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Post-Discharge Antibiotic Use for Prophylaxis Following Spinal Fusion

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Abstract

Objective: Despite recommendations to discontinue prophylactic antibiotics after incision closure or < 24 hours after surgery, prophylactic antibiotics are continued after discharge by some clinicians. The objective of this study was to determine the prevalence and factors associated with post-discharge prophylactic antibiotic use after spinal fusion.

Design: Multicenter retrospective cohort.

Patients: Patients aged ≥ 18 years undergoing spinal fusion or refusion from 7/2011–6/2015 at three sites. Patients with infection during the surgical admission were excluded.

Methods: Prophylactic antibiotics were identified at discharge. Factors associated with post-discharge prophylactic antibiotic use were identified using hierarchical generalized linear models.

Results: 8,652 spinal fusion admissions were included. Antibiotics were prescribed at discharge in 289 (3.3%) admissions. The most commonly prescribed antibiotics were trimethoprim/

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CONFLICTS OF INTEREST

MAO reports consultant work with Pfizer and grant funding through Pfizer, Merck, and Sanofi Pasteur for work outside the submitted manuscript. VJF reports her spouse is the Chief Clinical Officer at Cigna Corporation. DKW reports consultant work with Centene Corp., PDI Inc., Pursuit Vascular, Homburg & Partner, and Carefusion/BD and is a sub-investigator for a Pfizer-sponsored study for work outside the submitted manuscript. No other authors report conflicts of interest relevant to this article.

sulfamethoxazole (22.1%), cephalexin (18.8%), and ciprofloxacin (17.1%). Adjusted for study site, significant factors associated with prophylactic discharge antibiotics included American Society of Anesthesiologists (ASA) class ≥ 3 (odds ratio [OR], 1.31; 95% CI, 1.00–1.70), lymphoma (OR, 2.57; 95% CI, 1.11–5.98), solid tumor (OR, 3.63; 95% CI, 1.62–8.14), morbid obesity (OR, 1.64; 95% CI, 1.09–2.47), paralysis (OR, 2.38; 95% CI, 1.30–4.37), hematoma/seroma (OR, 2.93; 95% CI, 1.17–7.33), thoracic surgery (OR, 1.39; 95% CI, 1.01–1.93), longer length of stay, and intra-operative antibiotics.

Conclusions: Post-discharge prophylactic antibiotics were uncommon after spinal fusion. Patient and perioperative factors were associated with continuation of prophylactic antibiotics after hospital discharge.

INTRODUCTION

Surgical site infections (SSIs) are among the most common healthcare-associated infections in the United States.[1] The most recent Centers for Disease Control and Prevention (CDC) guidelines for the prevention of SSI recommend against administration of prophylactic antibiotics in clean surgeries after the surgical incision is closed, even in the presence of surgical drains,[2] due to lack of data showing benefit for this practice. Other organizations recommend discontinuing prophylactic antibiotics at the completion of surgery.[3-5] In practice, compliance with antibiotic discontinuation within 24 hours of surgery was found to vary from 58–100% in a study of National Surgical Quality Improvement Program hospitals.[6,7]

In a recent systematic review, the pooled incidence of SSI after spine surgery was 3.1% (range 0.2%–16.1%). Variation in SSI rates is associated with the indication for surgery (i.e., scoliosis), instrumentation, duration of surgery, and surgical approach.[8] There is limited information in the literature regarding post-operative antibiotic prophylaxis[9-16] and very sparse information on post-discharge antibiotic prophylaxis[17] and its impact on SSI rates after spinal fusion procedures. Most studies analyzing the impact of post-operative/post-discharge antibiotics report no difference in SSI rates between short versus prolonged antibiotic prophylaxis after spine procedures.[9-15,17] Overall, high-quality data are lacking, as these studies in general were underpowered to detect a difference in SSI rates given small sample sizes and low incidence of SSI.

A concern with the use of post-operative antibiotic prophylaxis is exposure of patients to unnecessary antibiotics. Unnecessary antibiotics may result in additional costs, adverse drug events, selection of antibiotic-resistant bacteria,[18] and the development of *Clostridioides difficile* infection.[19-22] The goal of our study was to determine the prevalence of post-discharge prophylactic antibiotic use and identify patient, operative, and surgeon factors associated with use in a cohort of adults undergoing spinal fusion at three academically-affiliated hospital study sites.

METHODS

Data Source:

We conducted a retrospective cohort study using electronic health record (EHR) and billing data from six hospitals at three study sites in different geographic regions of the country. Site 1 included one academic and one community hospital, site 2 included one academic hospital, and site 3 was comprised of one academic and two community hospitals. Information came from queries of the respective hospital EHR systems and manual medical record review.

