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Epidemiology of Surgical Site Infection in a Community Hospital Network

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Abstract

OBJECTIVE—To describe the epidemiology of complex surgical site infection (SSI) following commonly performed surgical procedures in community hospitals and to characterize trends of SSI prevalence rates over time for MRSA and other common pathogens

METHODS—We prospectively collected SSI data at 29 community hospitals in the southeastern United States from 2008 through 2012. We determined the overall prevalence rates of SSI for commonly performed procedures during this 5-year study period. For each year of the study, we then calculated prevalence rates of SSI stratified by causative organism. We created log-binomial regression models to analyze trends of SSI prevalence over time for all pathogens combined and specifically for MRSA.

RESULTS—A total of 3,988 complex SSIs occurred following 532,694 procedures (prevalence rate, 0.7 infections per 100 procedures). SSIs occurred most frequently after small bowel surgery, peripheral vascular bypass surgery, and colon surgery. *Staphylococcus aureus* was the most common pathogen. The prevalence rate of SSI decreased from 0.76 infections per 100 procedures in 2008 to 0.69 infections per 100 procedures in 2012 (prevalence rate ratio [PRR], 0.90; 95% confidence interval [CI], 0.82–1.00). A more substantial decrease in MRSA SSI (PRR, 0.69; 95% CI, 0.54–0.89) was largely responsible for this overall trend.

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CONCLUSIONS—The prevalence of MRSA SSI decreased from 2008 to 2012 in our network of community hospitals. This decrease in MRSA SSI prevalence led to an overall decrease in SSI prevalence over the study period.

Surgical site infection (SSI) is a serious complication of surgical procedures that occurs after approximately 2% of inpatient surgeries performed at hospitals in the United States.[1] An estimated 157,000 SSIs occurred in US acute care hospitals in 2011,[2] and 3% of patients with SSIs die as a result of the infection.[3–5] The hospital-related cost of a single SSI has been estimated at $12,000–$35,000,[6] and estimates of annual nationwide hospital costs of SSI have ranged from $3 billion to $10 billion.[7] Methicillin-resistant *Staphylococcus aureus* (MRSA) is a common cause of SSI and is associated with long and expensive hospitalizations as well as high mortality rates.[8,9]

SSI is the most common type of healthcare-associated infection (HAI) in our network of community hospitals.[10] We previously studied trends in the rates of SSI in our network and found that the overall prevalence rate of SSI increased from 2000 to 2005, as did the rate of SSI due to MRSA, which was the most common pathogen responsible for SSI.[11] More recent data from the Centers for Disease Control and Prevention's (CDC) National Healthcare Safety Network (NHSN) showed a decrease in overall SSI rates for many common procedures between 2008 and 2012.[12] These findings are concordant with results of other recent studies that reported similar declines in the rate of hospital-onset invasive MRSA infections.[13–15]

Only sparse recent data are available regarding the epidemiology of SSI in community hospitals. Most studies describing the epidemiology of SSI have been undertaken at university-affiliated hospitals and other tertiary-care teaching facilities. Published studies of SSI in community hospitals are hampered by single-hospital retrospective designs, small numbers of infections, or analysis of data on rates of SSI for a limited number of procedure types.[16–19] The objectives of this analysis were (1) to describe the epidemiology of SSI for commonly performed procedures in a large network of community hospitals and (2) to characterize the trends of SSI prevalence rates over time for MRSA and other pathogens frequently responsible for SSI.

METHODS

Setting

The Duke Infection Control Outreach Network (DICON) is a network of 42 community hospitals in 5 states in the southeastern United States.[20] Community hospitals within our network have access to expert infection control consultation, educational services, benchmark data, and detailed data analysis.[21] Trained and experienced infection preventionists prospectively enter data collected from patients undergoing 37 types of operative procedures[22] into a database. The database contains the following information: type of surgical procedure; hospital; primary surgeon; patient age; procedure date and duration; NHSN risk index (which is calculated from the patient's American Society of Anesthesiologists [ASA] classification system score, wound class, and operative duration)[23];

and the presence or absence of postoperative SSI, including causative organism, if a postoperative culture was obtained and was positive.

