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ORIGINAL ARTICLE

Outcomes are Local: Patient, Disease, and Procedure-Specific Risk Factors for Colorectal Surgical Site Infections from a Single Institution

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Abstract

Background Colorectal surgical site infections (SSIs) contribute to postoperative morbidity, mortality, and resource utilization. Risk factors associated with colorectal SSI are well-documented. However, quality improvement efforts are informed by national data, which may not identify institution-specific risk factors.

Method Retrospective cohort study of colorectal surgery patients uses institutional ACS-NSQIP data from 2006 through 2014. ACS-NSQIP data were enhanced with additional variables from medical records. Multivariable logistic regression identified factors associated with SSI development.

Results Of 2376 patients, 213 (9.0%) developed at least one SSI (superficial 4.8%, deep 1.1%, organ space 3.5%). Age < 40, BMI > 30, ASA3+, steroid use, smoking, diabetes, pre-operative sepsis, higher wound class, elevated WBC or serum glutamic-oxalocetic transaminase, low hematocrit or albumin, Crohn's disease, and prolonged incision-to-closure time were associated with increased SSI rate (all $P < 0.01$). After adjustment, BMI > 30, steroids, diabetes, and wound contamination were associated with SSI. Patients with Crohn's had greater odds of SSI than other indications.

Conclusion Institutional modeling of SSI suggests that many previously suggested risk factors established on a national level do not contribute to SSIs at our institution. Identification of institution-specific predictors of SSI, rather than relying upon conclusions derived from external data, is a critical endeavor in facilitating quality improvement and maximizing value of quality investments.

Keywords Colorectal surgery · Modeling · Quality improvement · Surgical outcomes · Surgical site infection

Introduction

Surgical site infections (SSIs) are the most common hospital-acquired infection in surgical patients.[1] SSIs result in significant postoperative morbidity, increased mortality, and excess resource utilization.[2,3] In a 1-day prevalence study of inpatients at nine acute-care hospitals in northern Florida, SSIs represented almost one-third of the hospital-acquired infections.[4] According to de Lissovoy and colleagues, SSIs associated with seven major categories of surgical procedures performed in the USA are estimated to be responsible for $1.6 billion in additional direct costs and nearly 1 million excess hospital days.[5] The impact of SSIs on both patients and the

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healthcare system has made SSI reduction a priority of surgeons, hospitals, governments, and payers.[6]

The SSI rates reported in the literature vary greatly according to specialty and type of procedure. A consistent finding, however, is that colorectal surgery (CRS) is associated with one of the highest SSI rates.[7] An elevated CRS SSI rate might be expected because of the nature of the colon and the associated potential for intraoperative and postoperative contamination. However, the large variation in reported CRS SSI rates, ranging from 5% to as high as 48%,[8,9] speaks to the complex interplay between patient-specific, disease-specific, technical, and system of care elements that contribute to SSI development.[10–12] Given the complexity of CRS SSI development, identification of a single or handful of interventions applied universally that will reduce the incidence of SSI seems unlikely. Prior risk prediction models have been based on simple factors such as operative approach, duration of operation, and wound classification, or American Society of Anesthesiologists (ASA), which can be subjective.[7,13–16] However, these models have questionable external validity when applied to data other than what was used for model development.[17] Therefore, institutional efforts to reduce CRS SSIs are best served by a detailed understanding of the factors that contribute to SSIs in the local system of care.[18]

In this study, we performed a retrospective cohort analysis of our prospectively collected institutional colorectal American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) dataset to identify risk factors associated with the development of SSIs within 30 days of procedure. To enrich the data, we combined elements of institutionally maintained data to provide CRS procedure-specific elements not captured in the ACS-NSQIP. Using these findings, we aimed to better delineate risk factors that could drive tailored SSI reduction interventions at our institution.

Methods

The ACS-NSQIP is a well described and validated clinical database used to assess and improve surgical quality of care.[19] Our institutional ACS-NSQIP dataset is an ACS-defined systematic sample of non-transplant and cardiac surgical patients, including approximately 15–20% of patients undergoing CRS at our institution. Trained clinical abstractors using a standardized sampling methodology collect patient-specific, disease-related, and intra-operative variables. These patients are then actively followed for 30 days to detect postoperative complications. The methodology for sampling and data structure for ACS-NSQIP as well as the auditing process have been detailed previously.[20] These data are then provided to providers and hospitals as individual events as well as risk-adjusted against the national data submitted by participating hospitals. Using this information, local quality improvement efforts can be initiated and tracked over time. Participation in ACS-NSQIP has been associated with improved clinical outcomes and reduced cost of care.[21,22]

