Postoperative infection in spine surgery: does the month matter?

Michael J. Durkin, MD[1,2], **Kristen V. Dicks, MD**[1,2], **Arthur W. Baker, MD**[1,2], **Rebekah W. Moehring, MD, MPH**[1,2,3], **Luke F. Chen, MBBS, MPH**[1,2], **Daniel J. Sexton, MD**[1,2], **Sarah S. Lewis, MD, MPH**[1,2], and **Deverick J. Anderson, MD, MPH**[1,2]

[1]Department of Medicine, Division of Infectious Diseases, Duke University Medical Center, Durham, North Carolina

[2]Duke Infection Control Outreach Network, Durham, North Carolina

[3]Durham VA Medical Center, Durham, North Carolina

Abstract

OBJECT—The relationship between time of year and surgical site infection (SSI) following neurosurgical procedures is poorly understood. Authors of previous reports have demonstrated that rates of SSI following neurosurgical procedures performed during the summer months were higher compared with rates during other seasons. It is unclear, however, if this difference was related to climatological changes or inexperienced medical trainees (the July effect). The aim of this study was to evaluate for seasonal variation of SSI following spine surgery in a network of nonteaching community hospitals.

METHODS—The authors analyzed 6 years of prospectively collected surveillance data (January 1, 2007, to December 31, 2012) from all laminectomies and spinal fusions from 20 hospitals in the Duke Infection Control Outreach Network of community hospitals. Surgical site infections were defined using National Healthcare Safety Network criteria and identified using standardized methods across study hospitals. Regression models were then constructed using Poisson distribution to evaluate for seasonal trends by month. Each analysis was first performed for all SSIs and then for SSIs caused by specific organisms or classes of organisms. Categorical analysis was performed using two separate definitions of summer: June through September (definition 1), and July through September (definition 2). The prevalence rate of SSIs during the summer was compared with the prevalence rate during the remainder of the year by calculating prevalence rate ratios and 95% confidence intervals.

Correspondence. Michael J. Durkin, Department of Medicine, Duke University Medical Center, 315 Trent Dr., Rm. 181, Durham, NC 27710. michael.durkin@dm.duke.edu.

RESULTS—The authors identified 642 SSIs following 57,559 neurosurgical procedures (overall prevalence rate = 1.11/100 procedures); 215 occurred following 24,466 laminectomies (prevalence rate = 0.88/100 procedures), and 427 following 33,093 spinal fusions (prevalence rate = 1.29/100 procedures). Common causes of SSI were *Staphylococcus aureus* (n = 380; 59%), coagulase-negative staphylococci (n = 90; 14%), and *Escherichia coli* (n = 41; 6.4%). Poisson regression models demonstrated increases in the rates of SSI during each of the summer months for all SSIs and SSIs due to gram-positive cocci, *S. aureus*, and methicillin-sensitive *S. aureus*. Categorical analysis confirmed that the rate of SSI during the 4-month summer period was higher than the rate during the remainder of the year, regardless of which definition for summer was used (definition 1, p = 0.008; definition 2, p = 0.003). Similarly, the rates of SSI due to gram-positive cocci and *S. aureus* were higher during the summer months than the remainder of the year regardless of which definition of summer was used. However, the rate of SSI due to gram-negative bacilli was not.

CONCLUSIONS—The rate of SSI following fusion or spinal laminectomy/laminoplasty was higher during the summer in this network of community hospitals. The increase appears to be related to increases in SSIs caused by gram-positive cocci and, more specifically, *S. aureus*. Given the nonteaching nature of these hospitals, the findings demonstrate that increases in the rate of SSI during the summer are more likely related to ecological and/or environmental factors than the July effect.