Spinal Fusion Population:

We identified spinal fusion operations among adults aged ≥ 18 years admitted between 7/1/2011 and 6/30/2015. Spinal fusion/refusion was defined using International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) procedure codes 81.00–81.08 and 81.30–81.39. We verified the spinal fusion procedures using provider Current Procedural Terminology, 4th edition (CPT-4) coding for spinal fusion (Appendix Table 1) at one study site, and by reviewing the operating room log for the surgeon description and anesthesia duration for the remaining two sites.

We excluded surgical admissions that would likely have antibiotics prescribed at discharge for therapeutic indications based on ICD-9-CM diagnosis codes during the fusion admission (i.e., gunshot wound, motor vehicle accident, SSI/cellulitis, pneumonia, urinary tract infection, sepsis, upper respiratory tract bacterial infections, serious gastrointestinal infections) and admissions wherein a patient was discharged on intravenous (IV) antibiotics (Appendix Table 2). We also excluded admissions lacking ICD-9-CM diagnosis codes (due to lack of comorbidity information) and admissions with a length of stay of >90 days and/or the patient died during the spinal fusion surgical admission.

Post-Discharge Prophylactic Antibiotics:

Prophylactic antibiotics were defined as oral antibiotics prescribed at discharge in the absence of an infectious diagnosis during the surgical admission. If the patient was admitted on oral antibiotic therapy and the same antibiotic was prescribed at discharge, it was not considered prophylactic. We characterized the distribution of individual antibiotics and grouped antibiotics based on activity against specific organisms or by class (Table 1).

Factors Associated with Prophylactic Antibiotic Use:

Potential factors associated with prophylactic antibiotic use included patient (e.g., demographics, comorbidities[23]), operative, and surgeon factors with clinical or biological plausibility for association with antibiotic use and/or risk for SSI. Comorbidities were defined by ICD-9-CM diagnosis codes[23] and operative factors by ICD-9-CM diagnosis and procedure codes during the surgical admission (Appendix Table 3). Demographics and other surgical details were abstracted from the medical records. Morbid obesity was defined as a body mass index ≥ 40 kg/m^2. Surgeon details, including board certification and specialty, were determined using the institution and Medicare physician directories.

Complications after Spinal Fusion:

SSIs within 90 days of the spinal operation were identified via standard hospital infection control surveillance using CDC National Healthcare Safety Network (NHSN) criteria.[24] We captured *C. difficile* infection (ICD-9-CM diagnosis code 008.45) through 90 days after surgery.

Statistical Analyses:

Univariate risk factors for prophylactic antibiotic use were evaluated using chi-square, Fisher's exact, logistic regression, or Mann-Whitney U tests, as appropriate. Patient and operative factors with $p < 0.2$ in univariate analysis were included along with study site in a multivariable logistic regression model with backward selection, with cutoff of $p < 0.1$ for inclusion. Multicollinearity was assessed with tolerance values to ensure independence of explanatory variables. Once the final patient and operative factors were identified, we developed a hierarchical generalized linear model adding surgeon factors as a second level. We used a random intercept at the level of the study site, and Laplace estimation techniques.[25] We performed likelihood ratio tests to assess model fit between the nested models. Data management was performed using REDCap and SAS v9.4 (SAS Institute Inc., Cary, NC); statistical analyses were performed using SAS. Post-hoc power calculations were performed using PASS 14 Power Analysis and Sample Size Software (2015; NCSS, LLC. Kaysville, Utah). This study was approved by the Human Research Protection Offices of the three institutions.

RESULTS

The initial study cohort included 9,502 spinal fusion admissions. A total of 850 admissions were excluded for the following: infection coded during the fusion admission (n = 599), spinal fusion was not performed based upon further review (n = 235), or patient was discharged on IV antibiotics (n = 16). The final study cohort included 8,652 spinal fusion admissions: 4,263 (49.3%) at study site 1, 1,589 (18.4%) at site 2, and 2,800 (32.4%) at site 3. None of the sites performed routine detection of intranasal *Staphylococcus aureus* colonization or decolonization, and only site 2 recommended preoperative bathing with chlorhexidine for spinal fusion patients during the study period.

In the final cohort of fusion admissions, the median age of patients was 58 years (interquartile range 49–67); 4,717 (54.5%) were female; 676 (7.8%) had trauma (i.e., sustained a fracture/dislocation and/or fall); and 301 (3.5%) had underlying cancer (Table 2).

Prevalence and Class of Prophylactic Antibiotics

Prophylactic antibiotics were prescribed post-discharge after 289 (3.3%) spinal fusion admissions; after 93 (2.2%) admissions at site 1, 81 (5.1%) admissions at site 2, and 115 (4.1%) admissions at site 3 ($p < 0.001$). The most common prophylactic antibiotics prescribed varied by study site: at site 1 ciprofloxacin (27.4%), trimethoprim/sulfamethoxazole (26.3%), and cephalexin (22.1%); at site 2 cephalexin (18.8%), doxycycline (14.1%), and cefadroxil , levofloxacin, and trimethoprim/sulfamethoxazole (all at 10.6%); and at site 3 trimethoprim/sulfamethoxazole (27.1%), ciprofloxacin (19.5%), and

cephalexin (16.1%). The distribution of antibiotics prescribed overall and by site and activity/class is presented in Table 1 and Figure 1. Antibiotics were prescribed by 16/33 (48%) spine surgeons at site 1, 7/11 (64%) surgeons at site 2, and 19/26 (73%) surgeons at site 3.