We identified all elective colorectal operations performed by the Division of Colon and Rectal Surgery at a tertiary-care academic medical center in the upper Midwest (Mayo Clinic Hospital, Methodist Campus) from April 2006 through June 2014 that were included in the institutional ACS-NSQIP data. Ten board-certified colorectal surgeons staffed all the procedures with general surgery residents or CRS fellows. During this reporting period, the division's practice was not to use any mechanical bowel preparation or oral antibiotics. All patients received intravenous antibiotics according to the national SCIP-guidelines within 60 min of incision and with discontinuation of antibiotics within 24 hours of incision. Postoperative care was routinely provided on two dedicated CRS nursing floors using standardized clinical pathways. We excluded patients who declined to participate in research ($n = 51$) or had incomplete data ($n = 15$).

The primary outcome of interest was the development of an SSI according to the classification scheme used by ACS-NSQIP: superficial, deep, or organ space. Potential predictors of SSI including demographic variables, health behaviors, comorbidities, and functional status were identified from the ACS-NSQIP data. We grouped diagnoses into six categories: colon cancer, rectal cancer, ulcerative colitis, Crohn's disease, diverticular disease, and other (polyp or polyposis syndrome, other cancers, other). Ulcerative colitis and Crohn's disease were also grouped as inflammatory bowel disease (IBD) for descriptive purposes. Procedures were identified by current procedural terminology codes provided in the ACS-NSQIP data, and those with current procedural terminology codes lacking specificity underwent chart review to better define the procedure(s). Procedures were categorized into the following groups: right colectomy, left colectomy, left colectomy with rectal procedure, total colectomy, total colectomy with rectal procedure, rectal procedure, ileal pouch-anal anastomosis, or abdominoperineal resection. Separate variables were constructed to identify open or laparoscopic procedures and colon only versus colorectal subgroups.

Statistical Analysis

We compared the rates of SSI across categorical patient factors using Chi-square tests or Fisher's exact tests when low expected cell counts were observed. The association of continuous patient factors with SSI was assessed with two-sample t tests or non-parametric rank sum tests when data were not normally distributed.

Using multivariable logistic regression, we tested for associations between patient and clinical factors and the development of a SSI. Due to the close interrelations between many

variables (including indication, age, steroid use, and procedure), we faced issues with co-linearity. For example, patients under 40 years of age had the highest unadjusted rate of SSI, as did patients with Crohn's disease, ulcerative colitis, and those who were on steroid medications. We recognize that IBD patients are frequently young and present for surgery on many immunosuppressive medications including steroids. After comparisons of multiple multivariable models, constructed with and without stepwise selection and with and without forcing any variables into the model, we chose to use stepwise selection without forcing any variables into the model (using a significance level of 0.10 for both entering effects and removing effects). Further, upon model review, non-Crohn's diagnoses had similar associations with SSI, so we collapsed the diagnosis category into Crohn's disease versus any other. Differences in predictors of superficial versus deep/organ space SSI were further investigated using the same model as for the analysis of any SSI.

A P value of less than 0.05 was considered statistically significant. The Mayo Clinic Institutional Review Board approved this study. SAS version 9.4 (SAS Institute, Cary, NC) was used for analysis.

Results

From April 2006 through June 2014, all 2376 patients meeting our criteria were selected. The median age was 58 years (interquartile range 44, 70). Roughly half (48.7%) were women and 27.5% of patients were obese (body mass index [BMI] of 30 or higher). Most patients had either colorectal cancer (38.0%) or IBD (26.6%, including 15.7% ulcerative colitis and 10.9% Crohn's). Stomas were common (43.8%) and included both ileostomies (32.5%) and colostomies (11.3%), while laparoscopic procedures accounted for just over half the cases (52.9%). Median operative time for all cases (including both laparoscopic and open procedures) was 186 min (interquartile range 136, 249).

Nine percent of patients (n = 213) developed one or more SSI: 4.8% superficial, 1.1% deep, and 3.5% organ space. Ten patients developed more than one type of SSI (n = 2 deep and organ space; n = 8 superficial and organ space). Due to the small number of patients experiencing a deep SSI, deep SSIs were grouped with organ space SSIs for analysis.

