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## ORIGINAL ARTICLE

# Risk Factors for Surgical Site Infection After Low Transverse Cesarean Section

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(See the commentary by Lee on pages 485–486)

**BACKGROUND.** Independent risk factors for surgical site infection (SSI) after cesarean section have not been well documented, despite the large number of cesarean sections performed and the relatively common occurrence of SSI.

**OBJECTIVE.** To determine independent risk factors for SSI after low transverse cesarean section.

**DESIGN.** Retrospective case-control study.

**SETTING.** Barnes-Jewish Hospital, a 1,250-bed tertiary care hospital.

**PATIENTS.** A total of 1,605 women who underwent low transverse cesarean section during the period from July 1999 to June 2001.

**METHODS.** Using the *International Classification of Diseases, Ninth Revision, Clinical Modification* diagnosis codes for SSI or wound complication and/or data on antibiotic use during the surgical hospitalization or at readmission to the hospital or emergency department, we identified potential cases of SSI in a cohort of patients who underwent a low transverse cesarean section. Cases of SSI were verified by chart review using the definitions from the Centers for Disease Control and Prevention's National Nosocomial Infections Surveillance System. Control patients without SSI or endomyometritis were randomly selected from the population of patients who underwent cesarean section. Independent risk factors for SSI were determined by logistic regression.

**RESULTS.** SSIs were identified in 81 (5.0%) of 1,605 women who underwent low transverse cesarean section. Independent risk factors for SSI included development of subcutaneous hematoma after the procedure (adjusted odds ratio [aOR], 11.6 [95% confidence interval {CI}, 4.1–33.2]), operation performed by the university teaching service (aOR, 2.7 [95% CI, 1.4–5.2]), and a higher body mass index at admission (aOR, 1.1 [95% CI, 1.0–1.1]). Cephalosporin therapy before or after the operation was associated with a significantly lower risk of SSI (aOR, 0.2 [95% CI, 0.1–0.5]). Use of staples for skin closure was associated with a marginally increased risk of SSI.

**CONCLUSIONS.** These independent risk factors should be incorporated into approaches for the prevention and surveillance of SSI after surgery.

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Surgical site infection (SSI) after a cesarean section increases maternal morbidity and medical costs.<sup>1</sup> The rates of SSI after cesarean section reported in the literature range from 3% to 15%, depending on the surveillance methods used to identify infections, the patient population, and the use of antibiotic prophylaxis.<sup>2–11</sup> The pooled mean rate of SSI after cesarean section for US hospitals participating in the Centers for Disease Control and Prevention's National Nosocomial Infections Surveillance System is 3.15%.<sup>12</sup>

Expanding our knowledge of the risk factors associated with SSI is essential to developing targeted prevention strategies to reduce the risk of SSI. Independent risk factors for SSI after cesarean section have not been well documented, despite the fact that it is the most commonly performed surgical procedure in the United States,<sup>13</sup> and the reported rate of SSI is rel-

atively high. We performed a large case-control study to determine clinically relevant independent risk factors for SSI after low transverse cesarean section. A low transverse uterine incision is the preferred type of incision for cesarean section, because it is associated with less blood loss and lower risk of subsequent uterine rupture than a vertical incision. It is used for the vast majority of cesarean section deliveries in the United States, whereas a vertical incision (alone or in combination with a low transverse incision) is typically used for a minority of cesarean section deliveries, for selected obstetric reasons or when there is need for rapid delivery.<sup>14</sup>

## METHODS

This study was conducted at Barnes-Jewish Hospital, a 1,250-bed tertiary care hospital. It is the academic hospital for the

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Washington University School of Medicine and has a referral base of patients from metropolitan St. Louis and within a 200-mile radius of the city. At the hospital, the obstetrics service performs approximately 4,000 deliveries per year and provides a full range of care, including high-risk maternal and fetal medicine. Obstetric care is provided by a full-time faculty in the department of obstetrics and gynecology at the Washington University School of Medicine and by an adjunct obstetric faculty in private practice.