DICON SSI surveillance methods have previously been described in detail.[20,24] Potential SSIs were identified through review of microbiology culture results, hospital readmissions following surgery, clinical rounds, and questionnaires sent to surgeons regarding postoperative patients. Infection preventionists used NHSN criteria to categorize SSIs into superficial (superficial incisional) and complex (deep incisional or organ-space) SSIs.[22]

Analysis Plan

We analyzed 532,694 consecutive NHSN operative procedures performed at the 29 DICON hospitals that were members of our network from January 2008 through December 2012. In 2013, the NHSN substantially decreased the time period of SSI surveillance following many procedures. Because this change in surveillance methods resulted in the exclusion of approximately 10% of our SSIs captured by traditional NHSN definitions,[25] we excluded procedures performed after 2012 from our analysis.

We focused our analysis on complex SSIs because superficial SSIs are less clinically relevant and costly than complex SSIs.[26] Furthermore, surveillance of superficial SSIs is difficult to standardize. However, for the procedure-specific analysis, we included total (complex and superficial) SSI rates to allow comparison to NHSN benchmark rates, which are not stratified by depth of infection.

First, we determined the overall prevalence rate of SSI during the 5-year study period and then stratified all collected data by procedure type, NHSN risk index, and pathogen responsible for infection. Then, for each year of the study from 2008 through 2012, we determined the prevalence rate of SSI, stratified by causative organism. We used unadjusted log-binomial regression to calculate annual crude prevalence rates and prevalence rate ratios (PRRs) for all SSIs independent of pathogen, as well as for MRSA SSI.

Next, we constructed 2 multivariate log-binomial regression models to further analyze SSI prevalence trends over time: one model analyzed all SSI, and the second model analyzed MRSA SSI only. We considered potential effect measure modifiers and confounders of the relationship between calendar year and SSI prevalence rate. Patient age,[5,24] NHSN risk index,[23,27] and procedure type[27] are well-established risk factors for SSI. Some data suggest that SSI prevalence also increases for surgeons with less experience performing certain procedures[28,29]; thus, we also created a variable reflecting surgeon experience.

We defined patient age as a continuous variable. The NHSN risk index variable was defined as an ordinal variable; scores from 0 to 3 represented increasing levels of SSI risk. We defined a procedure-associated risk variable with 3 categories based upon procedure-specific SSI prevalence rates in the DICON network. High-risk procedures were in the highest quartile of SSI; low-risk procedures were in the lowest quartile of SSI; and intermediate-risk procedures composed the middle 2 quartiles of SSI prevalence (Table 1). Surgeon experience was defined as a binary variable: procedures were deemed to have been performed by an “experienced” surgeon if the primary surgeon performed the particular NHSN procedure

type >1 standard deviation more times per year than the average surgeon in the network who performed the procedure.

We evaluated effect measure modification of the PRRs for each of the 4 covariates by comparing log-binomial regression models with interaction terms to the respective reduced models, using likelihood ratio tests to determine significance ($P < .10$). A directed acyclic graph[30] based upon findings of prior studies indicated that all 4 covariates were potential confounders; therefore, all covariates were initially included in both multivariate models. Multivariate generalized estimating equation models were fit to estimate the association between calendar year and SSI, adjusted for clustering of SSI at individual hospitals. We used likelihood ratio tests ($P < .05$) to determine which covariates were independent predictors of SSI. A backwards elimination strategy established which covariates exhibited meaningful confounding, changing PRR estimates by ≥10%.[31]

Patient and surgeon data were de-identified prior to entry into the DICON Surgical Database. The Duke University and University of North Carolina at Chapel Hill Institutional Review Boards approved this research. We maintained the data in a Microsoft Access database (Microsoft Corporation, Redmond, WA) and analyzed all data using SAS, version 9.4 (SAS Institute, Cary, NC).

RESULTS

A total of 3,988 complex SSIs occurred following 532,694 consecutive procedures performed over the 5-year study period, giving an overall prevalence rate of 0.7 infections per 100 procedures (Table 2). Among the 26 procedures that were performed more than 4,000 times during the study period, small bowel surgery had the highest prevalence rate of SSI (4.1 infections per 100 procedures), followed by peripheral vascular bypass surgery (3.0 infections per 100 procedures), colon surgery (2.4 infections per 100 procedures), and exploratory laparotomy (1.4 infections per 100 procedures). In general, the prevalence rates of total (complex and superficial) SSI, stratified by risk index, were similar to prevalence rates reported by the National Healthcare Safety Network (NHSN).

