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ORIGINAL ARTICLE

Developing a Risk Stratification Model for Surgical Site Infection after Abdominal Hysterectomy

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OBJECTIVE. The incidence of surgical site infection (SSI) after hysterectomy ranges widely from 2% to 21%. A specific risk stratification index could help to predict more accurately the risk of incisional SSI following abdominal hysterectomy and would help determine the reasons for the wide range of reported SSI rates in individual studies. To increase our understanding of the risk factors needed to build a specific risk stratification index, we performed a retrospective multihospital analysis of risk factors for SSI after abdominal hysterectomy.

METHODS. Retrospective case-control study of 545 abdominal and 275 vaginal hysterectomies from July 1, 2003, to June 30, 2005, at 4 institutions. SSIs were defined by using Centers for Disease Control and Prevention/National Nosocomial Infections Surveillance criteria. Independent risk factors for abdominal hysterectomy were identified by using logistic regression.

RESULTS. There were 13 deep incisional, 53 superficial incisional, and 18 organ-space SSIs after abdominal hysterectomy and 14 organ-space SSIs after vaginal hysterectomy. Because risk factors for organ-space SSI were different according to univariate analysis, we focused further analyses on incisional SSI after abdominal hysterectomy. The maximum serum glucose level within 5 days after operation was highest in patients with deep incisional SSI, lower in patients with superficial incisional SSI, and lowest in uninfected patients (median, 189, 156, and 141 mg/dL, respectively; $P = .005$). Independent risk factors for incisional SSI included blood transfusion (odds ratio [OR], 2.4) and morbid obesity (body mass index [BMI], >35; OR, 5.7). Duration of operation greater than the 75th percentile (OR, 1.7), obesity (BMI, 30–35; OR, 3.0), and lack of private health insurance (OR, 1.7) were marginally associated with increased odds of SSI.

CONCLUSIONS. Incisional SSI after abdominal hysterectomy was associated with increased BMI and blood transfusion. Longer duration of operation and lack of private health insurance were marginally associated with SSI.

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More than 600,000 hysterectomies are performed annually in the United States, and more than one-third of women have undergone the procedure by the age of 60 years.[1] In the 2000–2004 National Hospital Discharge Survey, abdominal hysterectomy accounted for about two-thirds of the procedures, and approximately one-third of the vaginal hysterectomies were performed laparoscopically.[1] The most common indications for hysterectomy were uterine leiomyoma, endometriosis, and uterine prolapse.[1]

The pooled rate of surgical site infection (SSI) after abdominal hysterectomy as reported by the National Healthcare Safety Network for 2006–2007 was 1.7%, and the rate after vaginal hysterectomy was 0.9%.[2] Rates of SSI after hysterectomy reported in individual studies range widely, depending on the approach and surgical method of hysterectomy (eg, vaginal, abdominal, or laparoscopic), the indication for operation, and the use of antimicrobial prophylaxis. SSI rates also vary depending on the definitions used for surveillance and whether postdischarge surveillance was used to identify infections. Recently, Reilly and colleagues reported that twice as many SSIs after abdominal hysterectomy were recorded when patients completed questionnaires and interviews to identify wound signs and symptoms after hospital discharge, compared with the SSI rate determined from routine surveillance relying on only hospital data.[3]

Reported SSI rates tend to be higher when the abdominal approach is used than when the vaginal approach is used and were higher in the era before presurgical prophylaxis was used than more recently. Before routine use of prophylactic antibiotic regimens, SSI rates reported for abdominal hysterectomy were 9% or higher in all[4-8] but 1 publication.[9] During the past decade, reported SSI rates after abdominal hyster-

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ectomy have ranged from 1.7% to 11%,[10-17] while SSI rates reported in individual studies after vaginal hysterectomy (ie, vaginal cuff cellulitis) ranged from 3.1% to 4.8%.[12,15,17] Thus, there seems to be a wider range of SSI rates reported from individual institutions after abdominal hysterectomy than after vaginal hysterectomy.