Keywords

surgical site infection; spinal fusion; laminectomy; seasonality; July effect; spine surgery

Surgical site infections (SSIs) lead to devastating patient outcomes. Surgical site infections are associated with a 5-fold increase in risk of readmission, a 2-fold increase in postoperative deaths, and additional societal costs from resultant chronic conditions and missed economic opportunities.[15,18,23] While there are well-established risk factors for postoperative SSI following spine surgery,[30] some potential risk factors remain inadequately addressed. Specifically, the relationship between seasonality, surgeon experience, and the risk of SSI is controversial.[37]

The prevalence of some bacterial infections is associated with season of the year. For example, infections caused by gram-negative bacteria such as *Escherichia coli, Acinetobacter baumanii, Pseudomonas aureginosa*, and *Enterobacter cloacae* occur more frequently in warmer summer and fall months than the remainder of the year.[13,24,29,31,33] Similarly, skin and soft-tissue infections caused by *Staphylococcus aureus* occur more frequently in the summer,[9,24,36] while pneumonia due to methicillin-resistant *S. aureus* (MRSA) may occur more frequently in the winter.[16,19,35]

Inexperienced surgeons have higher surgical complication rates.[14,25] Inexperienced surgical house staff may have higher rates of SSIs during their first few months in training.[4,5,22,26] For example, Raval et al. observed that resident involvement was associated with a 21.2% higher SSI rate in general and with vascular surgery procedures (5.34/100 procedures vs 3.47/100 procedures, respectively; p < 0.0001).[32] The association between new house staff and increased risk of adverse patient outcomes has been labeled as the July effect.

To date, few studies have examined the seasonality of SSI following neurosurgical procedures. Gruskay et al. recently studied more than 8100 spine surgeries between 2005 and 2009 at a single tertiary referral institution.[15] First, the authors noted a significantly higher rate of SSI during the summer months, defined as July through September (p = 0.03). Second, the rate of SSIs more than doubled when comparing the experienced outgoing house staff in June to inexperienced incoming ones in July (p = 0.02). Ultimately, the authors were unable to determine if the higher SSI rate observed during the summer was related to house staff experience or seasonal variation. Thus, the objective of our study was to determine if the rate of SSI following spinal procedures varies by season in nonteaching community hospitals.

Methods

Study Population

The Duke Infection Control Outreach Network (DICON) is a network of community hospitals in the Southeastern US that has been described previously.[2] In brief, DICON provides infection control consultation and educational services to more than 40 hospitals in 5 states. Infection preventionists at each hospital use standardized National Healthcare Safety Network (NHSN) definitions to prospectively identify cases of SSI.[27] Cases are identified through review of microbiology records, hospital readmissions, and postdischarge questionnaires. These methods have been previously validated.[20,21] Infection preventionists prospectively enter demographic, clinical, surgical, and microbiological data into a local database. Identifiers are removed from the data prior to transmission to a centralized DICON surgical database. As a result, this study was considered research not involving human subjects by the Duke University Health System Institutional Review Board.

We performed a retrospective analysis of surveillance data collected between January 1, 2007, and December 31, 2012, from 20 DICON-affiliated hospitals (median size 291 beds, range 50–490 beds). These 20 hospitals were selected because they had complete surgical surveillance data for the entire 6-year study period. The excluded hospitals had similar demographics (median size 224 beds, range 18–481 beds) and only represented 16% of total procedures in our cohort. All spinal fusion, laminectomy, and laminoplasty procedures, as identified by NHSN criteria,[7] were included in our analysis. Basic demographic information including age, sex, race, procedure type, surgical risk index, and risk classification were collected. Prevalence rates for SSI were calculated as the number of SSIs per 100 procedures.

Seasonality and SSI

We evaluated the seasonality of SSI following spine surgery using Poisson regression. We constructed generalized estimating equation models using Poisson distribution to compare rates of SSI during summer months versus rates of SSI during nonsummer months by calculating prevalence rates, prevalence rate ratios, and 95% confidence intervals (CIs). Overdispersion was observed in these models and corrected using the Pearson chi-square as the dispersion parameter. We tested for seasonality using two definitions of "summer." The first definition included June through September, as these are the 4 hottest months of the

year in North Carolina, with the average temperature in June being equivalent to the average temperature in September (http://www.usclimatedata.com/climate/raleigh/north-carolina/united-states/usnc0558). The second definition included July through September (summer solstice to fall equinox), which corresponds to the conventional definition of summer used in other studies.[3,10,15,29] We performed these two sets of analyses to test for seasonality for all cases of SSI, for SSIs due to gram-positive organisms, and for SSIs due to gram-negative organisms. We then constructed models with month as a continuous dependent variable, using first-, second-, and third-order polynomial terms to visualize trends. Finally, we compared the characteristics of cases performed in "summer" to cases performed during the rest of the year to determine if the patient populations and types of cases were different. Similarly, we compared average operative duration between the two groups to evaluate for potential confounding from trauma or complex cases.

