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Costs Associated with Surgical Site Infections in VA Hospitals

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Abstract

Importance—Surgical site infections (SSIs) are potentially preventable complications, associated with excess morbidity and mortality.

Objective—To determine the excess costs associated with total, deep, and superficial SSIs among all operations and for high-volume surgical specialties.

Design, Setting and Participants—Surgical patients from 129 Veterans Affairs (VA) hospitals were included. The Veterans Health Administration Decision Support System and VA National Surgical Quality Improvement Program databases were used to assess costs associated with SSIs among VA patients who underwent surgery in fiscal year 2010.

Main Outcomes and Measures—Linear mixed effects models were used to evaluate incremental costs associated with SSIs, controlling for patient risk factors, surgical risk factors and hospital-level variation in costs. Costs of the index hospitalization and subsequent 30-day readmissions were included. Additional analysis determined potential cost savings of quality improvement programs to reduce SSI rates at hospitals with the highest risk-adjusted SSI rates.

Results—Among 54,233 VA surgery patients, 1,756 (3.2%) experienced a SSI. Overall, 0.8% of the cohort had a deep SSI and 2.4% had a superficial SSI. The mean unadjusted costs for a patient (1) without an SSI were $31,580 and (2) with an SSI were $52,620. In the risk adjusted analyses, the relative costs were 1.43 times greater for patients with SSI, relative to patients without SSI (95%CI: 1.34, 1.52; difference=$11,876). Deep SSIs were associated with 1.93 times greater costs (95%CI: 1.71, 2.18; difference=$25,721) and superficial SSIs were associated with 1.25 times greater costs (95%CI: 1.17, 1.35; difference=$7,003). Among the highest volume specialties, the greatest mean cost attributable to SSI was $23,755 among patients undergoing neurosurgery, followed by orthopedic surgery, general surgery, peripheral vascular surgery, and urology. If

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hospitals in the highest 10th percentile (e.g. worst) reduced their SSI rates to the rates of the 50th percentile, the VHA system would save approximately $6.7 million per year.

Conclusions and Relevance—SSIs are associated with significant excess costs. Among analyzed surgery types, deep SSIs and SSIs among neurosurgery patients are associated with the highest risk-adjusted costs. Large potential savings per year may be achieved by improving SSI rates.

Introduction

Surgical site infections (SSIs) are associated with excess morbidity and mortality.[1–4] Treatment for SSIs often includes long courses of antibiotics, months of physical therapy, readmissions, and reoperations.[3,5–6] The costs of SSIs have recently been under scrutiny since the Centers for Medicare and Medicaid have stopped paying for the increased costs associated with SSIs after some surgical procedures citing that these are potentially preventable.[7] Thus, knowledge of the risk-adjusted costs of SSIs can inform policy makers and create a business case for implementing specific interventions to reduce the number of SSIs.

SSIs can be superficial infections involving the skin or subcutaneous tissue only or may be more serious infections involving tissue under the skin, organs, or implanted devices or material, which are classified as deep infections. Prior estimates of the cost of hospitalizations after SSIs vary widely and range from $24,000 to $100,000.[4,8–9] These prior estimates are based on a small number of complex cases and may be inaccurate for a variety of reasons. First, the portion of these costs that are directly attributable to the SSI versus other factors such as surgical complexity, facility-level variation in costs, and patient comorbidities is unclear. Also, the costs of SSIs may vary dramatically depending on whether the SSI is deep or superficial since deep infections are associated with much greater morbidity.

Using the VA's multicenter Surgical Quality Improvement Program (VASQIP) data and the Veterans Health Administration (VHA) Decision Support System (DSS) cost databases from fiscal year 2010, this study determined the excess costs associated with superficial and deep SSIs in VA hospitals nationwide, for all surgeries as well as separately for five high-volume surgical specialties. Additionally, we estimated potential savings by reducing SSI in hospitals with the highest risk-adjusted SSI rates to the median hospital rate. The VASQIP is ideal for investigating SSIs because it includes detailed data from a multitude of surgery types among 129 hospitals, and uses optimal measurement methods such as the Centers for Disease Control and Prevention National Healthcare Safety Network (CDC NHSN) definitions for SSIs, while the VA DSS cost database allows the application of advanced microcosting to determine the attributable cost of a SSI.