S. aureus was the most common organism causing SSI (0.25 infections per 100 procedures) and was responsible for 1,357 (34%) SSIs (Table 3). MRSA and methicillin-susceptible *S. aureus* (MSSA) SSIs occurred with equal frequency: each was responsible for 17% of the SSIs. *Escherichia coli* (12%) was the most common cause of Gram-negative SSI. Overall, 20% of SSIs were polymicrobial, and cultures were either negative or not obtained for 14% of SSIs.

The unadjusted prevalence rate of SSI decreased from 0.76 infections per 100 procedures in 2008 to 0.69 infections per 100 procedures in 2012 (prevalence rate ratio [PRR], 0.90; 95% confidence interval [CI], 0.82–1.00) (Table 4). A decline in *S. aureus* SSI prevalence was largely responsible for the overall decrease in SSIs, and this decline in *S. aureus* SSI occurred because the rate of MRSA SSI decreased from 0.14 infections per 100 procedures in 2008 to 0.10 infections per 100 procedures in 2012 (PRR, 0.69; 95% CI, 0.54–0.89). In

comparison, the prevalence rates of SSI from other pathogens remained relatively constant over this 5-year period (Figure 1).

Patient age, NHSN risk index, procedure type, and surgeon experience did not exhibit meaningful effect measure modification of the relationship between year of surgery and SSI prevalence in the regression model analyzing all SSI or in the model analyzing MRSA SSI. All 4 covariates were independent predictors of SSI from all pathogens combined (Table 5). All covariates except surgeon experience were also independent predictors of MRSA SSI (Table 6). The adjusted PRRs of SSI for each calendar year for both models were nearly identical to the crude PRRs of the unadjusted models. In fact, backward elimination demonstrated that none of the potential confounders changed any of the point estimates in either model by more than 10%, and adjusting for potential clustering of SSI at particular hospitals had minimal effect on the estimates. The precision of the estimates from the crude and adjusted models were also comparable.

DISCUSSION

Our study describes a large series of consecutive surgical procedures performed over a 5-year period at 29 community hospitals. The analysis revealed a statistically significant but modest decrease in the prevalence rate of SSI from all pathogens during the 5-year study period. This decline in rates was primarily due to a more impressive decline in the prevalence rate of SSI due to MRSA. Our regression analyses confirmed that neither influential clusters of SSI at certain hospitals nor confounding by changes in characteristics of surgical patients over time were responsible for the reduced rates of SSI.

Prevalence rates of SSI in our network were similar to rates of SSI previously reported by the NHSN for most procedures, but rates for certain common procedures and risk indices differed notably from NHSN benchmarks. For example, prevalence rates of SSI following colon surgery in our network were at least 35% lower than respective NHSN rates for each category of risk index.

Several factors may explain differences between SSI rates reported by our network and the NHSN. First, nearly 40% of hospitals in the NHSN are academic hospitals.[27] As a result, the benchmark SSI rates reported by NHSN may not be applicable to smaller community hospitals.[32] Also, the NHSN's most recent comprehensive procedure-associated module utilized SSI data collected from 2006 through 2008; thus, rates derived from these data may not be consistent with current SSI rates. Our data showed recent significant declines in the rates of SSI due to MRSA. These findings illustrate that rates of SSI currently utilized by the NHSN, based on data collected 8–10 years ago, are not appropriate benchmarks for hospitals in 2016. Finally, NHSN surveillance reports combine data from complex and superficial SSIs. We think that rates of complex SSI are much more meaningful than aggregate rates of SSI due to complex and superficial SSI because complex SSIs are of greater clinical significance and are easier to consistently detect and measure.[26]

Hospitals in our network experienced larger reductions in prevalence rate of SSI from all organisms combined and specifically from MRSA when we included superficial SSI in our

analysis (data not shown), but the validity and implications of surveillance data including superficial SSIs are not clear. Thus, we believe that it is more reliable and more clinically relevant to evaluate and time-trend data on rates of complex SSI than to evaluate data that do not distinguish complex from superficial SSIs.

Our findings are consistent with the reported results in several other recently published national studies. These studies also reported that the prevalence of invasive MRSA infections has recently declined, especially among healthcare-associated infections.[13–15] However, the downward trend of the rate of SSI due to MRSA in our community hospital network was opposite to the trend noted in our prior study, which showed an increase in rates of MRSA SSI from 2000 to 2005.