Few studies have determined risk factors for SSI after hysterectomy by using standard definitions for SSI and multivariable analysis. Risk factors for SSI identified with multivariable analysis in previous studies include obesity,[7,17] lower serum albumin level,[14] depth of subcutaneous tissue,[6] use of abdominal approach,[4,17] open vaginal cuff,[7] younger age,[4] nonprivate patient status,[4] and inadequate antimicrobial prophylaxis,[4,7,14,17] although only 3 studies used standard criteria to define SSI.[6,14,17] It is essential to identify independent risk factors in order to create a risk index specific to abdominal hysterectomy. The National Nosocomial Infection Surveillance (NNIS) risk index, most commonly used by hospital epidemiologists, performs better as a risk stratification method between different types of operations than within an individual type of operation.[18,19] A risk index tailored to abdominal hysterectomy would allow for more accurate comparison of SSI rates across institutions, which would help reveal the reasons for the wide range of reported SSI rates in individual studies.

We performed a retrospective multihospital analysis of risk factors for SSI after abdominal hysterectomy as part of a multicenter surveillance study for the Prevention Epicenter Program of the Centers for Disease Control and Prevention (CDC).

METHODS

Study Population

We conducted a retrospective case-control study of women who underwent hysterectomy (*International Classification of Diseases, Ninth Revision, Clinical Modification [ICD-9-CM]* procedure codes 68.39, 68.4, 68.6, 68.51, 68.59, and 68.7) at 4 participating CDC Prevention Epicenter Program hospitals from July 1, 2003, through June 30, 2005. Laparoscopically assisted abdominal hysterectomies (*ICD-9-CM* procedure code 68.31) were excluded. This study was performed in concert with a CDC Prevention Epicenter Program project to determine the validity of enhanced surveillance based on *ICD-9-CM* diagnosis codes and antimicrobial utilization in order to identify inpatient SSI (D. S. Yokoe, unpublished data, 2008).[20] Approval for this study was obtained from all institutional review boards at the participating centers.

Identification of Case Patients and Control Patients

Initial case patients with SSI within 30 days after operation were identified at all participating hospitals by means of routine infection control surveillance. At hospitals where more than 200 procedures were performed during the study period, 200 patients who did not have SSI identified with routine surveillance were selected for comparison (by selecting every nth procedure, where $n =$ total number of procedures divided by 200, rounded to the nearest integer). Medical records for the original surgical hospitalization and all subsequent inpatient rehospitalization(s) within 60 days after surgery were reviewed for case patients and control patients. Signs, symptoms, and potential risk factors for SSI were abstracted and entered directly into a Microsoft Access database. Patients initially selected as control patients on the basis of routine surveillance but who were subsequently determined to have an SSI on the basis of CDC/NNIS definitions[21] were defined as case patients in the analyses. Any patients determined to be prisoners were excluded from evaluation at 1 institution.

Risk Factor Data

Data on potential risk factors collected from case and control patients included age at date of hysterectomy, weight, height, type of health insurance, current smoking status, diabetes, congestive heart failure, indication for hysterectomy (ovarian, uterine, cervical, or other cancer or not cancer related), preoperative glucose level within 24 hours before incision, preoperative serum creatinine level, postoperative serum glucose level within 5 days after operation, postoperative serum creatinine level (during surgical hospitalization), blood transfusion during or after operation (during surgical hospitalization), duration of operation, and type of operation (determined on the basis of *ICD-9-CM* procedure codes).