Methods

Data Sources

This study was approved by University of Iowa Institutional Review Board and Iowa City VA Health Care System Research and Development Committee.

This was a retrospective cohort study of all patients who received surgery during inpatient hospitalizations in the VHA between October 1, 2009 and September 30, 2010 (fiscal year 2010) as identified in the VASQIP. The VASQIP includes noncardiac patients undergoing surgery under general, spinal, or epidural anesthesia from all VA medical centers that perform surgery.

The dataset includes patient demographics and preoperative risk factors, information about the operative procedure and anesthesia, and postoperative complications. Information contained in the VASQIP is abstracted by trained surgical clinical nurse reviewers from 129 acute care VA medical centers, who utilize standard CDC NHSN definitions to ensure data reliability. Data available from the VASQIP dataset are listed in Table 1 and include demographics, comorbid conditions, other preoperative laboratory values, wound classification (status of operative wound determined by surgeon: clean, clean/contaminated, contaminated, or dirty/infected), work relative value unit (RVU; as a measure of surgical complexity), and specialty of the operating surgeon.

Operations performed in VA hospital inpatient settings during FY2010 were identified in VASQIP data (N=57,654). Operations were excluded if they were preceded within 30 days by a prior operation (n=3,373), if they had DRG codes 452 or 453 (representing complications of previous treatment; n=10), or if any of the patient’s demographic or surgery-related variables were missing (n=38). The final sample included 54,233 patients who underwent general surgery in 127 VA hospitals during FY2010.

The VASQIP dataset also includes information about surgical complications that occur within 30 days of surgery. SSIs were defined using CDC criteria, with the exception that the CDC criteria require longer follow-up for some procedures (e.g., hip replacement). SSIs were also classified as superficial or deep according to CDC definitions.[10] Superficial SSIs involved the skin and subcutaneous tissue, while deep SSIs involved organs, spaces, and/or deep soft tissue.

In addition, the VA DSS cost database was used to identify the main outcome of this study, defined as total costs associated with the index admission and all subsequent readmissions within 30 days of discharge. The DSS uses “Activity-Based Costing,” which is similar to microcosting in that it uses automated data to assign costs based on relative resource use for each patient.[11] The DSS includes direct costs such as health care products and staff time, as well as indirect costs such as overhead, allocated based on specified algorithms. Thus, to determine the cost of a patient encounter, the departmental unit costs are multiplied by product quantities to derive the cost for each product (e.g., chest radiography, unit of blood), and total direct costs are calculated by summing the cost of all products used during a hospitalization. These costs can vary greatly from one hospital to another. In contrast to single-center studies, the use of data from multiple hospitals provides robust cost estimates.

Statistical Methods

First, data distributions were inspected for missing or out of range values. For most patient variables, the presence of missing values was minimal. As noted previously, we excluded a small number of patients (n=38) with missing data in variables reflecting demographics or details of the surgical procedure. However, important laboratory values were missing for a significant portion of patients (e.g., 27.6% for bilirubin, 5.7% for BUN, 23.4% for albumen, 30% for partial thromboplastin time, and 3% for white blood count and hematocrit). Therefore, multiple imputations were performed on laboratory values to provide complete laboratory data for all patients as previously described.[11,12] We performed 5 imputations using a Markov chain Monte Carlo method that assumed multivariate normality. All subsequent analyses were conducted on the imputed data and repeated using the original data that excluded patients with one or more missing laboratory values. Second, the unadjusted association between presence of SSI and cost was assessed using the Wilcoxon rank sum test.