We performed a case-control study nested within a cohort of 1,605 women who underwent low transverse cesarean section during the period from July 1999 to June 2001. Demographic, pharmacy, and laboratory data were obtained from the Barnes-Jewish Hospital Medical Informatics database. Risk factor data were collected from the medical records of each patient's surgical hospitalization, including all notes by physicians and/or nurses concerning the hospitalization.

Patient-related variables included age, race, marital status, type of insurance, body mass index (BMI) at admission, weight gain during pregnancy, presence of diabetes mellitus, gestational diabetes, systemic lupus erythematosus, sexually transmitted diseases during pregnancy (eg, gonorrhea, chlamydia, bacterial vaginosis, *Trichomonas vaginalis* infection, herpes simplex virus infection, or human immunodeficiency virus infection), group B *Streptococcus* (GBS) colonization, and use of alcohol, tobacco, illicit street drugs, and/or corticosteroids.

For the mother, obstetrics-related variables included the number of prior pregnancies, prior births, abortions, and previous cesarean sections; presence of cervical incompetence; the number of vaginal exams before cesarean section; presence of vaginal discharge at admission; the number of prenatal care visits; presence of preeclampsia, chorioamnionitis, maternal fever, fundal tenderness before delivery, maternal and fetal tachycardia, and/or vaginal bleeding; malpresentation; spontaneous or assisted rupture of membranes; interval since rupture of membranes; duration of labor; use of internal fetal monitors; use of Foley bulb for cervical ripening; receipt of amnioinfusion; and presence of meconium. For the infant, obstetrics-related variables included gestational age at delivery, birth weight, and Apgar score.

Operation-related variables included the American Society of Anesthesiologists score, urgency of operation, type of skin and uterine incision, exteriorization of the uterus, manual removal of placenta, presence of drains, receipt of shave with razor, use of staples for skin closure, receipt of an additional operative procedure, duration of time between hospital admission and operation, type of service (university teaching or private), volume of blood loss, and receipt of antibiotic therapy.

Cesarean sections were classified as elective, urgent, or emergent according to standardized criteria by the operative team. True emergent procedures were classified as emergent and did not include full surgical preparation. Hemoglobin and hematocrit levels were determined within 24 hours before incision and within 48 hours after incision. The highest serum glucose level, if available, was determined from blood obtained

within 24 hours before incision and within 48 hours after incision. Additional postoperative variables included receipt of blood transfusion (after incision during the cesarean section admission) and development of a subcutaneous hematoma.

## Definitions

Cohort patients were identified by an *International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)* procedure code for low transverse cesarean section (74.1) and were included only if the operative note indicated that a low transverse uterine incision had been used. Screening for wound complications was done during the surgical hospitalization or rehospitalization (inpatient, emergency department, or outpatient surgery admission) within 60 days after operation with use of *ICD-9-CM* discharge diagnosis codes for incisional infection, dehiscence, wound necrosis, seroma, or hematoma (998.5, 998.51, 998.59, 674.32, or 674.34) and/or data on excess use of antibiotics after operation.<sup>11,15</sup> We reviewed all of the hospital medical records of patients who met the screening criteria, to determine if they met the case definition for SSI using the definitions from the Centers for Disease Control and Prevention's National Nosocomial Infections Surveillance System.<sup>16</sup> We included case patients with SSI identified during the surgical hospitalization or during an inpatient rehospitalization, emergency department visit, or outpatient surgery with signs and/or symptoms of SSI within 30 days after operation. Questionable cases were verified by an obstetrician and gynecologist (D.M.W.). Control patients without SSI or endomyometritis were randomly selected from the women who underwent low transverse cesarean section during the study period.