Statistical Analysis

Statistical analyses were performed using SAS (version 9.3, SAS Institute). Categorical variables were compared using chi-square or Fisher exact tests; continuous variables were compared using the Student t-test or Wilcoxon rank-sum test, as appropriate. Statistical significance was defined as a p value < 0.05 and 95% CIs that do not contain a prevalence rate ratio of 1.00.

Results

A total of 642 SSIs were observed following 57,559 spine surgeries during the 6-year study period (overall rate 1.11/100 procedures); 427 SSIs occurred following 33,093 spinal fusion surgeries (rate = 1.29/100 procedures); and 215 SSIs occurred following 24,466 laminectomies (rate = 0.88/100 procedures; Table 1). The median age of surgical patients was 54 years; 9191 (78%) were white and 23,270 (51%) were female. Gram-positive cocci caused almost 80% of infections. Patients who underwent spinal surgical procedures in the summer were similar to patients who underwent their procedures during other times of the year, regardless of whether summer was defined as June through September or July through September (Table 1). *S. aureus* was the most common cause of SSI following spinal procedures (Table 2).

Analyses of all SSIs

The rate of SSI following spinal procedures varied by month according to polynomial regression analysis (Fig. 1). In particular, the projected rates were highest during the summer months. Categorical analyses confirmed this finding regardless of which of the two definitions for summer were used (Table 3). Using the definition of June through September for summer, the prevalence rate of SSI was significantly higher in summer compared with the rest of the year: 1.28/100 procedures (95% CI 1.12–1.44) versus 1.03/100 procedures (95% CI 0.93–1.13), respectively, prevalence rate ratio 1.24 (95% CI 1.06–1.45), p = 0.008. Using the definition of July through September for summer, the rate of SSI was significantly higher in summer compared with the rest of the year: 1.33/100 procedures (95% CI 1.15–1.53) versus 1.04/100 procedures (95% CI 0.95–1.14), respectively, prevalence rate ratio 1.29 (95% CI 1.09–1.52), p = 0.003.

Analyses of SSIs Stratified by Pathogens

The rates of SSI due to gram-positive organisms (Fig. 2A), *S. aureus* (Fig. 2B), and methicillin-sensitive *S. aureus* (MSSA; Fig. 2C) varied by month, with the highest rates during the summer months. The rate of SSI due to gram-negative pathogens also demonstrated statistically significant variation by month (Fig. 2D). However, the overall regression curve was suggestive of slightly higher SSI rates due to gram-negative pathogens during the nonsummer months. Categorical analyses confirmed statistically significant findings for gram-positive cocci, *S. aureus*, and MSSA regardless of the definition of summer used, while gram-negative organisms were not statistically significant (Table 3).

Discussion

Our large, multicenter study demonstrated that rates of SSIs after spinal procedures performed at nonteaching hospitals are highest during the summer months. The increase appears to be caused by an increase in the rate of SSIs due to gram-positive cocci and, in particular, *S. aureus*. To our knowledge, our study presents two "firsts" in the surgical literature. Our study is the first to demonstrate seasonal variation in SSIs following spine surgery in community hospitals; and due to the absence of trainees in our hospital network, our study is the first to confirm seasonal variation of SSIs following spine surgery in the absence of the July effect.

Several other, nonsurgical *S. aureus* infections peak during the summer. In fact, Leekha et al. performed a systematic review on *S. aureus* epidemiology and found that 31/41 (76%) of studies on *S. aureus* infection or colonization varied based on season.[24] In particular, all 10 studies that specifically addressed skin and soft-tissue infections noted higher rates between summer and autumn. Similarly, a recent time series analysis of 51,287 pediatric skin and soft-tissue infection clinical encounters found that rates of *S. aureus* infection were highest in the summer months.[36]

Seasonal variation of *S. aureus* infections may occur for several reasons. Specifically, investigators have found a statistically significant correlation between both temperature and humidity and *S. aureus* skin and soft-tissue infections.[36] McBride et al. found that *S. aureus* bacterial populations on the skin are significantly higher during warm and humid months.[28] Skin-to-skin contact, which plays a large role in the nosocomial transmission of *S. aureus*, increases in frequency during the late summer.[17] In addition, skin disruption from contact sports and insect bites occur during the summer and may contribute to *S. aureus* infections.[34] Finally, summer months also have higher rates of trauma-related admissions, a known risk factor for SSI.[15]