Third, multivariable risk adjustment models of the association between presence of SSI and cost were developed in an iterative process that incorporated multiple steps. First, previous studies based on VASQIP data[11,13–16] were reviewed to identify important predictors of cost and modeling techniques. Second, bivariate relationships between log-transformed costs and individual patient risk factors were examined using the t-test for risk factors measured as dichotomous variables, and analysis of variance for risk factors measured as ordinal or continuous variables. Candidate variables that were significantly related ($p<.01$) to costs were considered candidate variables for inclusion in multivariable models. Third, correlation among candidate variables was evaluated using both bivariable correlation coefficients as well as the variance inflation factor for multiple variables.[17] Redundant collinear variables were eliminated by retaining the variables that maximized model fit. Fourth, candidate variables were entered into several regression models with forward, backward, or stepwise elimination. For each model, selected variables were inspected for consistency with clinical expectation and previous literature based on analyses of VASQIP. Model fit was evaluated using Akaike's Information Criterion (AIC) and based on the r-squared between predicted and actual costs. After several iterations, a final set of variables was identified. These were included in a final model for costs, which was generated as a generalized linear model with gamma-distributed errors and a log-link function to account for the skew of costs, and incorporated fixed effects for VA hospitals to account for hospital-level variations in costs. (Appendix 1) The R-squared values for final cost models were 0.27 for the overall model, and 0.32, 0.31, 0.16, 0.29, and 0.28 for models that included general surgery, orthopedic surgery, peripheral vascular surgery, urology, and neurosurgery, respectively. The SAS software MIANALYZE procedure was used to accommodate the multiple models based on multiple data imputations (version 9.3, SAS Institute, Cary, NC).

Two sets of multivariable models were generated using the full cohort. The first evaluated the relationship between the presence of *any* SSI and costs, while the second evaluated deep SSI and superficial SSI costs separately. Subsequently, we performed separate analyses for the five highest volume surgical specialties as reported by the FY2010 VASQIP dataset (general, orthopedic, peripheral vascular, urology, and neurosurgery). All models included fixed effects for each VA facility to adjust for possible idiosyncratic assignment of cost across medical centers.[11]

Finally, we generated a risk-adjustment model for the occurrence of SSI.. Model development followed a procedure similar to that used for the cost multivariable models, except that models were estimated using logistic regression (final SSI models were estimated as a generalized linear model with logit link and binomial errors). Discrimination and fit of the logistic regression models were measured using the c-statistic and the Hosmer-Lemeshow test. The c-statistic for the overall SSI models was 0.78, and 0.76, 0.78, 0.79, 0.91, and 0.84 for general surgery, orthopedic surgery, peripheral vascular surgery, urology, and neurosurgery. The Hosmer-Lemeshow test was non-significant for all models, suggesting good fit across categories of patients defined by likelihood of SSI.

Based on the SSI model, hospitals were ranked by risk-adjusted SSI rates. In order to make a business case for reducing SSIs, we determined the cost savings to the entire VHA if hospitals in worst 10th percentile in terms of the risk adjusted SSI rates are targeted for quality improvement so that their risk-adjusted rates improve to be equal to the 50th percentile (median). This was also performed to evaluate the reduction in costs when hospitals moved from the worst 25th percentile or worst 50th percentile in terms of risk adjusted SSI rates to be equal to the rates of the hospitals in exactly the 50th percentile.

Results

Overall, 54,233 veterans had surgery in fiscal year 2010 and were included in the VASQIP dataset. Three percent (n=1,756) of these veterans were diagnosed with a SSI. Of these, 1,301 (74.1%) had a superficial SSI and 455 (25.9%) had a deep SSI.

Characteristics of the study population are displayed in Table 1. Patients who experienced an SSI were more likely to have preoperative comorbid conditions (e.g., diabetes, chronic obstructive pulmonary disease) and were more likely to drink more than 2 drinks per day in the two weeks before the operation ($p<0.05$). Patients who experienced an SSI were also more likely to have a higher ASA class, a more severe wound classification, and were more likely to undergo emergent surgery ($p<0.01$). Operations that resulted in an SSI had a higher mean number of work RVUs (18.1 vs. 16.4; $p<0.01$) compared with operations that did not result in an SSI. Therefore, these characteristics were included in the multivariable model to statistically adjust the association between SSIs and cost.

