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Independent risk factors for surgical site infection after cesarean delivery in a rural tertiary care medical center

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Abstract

Background—We aimed to determine the incidence of surgical site infection (SSI) after cesarean delivery (CD) and identify the risk factors in a rural population.

Methods—We identified 218 SSI patients by International Classification of Disease codes and matched them with 3131 parturients (control) from the electronic record database in a time-matched retrospective quality assurance analysis.

Results and discussion—The incidence of SSI after CD was 7.0 %. Risk factors included higher body mass index (BMI) [40.30 ± 10.60 kg/m² SSI (95 % CI 38.73–41.87) vs 34.05 ± 8.24 kg/m² control (95 % CI 33.75–34.35, $P < 0.001$)], years of education [13.28 ± 2.44 years SSI (95 % CI 12.9–13.66) vs 14.07 ± 2.81 years control (95 % CI 13.96–14.18, $P < 0.001$)], number of prior births [2 (1–9) SSI vs 1 (1–11) control ($P < 0.001$)], tobacco use (OR 1.49; 95 % CI 1.06–2.09, $P = 0.03$), prior diagnosis of hypertension (OR 1.80; 95 % CI 1.34–2.42, $P < 0.001$), gestational diabetes (OR 1.59; 95 % CI 1.18–2.13, $P = 0.003$), and an emergency/STAT CD (OR 1.6; 95 % CI 1.1–2.3, $P = 0.01$).

Conclusions—Risk factors for SSI after CD included higher BMI, less years of education, higher prior births, tobacco use, prior diagnosis of hypertension, gestational diabetes, and emergency/STAT CD. The presence of ruptured membranes was protective against SSI.

Keywords

Surgical site infection; Cesarean delivery; Risk factors; Electronic medical record

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Conflicts of interest None.

Introduction

Cesarean delivery (CD) is one of the most common surgical procedures performed in the United States [1]. Surgical site infection (SSI) after CD is an important key quality indicator of maternal care with a reported incidence of 3–15 % [2–4]. SSI after CD can result in significant morbidity and mortality [2, 4–6]. Obstetric infection can account for >12 % of maternal deaths, occurring most frequently in women who have CD following spontaneous or elective termination of pregnancy, and as a result of puerperal fever secondary to genital tract infection [4, 6]. Additionally, SSI increases length of hospital stay, 30-day readmission rate, and hospital costs [5–7]. In this study, we aimed to determine the incidence of SSI after CD and identify risk factors for SSIs in a rural tertiary teaching academic medical center.

Methods

After local institutional review board approval, we conducted a retrospective, case controlled, time-matched, quality assurance electronic medical record (EMR) analysis at West Virginia University Hospital. Because this study was a retrospective EMR analysis, it was not registered as a clinical trial. Over a period of 6 years and 3 months (January 1, 2009 until March 30, 2015), 218 patients with SSI after CD were identified based on International Classification of Disease (ICD), ninth revision, and Current Procedural Terminology (CPT) codes. ICD codes selected by our research group to identify SSI after CD included 998.59 (postoperative wound infection or other postoperative infection), 674.10 (disruption of cesarean wound), 674.12 (disruption of cesarean wound, delivered, with mention of postpartum complication), and 674.14 (disruption of cesarean wound, postpartum condition or complication). CPT codes included 59510 (cesarean delivery), 59514 (cesarean delivery only), 59515 (cesarean delivery including postpartum care), and 59618 (cesarean delivery after attempted vaginal birth after cesarean delivery [VBAC]). Those patients with a positive diagnosis in the time period from January 1, 2009 until March 30, 2015 were all matched to eligible women from a control data source of 3131 parturients from the West Virginia Clinical and Translational Science Institute (WVCTSI) integrated data repository quality assurance medical record database from the same hospital (West Virginia University Hospital) over the same time period. January 1, 2009 was chosen because it was the start date for implementation of our EMR system at our institution. All patients in both the SSI after CD group and the control group were matched to the same birth hospital (West Virginia University Hospital), the same time period (January 1, 2009 until March 30, 2015), and same type of surgical procedure (CD).