On univariate analysis, development of SSI varied across patient factors (Table 1). Patients at higher risk included those age <40, obese, American Society of Anesthesiologists (ASA) classification system 3 or 4, steroid users, smokers, and patients with diabetes, pre-operative sepsis, higher wound class, elevated white blood count or serum glutamic oxaloacetic transaminase (SGOT), or low hematocrit or albumin (all $P < 0.05$). Rates of SSI varied significantly by diagnosis ($P = 0.01$); patients with Crohn's disease had the highest rate of SSI (13.9%) and those with rectal cancer the lowest rate (7.0%).The SSIs were more common in open cases than laparoscopic cases (11.7 vs 6.5%; $P < 0.01$), and patients who developed an SSI had a longer median operative duration (215 vs 184 min; $P < 0.01$). Finally, the presence of a stoma at the end of the operation whether existing or newly constructed was associated with a higher rate of SSI (11.0 vs 7.3%; $P < 0.01$).

Upon multivariable analysis adjusting for procedure type and year of operation, patients with open procedures, a BMI of 30 or greater, ASA class of 3 or 4, hematocrit less than 38, SGOT of 40 or greater, diabetes, wound class IV versus I-II, and steroid users all had increased odds of any SSI ($P < 0.05$; Fig. 1 and Table 2). Patients with Crohn's disease were more likely to develop an SSI than patients with other operative indications (odds ratio [OR] 1.64; 95% confidence interval [CI] 1.02–2.64; $P = 0.04$). Neither smoking nor the use of antihypertensive agents was found to be associated with any SSI. Age and the presence of a stoma were not chosen by the stepwise selection as important risk factors to include in the model.

We repeated the multivariable model outlined above for the superficial SSI outcome (Fig. 1 and Table 2). The variables with a statistically significant odds ratio for superficial SSI were obese versus non-obese (OR 2.14; 95% CI, 1.40–3.29; $P < 0.01$), ASA class of 3–4 versus 1–2 (OR 1.69; 95% CI, 1.08–2.64; $P = 0.02$), steroid use (OR 1.72; 95% CI, 1.01–2.93; $P = 0.04$), hematocrit <38 (OR 1.58; 95% CI, 1.01–2.46; $P = 0.04$), unknown hematocrit (OR 3.04; 95% CI, 1.47–6.30; $P < 0.01$), and SGOT of 40 or greater (OR 2.24; 95% CI, 1.20–4.21; $P = 0.01$). The operative approach was not independently associated with superficial SSI ($P = 0.87$).

However, in a model predicting deep/organ space SSI, open procedures did have greater odds than laparoscopic procedures (OR 2.46; 95% CI, 1.47–4.11; $P < 0.01$; Fig. 1) as did steroid use (OR 1.86; 95% CI, 1.09–3.19; $P = 0.02$) and diabetes (OR 3.80; 95% CI, 2.08–6.94; $P < 0.01$) and wound class IV versus I-II (OR 3.63; 95% CI, 2.04–6.47; $P < 0.01$). Other variables with a statistically significant OR for deep/organ space SSI, but not overall or superficial SSI, were hypertension (OR 0.58; 95% CI, 0.34–0.99; $P = 0.046$) and smoking (OR 1.78; 95% CI, 1.05–3.00; $P = 0.03$).

Discussion

An analysis of SSI outcomes in 2376 CRS patients from a single institution's ACS-NSQIP data set demonstrated that many of the colorectal-specific SSI risk factors previously established by national or other large single institution reports were not confirmed as contributing to SSIs in our institution (Table 3). Beyond the basic established SSI drivers (ASA class, wound classification, steroid use, BMI, and diabetes),