The mean unadjusted 30-day post-operative costs among patients who developed an SSI were $52,620 (SD: $47,730). In comparison, the mean unadjusted 30-day post-operative costs accumulated by patients without an SSI were $31,580 (SD: $36,088) for an unadjusted mean difference of $21,040 (SD: $36,523; $p<0.01$). As expected, the unadjusted mean costs were higher for deep surgical site infections (mean=$73,533; SD=$55,751) compared with superficial surgical site infections (mean=$45,306; SD=$42,231). Table 2 presents the unadjusted mean difference in costs comparing patients with deep or superficial SSIs with those with no SSI.

The risk adjusted costs for patients who experienced an SSI were 1.43 (95% confidence interval [CI]: 1.34, 1.52) times higher than costs for patients without an SSI after statistically adjusting for age, gender, preoperative laboratory values (e.g., albumin, WBC), preoperative conditions (e.g., diabetes, COPD), wound classification, ASA class, surgery type, emergent surgery, and work RVUs associated with the surgery. This resulted in a risk adjusted difference in relative total costs of $11,876 for the average surgical patient (Table 2).

In the risk adjusted analysis, the costs were 1.25 times greater for patients with superficial SSIs compared with patients without an SSI (95% CI: 1.17, 1.35; risk adjusted mean difference=$7,001). The largest risk adjusted costs were found among patients with deep SSIs. For patients with deep SSIs, the risk adjusted costs were 1.93 times higher than patients without an SSI (95% CI: 1.71, 2.18; risk adjusted mean difference=$25,719) (Table 2).

The five highest volume surgical specialties were general surgery, orthopedic surgery, urology, peripheral vascular surgery and neurosurgery. Of these, the greatest mean cost attributable to SSI was among neurosurgery patients ($23,755). This was followed by orthopedic surgery, general surgery, peripheral vascular surgery, and urology (Table 2).

Next we assessed the cost savings to the VHA if hospitals with high risk-adjusted SSI rates improved. We ranked all included VA hospitals into percentiles according to their risk-adjusted SSI rates. If hospitals in the highest 10th percentile (e.g. worst) reduced their SSI rates to the rates of the 50th percentile, the VHA system would save approximately $6,742,080 in one year. Similarly, if hospitals in the highest 25th percentile reduced their risk-adjusted rates to the 50th percentile, the VHA system would save approximately $11,328,832 in one year. Finally, if hospitals in the highest 50th percentile reduced their SSI rates to exactly the 50th percentile rates, the annual savings to the VHA system would be $13,198,865.

Discussion

In this analysis of large multicenter datasets, we found that SSIs are associated with significantly increased costs. This was especially true for deep SSIs and SSIs after neurosurgery. These results are more conservative than some previously published estimates because the results presented here are adjusted for patient factors, surgical factors, and medical center level factors that could also contribute to increased post-surgical costs.

Three prior studies performed risk adjusted analyses of post-operative complications that included SSIs. In a study of FY2006 VASQIP and DSS data, we found that wound complications (defined as SSI or wound dehiscence or disruption) were associated with a 44% increase in risk adjusted costs after statistically adjusting for facility-level variation in costs and patient characteristics.[11] A study by Dimick et al., found that the attributable costs of post-surgical infectious complications was $1,398 (95% CI: $377, $2,418) after adjusting for procedure complexity, patient characteristics and other complications.[18] The current study extends this research by evaluating the risk adjusted costs of SSIs alone and stratified by deep or superficial SSIs. Both of these prior studies underestimate the costs of SSIs because wound dehiscence was included as an outcome even though wound dehiscence is less severe and requires fewer resources compared with SSIs.