Data from our study do not explain why rates of SSI caused by MRSA decreased in our network. We hypothesize that improved infection control practices, including specific interventions designed to reduce invasive MRSA infections, and national shifts in the genetics of *S. aureus* are 2 of several factors that contributed to the decreased prevalence of MRSA SSI.

DICON recommended 3 primary infection control practices to our member hospitals that may have contributed in particular to the reduction in prevalence of MRSA SSI over the study period. First, we recommended chlorhexidine-alcohol solutions for preoperative skin preparation.[33–35] Second, we recommended that surgeons include intravenous vancomycin in the perioperative antibiotic prophylaxis regimen for selected high-risk patients, such as those with history of MRSA infection or colonization, recent healthcare-facility exposure, or planned high-risk cardiac, vascular, or implant-associated surgeries.[36] Third, we recommended daily chlorhexidine bathing for all ICU patients.[37,38] DICON did not recommend the routine use of MRSA preoperative screening protocols or the use of decolonization strategies prior to surgery. We cannot quantify the impact that these infection control measures had upon SSI prevalence because DICON hospitals and surgeons did not uniformly adopt each of our infection control recommendations. Even hospitals that made similar changes in infection control practices during the study period may have changed protocols at different times or used different methods to implement new practices.

Clonal shifts in MRSA strain types may also have contributed to the decrease in MRSA SSI prevalence that we observed in our network. For example, USA300 MRSA strains have become important causes of healthcare-associated invasive MRSA infections.[14,39,40] A recent large study showed a significant overall decrease in hospital-onset MRSA bloodstream infections at US hospitals over the same time period as our study;[14] however, rates of MRSA infection and prevalence of USA300 strains showed substantial variation across different geographical areas. Thus, genetic shifts associated with decreased prevalence of USA300 or other MRSA strain types in our region may at least partially explain why rates of MRSA SSI decreased in our network.

Our study has several limitations. SSIs that occur in the outpatient setting are difficult to detect, and our surveillance may not capture all of these infections. However, our methods are highly sensitive in detecting postoperative infections that require repeat surgery or

readmission to the hospital, and inpatient management is usually required for complex SSIs. Also, 14% of SSIs in our study that met NHSN SSI definitions had negative cultures or cultures were not performed. Complex SSIs from MRSA are typically severe infections, and we doubt many MRSA infections were culture-negative or not cultured; however, more complete data on causative pathogen might change the microbiologic epidemiology of SSI from less virulent or fastidious organisms described in this study. Finally, the generalizability of our findings to community hospitals outside of the southeastern United States is uncertain. Our data for MRSA SSIs correlate well with national data for invasive MRSA infections; however, it is possible that other trends of SSI prevalence found in our network were not consistent with trends experienced at hospitals in other regions.

Our data, collected from a large cohort of community hospitals, demonstrated a decrease in SSI prevalence, particularly in SSI due to MRSA, from 2008 to 2012. The results are concordant with other recent studies performed in tertiary care hospitals that have reported declines in invasive infections caused by MRSA. Reasons for declines in SSI prevalence are likely multifactorial but are still largely unknown or unproven. Further time-trended studies are needed to determine whether these declines will continue or reverse. Such trends are important because they inform perioperative prevention measures, such as screening protocols, antibiotic prophylaxis, and skin antisepsis practices. In the meantime, our data are useful benchmarks that can be used for inter-hospital comparison and to monitor trends of SSI prevalence at community hospitals over time.