Data Analysis

Deidentified data were analyzed with SPSS, version 14.0 (SPSS), and SAS, version 9.1 (SAS Institute). Comparisons

TABLE 1. Characteristics of Operations and Patients at Participating Hospitals

Hospital	Total no. of hysterectomies included in study	No. (%) of abdominal hysterectomies	No. (%) of cancer-related hysterectomies	No. (%) of hysterectomies for patients without private health insurance
A	198	80 (40.4)	8 (4.0)	19 (9.6)
B	161	42 (26.1)	18 (11.2)	23 (14.3)
C	198	183 (92.4)	160 (80.8)	81 (40.9)
D	263	240 (91.3)	115 (43.7)	57 (21.7)
Total	820	545 (66.5)	301 (36.7)	180 (22.0)

TABLE 2. Data on Risk Factors for Organ-Space Surgical Site Infection (SSI) after Hysterectomy

Risk factor	Case patients ($n = 32$)	Control patients ($n = 722$)	P
Categorical risk factors			
Insurance status			
Private or Medicare	22 (68.8)	641 (88.8)	
None	4 (12.5)	24 (3.3)	.007
Medicaid	6 (18.8)	57 (7.9)	.020
Current smoker	14 (43.8)	106 (14.7)	<.001
Congestive heart failure	2 (6.3)	11 (1.5)	.102
Diabetes	2 (6.3)	82 (11.4)	.566
Cancer	6 (18.8)	258 (35.7)	.049
Perioperative blood transfusion	7 (21.9)	103 (14.3)	.301
Vaginal hysterectomy	14 (43.8)	261 (36.1)	.382
Continuous risk factors			
Age, years	45 (33–72)	52 (20–92)	.001
Body mass index[a]	26.5 (20.5–54.5)	27.5 (15.8–67.3)	.228
Duration of operation,[b] minutes	147 (44–369)	146 (33–476)	.769
Serum creatinine level,[c] mg/dL	0.7 (0.3–6.7)	0.7 (0.3–5.1)	.598
Serum glucose level,[d] mg/dL	129 (80–315)	140 (81–500)	.690

NOTE. Data are no. (%) of patients or median values (range).

[a] Weight in kilograms divided by height in meters squared; 56 control patients were missing values for weight and/or height.

[b] One control patient had missing values for operation start and stop times.

[c] Highest during surgical hospitalization. Nine case patients and 281 control patients were missing data for creatinine level during the surgical hospitalization.

[d] Highest from 24 hours before to 5 days after operation. Twenty-three case patients and 435 control patients were missing data for serum glucose level during the surgical hospitalization.

for categorical variables were made by using the χ^2 test for trend, and comparisons for continuous variables were made by using the Student *t* test or the Mann-Whitney *U* test, as appropriate. All variables with a *P* value of less than .20 in the univariate analysis or with a priori clinical importance were evaluated with stepwise logistic regression. Lack of private insurance (ie, Medicaid, Medicare, or no health insurance) was forced into the logistic regression model as a proxy for socioeconomic status. Missing values for body mass index (BMI), serum glucose level, and serum creatinine level were imputed by using multiple imputation with the SAS procedure PROC MI. Ten data sets were generated, each of which had an imputed value for the variables with missing values. The 10 data sets were analyzed with PROC LOGISTIC, and the results were combined for inference with PROC MIANALYZE.[22,23] After identification of the main effects, clinically relevant interactions between variables were tested for inclusion in the model, with a *P* value of less than .05 the criterion for inclusion. Model fit was assessed by using the C statistic. All tests were 2-tailed, and a *P* value of less than .05 was considered to indicate a significant difference.

RESULTS

From the 4 participating hospitals, 84 patients were identified with SSI following abdominal hysterectomy, 13 patients had organ-space SSI following nonlaparoscopic vaginal hysterectomy (8 patients with vaginal cuff cellulitis and 5 with intra-abdominal infection), and 1 patient had organ-space SSI (intra-abdominal infection) following laparoscopic vaginal hysterectomy. Of the 84 patients with SSI after abdominal hysterectomy, 53 (63%) had a superficial incisional SSI, 13 (15%) had a deep incisional SSI, and 18 (21%) had an organ-space SSI (5 patients with vaginal cuff cellulitis and 13 patients with intra-abdominal infection). A total of 722 control patients without SSI were randomly selected for comparison with the SSI case patients (261 with vaginal and 461 with abdominal hysterectomy).

