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Predictors and costs of surgical site infections in patients with endometrial cancer☆,,☆☆

Jamie N. Bakkum-Gamez[a,*], **Sean C. Dowdy**[a], **Bijan J. Borah**[b], **Lindsey R. Haas**[b], **Andrea Mariani**[a], **Janice R. Martin**[a], **Amy L. Weaver**[c], **Michaela E. McGree**[c], **William A. Cliby**[a], and **Karl C. Podratz**[a]

[a]Division of Gynecologic Surgery, Mayo Clinic, 200 First St SW, Rochester, MN 55905, USA

[b]Division of Health Care Policy and Research, Mayo Clinic, Rochester, MN, USA

[c]Division of Biomedical Statistics and Informatics, Mayo Clinic, Rochester, MN, USA

Abstract

Objective—Technological advances in surgical management of endometrial cancer (EC) may allow for novel risk modification in surgical site infection (SSI).

Methods—Perioperative variables were abstracted from EC cases surgically staged between January 1, 1999, and December 31, 2008. Primary outcome was SSI, as defined by American College of Surgeons National Surgical Quality Improvement Program. Counseling and global models were built to assess perioperative predictors of superficial incisional SSI and organ/space SSI. Thirty-day cost of SSI was calculated.

Results—Among 1369 EC patients, 136 (9.9%) had SSI. In the counseling model, significant predictors of superficial incisional SSI were obesity, American Society of Anesthesiologists (ASA) score >2, preoperative anemia (hematocrit <36%), and laparotomy. In the global model, significant predictors of superficial incisional SSI were obesity, ASA score >2, smoking, laparotomy, and intraoperative transfusion. Counseling model predictors of organ/space SSI were older age, smoking, preoperative glucose >110 mg/dL, and prior methicillin-resistant *Staphylococcus aureus* (MRSA) infection. Global predictors of organ/space SSI were older age, smoking, vascular disease, prior MRSA infection, greater estimated blood loss, and lymphadenectomy or bowel resection. SSI resulted in a $5447 median increase in 30-day cost.

Conclusions—Our findings are useful to individualize preoperative risk counseling. Hyperglycemia and smoking are modifiable, and minimally invasive surgical approaches should be the preferred surgical route because they decrease SSI events. Judicious use of lymphadenectomy may decrease SSI. Thirty-day postoperative costs are considerably increased when SSI occurs.

Keywords

Cost-effective surgical care; Endometrial cancer; Minimally invasive surgery; Surgical site infection

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*Corresponding author at: Fax: +1 507 266 9300. bakkum.jamie@mayo.edu (J.N. Bakkum-Gamez)..

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Introduction

Standard therapy for endometrial cancer (EC) begins with surgery which is essential for treatment, staging, prognostication, and determination of adjuvant treatments [1–3]. Surgical intervention carries with it inherent risks, including surgical site infection (SSI). The American College of Surgeons (ACS) National Surgical Quality Improvement Program (NSQIP) was developed to harness risk-adjusted perioperative data directly from patient medical charts to determine postoperative complications that are preventable with the goal of improving the quality of surgical care. NSQIP has defined 3 categories of SSI: superficial incisional, deep incisional, and organ/space [4–8] (Box 1). SSI is a major contributor to postoperative morbidity and death [9–11]. In fact, more than one-third of postoperative deaths are related, in part, to SSIs [9] and SSIs increase the cost of care. Among colorectal patients, SSI increases the cost of care more than $6000 per patient [12].

Minimally invasive approaches to abdominal and pelvic cancers have emerged and evolved over the past several decades. Laparoscopic colorectal, gastric, prostate, and hepatobiliary surgery have been shown to have lower rates of SSI and other postoperative complications, as well as shorter hospital stays, than open surgery [8,10,13–15]. Among women undergoing hysterectomy for benign indications, minimally invasive approaches decrease the risk of procedure-related complications without increasing the cost of care [16,17]. Laparoscopic staging for EC results in similar intraoperative complication rates and lower rates of overall postoperative complications compared to open staging [18–20]. Length of hospital stay is substantially shorter with laparoscopic staging; the ability to identify metastatic disease appears similar with laparoscopy [11,21], and quality of life is improved among women who undergo minimally invasive EC staging [19,21]. In addition, laparoscopic staging does not appear to adversely affect survival [22].