Of the discharges in patients given a prescription for an anti-MRSA antibiotic (Table 1), 59% (63/106) received intraoperative vancomycin or clindamycin prophylaxis. In contrast, of the discharges in patients given a prescription for a first generation cephalosporin or amoxicillin/ampicillin/amoxicillin-clavulanate, 93% (89/96) received intraoperative cefazolin prophylaxis.

Incidence of Surgical Site Infection and *C. difficile* Infection

Overall, 77 (0.9%) SSIs were detected by infection preventionists within 90 days of the spinal fusion procedure. Thirteen (16.9%) were classified as superficial incisional, 27 (35.1%) deep incisional, and 37 (48.1%) organ space SSIs. Cultures were performed on 76 of the 77 patients, and 69 (90.8%) were positive for one or more organisms (Table 3). Post-discharge prophylactic antibiotic use was not associated with SSI following spinal fusion (5/289 (1.7%) with versus 72/8,363 (0.9%) without, $p = 0.114$). A total of 20 (0.2%) patients were coded for *C. difficile* infection within 90 days after surgery; 1 (0.3%) versus 19 (0.2%) among admissions with and without post-discharge prophylactic antibiotics, respectively ($p = 0.494$).

Factors Associated with Prophylactic Antibiotic Use

In univariate analysis, utilization of prophylactic antibiotics varied by study site. Compared to patients who did not receive post-discharge prophylactic antibiotics, those who received post-discharge prophylactic antibiotics were more likely to be female, older, Black race, have Medicare or Medicaid health insurance, have spinal trauma, and multiple comorbidities (Table 4). Smokers were less likely to receive post-discharge prophylactic antibiotics. Operative factors associated with increased likelihood of post-discharge antibiotics included surgery at a community hospital, longer surgical admission length of stay, posterior surgical approach, surgery on the lumbar and thoracic regions, surgery involving increased number of spinal levels, hematoma/seroma during the surgical admission, multiple fusion operations during the surgical admission, and longer surgery duration. Use of vancomycin perioperative prophylaxis, compared to cefazolin or clindamycin-only, was associated with increased likelihood of post-discharge antibiotics. Surgery on the cervical spine was associated with decreased likelihood of receiving post-discharge antibiotics. Surgeon factors associated with use of post-discharge prophylactic antibiotics were neurosurgical (compared to orthopedic) specialty, and lower spinal fusion surgeon volume (Table 4). On average, surgeons who performed < 50 fusions per year prescribed post-discharge antibiotics in 7.0% of their procedures, while surgeons who performed 50–99 and ≥ 100 fusions per year prescribed post-discharge antibiotics in 4.4% and 2.9% of their procedures, respectively. While post-discharge prophylactic antibiotics were slightly more likely at a community vs. academic hospital (Table 4), patients undergoing surgery at academic hospitals had a significantly higher comorbidity burden based on the Charlson comorbidity index ($p < 0.001$, Kruskal-Wallis test).

We tested whether site-specific surgeon characteristics were independently associated with use of post-discharge prophylactic antibiotics using a hierarchical generalized linear model with random intercepts at the level of the study site (Table 5). The unconditional model with no patient-level covariates indicated that there was no significant covariance between patients treated at the same site ($p = 0.131$). The second model included patient and operative characteristics from the logistic regression model, and the model fit was significantly better than the empty model (−2LL= 2340.15, $p < 0.001$). Factors associated with significantly increased risk of prophylactic antibiotic use after spinal fusion in multivariable logistic regression analysis were ASA class of 3 or greater, lymphoma, solid tumor, morbid obesity, paralysis, longer length of stay, hematoma/seroma, thoracic spinal region, and choice of intra-operative antibiotic. The third model added surgeon spinal fusion volume; model fit was not significantly improved over model two (−2LL= 2335.53, $p = 0.099$).

DISCUSSION

We determined the prevalence, variation, and factors associated with post-discharge prophylactic antibiotic use after spinal fusion at three academic medical center study sites. We found a low prevalence of post-discharge prophylactic antibiotic use, but variation by study site ranging from 2.2–5.1% and by surgeon ranging from 0.5–9.8% among surgeons who performed at least 50 spinal fusions per year. Patient and operative factors associated with post-discharge antibiotic use included ASA class of 3 or higher, lymphoma, solid tumor, morbid obesity, paralysis, hematoma/seroma, type of intraoperative antibiotic, surgery on the thoracic spine, and longer length of stay.