Table 1 shows the case mix of procedures sorted according to participating hospital. Hospitals C and D had much larger proportions of abdominal hysterectomies compared with hospitals A and B. Over 80% of the hysterectomies at hospital C were performed for patients with a diagnosis of cancer, whereas the proportions of operations performed for patients with cancer at hospitals A and B were much smaller (4.0% and 11.2%, respectively). Of 275 vaginal hysterectomies performed at the 4 hospitals, 57 (20.7%) were laparoscopically assisted.

Univariate associations between demographic and clinical characteristics of patients with or without organ-space SSI after hysterectomy are shown in Table 2, and univariate associations between these characteristics of patients with or without incisional SSI (superficial incisional and deep inci-

TABLE 3. Data on Risk Factors for Incisional Surgical Site Infection (SSI) after Abdominal Hysterectomy

Risk factor	Case patients with deep incisional SSI (n = 13)	Case patients with superficial incisional SSI (n = 53)	Control patients (n = 461)	P[a]
Categorical risk factors				
Insurance status				
Private or Medicare	9 (69.2)	37 (69.8)	402 (87.2)	.002
None	2 (15.4)	5 (9.4)	17 (3.7)	
Medicaid	2 (15.4)	11 (20.8)	42 (9.1)	
Current smoker	4 (30.8)	11 (20.8)	72 (15.6)	.097
Congestive heart failure	0	3 (5.7)	10 (2.2)	.483
Diabetes	6 (46.2)	14 (26.4)	67 (14.5)	<.001
Cancer	8 (61.5)	29 (54.7)	232 (50.3)	.333
Perioperative blood transfusion	5 (38.5)	22 (41.5)	89 (19.3)	<.001
Continuous risk factors				
Age, years	61 (29–80)	50 (34–88)	51 (20–92)	.254
Body mass index[b]	33.3 (25.1–64.8)	37.6 (15.7–68.2)	29.7 (15.8–67.3)	<.001
Duration of operation, minutes, mean ± SD	216.6 ± 73.1	190.6 ± 75.1	154.4 ± 64.9	<.001[c]
Serum creatinine level, mg/dL	0.93 (0.7–1.7)	0.80 (0.5–3.1)	0.71 (0.3–5.1)	.001[d]
Serum glucose level, mg/dL	189 (103–399)	156 (108–500)	141 (82–500)	.005[e]

NOTE. Data are no. (%) of patients or median values (range), unless otherwise indicated. SD, standard deviation.

[a] The χ^2 test for trend or the Kruskal-Wallis test were used, as appropriate.

[b] Weight in kilograms divided by height in meters squared; 2 case patients and 24 control patients were missing values for weight and/or height.

[c] One-way analysis of variance.

[d] Ninety-two patients were missing values for serum creatinine level.

[e] Ninety-four patients were missing values for serum glucose level.

sional) after abdominal hysterectomy are shown in Table 3. Women with organ-space SSI were younger, more likely to smoke, and less likely to have private health insurance or cancer as an indication for the operation than were women without SSI (Table 2). Women with incisional SSI after abdominal hysterectomy had a higher median BMI and were more likely to have diabetes and to require perioperative blood transfusion than were women without SSI after abdominal hysterectomy (Table 3). Women with incisional SSI after abdominal hysterectomy were also more likely to lack private health insurance than were women without SSI after abdominal hysterectomy.

In univariate analysis, the maximum perioperative serum glucose levels and creatinine levels were significantly higher in women with deep incisional SSI and superficial incisional SSI than in women without SSI after abdominal hysterectomy (Table 3). Duration of operation was also significantly longer for women with deep incisional SSI and superficial incisional SSI than for women without SSI after abdominal hysterectomy (Table 3).