## Statistical Analysis

Comparisons for categorical variables were performed using the  $\chi^2$  or Fisher exact test. Continuous variables were compared using the Student *t* or Mann-Whitney *U* tests. Linearity assessments were performed on the variables of age and BMI. Fractional polynomials were used to determine the best fit for BMI.<sup>17</sup> Independent risk factors for SSI were determined by multivariate logistic regression. All variables with  $P < .20$  in the univariate analysis or with a priori clinical significance were evaluated by stepwise logistic regression for inclusion in the final model. The variable for lack of private insurance (ie, reliance on Medicaid or Medicare) was forced into the logistic regression model as a proxy for socioeconomic status. Interactions between the type and the timing of antibiotic prophylaxis were tested in the multivariate models, but they did not meet the criteria for inclusion ( $P < .05$  for interaction terms). Model fit was assessed using the C statistic. All tests were 2-tailed, and  $P < .05$  was considered significant. Statistical analyses were performed with SPSS version 14.0 (SPSS). Approval for this study was obtained from the Washington University Human Research Protection Office.

## RESULTS

During the 2-year study period, 1,759 patients underwent cesarean section in our academic tertiary care medical center. Of those patients, 1,605 (91%) underwent a low transverse uterine incision, and 81 (5.0%) of those 1,605 patients met the case definition for SSI with onset of infection within 30 days after low transverse cesarean section. Seventy-five (92.6%) of those 81 patients had SSIs that were classified as superficial incisional, 4 (4.9%) had deep incisional SSI, and 2 (2.5%) had organ space infection. Forty-eight (59.3%) of the 81 patients had SSI diagnosed during surgical hospitalization, 27 (33.3%) during rehospitalization, and 6 (7.4%) during an emergency department visit. A total of 310 control patients without endomyometritis were randomly selected for comparison with the 81 case patients with SSI.

The characteristics of the 81 case and 310 control patients are described in Table 1. Of these 391 patients, 239 (61.1%) were black, 71 (18.2%) smoked during their pregnancy, 34 (8.7%) had gonorrhea or chlamydial infection during their pregnancy, 129 (33.0%) had 1 or more cesarean sections previously, and 226 (57.8%) were admitted to the university teaching service. More than half of the patients were covered by either Medicaid or Medicare, or had no health insurance.

In the univariate analysis, SSI occurred significantly more often among women with the following risk factors: presence of chorioamnionitis, induction of labor, use of staples for skin closure, development of subcutaneous hematoma after operation, and admission to the university teaching service (Table 2). There was a significant association between a higher BMI at admission and SSI (median BMI, 36.4 for case patients vs 31.8 for control patients;  $P = .003$ ). Patients who had skin closure with staples had a significantly higher median BMI than patients who had skin closure with sutures (33.1 vs 29.6;  $P = .004$ ). Patients admitted to the university teaching service were significantly more likely to have skin closure with staples than patients admitted to the private service (216 [95.6%] of 226 vs 130 [78.8%] of 165 patients of patients;  $P < .001$ ). There was a marginal association between longer duration of operation and SSI (mean duration, 63.1 minutes for case patients vs 57.9 minutes for control patients;  $P = .090$ ). Only 83% of patients had the duration of operation recorded, and, for this reason, it was not included in further analyses.

Antibiotics were administered intravenously to 178 (45.5%) of 391 patients before incision, including 109 (27.9%) who were given ampicillin, penicillin, or clindamycin, presumably for anti-GBS prophylaxis, and 58 (14.8%) who received antibiotics for chorioamnionitis or fever (Table 3). Of the 109 women who received ampicillin, penicillin, or clindamycin, 36 (33.0%) had GBS colonization, and 55 (50.5%) had risk factors for GBS colonization (ie, urinary tract infection during pregnancy, fever, rupture of membranes 18 hours or more before incision, and/or preterm labor [before week 37 of gestation]<sup>18</sup>) without documented positive culture results. Of the 58 women who received ampicillin plus

TABLE 1. Characteristics of 391 Patients Who Underwent Low Transverse Cesarean Section at Barnes-Jewish Hospital During the Period From July 1999 to June 2001