Our primary objective was to determine perioperative variables associated with the risk of SSI in EC patients, to identify modifiable variables. A counseling model (preoperative variables only) and a global model (preoperative, intraoperative, and postoperative variables) for SSI development were constructed. We also determined the additional 30-day cost to the surgical episode of EC care associated with any SSI and each subtype of SSI that our patients had. Identification of fixed and modifiable variables in the surgical process of care is essential for preoperative patient counseling, risk management, development of preventive strategies, and risk-adjusted reimbursement.

Methods

Patient population and data collection

All women who underwent surgical staging for EC between January 1, 1999, and December 31, 2008, at Mayo Clinic in Rochester, Minnesota, were eligible for inclusion. In accordance with the Minnesota Statute for Use of Medical Information in Research, women were excluded who did not consent to the use of their medical records for study purposes. To assess the factors influencing the development of SSI within 30 days after surgery, weused the ACSNSQIP platform [23,24] to systematically annotate patient risk factors, process of care variables, and disease-specific parameters. These data were abstracted from the patient records by a dedicated registered nurse (J.R.M.). Each SSI diagnosis was reviewed, confirmed, and classified by a sole surgeon (J.N.B.). NSQIP definitions of superficial incisional SSI, deep incisional SSI, and organ/space SSI were used [6,25]. Mayo Clinic Institutional Review Board approval was secured for this study.

Surgical approaches

Minimally invasive surgery (MIS) was defined as hysterectomy and staging performed through any mode other than laparotomy. Thus, vaginal, laparoscopic, and robotic approaches were all considered MIS. If an MIS case was converted to laparotomy, it was considered staging through laparotomy. Laparoscopic pelvic and para-aortic lymphadenectomy was introduced at Mayo Clinic in Minnesota in April 2005 and robotic staging was initiated in December 2006. Throughout the study period, Mayo Clinic gynecologic oncologists performed vaginal hysterectomy for patients with low-risk EC [1–3] amenable to this approach.

Statistical analyses

All data analyses were performed with SAS version 9.2 (SAS Institute Inc.). Patient- and disease-specific characteristics and process of care variables were summarized using standard descriptive statistics. Comparisons between patients with and without SSI were evaluated with χ^2 or Fisher exact test for categorical variables and with Wilcoxon rank sum test for continuous variables. Counseling models were defined as the multivariate preoperative predictive models for the risk of superficial incisional SSI; the risk of organ/space SSI was developed through inherent patient factors and planned approach to surgical staging. Global predictive models for the risk of superficial incisional SSI and organ/space SSI were also developed including factors considered in the preoperative risk model (except preoperative laboratory values), as well as additional intraoperative factors. Stepwise and backward variable selection methods were used in both model-building processes, and variables with a *P* value <.05 were retained. Associations were summarized with odds ratio (OR) and corresponding 95% CI. Variables with more than 40% missing data were not considered in the final model. Because of limited numbers of deep incisional SSI and combinations of SSI types, predictive models for these SSIs were not generated. To avoid potential confounding, within the superficial incisional SSI analyses, we excluded those cases with deep incisional SSI or a combination of superficial incisional SSI and organ/space SSI in the model building process. Those with pure organ/space SSI were compared to all others (no SSI, superficial incisional SSI, and combination SSIs) in the analyses.

Cost analysis

Cost data for the study patients were captured from the Olmsted County (Minnesota) Healthcare Expenditure and Utilization Database [26]. These claims-based data contain all acute-care medical costs (regardless of payer or plan) for every service and procedure received by patients seen at Mayo Clinic. The database captures information about the use of medical resources, the associated fees, and the estimated economic costs for Mayo Clinic patients who receive care at the clinic and at associated inpatient locations. The database also offers a standardized, inflation-adjusted approximation of costs for the individual services and procedures delivered locally in 2010 constant Medicare dollars. The algorithm applies an inflation adjuster for geographical wage differences to estimate the costs in nationally representative constant dollars. The services provided denote the patterns of clinical practice at Mayo Clinic. However, we have adjusted the value of individual units to national norms through widely recognized valuation methods [27].