Table 1 Pre-operative and operative factors by any surgical site infection

	No SSI *n* = 2163 (91.04%)	SSI *n* = 213 (8.96%)	*P* value
Age, median (IQR)	58 (44, 70)	56 (36, 68)	0.002
Age, category			0.02
<40	420 (87.5)	60 (12.5)	
40–54	490 (91.9)	43 (8.1)	
55–64	448 (90.5)	47 (9.5)	
65–74	451 (91.9)	40 (8.1)	
75+	354 (93.9)	23 (6.1)	
Sex			0.74
Male	1112 (91.2)	107 (8.8)	
Female	1051 (90.8)	106 (9.2)	
BMI[a]			0.01
<30	1579 (91.9)	139 (8.1)	
30+	578 (88.7)	74 (11.3)	
Race			0.36
Non-Hispanic white	1905 (91.2)	183 (8.8)	
Other or unknown	258 (89.6)	30 (10.4)	
ASA			0.02
I or II	1465 (92.0)	127 (8.0)	
III or IV	698 (89.0)	86 (11.0)	
Hypertension[c]			0.19
No	1396 (90.5)	147 (9.5)	
Yes	767 (92.1)	66 (7.9)	
Steroid use[d]			<0.001
No	1830 (92.1)	156 (7.9)	
Yes	333 (85.4)	57 (14.6)	
Current smoker			0.02
No	1908 (91.6)	176 (8.4)	
Yes	255 (87.3)	37 (12.7)	
Diabetes mellitus			<0.001
No	1981 (91.7)	180 (8.3)	
Yes	182 (84.7)	33 (15.3)	
SIRS/Sepsis/Septic Shock[a]			<0.001
No	2103 (91.4)	197 (8.6)	
Yes	51 (78.5)	14 (21.5)	
Wound classification			<0.001
Clean, Clean/Contaminated	1948 (92.1)	166 (7.9)	
Contaminated	96 (87.3)	14 (12.7)	
Dirty/Infected	119 (78.3)	33 (21.7)	
Disseminated cancer			
No	2065 (91.3)	198 (8.7)	0.10
Yes	98 (86.7)	15 (13.3)	
WBC[a,b]			0.003
<11	1792 (92.0)	156 (8.0)	
11+	206 (86.2)	33 (13.8)	
Hematocrit[a,b]			<0.001
<38	919 (89.2)	111 (10.8)	
38+	1078 (93.3)	78 (6.7)	
Serum albumin[a,b]			<0.001
<3.5	166 (84.3)	31 (15.7)	
3.5+	894 (92.4)	74 (7.6)	

Table 1 (continued)

	No SSI *n* = 2163 (91.04%)	SSI *n* = 213 (8.96%)	*P* value
SGOT[a,b]			0.02
<40	1444 (92.0)	125 (8.0)	
40+	130 (86.7)	20 (13.3)	
Diagnosis			0.01
Colon cancer	481 (92.9)	37 (7.1)	
Rectal cancer	358 (93.0)	27 (7.0)	
Ulcerative colitis	331 (88.5)	43 (11.5)	
Crohn's	223 (86.1)	36 (13.9)	
Diverticular disease	281 (91.5)	26 (8.5)	
Other	489 (91.7)	44 (8.3)	
Operative approach			<0.001
Laparoscopic	1174 (93.5)	82 (6.5)	
Open	989 (88.3)	131 (11.7)	
Operative time, median (IQR)	184 (134,246)	215 (150, 274)	<0.001
Operative time, category			<0.001
≤2 h 14 min	551 (94.5)	32 (5.5)	
2 h 15 min to 2 h 59 min	471 (90.1)	52 (9.9)	
3 h - 3 h 59min	558 (92.1)	48 (7.9)	
≥4 h	583 (87.8)	81 (12.2)	
Stoma, any			0.002
No	1237 (92.7)	98 (7.3)	
Yes	926 (89.0)	115 (11.0)	
Stoma, type			0.007
No stoma	1237 (92.7)	98 (7.3)	
Ileostomy	689 (89.1)	84 (10.9)	
Colostomy	237 (88.4)	31 (11.6)	
Procedure type			<0.001
Right	628 (93.3)	45 (6.7)	
Left	123 (88.5)	16 (11.5)	
Left with rectal	679 (93.7)	46 (6.3)	
Total	239 (86.3)	38 (13.7)	
Total with rectal	42 (89.4)	5 (10.6)	
Rectal	102 (82.3)	22 (17.7)	
IPAA	152 (89.4)	18 (10.6)	
APR	198 (89.6)	23 (10.4)	
Total RVU, Median (IQR)	35.5 (30.0, 48.7)	36.9 (30.8, 52.0)	0.02

BMI body mass index, *APR* abdominal perineal resection, *ASA* American Society of Anesthesiologists, *h* hour, *IPAA* ileal pouch-anal anastomosis, *IQR* interquartile range, *min* minute, *RVU* relative value unit, *SIRS* systemic inflammatory response syndrome, *WBC* white blood cell count, *SGOT* serum glutamic-oxaloacetic transaminase, *SSI* surgical site infection

[a] Variables with missing values: BMI (*N* = 6), systemic sepsis (*N* = 11), WBC (*N* = 189), and hematocrit (*N* = 190)

[b] WBC (*N* = 189) and hematocrit (*N* = 190), serum albumin (*N* = 1211), SGOT (*N* = 657), pre-operative