For 4 of the 64 women with incisional SSI and perioperative glucose level measurements available for analysis, the highest glucose level measurement of the perioperative period was recorded prior to operation. Of the remaining 60 women with a postoperative glucose level measurement available, 12 had postoperative serum glucose level measurements that could have been obtained within 2 days before the diagnosis of incisional SSI. Of these 12 women, 7 had a maximum postoperative serum glucose level measurement of more than 150 mg/dL within 5 days of the operation. Among these 7 subjects, the date of maximum postoperative glucose level measurement was available for 5; for all 7 women, these values were obtained within 48 hours after operation and at least 2 days prior to the diagnosis of incisional SSI.

Independent risk factors for incisional SSI were identified by using multivariable logistic regression. To include all subjects in the analysis, multiple imputation was used to create values for missing BMI, serum glucose level, and serum creatinine level. The risk factors retained in the final model are shown in Table 4. Independent risk factors included perioperative blood transfusion and morbid obesity (BMI, >35). Duration of operation greater than the 75th percentile, lack of private health insurance, and obesity (BMI, 30–35) were marginally associated with increased risk of incisional SSI. In a preliminary multivariable model that excluded patients with missing glucose test results, a perioperative serum glucose level of more than 180 mg/dL was marginally associated with increased risk of incisional SSI ($P = .056$). In the final multivariable model, after missing values were imputed, a perioperative serum glucose level of more than 180 mg/dL was no longer associated with significantly increased odds of SSI ($P = .145$).

TABLE 4. Data on Independent Risk Factors for Incisional Surgical Site Infection after Abdominal Hysterectomy

Risk factor	Adjusted odds ratio (95% confidence interval)	*P*
Perioperative blood transfusion	2.4 (1.4–4.4)	.003
Duration of operation greater than 75th percentile	1.7 (1.0–3.0)	.074
Medicaid or no health insurance	1.7 (0.9–2.9)	.076
Body mass index		
<25	Reference	
25–30	2.4 (0.8–7.2)	.104
30–35	3.0 (1.0–9.6)	.058
>35	5.7 (2.1–15.6)	.001

NOTE. Model *C* statistic, 0.729.

DISCUSSION

Identification of independent risk factors for SSI is essential for the development of operation-specific risk stratification indices. In this multicenter study performed at 4 hospitals in the CDC Prevention Epicenter Program, we identified 2 independent risk factors for incisional SSI after abdominal hysterectomy: blood transfusion and morbid obesity. Duration of operation greater than the 75th percentile, obesity, and lack of private health insurance were marginally associated with increased odds of SSI in the multivariable analysis.

We determined independent risk factors for only abdominal incisional SSI in this study, since in univariate analysis, the risk factors for organ-space SSI seemed to be different. Crude risk factors for organ-space SSI included lack of private health insurance, current smoking, and younger age, while cancer as the indication for operation was associated with a significantly lower risk of organ-space SSI. Since these risk factors were substantially different from the incisional SSI risk factors, in subsequent analyses, we focused on risk factors for superficial incisional and deep incisional SSI after abdominal hysterectomy.

Morbid obesity was associated with the greatest odds of incisional SSI, with a dose-response relationship between risk and increased BMI. Obesity has been found to be a risk factor for SSI by many investigators, in particular after abdominal and gynecologic operations.[24] Obesity has also been shown to be independently associated with SSI after hysterectomy (vaginal or abdominal)[17] and, specifically, after abdominal hysterectomy.[6,7] In our current study, undergoing a blood transfusion was associated with significantly increased odds of incisional SSI. Persson and colleagues found blood loss of more than 1 L during surgery to be a risk factor for SSI,[8] and Shapiro and colleagues also found blood loss to be associated with increased risk of SSI in univariate analysis.[4] Both of these studies included vaginal and abdominal hysterectomies, and neither included blood loss in a multivariable model to control for confounding factors. We and others have previously noted that excessive blood loss that necessitates transfusion is associated with increased risk of SSI after a variety of operations,[25-28] although whether this association is due to the underlying anemia, to transfusion-related immunomodulation,[29] or to residual confounding is not clear.