Surprisingly, our study demonstrated no conclusive correlation between gram-negative rod infections and season. Several studies have previously demonstrated an increase in bloodstream infections, urinary tract infections, and dialysis-associated peritonitis due to gram-negative rod in the warmer, summer months.[3,8,12] Proposed risk factors for the increase in gram-negative rod infections in the summer are generally similar to risk factors for *S. aureus* infections, including temperature, humidity, and possibly human behavior (e.g., dietary habits and recreational activities).[6,10,11,13] For example, Ramos et al.

concluded that the incidence of *Pseudomonas aeruginosa* infections in a 660-bed tertiary care medical center in Brazil increased with climatic changes. Urinary tract infections were associated with higher precipitation (p = 0.04) and temperature (p = 0.02), while hospital-acquired pneumonia was associated with humidity (p = 0.03) and precipitation (p = 0.03).[31] It is unclear why the rate of SSI in our network due to *S. aureus* increased in the summer but the rate of SSI due to gram-negative rods did not.

Our study has limitations. First, we included surveillance data with limited patient information available. Thus, we were unable to address multiple known risk factors for SSI following spine surgery, including diabetes mellitus, prior SSI, and presence of obesity. In contrast, our analysis included prospectively collected, validated data from a large cohort. We analyzed several risk factors for SSI, including the American Society of Anesthesiologists index, which takes into account significant systemic diseases such as diabetes or severe obesity, and found no differences in patient populations. Second, we were unable to determine which surgical procedures were considered to be emergency surgery. Emergency surgeries are more likely to take place during the summer, have longer operative durations, and may be associated with an increased risk of SSI. However, there were no statistically significant differences in operative durations and start times between summer and other seasons in our study (data not shown). Third, our study was limited by a relatively low number of SSIs due to gram-negative bacilli. Therefore, our study may have lacked the power to detect seasonal variation in gram-negative bacilli infections. Fourth, our study only assessed the association between season and SSIs. The specific underlying risk factors that contribute to this association remain unknown. Without understanding the specific underlying risk factors, we are unable to give specific recommendations to surgeons on how this information can be used to reduce the incidence of SSIs. We consider our findings to be "hypothesis generating" and, as such, an important step forward regarding our knowledge of the risks of SSI. Finally, our findings can only be generalized to community hospitals. Of note, however, the majority of health care in the US is provided in these hospitals,[1] and Gruskay et al. found similar seasonal trends in an academic medical center.[15]

Conclusions

Our multicenter study is the first to evaluate the seasonality of SSIs following spinal procedures performed in a network of nonteaching community hospitals. This trend was largely due to SSIs caused by gram-positive cocci and *S. aureus*. Due to the absence of trainees in our hospital network, we believe the higher rate of SSIs after spine surgery in our study is unrelated to the July effect. Instead, our data support the concept that climatological, social, and/or other environmental factors contribute to a higher rate of SSIs during the summer months. It is unclear why SSIs due to gram-positive organisms are highest during warm summer months. Based on our analyses, we speculate that season-specific interventions to reduce the risk of gram-positive SSIs may be of value.