[c] Requiring medication

[d] For chronic condition

we observed in our institutional data that the underlying diagnosis was the primary driver of SSI rather than other reported patient or technical factors. These findings suggest that there is a complex interaction between local systems of care, patient-specific, and technical factors that may independently influence SSI occurrence after colorectal surgery at individual institutions. If true, this raises concerns regarding making inter-institutional comparisons of CRS SSI rates using predictive

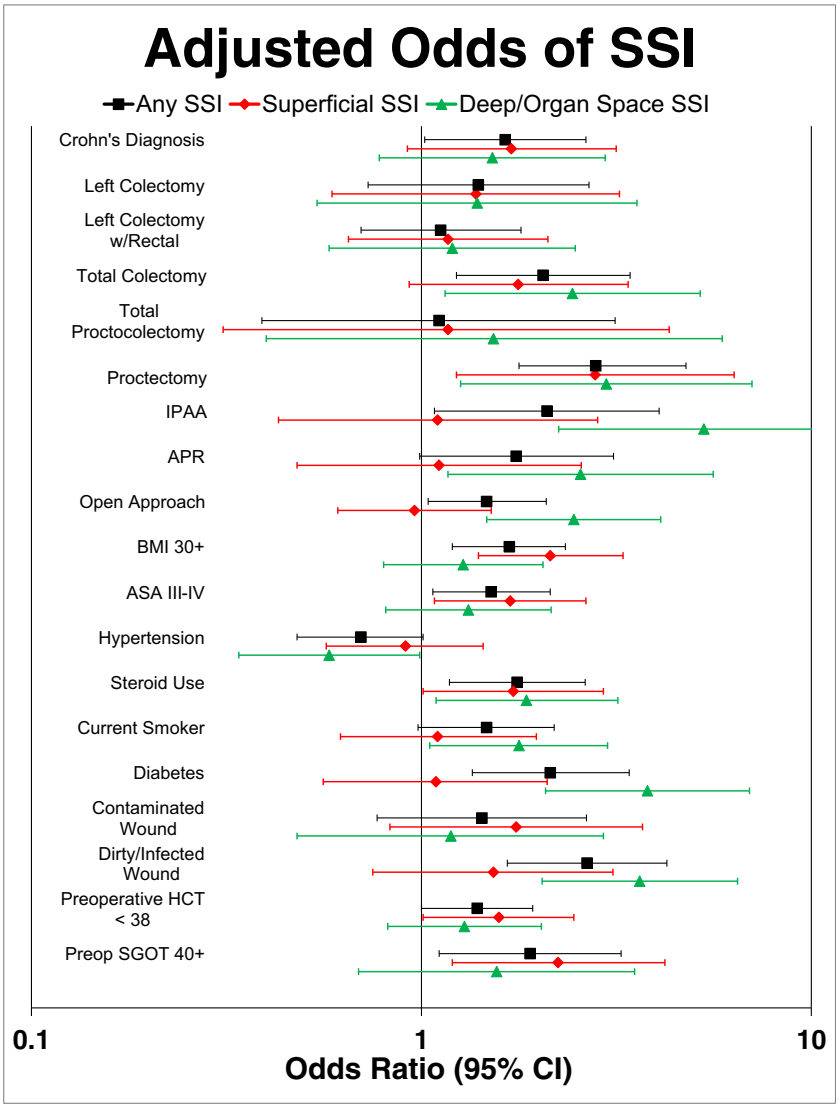

Fig. 1 Multivariable model of predictors of any, superficial, and deep/organ space SSI from Our Institutional Data Abbreviations: *APR* abdominal perineal resection, *ASA* American Society of Anesthesiologists, *CI* confidence interval, *HCT* hematocrit, *IPAA* ileal pouch-anal anastomosis, *OR* odds ratio, *SGOT* serum glutamic-oxaloacetic transaminase, *SSI* surgical site infection

models derived from national data that are unable to account for these numerous complex delivery system interactions despite patient and procedure level risk adjustment.