For the cost models of the effects of an SSI, propensity scores were used to match patients who had an SSI to non-SSI patients with a similar probability of having an SSI [28]. Propensity scores for the probability of having an SSI were estimated with a multivariate logistic regression model. All variables were eligible for inclusion, with the exception of any variables with more than 10% of the population missing values. One-to-one propensity match was conducted to provide evidence of equivalence between the 2 groups.

The primary outcome of the cost analysis was all-cause 30-day postsurgical costs. Following the approach of Stuart [29], we considered the matched cohorts as independent and, therefore, the median difference in cost for an SSI vs no SSI was estimated with Wilcoxon rank sum test, and a P value < .05 was regarded as statistically significant.

Results

Distribution of SSI types and patient demographic characteristics

In total, 1369 patients met the study inclusion criteria. Of them, 136 (9.9%) had an SSI within 30 days of EC staging surgery. Most SSIs were superficial incisional (89 [65.4%]), followed in frequency by organ/space (31 [22.8%]) and deep incisional (11 [8.1%]). In addition, 5 cases (3.7%) had 2 separate SSI diagnoses. Three patients (2.2%) had both superficial incisional and organ/space SSIs and 2 (1.5%) had both deep incisional and organ/space SSIs. Overall, 1189 patients (86.9%) underwent staging with laparotomy, 76 (5.6%) were staged with laparoscopy or robotic surgery with or without vaginal hysterectomy, and 104 (7.6%) underwent vaginal hysterectomy only. Among those who underwent laparotomy, 134 patients (11.3%) had some type of SSI. This group constituted 98.5% of the patients who had an SSI. Patient demographic characteristics in regard to any SSI vs no SSI are presented in Table 1.

Risk factors for superficial incisional SSI

Preoperative factors associated with superficial incisional SSI in univariate analysis included body mass index (BMI). Mean (SD) BMI for patients who did not have superficial incisional SSI was 32.8 (9.1) vs 39.0 (9.9) for those who had this SSI type ($P < .001$). In addition, having an American Society of Anesthesiologists (ASA) score >2 (62.9% vs 38.3%; P b .001), diabetes mellitus (30.3% vs 19.8%; P = .02), pulmonary dysfunction such as sleep apnea or chronic pulmonary obstructive disease (29.2% vs 14.8%; $P < .001$), and preoperative anemia (hematocrit <36%) (34.5% vs 20.4%; $P = .002$) were associated with increased risk of superficial incisional SSI. There were 1111 patients who underwent laparotomy for EC staging. Among them, 79 (7.1%) had superficial incisional SSI. Of the 180 patients who underwent MIS, only 1 (0.6%) had superficial incisional SSI. In addition, the treatment of 78 patients was converted from MIS to laparotomy and 9 (11.5%) had superficial incisional SSI. The difference in superficial incisional SSI among these 3 surgical groups was significant ($P < .001$).

In the counseling multivariate model, obesity was significantly associated with superficial incisional SSI; the greater the obesity, the greater the risk of superficial incisional SSI. ASA score >2, preoperative anemia, and staging through laparotomy were also independently associated with increased risk of superficial incisional SSI. In fact, the risk of superficial incisional SSI was more than 14-fold higher in women undergoing staging through laparotomy than those undergoing a minimally invasive approach (Table 2).

Additional perioperative risk factors associated with an increased rate of superficial incisional SSI via univariate analysis included greater estimated blood loss (EBL) (mean [SD], 514.6 [419.3] vs 413.2 [426.1] mL; $P < .001$) and receipt of an intraoperative packed red blood cell transfusion (PRBCT) (24.7% vs 13.4%; $P = .003$). The global multivariate analyses identified increasing obesity, ASA score >2, current smoking at the time of surgery, staging through laparotomy, and intraoperative PRBCT receipt as independent factors associated with increased superficial incisional SSI. Compared to laparotomy, MIS was associated with a 15-fold decrease in SSI (Table 3).