Acknowledgments

ABBREVIATIONS

CI   confidence interval

DICON   Duke Infection Control Outreach Network

MRSA   methicillin-resistant *Staphylococcus aureus*

MSSA   methicillin-sensitive *Staphylococcus aureus*

NHSN   National Healthcare Safety Network

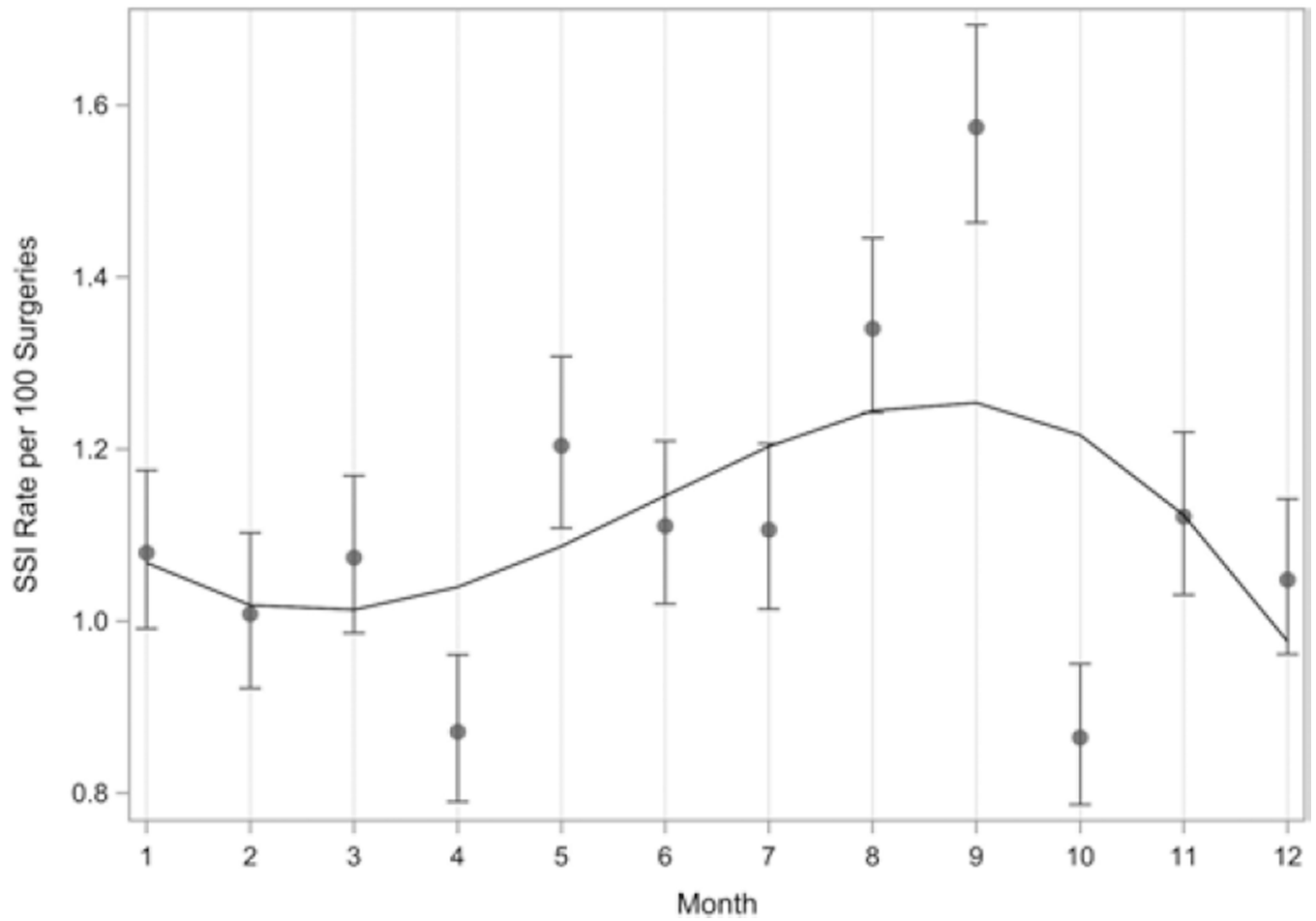**SSI**   surgical site infection

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FIG. 1.