Of the patient-level factors associated with increased use of post-discharge prophylactic antibiotics, morbid obesity,[26,27] cancer,[28,29] higher ASA score,[26,29] and paralysis[30] are known to be associated with increased risk of SSI after spinal fusion. Thoracic surgery was associated with increased antibiotic use, consistent with invasiveness of spine surgery[31] and correspondingly with increased risk of SSI.[32] The association of these factors suggest that surgeons may be assessing infection risk in patients and selectively prescribing continuation of prophylaxis for higher risk patients in an attempt to prevent SSI. Interestingly, there was more consistency in post-discharge use of first-generation cephalosporin/penicillin in persons who received intraoperative cefazolin than for use of an anti-MRSA antibiotic in persons who received intraoperative vancomycin or clindamycin prophylaxis. This suggests that other factors outweighed simple continuation of surgical prophylaxis at hospital discharge.

While surgeons may be targeting high risk patients for post-discharge antibiotics, continuing antibiotics after incision closure is not recommended by the CDC, European Centre for Disease Prevention and Control, or the World Health Organization.[2-4] The North American Spine Society does make an exception for complex procedures including trauma, diabetes, obesity, and multilevel instrumented surgery, but does not specify a recommended duration or if prophylaxis should be discontinued before discharge.[5] There is little evidence that use of prolonged prophylaxis among fusion patients is associated with benefit.[9-17] A single-institution study found significantly reduced SSI rates in patients undergoing instrumented

spine surgery who were given antibiotic prophylaxis for 72 hours (2009–2014) compared to a single perioperative dose (2003–2008), but this finding has not been replicated in other cohorts and the investigators did not assess utilization of post-discharge antibiotics.[16] Inabathula and colleagues reported a significant decrease in infections following hip and knee arthroplasty after implementing oral antibiotic prophylaxis for 7 days post-discharge among patients at high risk for infection at one academic medical center.[33] In this study, however, 60% and 70% of the hip and knee cohorts, respectively, were considered high risk, calling into question the benefit of stratification. In addition to lack of evidence for benefit among spinal fusion patients, there is clear potential for harm with unnecessary use of antibiotics, including selection of antibiotic-resistant bacteria,[18] *C. difficile* infection,[19-22] and acute kidney injury.[20] In our study, the incidence of *C. difficile* did not differ by discharge antibiotic use, however our study was not adequately powered for this comparison.

Inclusion of surgeon factors in the hierarchical model did not significantly improve the model fit, although in this model surgeons who performed 50–99 spinal fusions per year were 1.34 times more likely to prescribe prophylactic antibiotics at discharge compared to higher volume surgeons (≥ 100 fusions per year). Low volume surgeons (<50 fusions per year) had a trend towards increased utilization of post-discharge prophylactic antibiotics, albeit not significant (odds ratio 1.20; 95% confidence interval 0.80, 1.80), likely due to the smaller number of fusions by low volume surgeons. Given the variation in discharge antibiotic prescribing at the level of the individual physician, surgeon education would be important to improve the success of hospital antibiotic stewardship programs.[34]

Variation existed by study site with respect to post-discharge antibiotic use and choice of antibiotic. Use of prophylactic discharge antibiotics was highest at site 2 (5.1%), followed by site 3 (4.1%), and lowest at site 1 (2.2%). While site 2 had the highest proportion of fusion admissions with spinal trauma (10.1%), the surgeries were generally less complex and invasive (e.g., fewer multi-level and thoracic procedures, smaller percentage involving both anterior and posterior approaches), and thus carried a lower risk of infection.[32]

Ciprofloxacin, trimethoprim/sulfamethoxazole, and cephalexin were the top three antibiotic choices for post-discharge prescriptions at sites 1 and 3. More than 25% of antibiotic prescriptions at sites 1 and 3 were for trimethoprim/sulfamethoxazole, suggesting that surgeons at these sites were concerned about prophylaxis against methicillin-resistant *S. aureus*. Site 2 used a broader mix of post-discharge antibiotics than the other two sites, with cephalexin and doxycycline most commonly prescribed. During the study period the antibiotic stewardship program at site 2 restricted use of fluoroquinolones during inpatient stays, which may have carried over to the prescribing pattern of discharge antibiotics. In contrast, use of doxycycline or levofloxacin was rare at sites 1 and 3 (cumulative 2.1% and 9.3% by site, respectively). Antibiotic heterogeneity was not explained by the number of surgeons, as site 2 had the most variation in antibiotics, but only 7 spine surgeons who prescribed post-discharge antibiotics. Sites 1 and 3 had less heterogeneity in antibiotic choice, but more surgeons who prescribed post-discharge antibiotics (16 and 19, respectively).