Risk factors for organ/space SSI

In univariate analyses of preoperative factors, women who had an organ/space SSI were older (mean [SD] age, 69.6 [11.2] vs 64.1 [11.6] years; $P = .01$), were more likely to have vascular disease ($P = .02$), and had a preoperative glucose level >110 mg/dL ($P = .01$). In the counseling model multivariate analyses, older age continued to be an independent predictor for organ/space SSI (OR, 1.6 per 10-year increase). In addition, being a current smoker at the time of surgery increased the risk of organ/space SSI by 4-fold; an elevated preoperative glucose level >110 mg/dL was associated with a 2.3-fold increase in risk; and prior history of methicillin-resistant *Staphylococcus aureus* (MRSA) infection increased organ/space SSI risk by greater than 12-fold (Table 4).

Intraoperative factors associated with organ/space SSI in univariate analyses included having a longer operative time (mean [SD], 212.8 [77.5] vs 163.9 [81.1] minutes in patients without organ/space SSI; $P < .001$) or greater EBL (mean [SD], 672.2 [459.5] vs 416.9 [426.9] mL; $P < .001$); receiving intraoperative PRBCT (38.9% vs 13.8%; $P < .001$); undergoing pelvic lymphadenectomy (3.65% vs 0.65%; $P < .001$), paraaortic lymphadenectomy (4.0% vs 1.2%; $P = .001$), or splenectomy (15.4% vs 2.5%; $P = .04$); or requiring bowel resection (20.0% vs. 2.2%; $P < .001$). In the global multivariate analyses, older age (OR, 1.6 per 10-year age increment), being a current smoker at the time of surgery (OR, 3.5), having an increased EBL (OR, 1.6 per each doubling), undergoing any lymph node dissection (OR, 4.1), or undergoing resection of small or large bowel (OR, 6.3) were independent predictors of organ/space SSI. In addition, having a personal history of vascular disease was associated with a 5-fold increase in the risk of an organ/space SSI. A history of MRSA infection, although rare in our cohort (only 5 patients), portended a more than 25-fold increase in risk of organ/space SSI (Table 5).

Cost of SSI within 30 days of EC staging surgery

Cost analysis was performed on a final analytical sample of 119 patients with any SSI and a matched cohort of 119 controls without SSI. Propensity score matching yielded more balanced groups in terms of the measured covariates, where all covariates with statistically significant differences before matching had no significant differences after matching. Median all-cause 30-day postsurgical costs were $25,788.10 (interquartile range, $17,411.50–$38,822.70) in the SSI cohort vs $19,341.60 (interquartile range, $15,502.40–$26,390.00) in the cohort without SSI, resulting in a median increase in cost for any SSI of $5447 ($P < .001$).

Among all SSI types and combinations, the most costly SSI was the combination of deep incision and organ/space sites (median cost, $75,846.37). This cost was more than 2.5 times that of superficial incisional SSI ($28,887.77) and quadrupled the baseline cost of care in the clinical setting of no SSI. Median costs of the other SSIs were as follows: deep incisional SSI, $22,686.60; organ/space SSI, $39,800.09; and the combination of superficial incisional and organ/space SSI, $44,890.77.

Discussion

Advances in the surgical approach to EC have included an improved understanding of the natural history and disease process [1,2,30],as well as the introduction of MIS techniques [11,18–20,22]. Although MIS techniques in particular have improved outcomes such as hospital stay and quality of life, the surgical treatment that patients with EC receive is subject to great variability across the country and the world. To improve outcomes, surgeons must focus not only on oncologic results, but also on postoperative morbidity. The additive cost associated with managing an SSI has come into focus for the Centers for Medicare and

Medicaid Services, and reimbursement for surgical services may soon be altered secondary to a postoperative SSI diagnosis [31]. Thus, identification of ways to decrease the risk of SSI in high-risk patients is paramount.

The overall SSI rate in our EC cohort (9.9%) was remarkably higher than in other publications of SSI after hysterectomy for benign indications (1.8%–4%) [32,33]. However, EC risk factors include obesity, diabetes, and cardiovascular disease [34–38] and the mean BMI of our entire cohort was >33 kg/m^2 while the mean BMI in prior benign hysterectomy reports do not meet criteria for obesity [33]. Such medical comorbidities and their management can inhibit wound healing, promote SSI, and increase morbidity [11,39–41]. Smoking has been well documented as a risk factor for SSI [42,43] and was found to be an independent risk factor for both superficial incisional and organ/space SSI in our study. Being a former smoker had no impact on SSI development, which further supports the notion that preoperative smoking cessation may modify postoperative sequelae [43]. Only 2% of our cohort utilized long term steroids preoperatively and this was not found to be a significant risk factor for SSI. Additionally, undergoing a surgical procedure within the prior 30 days did not significantly increase SSI risk; however, nearly all prior surgeries were dilation and curettage. Increased EBL and receipt of perioperative PRBCT have previously been linked to an increased risk of SSI in gynecologic surgery [33]. Even in our preoperative risk model, the presence of anemia before surgery portended an increased risk of superficial SSI. EBL and the need for PRBCT are modifiable variables as MIS procedures result in minimized EBL [14,17,18] and ultimately fewer transfusions.