Surgical site infection prevalence rate per 100 surgeries by month for all organisms.
Polynomial regression analysis resulted in a best-fit line that showed statistically significant
seasonal variation with the highest SSI prevalence rate during the summer months.
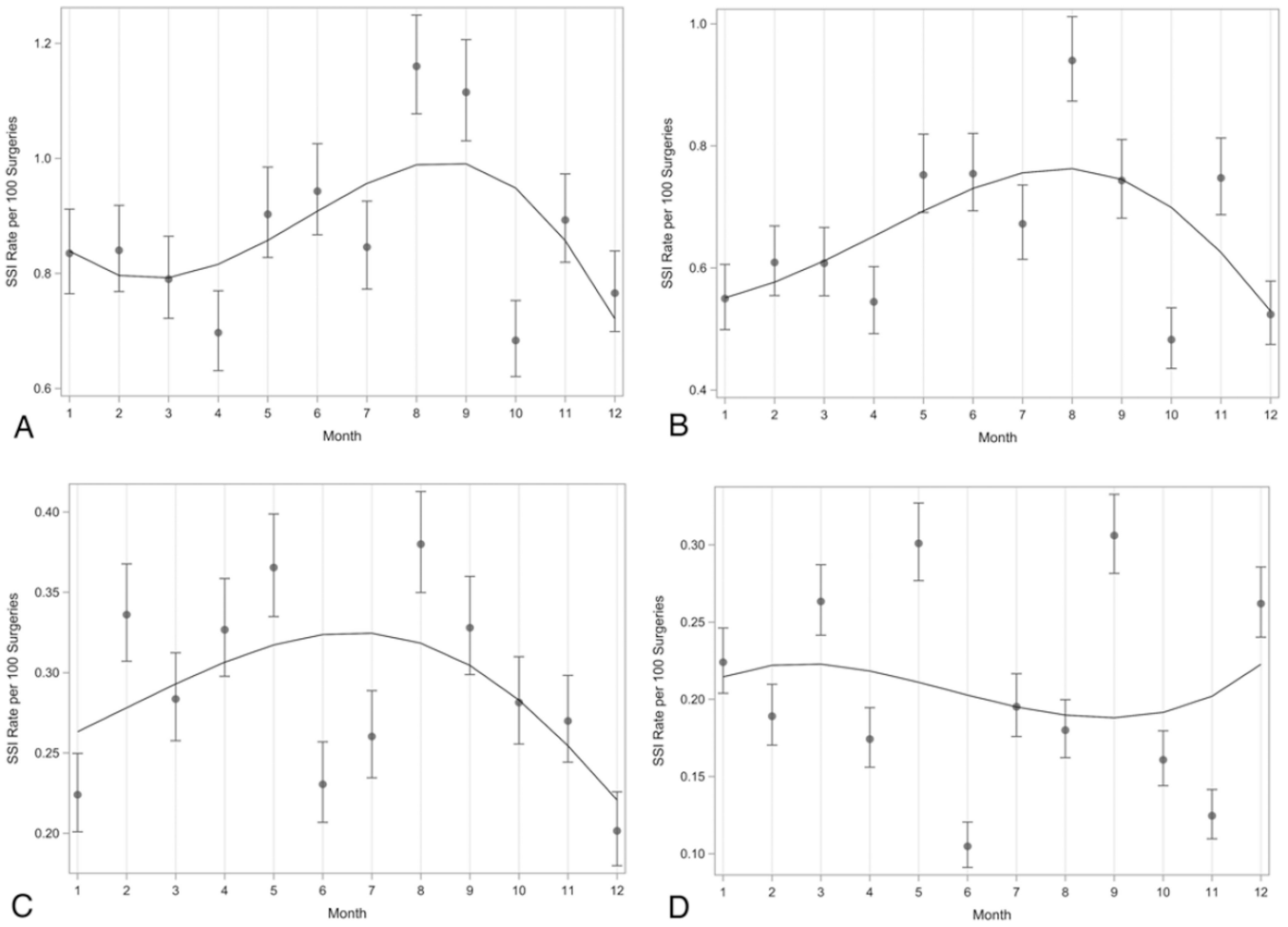
FIG. 2.

Surgical site infection rates per 100 surgeries by month for gram-positive cocci (**A**), *S. aureus* (**B**), MSSA (**C**), and gram-negative bacilli (**D**). Polynomial regression analysis resulted in a best-fit line that showed statistically significant seasonal variation with the highest SSI prevalence rate during the summer months for gram-positive cocci (A), *S. aureus* (B), and MSSA (C), and during the nonsummer months for gram-negative bacilli (D).