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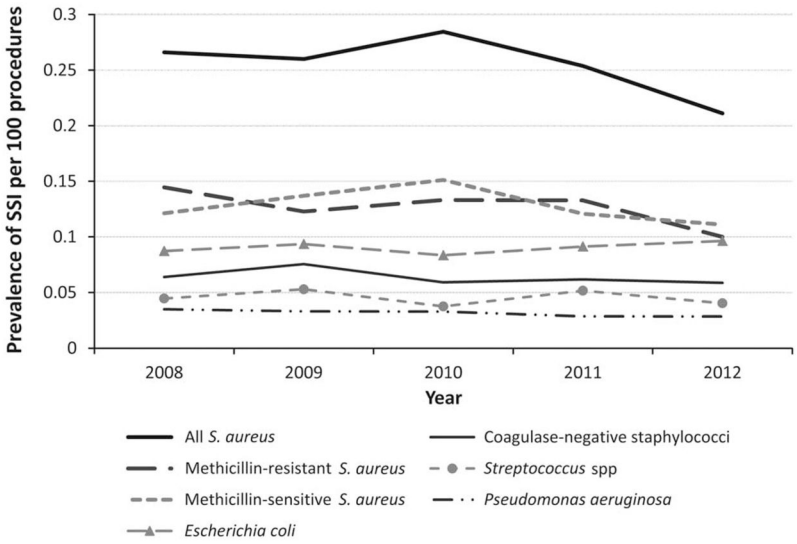

FIGURE 1.

Prevalence rates of complex surgical site infection (SSI), by causative pathogen, at our network of 29 community hospitals from 2008 through 2012. Rates were calculated per 100 procedures. Complex SSIs included deep-incisional and organ-space infections. *S. aureus*, *Staphylococcus aureus*; spp, species.

TABLE 1

Surgical Procedures Stratified by Risk of Complex Surgical Site Infection (SSI) at Network of 29 Community Hospitals from 2008 through 2012

SSI Risk[a]	Procedure Type[b]
High risk	Liver transplant; bile duct, liver, or pancreatic surgery; small bowel surgery; peripheral vascular bypass; kidney transplant; spleen surgery; colon surgery; ventricular shunt; exploratory laparotomy; hip prosthesis; coronary artery bypass graft; craniotomy; open gallbladder surgery; spinal fusion
Intermediate risk	Knee prosthesis, open appendix surgery, open reduction of fracture, abdominal hysterectomy, laparoscopic appendix surgery, limb amputation, other joint prosthesis (not hip or knee prosthesis), cardiac surgery, gastric surgery, laminectomy, herniorrhaphy, breast surgery, abdominal aortic aneurysm repair, skin graft, kidney surgery, vaginal hysterectomy
Low risk	Thoracic surgery, Cesarean section, pacemaker surgery, laparoscopic gallbladder surgery, carotid endarterectomy, prostatectomy, thyroid-parathyroid surgery

NOTE. Complex SSIs included deep-incisional and organ-space infections.

[a]High-risk procedures were in the highest quartile of SSI prevalence in the Duke Infection Control Outreach Network; low-risk procedures were in the lowest quartile of SSI prevalence; and intermediate-risk procedures composed the middle 2 quartiles of SSI prevalence.

[b]Procedure types in each risk category are listed in descending order of complex SSI prevalence rate.

TABLE 2

Prevalence Rates of Surgical Site Infection (SSI) following Common Surgical Procedures at Network of 29 Community Hospitals from 2008 through 2012

NHSN Procedure Category (DICON SSI Rank[a]), Risk Index	No. of Procedures	No. of Complex SSIs	Prevalence Rate, Complex SSI	No. of Total SSIs	Prevalence Rate, Total SSI	NHSN Prevalence Rate, Total SSI[b,c]
Small bowel surgery (1)						
All	5,133	212	4.1	281	5.5	6.0
0	1,188	37	3.1	51	4.3	3.4
1, 2, 3	3,945	175	4.4	230	5.8	6.7
Peripheral vascular bypass (2)						
All	4,311	128	3.0	188	4.4	6.7
0	295	7	2.4	11	3.7	2.9
1, 2, 3	4,016	121	3.0	177	4.4	7.0
Colon surgery (3)						
All	17,973	428	2.4	671	3.7	5.5
0	4,794	79	1.6	124	2.6	4.0
1	9,243	238	2.6	374	4.0	5.6
2	3,576	100	2.8	156	4.4	7.1
3	360	11	3.1	17	4.7	9.5
Exploratory laparotomy (4)						
All	11,132	155	1.4	237	2.1	2.0
0,1	8,277	97	1.2	154	1.9	1.7
2,3	2,855	58	2.0	83	2.9	2.8
Hip prosthesis (5)						
All	27,334	302	1.1	413	1.5	1.3
0	9,527	72	0.8	96	1.0	0.7
1	14,952	176	1.2	248	1.7	1.4
2, 3	2,855	54	1.9	69	2.4	2.4
Coronary artery bypass graft (6)						
All	12,018	122	1.0	219	1.8	2.8
0, 1	9,882	85	0.9	160	1.6	2.5