Perhaps the most striking finding is the magnitude of superficial incisional SSI risk associated with patients undergoing laparotomy. Choice of surgical staging approach has consistently been shown to impact SSI in EC management, as well as in management of other cancers [11,15,16,19,44]. In our study, staging through MIS afforded a 14-fold decrease in superficial incisional SSI. While the Gynecologic Oncology Group LAP2 study comparing staging through laparotomy vs laparoscopy revealed similar rates of each acute postoperative infection between laparotomy and laparoscopy cohorts, the procedure for more than 1 in 4 patients who were randomly assigned to laparoscopy was converted to laparotomy, and there was a significantly higher rate of perioperative antibiotic use in the laparotomy group [20]. In addition to decreased SSI and overall postoperative complications [11,20,45], MIS management of EC results in quicker recovery and better quality of life than with laparotomy [19,21] and oncologic outcomes appear equivalent among patients who undergo laparoscopic staging compared to laparotomy [22]. Since surgical approach is a decision made between surgeon and patient in the preoperative counseling process, this is a modifiable SSI risk factor and patients should be offered minimally invasive options.

A uniquely different combination of risk factors predicted organ/space SSI. While active smoking status remained a dominant factor, vascular disease is notoriously associated with poor wound healing and spontaneous infections [46]. In our patient population, where 58% were obese and 21% had diabetes mellitus, vascular disease may be under recognized and its impact may be greater than we can currently quantify. And although our numbers of cases with prior documented MRSA were low, it was a substantial predictor of organ/space SSI. Prior colonization of the patient and subsequent inadequate antibiotic coverage may have led to this result. As such, preoperative dosing with MRSA-appropriate antibiotics in such patients appears warranted. Recognizing that EBL is less in MIS-managed EC [18], surgical approach should modify this organ/space SSI risk factor. The rate of bowel resection in our cohort was low at 2.2%; however, undergoing this procedure independently increased the risk of organ/space SSI by 6-fold. Because debulking of advanced-stage EC has been shown to improve survival, this may not be a modifiable risk factor [47]. However, lymphadenectomy was also an independent risk factor for organ/space SSI with a 4-fold increased risk, and thus judicious use of lymphadenectomy in patients at risk for lymph node metastases [1] could impact the organ/space SSI risk.

Total average costs of MIS for both benign hysterectomy [17] and hysterectomy for EC [18] have been shown to be equivalent and even lower than laparotomy costs, respectively. MIS for EC management also appears to decrease the hospital length of stay and shorten the time to return to work, without increasing the overall cost of the surgical episode of care [18,48]. The overall impact of postoperative sequelae on health care cost is quantifiable [45] and SSI represents a unique complication with varying degrees of cost depending on SSI severity. With a median increased cost of $5547 per SSI, the approximate 30-day cost of SSI in our cohort was $754,392. This amount does not take into account nonbillable patient expenses or wages lost. By comparison, the emotional impact of SSI is not quantifiable. In addition, resultant delays in adjuvant chemotherapy or irradiation have the potential to impact oncologic outcomes.

Perioperative risk modification tools are warranted for women undergoing surgical staging for EC [49]. In addition to addressing modifiable risk factors such as hyperglycemia and preoperative smoking cessation, use of MIS may favorably impact the effects of minimally modifiable risk factors, such as obesity, EBL, and the need for intraoperative PRBCT. The SSI prediction models for superficial incisional and organ/space SSI may help stratify and identify patients with a priori increased SSI risk. Reducing SSI events will lead to calculable decreases in costs of care.