Our study has several limitations. We included only three study sites, so our findings might not reflect practices in the community, particularly community hospitals that are not associated with a teaching hospital. We did not collect information on continuation of prophylactic antibiotics after incision closure or use of intraoperative vancomycin powder before incision closure. There was a possibility of misclassification of a therapeutic antibiotic as prophylactic if an infectious diagnosis was not recorded during the fusion admission and/or if a continued therapeutic antibiotic was only coded at discharge and not at hospital admission. Because of low post-discharge antibiotic use in our study cohort, we did not have enough power to detect differences in SSI or *C. difficile* infection rates by post-discharge antibiotic use or by individual surgeon. Notably, in our hierarchical model, study site was not significantly associated with variation in post-discharge antibiotic use, likely due to the small number of study sites with insufficient power to identify clustering. A future study with additional study sites would be of interest. Also of interest, although the surgeon volume variable did not significantly improve our hierarchical model, there was a trend towards more post-discharge antibiotic use by lower volume surgeons. Future studies examining surgeon-based factors for prescribing post-discharge antibiotics would be helpful given that guidelines recommend against prolonged use of postoperative prophylactic antibiotics.

In summary, we found that post-discharge prophylactic antibiotic use was uncommon after spinal fusion, but varied by study site. Patient characteristics associated with risk of SSI were associated with use of post-discharge prophylactic antibiotics. Stewardship efforts to discourage continuation of antibiotics after hospital discharge are needed to avoid further increases in antimicrobial resistance and adverse events.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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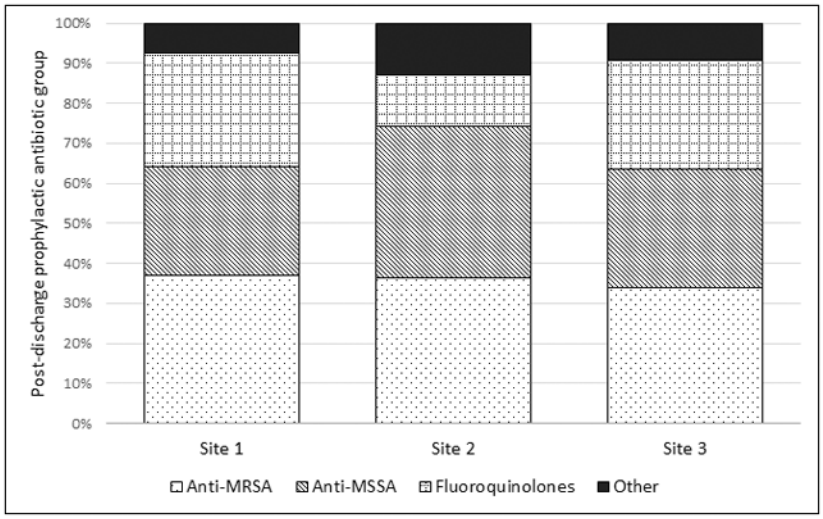

Figure 1. Distribution of post discharge prophylactic antibiotic group after spinal fusion by study site.

NOTE. MRSA, Methicillin resistant *Staphylococcus aureus;* MSSA, Methicillin sensitive *S. aureus*.

Table 1.

Categorization of Post-Discharge Antibiotics by Class or Activity against Specific Organisms

Antibiotic group	Antibiotic name	Number discharged[a]
Anti-methicillin resistant *Staphylococcus aureus*	clindamycin	20
	doxycycline	17
	linezolid	0
	minocycline	2
	trimethoprim/sulfamethoxazole	66
	tetracycline	1
Anti-methicillin sensitive *S. aureus*	amoxicillin/clavulanate	20
	cefaclor	0
	cefadroxil	9
	cefdinir	2
	cefixime	0
	cefpodoxime	2
	cefprozil	0
	ceftibuten	0
	cefuroxime	4
	cephalexin	56
	cloxacillin	0
	dicloxacillin	0
Fluoroquinolones	ciprofloxacin	51
	gatifloxacin	0
	gemifloxacin	0
	levofloxacin	17
	moxifloxacin	2
	ofloxacin	0
Other antibiotics	amoxicillin	9
	ampicillin	2
	azithromycin	6
	clarithromycin	3
	erythromycin	3
	metronidazole	6

[a]There were 298 prophylactic discharge antibiotics among 289 admissions with prophylactic discharge antibiotics

Table 2.