The rate of SSI in our institutional data is somewhat lower than previously reported in national ACS-NSQIP data (9 vs 13%).[12] We found in our practice that the diagnosis of Crohn's disease had the highest odds of SSI development among diagnostic indications and was an independent predictor of SSI development compared to all other indications for colorectal surgery which is contrary to prior SSI modeling studies using data from Europe[23] and the USA. This is interesting to note because while our overall SSI rate is lower than the national benchmark, our proportion of IBD, especially Crohn's, is significantly higher than reported in ACS-NSQIP, 27 versus 7%, respectively.[12] Additionally, multiple institutional studies have failed to show a similar disease specific association.[24,25]

In our experience, frequently reported risk factors for colorectal SSI such as gender and presence of a stoma were not identified as important risk factors. However, this should not be surprising because across the literature on colorectal SSI from individual institutions and large registries, there are frequently conflicting risk factors identified. For example, Morikane et al., using the Japanese national surveillance data set, identified male sex and placement of an ostomy as strongly predictive of a SSI after colorectal surgery[26] while Pedroso-Fernandez et al. found that female sex, contaminated/dirty wounds, and open surgery were the strongest predictors of CRS SSI at their institution but not ostomies.[27] Other contradictory evidence include the location of resection, with some authors reporting that left-sided resections have a higher rate of SSI as compared to right-sided resections, while others found no difference.[28,29] As recent works report, there are different risk factor profiles for the different types of SSI

Table 2 Multivariable logistic regression of any, superficial, deep/organ space surgical site infection

	Any SSI		Superficial SSI		Deep/organ space SSI	
	OR (95% CI)	*P* Value	OR (95% CI)	*P* Value	OR (95% CI)	*P* value
Diagnosis Crohn's (Ref. Other)	1.64 (1.02–2.64)	0.04	1.70 (0.92–3.16)	0.09	1.52 (0.78–2.96)	0.21
Procedure Type (Ref. Right)						
Left vs Right	1.40 (0.73–2.69)	0.31	1.38 (0.59–3.22)	0.46	1.39 (0.54–3.57)	0.49
Left with rectal vs Right	1.12 (0.70–1.80)	0.64	1.17 (0.65–2.11)	0.60	1.20 (0.58–2.48)	0.63
Total vs Right	2.05 (1.23–3.43)	0.006	1.77 (0.93–3.39)	0.09	2.44 (1.15–5.19)	0.02
Total with rectal vs Right	1.11 (0.39–3.14)	0.85	1.17 (0.31–4.32)	0.82	1.53 (0.40–5.91)	0.54
Rectal vs Right	2.80 (1.50–5.23)	0.001	2.79 (1.23–6.34)	0.01	2.98 (1.26–7.04)	0.01
IPAA vs Right	2.10 (1.08–4.07)	0.03	1.10 (0.43–2.83)	0.85	5.30 (2.25–12.51)	<0.001
APR vs Right	1.75 (0.99–3.11)	0.06	1.11 (0.48–2.57)	0.82	2.56 (1.17–5.60)	0.02
Open Approach (Ref. Lap)	1.47 (1.04–2.09)	0.03	0.96 (0.61–1.51)	0.87	2.46 (1.47–4.11)	<0.001
BMI 30+ (Ref. <30/unknown)	1.68 (1.20–2.34)	0.002	2.14 (1.40–3.29)	<0.001	1.28 (0.80–2.05)	0.31
ASA III-IV (Ref. I-II)	1.51 (1.07–2.14)	0.02	1.69 (1.08–2.64)	0.02	1.32 (0.81–2.15)	0.26
Hypertension (Ref. no)	0.70 (0.48–1.01)	0.05	0.91 (0.57–1.44)	0.67	0.58 (0.34–0.99)	0.046
Steroid use (Ref. no)	1.76 (1.18–2.63)	0.006	1.72 (1.01–2.93)	0.04	1.86 (1.09–3.19)	0.02
Current smoker (Ref. no)	1.47 (0.98–2.19)	0.06	1.10 (0.62–1.97)	0.74	1.78 (1.05–3.00)	0.03
Diabetes (Ref. no)	2.14 (1.35–3.41)	0.001	1.09 (0.56–2.10)	0.80	3.80 (2.08–6.94)	<0.001
Wound Class (Ref. Clean, Clean/Contaminated)						
Contaminated(III)	1.43 (0.77–2.65)	0.26	1.75 (0.83–3.69)	0.14	1.19 (0.48–2.93)	0.71
Dirty/Infected (IV)	2.66 (1.66–4.26)	<0.001	1.53 (0.75–3.10)	0.24	3.63 (2.04–6.47)	<0.001
Hematocrit[a,b] (Ref. 38+)						
<38	1.39 (1.00–1.93)	0.048	1.58 (1.01–2.46)	0.04	1.29 (0.82–2.03)	0.27
Unknown	1.82 (1.04–3.19)	0.04	3.04 (1.47–6.30)	0.003	1.23 (0.57–2.70)	0.60
SGOT[a] (Ref. <40)						
40+	1.90 (1.11–3.25)	0.02	2.24 (1.20–4.21)	0.01	1.56 (0.69–3.52)	0.28
Unknown	1.32 (0.92–1.91)	0.14	0.89 (0.53–1.50)	0.66	1.83 (1.13–2.98)	0.02