NHSN Procedure Category (DICON SSI Rank[a]), Risk Index	No. of Procedures	No. of Complex SSIs	Prevalence Rate, Complex SSI	No. of Total SSIs	Prevalence Rate, Total SSI	NHSN Prevalence Rate, Total SSI[b,c]
2, 3	2,136	37	1.7	59	2.8	4.3
Spinal fusion (7)						
All	31,970	285	0.9	398	1.2	1.5
0	16,119	85	0.5	127	0.8	0.7
1	13,077	127	1.0	175	1.3	1.8
2, 3	2,774	73	2.6	96	3.5	4.1
Knee prosthesis (8)						
All	45,843	392	0.9	495	1.1	0.9
0	16,872	104	0.6	135	0.8	0.6
1	24,475	208	0.8	264	1.1	1.0
2, 3	4,496	80	1.8	96	2.1	1.6
Abdominal hysterectomy (11)						
All	24,423	186	0.8	274	1.1	1.7
0	14,148	82	0.6	111	0.8	1.1
1	8,593	68	0.8	101	1.2	2.2
2, 3	1,682	36	2.1	62	3.7	4.0
Cesarean section (21)						
All	38,946	124	0.3	283	0.7	1.7
0	29,490	73	0.2	162	0.5	1.5
1	8,185	39	0.5	93	1.1	2.4
2, 3	1,271	12	0.9	28	2.2	3.8
All 37 procedure types	532,694	3,988	0.7	5,685	1.1	…

NOTE. Rates were calculated per 100 procedures. Complex SSIs included deep-incisional and organ-space infections. Total SSIs also included superficial-incisional infections. NHSN, National Healthcare Safety Network; DICON, Duke Infection Control Outreach Network.

[a] The 26 procedure types performed at least 4,000 times over the study period were ranked in descending order of complex SSI prevalence rate.

[b] The 2009 NHSN report[27] summarized data from participating hospitals from 2006 through 2008 and did not distinguish complex from superficial SSIs.

[c] NHSN prevalence rates for risk index category “all” were standardized to the DICON distribution of NHSN risk index scores for each procedure.

TABLE 3

Most Common Organisms Causing Complex Surgical Site Infections (SSI) at Network of 29 Community Hospitals from 2008 through 2012

Organism	No. (%)of SSIs (n =3,988)	Prevalence Rate, Complex SSI
Bacteria		
Staphylococcus aureus	1,357 (34)	0.25
MSSA	683 (17)	0.13
MRSA	674 (17)	0.13
Escherichia coli	482 (12)	0.09
Enterococcus spp.	467 (12)	0.09
Coagulase-negative staphylococci	340 (9)	0.06
Klebsiella spp.	246 (6)	0.05
Streptococcus spp.	242 (6)	0.05
Pseudomonas aeruginosa	168 (4)	0.03
Enterobacter spp.	161 (4)	0.03
Other		
Fungi	121 (3)	0.02
Polymicrobial[a]	787 (20)	0.15
No pathogen identified[b]	566 (14)	0.11

NOTE. Rates were calculated per 100 procedures. Complex SSIs included deep-incisional and organ-space infections. MSSA, methicillin-susceptible *Staphylococcus aureus*; MRSA, methicillin-resistant *Staphylococcus aureus*; spp, species.

[a]Polymicrobial infections were also included in individual SSI counts for each organism isolated.

[b]Negative cultures or no cultures taken.

TABLE 4

Prevalence Rates of Complex Surgical Site Infection (SSI) at Network of 29 Community Hospitals from 2008 through 2012

Year	No. of Procedures	No. of SSIs (All Pathogens)	PR (95% CI)	PRR (95% CI)	No. of MRSA SSIs	PR (95% CI)	PRR (95% CI)
2008	103,040	786	0.76 (0.71–0.82)	1.00	149	0.14 (0.12–0.17)	1.00
2009	105,797	841	0.79 (0.74–0.85)	1.04 (0.95–1.15)	130	0.12 (0.10–0.14)	0.85 (0.67–1.08)
2010	106,514	790	0.74 (0.69–0.79)	0.97 (0.88–1.07)	142	0.13 (0.11–0.15)	0.92 (0.73–1.16)
2011	108,383	821	0.76 (0.71–0.81)	0.99 (0.90–1.10)	144	0.13 (0.11–0.15)	0.92 (0.73–1.16)
2012	108,960	750	0.69 (0.64–0.74)	0.90 (0.82–1.00)	109	0.10 (0.08–0.12)	0.69 (0.54–0.89)