Characteristics of 8,652 Spinal Fusion Admissions by Study Site

Variable	Category	Overall n (%)	Site 1 n (%)	Site 2 n (%)	Site 3 n (%)
Total N (% of overall population)		8,652 (100)	4,263 (49.3)	1,589 (18.4)	2,800 (32.4)
Patient factors					
Female sex		4,717 (54.5)	2,302 (54.0)	849 (53.4)	1,566 (55.9)
Age, median (IQR)		58 (49–67)	57 (48–65)	56 (47–66)	60 (51–69)
Race[a]	White	7,271 (84.0)	3,812 (89.4)	1,243 (78.2)	2,216 (79.1)
	Black	1,043 (12.1)	354 (8.3)	242 (15.2)	447 (16.0)
	Other	209 (2.4)	66 (1.5)	66 (4.2)	77 (2.8)
Payer	Private/VA	4,576 (52.9)	2,575 (60.4)	904 (56.9)	1,097 (39.2)
	Dual Medicare/Medicaid	191 (2.2)	184 (4.3)	7 (0.4)	0 (0.0)
	Medicaid	424 (4.9)	163 (3.8)	174 (11.0)	87 (3.1)
	Medicare	3,244 (37.5)	1,277 (30.0)	504 (31.7)	1,463 (52.3)
	Self-pay/none	217 (2.5)	64 (1.5)	0 (0.0)	153 (5.5)
Spinal trauma		676 (7.8)	417 (9.8)	160 (10.1)	99 (3.5)
Cancer		301 (3.5)	181 (4.2)	74 (4.7)	46 (1.6)
Operative factors					
Length of stay, median (IQR)		4 (2–6)	4 (2–6)	4 (3–6)	3 (3–5)
Surgical approach	Anterior	3,546 (41.0)	1,635 (38.4)	686 (43.2)	1,225 (43.8)
	Posterior	4,266 (49.3)	2,318 (54.4)	893 (56.2)	1,055 (37.7)
	Anterior and posterior	840 (9.7)	310 (7.3)	10 (0.6)	520 (18.6)
Spinal levels operated upon	1–2 levels	5,958 (68.9)	2,786 (65.4)	1,374 (86.5)	1,798 (64.2)
	3–7 levels	2,174 (25.1)	1,108 (26.0)	213 (13.4)	853 (30.5)
	≥ 8 levels	520 (6.0)	369 (8.7)	2 (0.1)	149 (5.3)
Spinal region[b]	Cervical	4,517 (52.2)	2,408 (56.5)	830 (52.2)	1,279 (45.7)
	Lumbar	3,424 (39.6)	1,421 (33.3)	668 (42.0)	1,335 (47.7)
	Thoracic	1,324 (15.3)	879 (20.6)	95 (6.0)	350 (12.5)
Post-discharge prophylactic antibiotic use		289 (3.3)	93 (2.2)	81 (5.1)	115 (4.1)

Note. IQR, interquartile range; VA, Veterans Affairs.

[a] 129 (1.5%) admissions were missing race.

[b] Categories were not mutually exclusive. 600 (6.9%) patients had >1 spinal region operated upon.

Table 3.

Organisms Identified from 77 Patients with Surgical Site Infection after Spinal Fusion[a]

Organism	n (%)
Staphylococcus aureus	
Methicillin sensitive *S. aureus*	17 (21.0)
Methicillin resistant *S. aureus*	7 (8.6)
Coagulase negative staphylococci	10 (12.3)
Enterococcus spp	2 (2.5)
Streptococcus spp	2 (2.5)
Corynebacterium spp	1 (1.2)
Enterobacteriacae	
Escherichia coli	12 (14.8)
Enterobacter cloacae	7 (8.6)
Proteus mirabilis	4 (4.9)
Klebsiella oxytoca	2 (2.5)
Klebsiella pneumoniae	2 (2.5)
Serratia marcescens	2 (2.5)
Citrobacter freundii	1 (1.2)
Morganella morganii	1 (1.2)
Providencia spp	1 (1.2)
Pseudomonas aeruginosa	5 (6.2)
Cutibacterium spp	3 (3.7)
Fusobacterium nucleatum	1 (1.2)
Candida guilliermondii	1 (1.2)

[a]Of 77 surgical site infections, 1 was not cultured, 7 were cultured with no growth, and 69 had a positive culture. The table presents the 81 organisms identified among the 69 infections with a positive culture (7 cases had two organisms isolated, 1 case had three organisms, and 1 case had four organisms isolated).

Table 4.

Univariate Factors Associated with Post-Discharge Prophylactic Antibiotic Use after Spinal Fusion[a]