Adjusted for year of operation

BMI body mass index, *APR* abdominal perineal resection, *ASA* American Society of Anesthesiologists, I*PAA* ileal pouch-anal anastomosis, *Ref.* reference, *SGOT* serum glutamic-oxaloacetic transaminase, *SSI* surgical site infection, *vs* versus

[a] Pre-operative

(superficial, deep, and organ space).[30,31] While we also found varying profiles in our data, again we found differences to previously published models. In the previous reports, a minimally invasive approach was associated with a decreased risk of all SSI types; surprisingly, we found no association between open or minimally invasive approach for superficial SSIs. We only saw a higher risk deep/organ space SSIs associated with an open approach.

Despite the large number of patients evaluated, the primary limitation of this study is that it represents the practice outcomes of a single institution**;** this is somewhat by design given that our primary goal was to determine driving forces of colorectal SSI occurrence in our practice while comparing it to a national benchmark, ACS-NSQIP. Although the methodology of this study is generalizable and could be used by others to aid in the development of an institutional-specific SSI model, the results and learning of risk factors we report for our practice should not be directly applied to other institutional practice as case mix, technical, and hospital system factors may differ substantially. Our institution has a unique surgical population and associated risk factors, and therefore, these results are not necessarily appropriate for application to other institutions as demonstrated by our lack of concordance on validation with the national data on many important risk factors. We know that modeling SSI occurrence is complicated by numerous factors associated with SSI occurrence that differ between institutions[10–12] and that variations in case mix further confound the true SSI picture.[32] This creates a substantial challenge for national quality improvement initiatives to provide actionable practice level data to individual participating institutions hoping to reduce their institutional SSI rates.

The difference in institution specific case mix and other institutional specific risk factors suggests that caution should be used when interpreting institutional performance against a

Table 3 Comparison of model inclusion and adjusted odds ratios for selected risk factors for any surgical site infection across ACS-NSQIP studies

	Mayo Clinic in Rochester[a]	Kiran et al.[36b]	Segal et al.[31c]	Lawson et al.[30d]
Population	Institutional ACS-NSQIP Elective Colorectal Surgery	National ACS-NSQIP Colorectal Surgery	National ACS-NSQIP Colon Surgery	National ACS-NSQIP Colon Surgery
Timeframe	Apr 2006–Jun 2014	2006–2007	2007–2009	2011
Open vs Laparoscopic Approach	1.47 (1.04–2.09)	1.62 (1.39–1.90)	1.52[e] (1.43–1.61)	1.74[e] $P < 0.001$
BMI	BMI of 30+ vs. under/unknown: 1.68 (1.20–2.34)	Per 5-unit increase 1.16 (1.10–1.22)	BMI of 30–34.99 vs. 18.50–24.99 1.45 (1.34–1.57)	BMI of 30–34.9 vs. 18.5–24.9 1.38 $P < 0.001$
Smoking	1.47 (0.98–2.19) (Non Significant)	1.21 (1.02–1.44)	1.10 (1.03–1.17)	1.23 $P < 0.001$
Diabetes	2.14 (1.35–3.41)	1.25 (1.03–1.52)	Not included in model	Diabetes requiring insulin vs. none 1.10 $P = 0.28$
Steroid use	1.76 (1.18–2.63)	0.89 (0.67–1.17) (Non Significant)	1.13 (1.02–1.25)	1.05 $P = 0.55$ (Non Significant)
Operation time	Not included in model	180+ minutes vs. <180 min 1.42 (1.22–1.62)	Per hour increase 1.17 (1.16–1.19)	Not included in model
Diagnosis	Crohn's disease vs. other 1.64 (1.02–2.64)	Regional enteritis vs. benign neoplasm 1.55 (1.17–2.29)	Enteritis or colitis vs. neoplasm 1.14 (1.00–1.29)	Ulcerative colitis/ Crohn disease vs. benign neoplasm 1.36 $P < 0.01$
Preoperative Hematocrit <38 vs. 38+	1.39 (1.00–1.93)	Not included in model	Not included in model	Not included in model
Preoperative SGOT 40+ vs <40	1.90 (1.11–3.25)	Not included in model	Not included in model	Not included in model
Male vs female	Not included in model	Not included in model	1.08(1.02–1.14)	1.10 $P = 0.02$
Alcohol >2 drinks/-day	Not included in model	Not included in model	1.23 (1.08–1.40)	0.98 $P = 0.92$ (Non Significant)
COPD	Not included in model	Not included in model	1.12 (1.01–1.23)	1.09 $P = 0.34$ (Non Significant)
Dependent Functional Status	Not included in model	Not included in model	1.12 (1.03–1.22)	0.60 $P = 0.01$
Weight loss >10% within 6 Mo	Not included in model	Not included in model	1.14 (1.03–1.27)	0.97 $P = 0.72$ (Non Significant)
Preoperative Platelets 100	Not included in model	Not included in model	1.04 (1.02–1.06)	Not included in model
Renal Failure	Not included in model	Not included in model	Not included in model	0.60 $P = 0.005$
Congestive Heart Failure	Not included in model	Not included in model	Not included in model	0.66 $P = 0.05$
Disseminated Cancer	Not included in model	Not included in model	Not included in model	1.28 $P = 0.004$