Abbreviations

ASA	American Society of Anesthesiologists
BMI	body mass index
EBL	estimated blood loss
EC	endometrial cancer
MIS	minimally invasive surgery
MRSA	methicillin-resistant *Staphylococcus aureus*
OR	odds ratio
PRBCT	packed red blood cell transfusion
SSI	surgical site infection

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HIGHLIGHTS

- MIS approaches decrease the risk of superficial incisional SSI following EC staging.
- Hyperglycemia and smoking are modifiable risk factors that increase organ/space SSI.
- The 30-day costs of SSI are substantial and vary according to SSI type.

Box 1

American College of Surgeons National Surgical Quality Improvement Program (NSQIP) surgical site infection (SSI) definitions

Superficial incisional SSI[a]

1) Purulent incisional drainage from above the fascia

2) Organisms isolated from an aseptically obtained culture of fluid or tissue from the superficial incision

3) Pain/tenderness, wound swelling, redness, or heat, and the superficial incision is deliberately opened by the surgeon (unless its culture is negative for organisms)

Deep incisional SSI[b]

1) Purulent drainage from the deep incision

2) Spontaneous dehiscence or deliberate opening of the fascia in the setting of fever or localized pain/tenderness (unless it is culture negative)

3) An abscess is found involving the deep incision through physical examination, reoperation, or radiologic examination

Organ/space SSI

1) Purulent drainage from an intraperitoneal drain

2) Presence of organisms in culture of fluid obtained aseptically from an organ or space

3) Abscess or other infection involving an organ or space on physical examination, reoperation, or histopathologic or radiologic examination

[a]Surgeon diagnosis of any of the 3 types of SSI also meets NSQIP criteria.

[b]Involves deep soft tissues, such as the fascia or muscle layers of the incision.

Table 1

Patient demographic characteristics.

Patient characteristics	No SSI(n = 1233)	Any SSI (n = 136)	Total (N = 1369)	*P* value[a]
Age, mean (SD), y	64.3 (11.5)	63.8 (12.6)	64.2 (11.6)	.76
BMI, mean (SD), kg/m^2	32.8 (9.0)	38.0 (10.6)	33.3 (9.3)	<.001
ASA score >2, no. (%)	464 (37.6)	81 (59.6)	545 (39.8)	<.001
Past medical history, no. (%)				
Smoking status				.01
No smoking history	832 (67.5)	82 (60.3)	914 (66.8)	
Former smoker	321 (26.0)	36 (26.5)	357 (26.1)	
Current smoker	80 (6.5)	18 (13.2)	98 (7.2)	
Diabetes mellitus	242 (19.6)	40 (29.4)	282 (20.6)	.007
Hypertension	636 (51.6)	81 (59.6)	717 (52.4)	.08
Sleep apnea	75 (6.1)	18 (13.2)	93 (6.8)	.002
Prior operation within 30 d	209 (17.0)	24 (17.6)	233 (17.0)	.84
Prior cardiac event/intervention	67 (5.4)	8 (5.9)	75 (5.5)	.83
Pulmonary dysfunction	182 (14.8)	39 (28.7)	221 (16.1)	<.001
Vascular disease	15 (1.2)	3 (2.2)	18 (1.3)	.41
Bleeding disorders	6 (0.5)	0 (0.0)	6 (.04)	.99
Long-term corticosteroid use	22 (1.8)	4 (2.9)	26 (1.9)	.32
Current open wound	7 (0.6)	1 (0.7)	8 (0.6)	.57
History of MRSA infection	4 (0.3)	1 (0.7)	5 (0.4)	.41
Preoperative laboratory values, no. (%)[b]				
Hematocrit <36%	235 (20.4)	37 (28.7)	272 (21.2)	.03
Glucose >110 mg/dL	400 (35.9)	56 (44.1)	456 (36.7)	.07
Albumin ≤3.0 g/dL	15 (5.3)	2 (5.7)	17 (5.4)	.99
Creatinine ≥1.5 mg/dL	45 (3.8)	10 (7.6)	55 (4.2)	.04
AST >40 U/L	28 (7.8)	8 (17.8)	36 (8.9)	.05
Total bilirubin ≥1.1 mg/dL	9 (4.6)	1 (4.2)	10 (4.6)	.99
Platelet count <400 × 10^9/L	80 (6.9)	13 (10.1)	93 (7.2)	.19
Surgical characteristics, no. (%)				
Surgical approach				<.001
Planned laparotomy	988 (80.1)	123 (90.4)	1111 (81.2)	
MIS converted to laparotomy	67 (5.4)	11 (8.1)	78 (5.7)	
MIS	178 (14.4)	2 (1.5)	180 (13.1)	
Pelvic lymphadenectomy only	805 (65.3)	99 (72.8)	904 (66.0)	.08
Para-aortic lymphadenectomy only	617 (50.0)	83 (61.0)	700 (51.1)	.02
Pelvic and/or para-aortic lymphadenectomy	811 (65.8)	100 (73.5)	911 (66.5)	.07
Splenectomy	10 (0.8)	3 (2.2)	13 (0.9)	.13
Small- or large-bowel resection	22 (1.8)	8 (5.9)	30 (2.2)	.01
Panniculectomy	144 (11.7)	22 (16.2)	166 (12.1)	.13
Process-of-care characteristics				