Characteristic	Value
Age, years	26.5 (15–43)
Body mass index at admission	32.3 (17–65)
Race	
Black	239 (61.1)
White	127 (32.5)
Other	25 (6.4)
Tobacco use	
Never	294 (75.2)
Prior use, quit during pregnancy	26 (6.6)
Current use	71 (18.2)
Had gonorrhea or <i>Chlamydia</i> infection during pregnancy	34 (8.7)
HIV infection	4 (1.0)
Type of insurance	
Private	155 (39.6)
Medicaid and/or Medicare	236 (60.4)
Service performing operation	
University teaching	226 (57.8)
Private	165 (42.2)
No. of prior cesarean sections	
0	262 (67.0)
1	87 (22.3)
2	32 (8.2)
3	10 (2.6)
Onset of labor	
Spontaneous	121 (30.9)
Induced	85 (21.7)
No labor	185 (47.3)
Type of cesarean section	
Elective	114 (29.2)
Urgent	215 (55.0)
Emergent	62 (15.9)
Type of skin incision	
Vertical	10 (2.6)
Transverse	381 (97.4)

NOTE. Data are no. (%) of patients or median value (range). Body mass index is defined as the weight in kilograms divided by the square of the height in meters.

gentamycin or tobramycin, or ampicillin-sulbactam, 35 (60.0%) had chorioamnionitis diagnosed.

Patients who were not given intravenous antibiotics before or after incision were significantly more likely to have undergone an elective operation than patients who were given antibiotics (19 [42.2%] of 45 vs 95 [27.6%] of 346 patients;  $P = .040$ ). Twenty-two (48.9%) of the 45 patients who were not given antibiotics were attended by a private physician ( $P = .334$ ). For 20 patients who did not receive antibiotic prophylaxis, the operation was classified as urgent; for 6 patients who did not receive antibiotic prophylaxis, the operation was classified as emergent. When the analysis of the categories of antibiotics and the SSI risk was repeated using only the patients who underwent elective surgery without antibiotic prophylaxis

TABLE 2. Univariate Comparisons of Risk Factors for Surgical Site Infection (SSI) in Patients With and Patients Without SSI After Low Transverse Cesarean Section at Barnes-Jewish Hospital, July 1999 to June 2001