Poultsides et al., analyzed the Agency for Healthcare Research and Quality Healthcare Cost and Utilization Project National Inpatient Sample (AHRQ HCUP NIS) data and found that among primary hip and knee arthroplasty patients, the average cost of in-hospital care was double for SSI versus non-SSI patients.[4] We also found that among orthopedic surgery patients, the postoperative costs nearly doubled. However, our study assessed a wider variety of surgery types.

Our study had several potential limitations. First, the VASQIP data only included patients followed for 30 days post-operatively even though CDC guidelines suggest that patients who receive a surgical implant should be followed for a year.[10] Therefore, our results may underestimate the costs associated with SSIs, particularly for orthopedic operations. However, we do not think this will be a large underestimate since other studies have shown that over 75% of SSIs are detected within 30 days and most SSI manifest within 22 days.[19–23] Second, the costs and burden of superficial SSIs are usually incurred in the outpatient setting and would not be captured in our cost analysis. Thus our analysis is an underestimate of the costs of all SSIs. Similarly, the cost of SSIs may be greater if analyzed from the perspective of society or a patient rather than the current hospital perspective. Third, we utilized VHA datasets, thus it may be inappropriate to generalize our findings outside the VA system. The VA population is generally sicker[24,25] and much more likely to be male compared with the population of private hospitals. Finally, our data do not include information on cardiac operations since these operations are not included in the VASQIP data set.

Although neurosurgery is among the five most common surgery types in this data set and is associated with the highest costs attributable to SSI, cost-benefit analyses should be performed to determine which surgical groups should be targeted for prevention efforts. For example, 40.5% of all SSIs reported to the CDC NHSN were following orthopedic surgery while only 2.4% of reported SSIs were following neurological surgery.[26] Interventions that can be implemented across multiple types of surgery may be ideal for preventing SSIs and their associated costs.

For more than two decades, the VHA has been a leader in implementing strategies to reduce healthcare-associated infections, specifically SSIs.[27,28] For instance, the VHA was involved in the early development of the Surgical Care Improvement Project and the VA implemented the National Surgical Quality Improvement Program (NSQIP, predecessor to VASQIP) before it became widespread in the private sector.[28,29] The proportion of surgical patients with an SSI in our VA cohort is consistent with that among the private sector NSQIP cohort.[30,31] Nonetheless, our results demonstrate that the VHA could financially benefit if they continued to implement additional strategies to prevent SSIs.

In conclusion, SSIs are associated with a significant increase in attributable post-surgical costs, even after adjusting for patient-level, surgical-level and facility-level factors. These increases in costs were highest among deep SSIs and neurosurgery. Hospital administration, policy makers, surgeons and hospital epidemiologists can use these data to make a business case for quality improvement efforts focused on SSIs.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1:

Characteristics of the Study Population by Surgical Site Infection

	SSI (n=1,756)	**No SSI (n=52,477)**	***P* Value**
Mean Age (SD)	63.24 (10.76)	62.98 (12.11)	0.38
Female Gender	96 (5.47%)	3,208 (6.11%)	0.27
Surgery Type			
General	888 (50.57%)	14,576 (27.78%)	
Neurosurgery	61 (3.47%)	4,214 (8.03%)	
Orthopedic	206 (11.73%)	13,422 (25.58%)	
Peripheral Vascular	355 (20.22%)	7,462 (14.22%)	
Urology	83 (4.73%)	6,192 (11.80%)	
Oral Surgery	2 (0.11%)	108 (0.20%)	<0.01
Otolaryngology	43 (2.45%)	1,708 (3.25%)	
Plastic Surgery	37 (2.11%)	811 (1.55%)	
Podiatry	11 (0.63%)	388 (0.74%)	
Thoracic Surgery	44 (2.50%)	2,707 (5.16%)	
Other	26 (1.48%)	889 (1.69%)	
Emergent Surgery	219 (12.47%)	5,209 (9.93%)	<0.01
Pre-operative conditions			
Alcohol use (>2 drinks per day)	170 (9.68%)	4,293 (8.18%)	0.02
History of diabetes	301 (17.14%)	6,228 (11.87%)	<0.01
History of chronic obstructive pulmonary disease	354 (20.16%)	8,230 (15.68%)	<0.01
History of rest pain/Gangrene	201 (11.45%)	2,773 (5.28%)	<0.01
History of myocardial infarction	15 (0.85%)	393 (0.75%)	0.62
Sepsis in 48 hours prior to surgery	58 (3.30%)	1,451 (2.77%)	0.18
Current pneumonia	12 (0.68%)	489 (0.93%)	0.28
Weight Loss[a]	103 (5.87%)	2,057 (3.92%)	<0.01
History of angina in 30 days prior to surgery	36 (2.05%)	711 (1.35%)	0.01
Bleeding Disorder	141 (8.03%)	3,561 (6.79%)	0.04
Congestive heart failure in 30 days prior to surgery	33 (1.88%)	603 (1.15%)	<0.01
Steroid use in 30 days prior to surgery	44 (2.51%)	1,264 (2.41%)	0.79
Acute renal failure	12 (0.68%)	364 (0.69%)	0.96
Dialysis in 2 weeks prior to surgery	32 (1.82%)	1,061 (2.02%)	0.56
Ventilator dependent in 48 hours prior to surgery	10 (0.57%)	428 (0.82%)	0.25
Ascites	16 (0.91%)	445 (0.85%)	0.78
Preoperative Laboratory Tests			
Mean hematocrit, % (SD)	38.66 (6.02)	39.36 (5.91)	<0.01
Mean serum albumin, g/dl (SD)	3.68 (0.75)	3.77 (0.97)	<0.01
Mean White Blood Count (WBC), X 1000/mm^3 (SD)	8.62 (3.75)	8.31 (4.35)	<0.01

	SSI (n=1,756)	**No SSI (n=52,477)**	***P* Value**
Mean Blood Urea Nitrogen (BUN), mg/dl (SD)	17.34 (10.60)	17.79 (10.66)	0.09
Mean Partial thromboplastin time, seconds (SD)	32.01 (11.14)	31.19 (8.97)	<0.01
Mean bilirubin, mg/dl (SD)	0.73 (0.65)	0.75 (0.93)	0.34
ASA Class			
1–2	247 (14.07%)	10,590 (20.18%)	
3	1,180 (67.24%)	34,411 (65.58%)	<0.01
4–5	328 (18.69%)	7,470 (14.24%)	
Wound Classification			
Clean	634 (36.10%)	28,888 (55.05%)	
Clean/Contaminated	794 (45.22%)	17,161 (32.70%)	<0.01
Contaminated	183 (10.42%)	2,874 (5.48%)	
Dirty/Infected	145 (8.26%)	3,554 (6.77%)	

[a] Loss of >10% body weight in last six months

[b] All of the variables in Table 1 were assessed for inclusion in the multivariable model

Table 2:

Relative Total Costs Difference of SSI compared with no SSI (US Dollars)

	Total Cost (SD)	Unadjusted Cost Difference (95% CI)	Risk-adjusted Cost Difference
Any SSI	$52,620 (SD=47,730)	$21,040 (18,785–23,295)	$11,876
BY DEPTH OF SSI:			
Superficial SSI	$45,306 (SD=42,231)	$13,726 (11,408–16,043)	$7,003
Deep SSI	$73,533 (SD=55,751)	$41,952 (36,807–47,098)	$25,721
BY SURGICAL CATEGORY:			
Neurosurgery	$48,429 (SD=51,720)	$17,896 (4,615–31,178)	$23,755
Orthopedic	$48,123 (SD=37,259)	$19,499 (14,365–24,632)	$15,243
General Surgery	$56,052 (SD= 48,502)	$20,649 (17,381–23,917)	$10,849
Peripheral Vascular	$46,976 (SD= 47,007)	$15,380 (10,405–20,356)	$7,354
Urology	$42,575 (SD= 40,583)	$22,198 (13,315–31,081)	$4,842