Patient characteristics	No SSI(n = 1233)	Any SSI (n = 136)	Total (N = 1369)	*P* value[a]
Antibiotic prophylaxis ≤60 min of incision	929 (75.3)	102 (75.0)	1031 (75.3)	.93
Operative time, mean (SD), min	162.5 (81.0)	189.7 (80.2)	165.2 (81.3)	<.001
EBL, mean (SD), mL	408.9 (426.0)	557.2 (440.5)	423.6 (429.6)	<.001
Intraoperative PRBCT receipt, no. (%)	159 (12.9)	38 (27.9)	197 (14.4)	<.001
Lowest intraoperative temperature, mean (SD), °C	35.4 (0.7)	35.3 (0.8)	35.4 (0.7)	.41
Ending intraoperative temperature, mean (SD), °C	35.9 (0.7)	35.9 (0.8)	35.9 (0.7)	.98
FIGO stage ≥ III, no. (%)	229 (18.6)	39 (28.7)	268 (19.6)	.005
Postoperative glucose >120 mg/dL, no. (%)[b]	336 (78.7)	67 (88.2)	403 (80.1)	.06
Postoperative hematocrit <36%, no. (%)[b]	1144 (93.4)	130 (96.3)	1274 (93.7)	.19
Time from surgery to discharge, mean (SD), d	4.3 (2.8)	7.2 (8.8)	4.6 (3.9)	<.001

Abbreviations: ASA, American Society of Anesthesiologists; AST, aspartate aminotransferase; BMI, body mass index; EBL, estimated blood loss; FIGO, International Federation of Gynecology and Obstetrics; MIS, minimally invasive surgery; MRSA, methicillin-resistant *Staphylococcus aureus*; PRBCT, plasma and red blood cell transfusion; SSI, surgical site infection.

[a] $\chi 2$ or Fisher exact test for categorical variables; Wilcoxon rank sum test for continuous variables.

[b] Missing laboratory values for differing numbers of patients.

Table 2

Multivariate analysis of preoperative patient risk factors and selected surgical approach associated with superficial incisional SSI.

Factor	Any superficial incisional SSI, no. (%)	Multivariate analysis	
		OR (95% CI)	*P* value
BMI			<.001
Underweight, normal, or overweight (n = 572)	15 (2.6)	Referent	
WHO class I or II (n = 496)	36 (7.3)	3.2 (1.7–6.0)	
WHO class III (n = 204)	25 (12.3)	4.3 (2.1–8.7)	
Super obese (n = 78)	13 (16.7)	5.2 (2.2–12.4)	
ASA score			.005
1 or 2 (n = 806)	33 (4.1)	Referent	
3 or 4 (n = 535)	56 (10.5)	2.0 (1.2–3.3)	
Preoperative hematocrit <36%			.007
No (n = 997)	55 (5.5)	Referent	
Yes (n = 270)	29 (10.7)	2.0 (1.2–3.2)	
Minimally invasive surgery			.009
No (n = 1173)	88 (7.5)	14.1 (1.9–102.2)	
Yes (n = 180)	1 (0.6)	Referent	

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; OR, odds ratio; SSI, surgical site infection; WHO, World Health Organization.