Longer duration of operation and lack of private health insurance were marginally associated with increased odds of SSI after abdominal hysterectomy. Duration of operation greater than the 75th percentile is part of the standard NNIS risk index. It is not clear whether the risk associated with longer operations is truly due to the length of the operation or whether longer duration is at least in part a proxy for the complexity of the operation or for the skill of the operating staff.

We used lack of private health insurance as a proxy for low socioeconomic status in this study. Previously, Shapiro et al found that being a clinic patient (as opposed to being a private patient) was an independent risk factor for SSI after vaginal or abdominal hysterectomy.[4] In general, lower socioeconomic status is considered to be a risk factor for infection after a gynecologic operation,[30] but the reasons for this association are not known.

In univariate analysis, there was a trend toward increasing perioperative serum glucose levels in patients with superficial incisional SSI and deep incisional SSI, compared with women with no SSI after abdominal hysterectomy. We used a perioperative window of 24 hours before operation to 5 days after operation for assessment of maximum serum glucose level measurements. It is unlikely that active infection could have explained the high glucose values, since the onset of incisional SSI occurred at least 2 days after the highest serum glucose level in all but 2 patients (with missing dates of glucose measurement). Serum glucose level did not remain as an independent risk factor in the multivariable model. In part, this may be due to the relatively large number of patients without laboratory results for serum glucose level during the perioperative period. We used multiple imputation to impute a set of plausible glucose values that represent the uncertainty about the correct value, but it is possible that a higher glucose level would have remained associated with an increased risk of incisional SSI if serum glucose level measurements had been available for all patients. Determination of the risk of incisional SSI associated with perioperative hyperglycemia will require more complete glucose testing of patients at risk for hyperglycemia (eg, with obesity and/or family history of diabetes) before and after operation. Given the increasingly widespread epidemics of obesity and diabetes in the United States, there are increasing numbers of hospitalized patients with undiagnosed and untreated diabetes.[31,32] Earlier and more accurate diagnosis of diabetes before surgery is necessary. Additional studies to evaluate the relationship between perioperative glucose control and SSI and wound complications are needed.

The limitations of this study include the retrospective observational nature of the study, which precluded collecting data on some potential risk factors for SSI (eg, adequacy of preoperative skin antisepsis and operative hemostasis). In addition, the collection of data from 4 hospitals necessitated restricting the investigation to a relatively small number of risk factors to ensure that data collection was as complete and accurate as possible. Also, the surveillance strategy that we used excluded SSI diagnosed and treated solely in outpatient settings. Because we reviewed only hospital records, it is possible that some individuals classified as uninfected control patients had SSI, resulting in misclassification of the outcome, which would potentially result in bias of results toward the null.

The advantages of this study included its multicenter nature, with collection of data from patients admitted for hysterectomy to 4 academic hospitals. Inclusion of data from a variety of different types of hospital, including hospitals with different patient populations with different indications for hysterectomy, expands the generalizability of the results to other academic medical centers. In addition, we used standardized definitions for SSI and enhanced surveillance to identify infections during the hospitalization for surgery and during rehospitalization. We focused our analysis on the risk factors for incisional SSI after abdominal hysterectomy, since the risk factors associated with organ-space SSI seem to differ from the risk factors for incisional SSI after hysterectomy.

In summary, we identified morbid obesity and perioperative blood transfusion as independent risk factors for superficial incisional and deep incisional SSI after abdominal hysterectomy. Obesity, longer duration of operation, and lack of private health insurance were marginally associated with increased odds of incisional SSI. Additional studies are needed to determine the association of perioperative hyperglycemia with SSI after abdominal hysterectomy. The risk factors identified in this study can be used in the future to create a risk stratification index specific for abdominal hysterectomy and incisional SSI.

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