Risk factor	No. (%) of patients		OR (95% CI)	P
	Case group (n = 81)	Control group (n = 310)		
<b>Demographic factors</b>				
Age <18 years	6 (7.4)	17 (5.5)	1.4 (0.5–3.6)	.514
Race				
White	27 (33.3)	100 (32.3)	1.0	...
Black	49 (60.5)	190 (61.3)	1.0 (0.6–1.6)	.865
Other	5 (6.2)	20 (6.5)	0.9 (0.3–2.7)	.888
Had diabetes mellitus or gestational diabetes	8 (9.9)	30 (9.7)	1.0 (0.4–2.3)	.957
Had gonorrhea or <i>Chlamydia</i> infection during pregnancy	10 (12.3)	24 (7.7)	1.7 (0.8–3.7)	.194
Had <i>Trichomonas</i> infection during pregnancy	11 (13.6)	27 (8.6)	1.6 (0.8–3.5)	.191
Had documented GBS colonization	15 (18.5)	46 (14.8)	1.3 (0.7–2.5)	.417
Tobacco use (past or present)	25 (30.9)	72 (23.2)	1.5 (0.9–2.5)	.158
Type of insurance				
Private	30 (37.0)	125 (40.3)	1.0	...
Medicaid and/or Medicare	51 (63.0)	185 (59.7)	1.1 (0.7–1.9)	.590
Type of service				
Private	18 (22.2)	147 (47.4)	1.0	...
University teaching	63 (77.8)	163 (52.6)	3.2 (1.8–5.6)	<.001
<b>Obstetric factors</b>				
Use of internal monitors	40 (49.4)	118 (38.1)	1.6 (1.0–2.6)	.066
Had chorioamnionitis <sup>a</sup>	21 (25.9)	41 (13.2)	2.3 (1.3–4.2)	.006
No. of vaginal examinations				
0	12 (14.8)	63 (20.3)	1.0	...
1–6	49 (60.5)	192 (61.9)	1.3 (0.7–2.7)	.408
≥7	20 (24.7)	55 (17.7)	1.9 (0.9–4.3)	.114
Induction of labor	45 (55.6)	123 (39.7)	1.9 (1.2–3.1)	.011
Duration of labor				
No labor	35 (43.2)	150 (48.4)	1.0	...
<6 hours	11 (13.6)	59 (19.0)	0.8 (0.4–1.7)	.553
6–12 hours	11 (13.6)	47 (15.2)	1.0 (0.5–2.1)	.994
>12 hours	24 (29.6)	54 (17.4)	1.9 (1.0–3.5)	.037
<b>Surgical factors</b>				
Use of drains	10 (12.3)	20 (6.5)	2.0 (0.9–4.6)	.081
Use of staples for skin closure	79 (97.5)	267 (86.1)	6.4 (1.5–26.8)	.012
Type of cesarean section				
Elective	19 (23.5)	95 (30.6)	1.0	...
Urgent	50 (61.7)	165 (53.2)	1.5 (0.8–2.7)	.164
Emergent	12 (14.8)	50 (16.1)	1.2 (0.5–2.7)	.655
<b>Postoperative factors</b>				
Transfusion after incision during the surgical hospitalization	11 (13.6)	22 (7.1)	2.1 (1.0–4.4)	.066
Development of subcutaneous hematoma after operation	16 (19.8)	6 (1.9)	12.5 (4.7–33.1)	<.001

NOTE. CI, confidence interval; GBS, group B *Streptococcus*; OR, odds ratio.

<sup>a</sup> Determined by the symptoms of fever during labor and/or fundal tenderness, and/or by physician diagnosis.

as the reference group, there were no significant differences in risk of SSI associated with the various categories of antibiotics (all  $P > .100$ ). This analysis was limited by the small number of patients in the reference group; there were only 19 patients who underwent elective surgery without antibiotic prophylaxis.

Suboptimal timing of antibiotic prophylaxis was also associated with a higher risk of SSI in univariate analysis. Receipt of antibiotics more than 1 hour before incision was associated

with a 2.1-fold increased odds of SSI, compared with receipt of standard surgical prophylaxis at the time the umbilical cord was clamped (Table 3). The patients who received antibiotics more than 1 hour before incision were much more likely to have a diagnosis of chorioamnionitis than patients who received antibiotics within 1 hour before or after incision (61 [48%] of 128 vs 45 [21%] of 218 patients;  $P < .001$ ).

Independent risk factors for SSI identified in the multivariate logistic regression analysis included higher BMI, admission

TABLE 3. Univariate Comparisons of Antibiotic Therapy Given to Patients With and Patients Without Surgical Site Infection (SSI) After Low Transverse Cesarean Section at Barnes-Jewish Hospital, July 1999 to June 2001

Antibiotic therapy	No. (%) of patients		OR (95% CI)	P
	Case group (n = 81)	Control group (n = 310)		
Category or indication				
No intravenous antibiotics <sup>a</sup>	15 (18.5)	30 (9.7)	1.00	...
Cephalosporin surgical prophylaxis <sup>b</sup>	24 (29.6)	155 (50.0)	0.3 (0.1–0.7)	.002
Anti-GBS agents <sup>c</sup>	16 (19.8)	36 (11.6)	0.9 (0.4–2.1)	.787
Surgical prophylaxis plus anti-GBS agents <sup>d</sup>	11 (13.6)	46 (14.8)	0.5 (0.2–1.2)	.110
Therapy for chorioamnionitis or fever <sup>e</sup>	15 (18.5)	43 (13.9)	0.7 (0.3–1.6)	.409
Timing of administration				
Only after incision	23 (28.4)	145 (46.8)	1.0	...
Within 1 hour before incision <sup>a</sup>	11 (13.6)	39 (12.6)	1.8 (0.8–4.0)	.159
Between 1 and 8 hours before incision	32 (39.5)	96 (31.0)	2.1 (1.2–3.8)	.014

NOTE. CI, confidence interval; GBS, group B *Streptococcus*; OR, odds ratio.