Table 3 (continued)

	Mayo Clinic in Rochester[a]	Kiran et al.[36b]	Segal et al.[31c]	Lawson et al.[30d]
Preoperative Blood Transfusion	Not included in model	Not included in model	Not included in model	1.26 $P = 0.02$

Other statistically-significant predictors include:

BMI body mass index, *ASA* American Society of Anesthesiologists, *Ref.* reference, *SGOT* serum glutamic-oxaloacetic transaminase, *SSI* surgical site infection, *vs* versus

[a] ASA, procedure type, wound class

[b] ASA, age, ACS-NSQIP morbidity probability, procedure type

[c] ASA, age, wound class, pre-operative sepsis

[d] ASA, age, wound class, pre-operative sepsis

[e] Inverse reported in cited work

model developed using data from a national source or from outside that institution. Furthermore, review of institutional data at a more granular level, including at the surgeon level, is important to ensure the highest quality outcomes. Taken together, development of colorectal SSI is most likely associated with a unique set of contributing factors at each institution.[10,11,14] This suggests that a 'one-size-fits-all' approach to understanding the risk factors that drive SSIs in individual hospitals should not be expected to be highly reliable and makes the validity of using such data for inter-hospital comparisons questionable. More importantly, it also makes nationally directed interventions at reducing SSI and linking an expectation of performance-based compliance with these efforts problematic. The failure of the Surgical Care Improvement Program (SCIP) to achieve the dramatic SSI reduction that were expected from the initial trial is well documented.[33,34]

Institutionally based quality improvement initiatives to reduce SSI have shown promise—in particular with the involvement of a multidisciplinary team tasked with developing quality improvement interventions across all phases of care.[18] In our own institution, we have seen a substantial reduction in the rate of SSI through such an approach. One key point with any risk reduction initiative is that many of the SSI risk factors, which have been established previously and in the current study, are not modifiable. The patient's indication for surgery, ASA class, wound classification, and the operative duration is in most cases fixed. However, in an effort to change outcomes, surgeons may need to consider approaches to surgical management that might impact SSI outcomes. For example, Zittan et al. reported that changing their institutional surgical approach for chronic ulcerative colitis from the traditional two-staged approach, total proctocolectomy with ileal pouch anal anastomosis (IPAA), and diverting loop ileostomy, to a modified two-stage approach, subtotal colectomy with ileostomy followed by a proctectomy with IPAA with no diverting ileostomy, reduced the rate of anastomotic leaks and associated infections from 15.7 to 4.6%.[35] This highlights the importance of an institution using their own data to develop models of their specific SSI occurrence permitting tailored reduction approaches or exploring alternate surgical management decisions in high-risk patient in an attempt to SSI reduction efforts.

Conclusions

Using institutional data focused on postoperative outcomes within 30 days, a number of risk factors previously reported to be predictors of colorectal SSI were not confirmed at our high volume institution. Furthermore, some known risk factors were important in specific types of cases but not in others. We believe that determining institution-specific risk factors, rather than just assuming that reported risk factors are applicable at a single institution, is essential to driving local SSI reduction efforts. These findings suggest that local institution system of care and case mix factors significantly and independently influence outcomes, thus rendering inter-institutional comparisons using models based on national data problematic. Focusing on mitigating nationally reported risk factors or implementing specific interventions developed elsewhere may not be useful at an individual institution.

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Compliance with Ethical Standards

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