NOTE. Rates were calculated per 100 procedures. Prevalence rates (PRs), prevalence rate ratios (PRRs), and confidence intervals (CIs) were calculated with log-binomial regression models. Complex SSIs included deep-incisional and organ-space infections. MRSA, methicillin-resistant *Staphylococcus aureus*.

TABLE 5

Results of Multivariate Analyses Determining Independent Predictors of Complex Surgical Site Infection (SSI) (All Pathogens) at Network of 29 Community Hospitals from 2008 through 2012

Independent Predictor	Prevalence Rate Ratio (95% CI)
Year of procedure[a]	
2008	1.00
2009	1.03 (0.94–1.12)
2010	0.97 (0.87–1.09)
2011	0.98 (0.87–1.11)
2012	0.89 (0.80–1.00)
Age[b]	
25 year increase in age	1.09 (1.02–1.17)
NHSN risk index[b]	
1 category increase in risk index	1.89 (1.71–2.09)
Procedure type[c]	
Intermediate-risk procedure	1.00
High-risk procedure	1.85 (1.67–2.06)
Low-risk procedure	0.36 (0.29–0.45)
Surgeon experience[d]	
High experience level	1.00
Low experience level	1.09 (1.00–1.19)

NOTE. Complex SSIs included deep-incisional and organ-space infections. Generalized estimating equation models were fit to adjust for clustering of SSI at individual hospitals. Prevalence rate ratios were individually adjusted for potential confounders based upon directed acyclic graphs.[30] CI, confidence interval; NHSN, National Healthcare Safety Network.

[a]Adjusted for age, NHSN risk index, procedure type, and surgeon experience.

[b]Adjusted for calendar year, procedure type, and surgeon experience.

[c]Adjusted for age, calendar year, NHSN risk index, and surgeon experience. High-risk procedures were in the highest quartile of SSI prevalence in the Duke Infection Control Outreach Network; low-risk procedures were in the lowest quartile of SSI prevalence; and intermediate-risk procedures composed the middle 2 quartiles of SSI prevalence.

[d]Adjusted for age, calendar year, NHSN risk index, and procedure type. A procedure performed by a surgeon with a high level of experience was performed by a surgeon who performed the particular NHSN procedure >1 SD more times than the average surgeon in the network who performed the procedure. Otherwise, the procedure was considered to have been performed by a surgeon with a low level of experience.

TABLE 6

Results of Multivariate Analyses Determining Independent Predictors of Complex MRSA Surgical Site Infection (SSI) at Network of 29 Community Hospitals from 2008 through 2012

Independent Predictor	Prevalence Rate Ratio (95% CI)
Year of procedure[a]	
2008	1.00
2009	0.84 (0.66–1.08)
2010	0.92 (0.69–1.22)
2011	0.90 (0.75–1.09)
2012	0.69 (0.53–0.89)
Age[b]	
25 year increase in age	1.60 (1.37–1.86)
NHSN risk index[b]	
1 category increase in risk index	2.06 (1.87–2.27)
Procedure type[c]	
Intermediate-risk procedure	1.00
High-risk procedure	1.62 (1.38–1.90)
Low-risk procedure	0.25 (0.18–0.35)

NOTE. Complex SSIs included deep-incisional and organ-space infections. Generalized estimating equation models were fit to adjust for clustering of SSI at individual hospitals. Prevalence rate ratios were individually adjusted for potential confounders based upon directed acyclic graphs.[30]

CI, confidence interval; NHSN, National Healthcare Safety Network.

[a]Adjusted for age, NHSN risk index, and procedure type.

[b]Adjusted for calendar year and procedure type.

[c]Adjusted for age, calendar year, and NHSN risk index. High-risk procedures were in the highest quartile of SSI prevalence in the Duke Infection Control Outreach Network; low-risk procedures were in the lowest quartile of SSI prevalence; and intermediate-risk procedures comprised the middle 2 quartiles of SSI prevalence.