<sup>a</sup> Three patients received oral antibiotics within 8 hours before incision (2 between 4 and 6 hours before incision and 1 >7 hours before incision). The remaining 42 patients received no antibiotics before incision.

<sup>b</sup> Cefazolin or cefotetan.

<sup>c</sup> Ampicillin, penicillin, or clindamycin (1 patient received vancomycin alone within 1 hour before incision).

<sup>d</sup> Ampicillin, penicillin, or clindamycin, plus cefazolin or cefotetan.

<sup>e</sup> Ampicillin plus gentamycin or tobramycin, or ampicillin-sulbactam.

to the university teaching service, and development of subcutaneous hematoma after operation (Table 4). Receipt of cephalosporin prophylaxis before or during operation was associated with a 77% lower odds of SSI, compared with no receipt of antibiotics before or after incision ( $P < .001$ ). After adjusting

TABLE 4. Multivariate Model of Risk Factors for Surgical Site Infection (SSI) After Low Transverse Cesarean Section at Barnes-Jewish Hospital, July 1999 to June 2001

Risk factor	aOR <sup>a</sup> (95% CI)	P
Body mass index at admission	1.1 (1.0–1.1)	.003
Service performing operation		
Private	1.0	...
University teaching	2.7 (1.4–5.2)	.003
Use of staples for skin closure	3.3 (0.7–14.7)	.118
Development of subcutaneous hematoma after operation	11.6 (4.1–33.2)	<.001
Antibiotic therapy		
None	1.00	...
Cephalosporin surgical prophylaxis <sup>b</sup>	0.2 (0.1–0.5)	<.001
Anti-GBS agents <sup>c</sup>	0.5 (0.2–1.4)	.215
Surgical prophylaxis plus anti-GBS agents <sup>d</sup>	0.3 (0.1–0.8)	.018
Therapy for chorioamnionitis or fever <sup>e</sup>	0.4 (0.2–1.2)	.095

NOTE. Two patients were excluded from the multivariate regression model because their height measurements, which are necessary for calculation of BMI, were missing (model C-statistic, 0.781). aOR, adjusted odds ratio; CI, confidence interval; GBS, group B *Streptococcus*.

<sup>a</sup> Model adjusted for type of insurance (private vs. Medicaid and/or Medicare).

<sup>b</sup> Cefazolin or cefotetan.

<sup>c</sup> Ampicillin, penicillin, or clindamycin.

<sup>d</sup> Ampicillin, penicillin, or clindamycin, plus cefazolin or cefotetan.

<sup>e</sup> Ampicillin plus gentamycin or tobramycin, or ampicillin-sulbactam.

for other independent risk factors, we found that skin closure with staples was associated with marginally increased odds of SSI. GBS colonization and risk factors for GBS colonization did not confound the relationship between type of antibiotic and SSI when these variables were forced into the logistic regression model. In addition, there was no effect modification by receipt of antibiotic more than 1 hour before incision on the type of antibiotic used ( $P > .50$  for all interaction terms).

## DISCUSSION

This is, to our knowledge, the largest study to date examining independent risk factors for SSI after low transverse cesarean section in the United States that has used definitions from the Centers for Disease Control and Prevention's National Nosocomial Infections Surveillance System and 30-day hospital-based surveillance to identify patients with SSI. Independent risk factors for SSI after low transverse cesarean section included a higher BMI at admission, admission to the university teaching service, absence of cephalosporin prophylaxis before or during operation, and development of subcutaneous hematoma after operation. The rate of SSI after low transverse cesarean during this 2-year study section was 5.0%, which is consistent with estimates from other studies.