Variable	Category	Post-discharge prophylactic antibiotic use		*P*
		Yes n (%)	No n (%)	
Total		289	8,363	
Patient factors				
Female sex		170 (58.8)	4,547 (54.4)	0.135
Age in years, median (interquartile range)		61 (51–69)	58 (49–66)	<0.001
Race[b]	White	235 (81.3)	7,036 (84.1)	Ref.
	Black	43 (14.9)	1,000 (12.0)	0.135
	Other	8 (2.8)	201 (2.4)	0.632
Payer	Private/VA	119 (41.2)	4,457 (53.3)	Ref.
	Dual Medicare/Medicaid	3 (1.0)	188 (2.2)	0.383
	Medicaid	24 (8.3)	400 (4.8)	<0.001
	Medicare	134 (46.4)	3,110 (37.2)	<0.001
	Self-pay/none	9 (3.1)	208 (2.5)	0.171
Spinal trauma		39 (13.5)	637 (7.6)	<0.001
Previous hospitalization within 30 days		9 (3.1)	190 (2.3)	0.348
Patient factors-comorbidities				
Alcohol abuse		8 (2.8)	122 (1.5)	0.072
ASA class ≥ 3		187 (64.7)	4,147 (49.6)	<0.001
Cancer- lymphoma		7 (2.4)	49 (0.6)	<0.001
Cancer- metastatic		12 (4.2)	190 (2.3)	0.037
Cancer- solid tumor		8 (2.8)	40 (0.5)	<0.001
Chronic heart failure		9 (3.1)	134 (1.6)	0.048
Chronic kidney disease		10 (3.5)	184 (2.2)	0.155
Chronic pulmonary disease		28 (9.7)	903 (10.8)	0.550
Coagulopathy		13 (4.5)	157 (1.9)	0.002
Deficiency anemias		19 (6.6)	370 (4.4)	0.083
Depression		33 (11.4)	1,045 (12.5)	0.586
Diabetes with or without chronic complications		36 (12.5)	972 (11.6)	0.664
Drug abuse		6 (2.1)	115 (1.4)	0.318
Fluid and electrolyte disorders		45 (15.6)	741 (8.9)	<0.001
Hypertension		115 (39.8)	2,889 (34.5)	0.065
Hypothyroidism		27 (9.3)	635 (7.6)	0.271
Liver disease		2 (0.7)	61 (0.7)	0.942
Morbid obesity		29 (10.0)	499 (6.0)	0.005
Other neurological disorders		16 (5.5)	400 (4.8)	0.556
Paralysis		14 (4.8)	122 (1.5)	<0.001
Peripheral vascular disease		7 (2.4)	146 (1.7)	0.391
Psychoses		8 (2.8)	201 (2.4)	0.691

Variable	Category	Post-discharge prophylactic antibiotic use		*P*
		Yes n (%)	No n (%)	
Pulmonary circulation disease		3 (1.0)	73 (0.9)	0.767
Rheumatoid arthritis/collagen vascular disease		8 (2.8)	282 (3.4)	0.575
Smoker		32 (11.1)	1,412 (16.9)	0.009
Previous *Staphylococcus aureus* infection within 365 days		1 (0.3)	33 (0.4)	0.897
Valvular disease		11 (3.8)	216 (2.6)	0.201
Weight loss		2 (0.7)	77 (0.9)	0.688
Operative factors				
Study site	1	93 (32.2)	4,170 (49.9)	Ref.
	2	81 (28.0)	1,508 (18.0)	<0.001
	3	115 (39.8)	2,685 (32.1)	<0.001
Teaching status of hospital	Community	62 (21.5)	1,462 (17.5)	Ref
	Academic	227 (78.5)	6,901 (82.5)	0.081
Inpatient procedure		275 (95.2)	7,859 (94.0)	0.405
Length of stay	1–2 days	32 (11.1)	2,367 (28.3)	Ref.
	3–4 days	75 (26.0)	2,863 (34.2)	0.002
	5–6 days	65 (22.5)	1,651 (19.7)	<0.001
	≥ 7 days	117 (40.5)	1,482 (17.7)	<0.001
Surgical approach	Anterior	70 (24.2)	3,476 (41.6)	Ref.
	Posterior	185 (64.0)	4,081 (48.8)	<0.001
	Anterior and posterior	34 (11.8)	806 (9.6)	0.001
Spinal levels operated upon	1–2 levels	165 (57.1)	5,793 (69.3)	Ref.
	3–7 levels	97 (33.6)	2,077 (24.8)	<0.001
	≥ 8 levels	27 (9.3)	493 (5.9)	0.002
Spinal region[c]	Cervical	101 (34.9)	4,416 (52.8)	<0.001
	Lumbar	150 (51.9)	3,274 (39.1)	<0.001
	Thoracic	75 (26.0)	1,249 (14.9)	<0.001
Bone morphogenetic protein use		62 (21.5)	1,605 (19.2)	0.338
Dural tear		10 (3.5)	217 (2.6)	0.366
Hemorrhage		1 (0.3)	18 (0.2)	0.641
Hematoma/seroma		6 (2.1)	35 (0.4)	<0.001
Multiple spinal fusion operations during admission		11 (3.8)	174 (2.1)	0.046
Surgery duration >254 minutes (>75th percentile for cohort)		190 (65.7)	6,310 (75.5)	<0.001
Intra-operative antibiotics	Cefazolin or clindamycin -only	138 (47.8)	4,608 (55.1)	Ref.
	Any vancomycin	134 (46.4)	3,397 (40.6)	0.026
	Single antibiotic (other than vancomycin, cefazolin, or clindamycin) or >1 antibiotic	13 (4.5)	289 (3.5)	0.170
	No antibiotic documented	4 (1.4)	69 (0.8)	0.205
Year	2011	19 (6.6)	535 (6.4)	0.491
	2012	39 (13.5)	1,336 (16.0)	Ref.