Table 3

Multivariate analysis of perioperative (preoperative, intraoperative, and select postoperative) patient risk factors and selected surgical approach associated with superficial incisional SSI.

Factor	Any superficial incisional SSI, no. (%)	Multivariate analysis	
		OR (95% CI)	*P* value
BMI			<.001
Underweight, normal, or overweight (n = 572)	15 (2.6)	Referent	
WHO class I or II (n = 496)	36 (7.3)	3.0 (1.6–5.7)	
WHO class III (n = 204)	25 (12.3)	4.7 (2.4–9.4)	
Super obese (n = 78)	13 (16.7)	5.4 (2.4–12.6)	
ASA score			.007
1 or 2 (n = 806)	33 (4.1)	Referent	
3 or 4 (n = 535)	56 (10.5)	2.0 (1.2–3.2)	
Smoking status			.02
No smoking history (n = 904)	51 (5.6)	Referent	
Former smoker (n = 354)	27 (7.6)	1.4 (0.8–2.3)	
Current smoker (n = 95)	11 (11.6)	2.7 (1.3–5.6)	
Minimally invasive surgery			.008
No (n = 1173)	88 (7.5)	15.0 (2.1–109.7)	
Yes (n = 180)	1 (0.6)	Referent	
Intraoperative PRBCT			.04
No (n = 1156)	67 (5.8)	Referent	
Yes (n = 190)	22 (11.6)	1.8 (1.0–3.0)	

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; OR, odds ratio; PRBCT, packed red blood cell transfusion; SSI, surgical site infection; WHO, World Health Organization.

Table 4

Multivariate analysis of preoperative patient risk factors and selected surgical approach associated with organ/space SSI.

Factor	Any organ/space SSI, no. (%)	Multivariate analysis	
		OR (95% CI)	*P* value
Age at surgery (per 10-y increment)	NA	1.6 (1.2–2.3)	.003
Smoking status			.007
No smoking history (n = 914)	24 (2.6)	Referent	
Former smoker (n = 357)	6 (1.7)	0.6 (0.3–1.6)	
Current smoker (n = 98)	6 (6.1)	3.9 (1.5–10.4)	
Preoperative glucose >110 mg/dL			.03
No (n = 785)	15 (1.9)	Referent	
Yes (n = 456)	20 (4.4)	2.2 (1.1–4.5)	
Prior MRSA infection			.03
No (n = 1364)	35 (2.6)	Referent	
Yes (n = 5)	1 (20.0)	12.4 (1.2–127.3)	

Abbreviations: MRSA, methicillin-resistant *Staphylococcus aureus*; NA, not applicable; OR, odds ratio; SSI, surgical site infection.

Table 5

Multivariate analysis of perioperative (preoperative, intraoperative, and select postoperative) variables associated with organ/space SSI.

Factor	Any organ/space SSI, no. (%)	Multivariate analysis	
		OR (95% CI)	*P* value
Age at surgery, per 10-y increment	NA	1.6 (1.2–2.3)	.006
Smoking status			.01
No smoking history (n = 914)	24 (2.6)	Referent	
Former smoker (n = 357)	6 (1.7)	0.7 (0.3–1.7)	
Current smoker (n = 98)	6 (6.1)	3.5 (1.3–9.6)	
Vascular disease			.04
No (n = 1351)	34 (2.5)	Referent	
Yes (n = 18)	2 (11.1)	5.1 (1.1–24.5)	
Prior MRSA infection			.02
No (n = 1364)	35 (2.6)	Referent	
Yes (n = 5)	1 (20.0)	25.3 (1.8–355.3)	
EBL (per each doubling), mL	NA	1.6 (1.1–2.1)	.008
Any lymphadenectomy			.03
No (n = 458)	3 (0.7)	Referent	
Yes(n = 911)	33 (3.6)	4.1 (1.2–14.1)	
Small- or large-bowel resection			<.001
No (n = 1339)	30 (2.2)	Referent	
Yes (n = 30)	6 (20.0)	6.3 (2.1–18.5)	

Abbreviations: EBL, estimated blood loss; MRSA, methicillin-resistant *Staphylococcus aureus*; NA, not applicable; OR, odds ratio; SSI, surgical site infection.