Previous studies that had sufficient sample sizes and that used multivariate analysis to identify independent risk factors for SSI after cesarean section identified the following factors associated with increased risk of SSI: younger age; obesity; presence of hypertension or preeclampsia; diabetes mellitus; chorioamnionitis; preoperative infection at a remote body site; high preoperative severity of illness; nulliparity; fewer than 7 prenatal visits; longer interval since rupture of membranes; premature rupture of membranes; emergency delivery; ab-

sence of antibiotic prophylaxis; longer duration of operation; use of staples for skin closure; and twin delivery.<sup>3,7,8,19</sup> The wide variety of reported independent risk factors for SSI may be due to the variability in potential risk factors selected for analysis. Killian et al.<sup>3</sup> included only a very small number of potential risk factors, whereas other studies included a more comprehensive collection.<sup>7,8</sup> Also, of the 4 studies that used multivariate analysis with sufficient sample size, 1 study conducted SSI surveillance only during the original surgical admission.<sup>7</sup>

Our study of a university-affiliated tertiary care hospital obstetrics population undergoing low transverse cesarean section included women from a wide spectrum of society with regard to socioeconomic and health status. More than half the deliveries were performed by the university teaching service, including patients with low socioeconomic status and/or with severe maternal or fetal health conditions. Compared with patients with private insurance, patients without private insurance had a relatively higher number of high-risk characteristics, increasing their underlying risk of SSI; therefore, we included an indicator of socioeconomic status in the analysis. Our finding of increased risk of SSI among patients admitted to the university teaching service is consistent with previous reports of increased risk of SSI associated with operation by trainee or inexperienced surgeons.<sup>20,21</sup> In our institution, house staff members in the university teaching service are actively involved in surgery, with faculty supervision, and this likely contributes to the increased risk of postoperative infection.

Obesity is a well-known risk factor for SSI.<sup>3,7,8,22</sup> Possible biological explanations for this association include the relative avascularity of adipose tissue,<sup>8,23</sup> the increase in wound area,<sup>24</sup> and the poor penetration of prophylactic antibiotics in adipose tissue.<sup>25</sup> Our study calculated the BMI of patients from their weight and height at admission, because the prepregnancy BMI was not available for all patients. In addition, given the range of weight change during pregnancy in our study (ranging from 11.8 kg in weight loss to 54.4 kg weight gain), we hypothesized that the BMI at admission was a better indicator of body mass during the at-risk time for development of SSI than was the prepregnancy BMI.

We did not detect an association between diabetes and SSI in this study. It is possible that the perioperative serum glucose level, which has been associated with increased risk of SSI after cardiac surgery,<sup>26-29</sup> may be a more sensitive predictor of SSI than is diabetes. Although we attempted to assess this relationship, only 17% of patients had documented perioperative blood glucose levels measured during the surgical hospitalization. Evaluating the association between hyperglycemia and SSI will require a much larger study with systematic collection of perioperative blood glucose levels.

Estimating the protective effect of antibiotics is problematic because they are used both therapeutically and prophylactically in this patient population. In the case of cephalosporin therapy, patients treated with a cephalosporin had an a priori lower risk of SSI than patients who received other antibiotics during labor for suspected chorioamnionitis. Administration

of cephalosporins before or after incision independently decreased the odds of SSI by 77%, compared with no administration of antibiotics before or after incision. Interestingly, the adjusted OR for SSI was very similar for the group who received anti-GBS prophylaxis and a cephalosporin before or after incision and for the group who received a cephalosporin only (0.3 vs 0.2). In contrast, patients given anti-GBS prophylaxis alone during labor had a higher adjusted OR for SSI (0.5). This suggests the possible benefit of either the addition of cephalosporin therapy or antibiotic administration within 1 hour before or after incision, although we were unable to detect a significant interaction between timing of administration and type of antibiotic given as prophylaxis.

