and widely used for SSI prevention; its efficacy depends on optimized timing, dosing, and choice of agents.[2-4]

For arthroplasty and spine fusion surgeries, prophylactic antimicrobials have been shown to significantly reduce SSI rates. The effectiveness of antimicrobial prophylaxis, however, depends on the susceptibility of those bacteria most likely to be encountered during the operation. Despite emerging resistant bacteria, cefazolin is the antimicrobial prophylaxis most commonly prescribed for orthopedic surgery[2]—it targets skin flora such as *Staphylococcus aureus* and *Streptococcus* spp.

Over the past decade, studies and quality improvement measures addressing surgical antimicrobial prophylaxis have largely focused on optimizing the timing of administration.[2,5] However, recent SSI microbiological data, which would better inform choice of agents and dosing in our era of multidrug bacterial resistance, are limited.[6]

We conducted a study of the microbiology of SSIs at an orthopedic specialty hospital in New York City—where the incidence of multidrug-resistant bacteria is high[7]—to provide data-driven stewardship for surgical prophylaxis for arthroplasty and spine fusion surgeries.

Materials and Methods

We retrospectively reviewed all arthroplasty and spine fusion surgeries performed at a single-specialty orthopedic hospital between January 1, 2008 and July 31, 2010 that were complicated by surgical site infections (SSIs). Each SSI was counted separately; for example, 2 infections were counted for a patient who had 2 infections. We used Centers for Disease Control and Prevention (CDC) National Healthcare Safety Network (NHSN) criteria to define SSIs.[8] Cases were identified by review of daily microbiology culture reports, review of readmissions, and daily infection control rounds. Infections were stratified by NHSN case definition, surgery type, and anatomical location. Microbiological data, including antimicrobial susceptibility data for cultured isolates, were obtained by medical record review. During the review period, routine perioperative antibiotic prophylaxis was cefazolin 1 g every 8 hours (3 doses); intravenous clindamycin 600 mg was substituted for patients with penicillin allergy, and vancomycin was substituted if preoperative screening revealed the patient was colonized with methicillin-resistant *S aureus* (MRSA). Data were analyzed using SPSS for Windows version 17.0.

Results

During the study period, 5,323 primary arthroplasties (2,237 hip, 2,857 knee, 229 shoulder) were performed at our institution. Also performed were 3,105 primary and revision spine fusion surgeries (748 cervical, 756 dorsal, 1,601 lumbar). Sixty-nine arthroplasty SSIs (31 hip, 37 knee, 1 shoulder) and 80 spine fusion SSIs (10 cervical, 27 dorsal, 43 lumbar) were identified. For the 3-year study period, the combined rates

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of deep and superficial SSIs were 1.26 (per 100 arthroplasties) and 2.58 (per 100 spine fusion surgeries). Eighty-one percent of arthroplasty SSIs and 75% of spine fusion SSIs were deep. This finding persisted across anatomical locations. Of the 69 patients who had arthroplasty SSIs, 47 (68%) received cefazolin for surgical prophylaxis, 11 (16%) received clindamycin, and 11 (16%) received vancomycin. Of the 79 patients who had spine fusion SSIs and for whom antibiotic data were available, 55 (70%) received cefazolin, 19 (24%) received clindamycin, and 5 (6%) received vancomycin (1 patient), daptomycin (1 patient), or combination therapy (3 patients) based on clinical history.

Of the 69 arthroplasty SSIs, 55 (80%) were caused by Gram-positive bacteria, and 21 (30%) by Gram-negative bacteria (7 cases were polymicrobial). Of 68 Gram-positive isolates, 42 (62%) were staphylococcal species, half *S aureus* and half coagulase-negative staphylococci (CNS). Seven *S aureus* isolates (33%) were MRSA (86% deep infections), and 16 CNS isolates (76%) were methicillin-resistant *Staphylococcus epidermidis* (MRSE) (81% deep infections). All staphylococcal isolates were susceptible to vancomycin. Of 27 Gram-negative isolates, 12 (44%) were resistant to cefazolin (75% deep infections), and 2 (7%) to gentamicin (50% deep infections) (**Table**). The infections were diagnosed on average on postoperative day (POD) 15 (range, POD 4 to 95). It is possible that a few patients received inoculations after discharge, but the majority with infections had wound issues and concerns early in their postoperative course. We did not use drains in any of our patients. It is possible that choice of prophylactic antibiotics had no bearing on late-diagnosed infections.