Variable	Category	Post-discharge prophylactic antibiotic use		*P*
		Yes n (%)	No n (%)	
	2013	68 (23.5)	1,714 (20.5)	0.133
	2014	114 (39.4)	3,127 (37.4)	0.238
	2015	49 (17.0)	1,651 (19.7)	0.940
Surgeon factors				
US medical school graduate		259 (89.6)	7,599 (90.9)	0.471
Medical school graduation year	1970–1979	15 (5.2)	402 (4.8)	Ref.
	1980–1989	86 (29.8)	2,817 (33.7)	0.481
	1990–1999	64 (22.1)	1,781 (21.3)	0.898
	≥ 2000	124 (42.9)	3,363 (40.2)	0.966
Specialty	Neurosurgery	177 (61.2)	4,650 (55.6)	0.058
	Orthopedics	112 (38.8)	3,713 (44.4)	Ref.
Surgical volume (cases per year)	< 50	33 (11.4)	826 (9.9)	0.046
	50–99	120 (41.5)	2,483 (29.7)	<0.001
	≥ 100	136 (47.1)	5,054 (60.4)	Ref.

NOTE. ASA class, American Society of Anesthesiologists (ASA) Physical Status Classification System; Ref, reference group; VA, Veterans Affairs.

[a]The following factors had an overall n < 15 and were excluded from the table: acquired immune deficiency syndrome, chronic blood loss anemia, and dehiscence/necrosis.

[b]129 admissions were missing race.

[c]Categories were not mutually exclusive. 600 (6.9%) patients had >1 spinal region operated upon.

Table 5.

Hierarchical Model of Factors Associated With Post-Discharge Prophylactic Antibiotic Use after Spinal Fusion[a]

Variable	Category	Model 2, including patient and operative factors	Model 3, including patient, operative, and surgeon factors
		FINAL MODEL	
		OR (95% CI)	OR (95% CI)
Patient factors			
ASA class ≥ 3		1.31 (1.00, 1.70)	1.32 (1.01, 1.71)
Cancer- lymphoma		2.57 (1.11, 5.98)	2.55 (1.09, 5.93)
Cancer- solid tumor		3.63 (1.62, 8.14)	3.54 (1.58, 7.95)
Morbid obesity		1.64 (1.09, 2.47)	1.67 (1.11, 2.52)
Paralysis		2.38 (1.30, 4.37)	2.39 (1.30, 4.39)
Smoker		0.71 (0.49, 1.05)	0.72 (0.49, 1.05)
Operative factors			
Length of stay	1–2 days	1.00	1.00
	3–4 days	1.19 (0.76, 1.86)	1.16 (0.74, 1.82)
	5–6 days	1.79 (1.10, 2.91)	1.77 (1.09, 2.87)
	≥ 7 days	3.32 (2.07, 5.32)	3.17 (1.98, 5.10)
Hematoma or seroma		2.93 (1.17, 7.33)	3.01 (1.20, 7.54)
Lumbar spinal region		1.26 (0.96, 1.65)	1.27 (0.97, 1.67)
Thoracic spinal region		1.39 (1.01, 1.93)	1.33 (0.96, 1.84)
Intraoperative antibiotics	Cefazolin/clindamycin-only	1.00	1.00
	Any vancomycin	1.27 (0.95, 1.69)	1.19 (0.89, 1.60)
	Single antibiotic (other than vancomycin, cefazolin, or clindamycin) or >1 antibiotic	1.68 (0.91, 3.07)	1.60 (0.87, 2.93)
	No antibiotic documented	3.31 (1.15, 9.54)	3.10 (1.07, 8.99)
Surgeon factors			
Surgical volume (cases per year)	< 50		1.20 (0.80, 1.80)
	50–99		1.34 (1.03, 1.76)
	≥ 100		1.00
Model fit			
−2LL[b]		2340.15	2335.53
P		<0.001[c]	0.099[d]

NOTE. ASA class, American Society of Anesthesiologists (ASA) Physical Status Classification System; CI, confidence interval; LL, log-likelihood; OR, odds ratio.

[a]Hierarchical generalized linear model with random intercepts at the level of the hospital site.

[b]Empty model −2LL = 2505.50.

[c]*P* value comparing −2LL of the model with patient and operative factors versus the empty model with only random effects for study site.

[d]*P* value comparing −2LL of model 3 with patient, operative, and surgeon factors versus model 2 with only patient and operative factors.