TABLE 1

Perioperative characteristics of patients undergoing spine surgery in DICON community hospitals overall and by season (January 1, 2007, to December 31, 2012)

Variables	Overall	June–September	October–May	p Value
No. of patients	57,559	18,957	38,602	
Median age in yrs (IQR)	54 (44–65)	54 (44–65)	54 (44–64)	0.18
Median operation duration in mins (IQR)	113 (74–179)	112 (74–179)	113 (74–178)	0.30
Sex (%)				0.13[*]
Male	22,691 (49)	7382 (49)	15,309 (50)	
Female	23,270 (51)	7723 (51)	15,547 (50)	
Race (%)				0.82[*]
White	9191 (78)	2902 (78)	6289 (78)	
Black	2244 (19)	699 (19)	1521 (19)	
Other	316 (3)	105 (3)	211 (3)	
Procedure (%)				0.25
Laminectomy	24,466 (42)	8122 (43)	16,344 (42)	
Spinal fusion	33,093 (58)	10,835 (57)	22,258 (58)	
NHSN risk index (%)				0.37[*]
0	28,605 (50)	9382 (49)	19,223 (50)	
1	23,496 (41)	7807 (41)	15,689 (41)	
2	5414 (9)	1756 (9)	3661 (10)	
3	44 (0.08)	15 (0.08)	29 (0.08)	
ASA classification (%)[†]				0.48[*]
1	3884 (7)	1319 (7)	2565 (7)	
2	30,186 (52)	9863 (52)	20,343 (53)	
3	21,443 (37)	7110 (37)	14,333 (37)	
4	2031 (4)	661 (4)	1370 (4)	
5	15 (0.03)	4 (0.02)	11 (0.03)	
Infection class (%)[‡]				0.19[*]
Superficial incisional	185 (29)	77 (32)	108 (27)	
Deep incisional	352 (55)	123 (51)	229 (57)	
Organ/space	104 (16)	42 (17)	62 (16)	

IQR = interquartile range.

[*] Categorical and ordinal variables were converted into dichotomous variables to calculate p values.

[†] American Society of Anesthesiologists physical status classification system.

[‡] One SSI during the summer had an unknown infection class and was excluded from this table.

TABLE 2

Summary of 642 SSIs following spine surgery isolated in 20 community hospitals by organism[*]

Organism	Value (%)
Gram-positive cocci	502 (78)
S. aureus	380 (59)
MSSA	213 (33)
MRSA	167 (26)
Coagulase-negative staphylococci	90 (14)
Gram-negative rods	119 (19)
E. coli	41 (6.4)
Pseudomonas spp.	23 (3.6)
Proteus spp.	21 (3.3)
Yeast	5 (0.8)
No pathogen identified	45 (7.0)

[*] Organisms from polymicrobial infections were counted in each category. List contains only the most commonly identified organisms.

TABLE 3

Prevalence rates of SSIs following spine surgery with 95% CIs for 2 separate definitions of summer

Definition of Summer	Organism	Prevalence Rate for Summer (95% CI)	Prevalence Rate for Rest of Yr (95% CI)	Prevalence Rate Ratio (95% CI)	p Value
June–September					
	All SSIs	1.28 (1.12–1.44)	1.03 (0.93–1.13)	1.24 (1.06–1.45)	0.008
	GPC	1.02 (0.88–1.16)	0.80 (0.71–0.89)	1.27 (1.06–1.52)	0.008
	S. aureus	0.78 (0.66–0.91)	0.60 (0.52–0.68)	1.06 (1.06–1.60)	0.01
	MSSA	0.48 (0.38–0.58)	0.32 (0.26–0.37)	1.52 (1.16–1.99)	0.002
	MRSA	0.30 (0.22–0.38)	0.28 (0.23–0.34)	1.06 (0.77–1.46)	0.74
	GNR	0.20 (0.13–0.26)	0.21 (0.17–0.26)	0.92 (0.62–1.35)	0.47
July–September					
	All SSIs	1.33 (1.15–1.53)	1.04 (0.95–1.14)	1.29 (1.09–1.52)	0.003
	GPC	1.04 (0.88–1.21)	0.82 (0.73–0.90)	1.28 (1.06–1.55)	0.01
	S. aureus	0.79 (0.64–0.94)	0.62 (0.54–0.69)	1.28 (1.03–1.59)	0.03
	MSSA	0.47 (0.35–0.58)	0.34 (0.28–0.39)	1.37 (1.03–1.83)	0.03
	MRSA	0.32 (0.23–0.42)	0.28 (0.23–0.33)	1.16 (0.83–1.63)	0.38
	GNR	0.23 (0.15–0.30)	0.20 (0.16–0.24)	1.12 (0.75–1.69)	0.57

GNR = gram-negative rods; GPC = gram-positive cocci.