Of the 80 spine fusion SSIs, 64 (80%) were caused by Gram-positive bacteria, and 20 (25%) by Gram-negative bacteria (4 cases were polymicrobial). Of 75 Gram-positive isolates, 55 (73%) were staphylococcal species. Eight *S aureus* isolates (26%) were MRSA (88% deep infections), and 16 CNS isolates (67%) were MRSE (75% deep infections). Again, all staphylococcal isolates were reported as sensitive to vancomycin; however, 1 MRSA isolate had a vancomycin MIC (minimum inhibitory concentration) of 2. Of 21 Gram-negative isolates, 12 (57%) were resistant to cefazolin (83% deep infections), and 2 (10%) to gentamicin (100% deep infections) (**Table**).

We also reviewed the preoperative weight of a subset of patients who had hip arthroplasty or spine fusion surgery. We wanted to determine what proportion of patients may have been inadequately dosed with vancomycin 1 g in the absence of institutional guidelines for weight-based vancomycin dosing for perioperative prophylaxis. Of the 1,692 patients who had hip arthroplasty between January 1, 2009 and December 31, 2010, 1,271 (75.1%) had a baseline weight of more than 66.7 kg and therefore would have received suboptimal perioperative prophylaxis with a dosing regimen of vancomycin 1 g every 12 hours. Of the 1,786 patients who had spine fusion surgery during the same 2-year time period, 1,331 (74.5%) weighed more than 66.7 kg and therefore would have also been underdosed with vancomycin 1 g for prophylaxis.

Discussion

Consistent with results from other studies,[9,10] our results showed that staphylococcal bacteria were the most common type of bacteria isolated from orthopedic SSIs, encompassing 44% of the bacteria isolated from arthroplasty SSIs and 57% of the pathogens isolated from spine fusion SSIs. Notably, however, of the staphylococcal species identified, a significant proportion showed resistance to methicillin and first-generation cephalosporins (55% for arthroplasty SSIs, 44% for spine fusion SSIs). All but 1 of these isolates were sensitive to vancomycin (defined as MIC ≤ 1).

Overall, the proportion of staphylococci isolated from SSIs in our population was lower than values reported in other studies.[9,10] The lower proportion may derive from the emergence of resistant Gram-negative organisms as pathogens responsible for SSIs. In our cohort, Gram-negative pathogens comprised 28% of all pathogens for arthroplasty SSIs and 22% for spine fusion SSIs. For the Gram-negatives isolates, cefazolin resistance was found in 44% and 57% of these arthroplasty SSIs and spine fusion SSIs, respectively—raising the concern that the agent may not provide adequate prophylaxis. Gentamicin resistance rates were low, 7% in Gram-negative arthroplasty SSIs and 10% in Gram-negative spine fusion SSIs.

Our stewardship program incorporated the microbiological data from this review into new institution-specific recommendations for perioperative prophylaxis for adult orthopedic procedures. Updated guidelines for perioperative antimicrobial prophylaxis for orthopedic procedures were drafted by a working group of 2 hospital epidemiologists, 1 orthopedic surgeon, 1 anesthesiologist, and 1 infectious diseases fellow. Our current prophylactic regimen includes weight-based dosing of antibiotics, including cefazolin. At the time of this study, however, we used the standard non-weight-based cefazolin dose of 1 g.

Based on working group consensus, we added gentamicin to cefazolin or clindamycin (in patients with a penicillin allergy) for prophylaxis in thoracic/lumbar fusion, hip fracture repair, and total joint arthroplasty surgeries. In addition, for patients with a history of MRSA infection or colonization, the recommended prophylaxis was changed to weight-based vancomycin and gentamicin. All patients scheduled for arthroplasty or spine fusion surgery are screened for MRSA colonization. Although this review's MRSE-SSI rates are a concern, given the challenges of vancomycin infusion completion, particularly before tourniquet application in knee surgeries, we did not expand vancomycin prophylaxis to all patients at this time. All new recommendations included guidance on weight-based dosing and on timing of antimicrobial administration in relation to application of tourniquet for knee surgeries. Although we did not review the accuracy of individual doses administered for perioperative prophylaxis, we found that three-fourths of our orthopedic implant surgery population would have been underdosed if a regimen of vancomycin 1 g was used rather than weight-based dosing. This highlights the importance of preoperative calculations of weight-based dosing, for agents such as vancomycin and gentamicin, in

Table. **Microbiology and Resistance Rates From Arthroplasty and Spine Fusion Surgical Site Infections (SSIs)**