Our adjusted estimate of the protective effect of cephalosporin surgical prophylaxis closely reflects the 59% reduction in the incidence of wound infection reported in a Cochrane meta-analysis comparing prophylaxis with an antibiotic and with placebo during cesarean section.<sup>30</sup> The reference group for our analysis included all patients who did not receive antibiotics. During the study period, the American College of Obstetricians and Gynecologists recommended antibiotic prophylaxis only for high-risk cesarean sections but did not recommend routine administration of antibiotic prophylaxis for low-risk surgeries.<sup>31</sup>

The relationship between use of staples for skin closure and SSI after cesarean section remains unresolved. Of 5 very small randomized controlled trials in cardiovascular surgery that compared use of staples with use of sutures for skin closure, 3 reported higher infection rates with use of staples, and 2 reported no difference.<sup>32</sup> Our estimate is similar to the findings of Johnson et al.,<sup>19</sup> who report that skin closure with staples doubled the risk of SSI after cesarean section. In our study, patients with staples had a significantly higher BMI than patients with sutures. Interestingly, Trick et al.<sup>27</sup> reported that use of staples for skin closure was significantly associated with deep incisional sternal SSI after coronary artery bypass surgery in normal-weight or overweight patients, but not in obese patients (BMI, >30). We were unable to assess the effect modification of BMI on the relationship between use of staples and risk of SSI because 97.5% of the patients with SSI had staples used for skin closure.

A unique strength of this study is the examination of postoperative risk factors for SSI, particularly the development of subcutaneous hematoma. Previous cesarean section studies have generally omitted postoperative maternal factors from their analyses. To our knowledge, this is the first multivariate study to establish the development of subcutaneous hematoma as an independent risk factor for SSI after cesarean section, despite awareness that hematomas may provide a medium for bacterial growth.<sup>25,33-35</sup> Notably, development of a subcutaneous hematoma was the strongest independent risk factor for SSI in our model.

The limitations of this study include the potential for misclassification of the outcome. Our SSI rate is most likely an underestimate, because the surveillance strategy we used only



captured data on infections managed in the hospital or diagnosed during an emergency department visit. The infections that were missed by our surveillance strategy were most likely superficial incisional SSI treated with oral antibiotics. In addition, there is also the potential for information bias in our study, because information for some confounders may also have been incompletely captured (eg, for subcutaneous hematoma, since small hematomas that developed after hospital discharge may have been managed exclusively in the outpatient setting).

Other limitations include a lack of generalizability as a result of the performance of this study in an academic, tertiary care, urban hospital. Our patient population was not representative of the typical obstetrics population, because it had a higher percentage of women with low socioeconomic status, a higher percentage of women who were obese, and a higher prevalence of sexually transmitted diseases during pregnancy than would be expected in the average obstetrics population.

The major strengths of this study were the inclusion of a very large number of potential risk factors and the use of multivariate analysis. Of the limited number of previous studies on risk factors for SSI after cesarean section that used multivariate analysis, this is the first to include a variety of postoperative maternal factors. Patients with endomyometritis were excluded from the control population because of concern about overlapping risk factors for infection at the surgical site. We used hospital-based surveillance to identify SSI cases, on the basis of ICD-9-CM diagnosis codes and/or data on excess antibiotic use, and confirmed each case using definitions of SSI from the Centers for Disease Control and Prevention's National Nosocomial Infections Surveillance System.

Knowledge of the independent risk factors for SSI is critical for the development of strategies for reducing the incidence of SSI and for identifying high-risk patients requiring intensive postoperative surveillance. The results of our study indicate that a higher BMI, an operation performed by the teaching service, the absence of cephalosporin therapy before or during operation, and the development of a subcutaneous hematoma independently increase the risk of SSI. These characteristics should be systematically incorporated into approaches for the prevention and surveillance of SSI.

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