Arthroplasty Gram-Positive SSIs			
Site	**MRSA/Total *S aureus***	**Superficial**	**Deep**
Hip	4/10 (40%)	0	4/10 (40%)
Knee	3/10 (30%)	1/3 (33%)	2/7 (29%)
Shoulder	0/1 (0%)	0	0/1 (0%)
Total	**7/21 (33%)**	**1/3 (33%)**	**6/18 (33%)**
Site	**MRSE/Total CNS**	**Superficial**	**Deep**
Hip	3/5 (60%)	0/1 (0%)	3/4 (75%)
Knee	13/16 (81%)	3/3 (100%)	10/13 (77%)
Shoulder	0	0	0
Total	**16/21 (76%)**	**3/4 (75%)**	**13/17 (76%)**
Arthroplasty Gram-Negative SSIs			
Site	**Cefazolin-Resistant/Total GN**	**Superficial**	**Deep**
Hip	6/18 (25%)	2/6 (33%)	4/12 (33%)
Knee	6/9 (67%)	2/4 (50%)	4/5 (80%)
Total	**12/27 (44%)**	**4/10 (40%)**	**8/17 (47%)**
Site	**Gentamicin-Resistant/Total GN**	**Superficial**	**Deep**
Hip	1/18 (5.6%)	0/6 (0%)	1/12 (8%)
Knee	1/9 (11%)	1/4 (25%)	0/5 (0%)
Total	**2/27 (7%)**	**1/10 (10%)**	**1/17 (6%)**
Spine Fusion Gram-Positive SSIs			
Site	**MRSA/Total *S aureus***	**Superficial**	**Deep**
Cervical	0/6 (0%)	0/2 (0%)	0/4 (0%)
Dorsal	2/6 (33%)	0/1 (0%)	2/5 (40%)
Lumbar	6/19 (32%)	1/3 (33%)	5/16 (31%)
Total	**8/31 (26%)**	**1/6 (17%)**	**7/25 (28%)**
Site	**MRSE/Total CNS**	**Superficial**	**Deep**
Cervical	2/5 (40%)	1/2 (50%)	1/3 (33%)
Dorsal	7/8 (88%)	0	7/8 (88%)
Lumbar	7/11 (64%)	3/4 (75%)	4/6 (67%)
Total	**16/24 (67%)**	**4/6 (67%)**	**12/17 (71%)**
Spine Fusion Gram-Negative SSIs			
Site	**Cefazolin-Resistant/Total GN**	**Superficial**	**Deep**
Cervical	1/2 (50%)	0/1 (0%)	1/1 (100%)
Dorsal	8/11 (73%)	2/4 (50%)	6/7 (86%)
Lumbar	3/8 (38%)	0/3 (0%)	3/5 (60%)
Total	**12/21 (57%)**	**2/8 (25%)**	**10/13 (79%)**
Site	**Gentamicin-Resistant/Total GN**	**Superficial**	**Deep**
Cervical	0/2 (0%)	0/1 (0%)	0/1 (0%)
Dorsal	1/11 (9%)	0/4 (0%)	1/7 (14%)
Lumbar	1/8 (13%)	0/3 (0%)	1/5 (20%)
Total	**2/21 (10%)[a]**	**0/8 (0%)**	**2/13 (15%)**

Abbreviations: MRSA, methicillin-resistant *Staphylococcus aureus;* MRSE, methicillin-resistant *Staphylococcus epidermidis;* CNS, coagulase-negative staphylococci; GN, Gram-negative.
[a]Gentamicin-resistant organisms reflect 2 *Acinetobacter* spp. isolates.

helping to optimize antibiotic prophylaxis for SSI prevention.

The guidelines were subsequently reviewed and approved by the antimicrobial subcommittee of our hospital's pharmacy and therapeutics committee. The impact of the change in antimicrobial prophylaxis at our institution will be evaluated with prospective review of trends in SSI microbiology and the hospital-wide antibiogram. On reviewing the postoperative course of all 1,845 patients who received gentamicin, we found that no patient had any complications referable to gentamycin. Specifically, there were no instances of ototoxicity or renal failure in our patients. As with any intervention, the risk–benefit ratio must be addressed. However, the risk posed by a single weight-based dose of gentamycin in patients having elective orthopedic surgery is extremely low, and renal impairment is independent of short-term gentamicin administration.[11]

Conclusion

Review of antimicrobial susceptibilities of pathogens causing SSIs at our institution provided an important opportunity for antimicrobial stewardship in the area of surgical prophylaxis. Our data suggest that perioperative cefazolin may be inadequate prophylaxis for prevention of orthopedic SSIs. In light of these bacterial resistance trends, the addition of perioperative gentamicin and, when indicated, the substitution of vancomycin for cefazolin may provide enhanced prophylaxis for arthroplasty and spine fusion SSIs at our institution. Further study is needed to evaluate the efficacy and limitations of these combinations of agents in preventing orthopedic SSIs.

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This paper will be judged for the Resident Writer's Award.