The study included information covering demographic, obstetric, maternal, operative, and neonatal variables. These variables were chosen based on factors that were previously linked to the risk of surgical site infection after CD in other studies [2, 3, 8–10], and their availability in our current clinical database. Demographic variables included age, race/ethnicity, height, body mass index (BMI), years of education, and type of health insurance.

Obstetric variables included number of prior pregnancies and births, previous cesarean deliveries, number of prenatal care visits, group B streptococcus (GBS) colonization, malpresentation, use of steroids during pregnancy, treatment with antibiotics during

pregnancy, cervical incompetence, number of vaginal examinations before CD, rupture of membranes (spontaneous or assisted), use of internal fetal monitor, need for amnioinfusion, presence of meconium, history or diagnosis of chorioamnionitis, maternal fever, vaginal bleeding during pregnancy, use of Foley bulb for cervical ripening, and intra-operative antibiotic use.

Maternal medical conditions included ASA (American Society of Anesthesiologists) Physical Status classification, a diagnosis of diabetes mellitus, gestational diabetes, hypertension, preeclampsia, systemic lupus erythematosus (SLE), sexually transmitted disease (STD) during pregnancy (e.g., gonorrhea, chlamydia, bacterial vaginosis, trichomonas vaginalis infection, herpes simplex virus infection, or human immunodeficiency virus infection), and use of tobacco.

Operative variables included urgency of operation (elective, urgent, emergency, STAT), type of uterine incision (low transverse, low cervical, low vertical, or classical), and time between admission and operation.

Neonatal variables included gestational age at delivery, birth weight, and Apgar scores.

Provision of anesthesia

All patients within the study period received a standard labor epidural or spinal anesthetic technique—in the sitting position, the epidural catheter or spinal was placed using the midline approach at the L3–4 or L4–5 vertebral interspace using loss of resistance to saline technique. We adhered to strict aseptic precautions such as hand washing, use of head covering, mask, sterile gloves, sterile kit and antiseptic solution on the skin as infection control measures. For labor epidural analgesia, the epidural catheter was inserted 5 cm into the epidural space and secured with adhesive tape. After a negative test dose (3 mL of 1.5 % lidocaine with 1:200,000 epinephrine), an initial bolus of 10 mL of 0.125 % bupivacaine and 100 µg fentanyl, the patient was placed on a patient-controlled epidural (PCEA) infusion of 0.125 % bupivacaine with fentanyl (2 µg/mL) at a rate of 10 mL/h, PCEA demand bolus dose of 4 mL, PCEA demand bolus dose lockout every 15 min, and PCEA 1-h total lockout of 26 mL. For CD, a bolus of either 2 % lidocaine with 1:100,000 epinephrine or 3 % chloroprocaine was given through the epidural catheter to obtain a bilateral dermatome T4 level to pin prick. For patients receiving a standard spinal anesthetic, the technique consisted of 12–15 mg of bupivacaine plus 0.2 mg of preservative-free morphine with 100 µg fentanyl to obtain a bilateral dermatome T4 level to pin prick.

For those patients requiring general endotracheal anesthesia, a standardized general anesthetic was provided utilizing a rapid sequence induction with cricoid pressure. Induction medications included intravenous propofol (2–3 mg/kg), succinylcholine (1–1.5 mg/kg) or rocuronium (0.6–0.8 mg/kg) to facilitate endotracheal intubation. Maintenance of general anesthesia consisted of 0.8–2.5 percent sevoflurane in oxygen and fentanyl boluses as needed for analgesia after delivery (total 5 µg/kg). Additional doses of rocuronium were used as necessary for muscle relaxation. Muscle relaxation was reversed at the end of surgery with 0.01 mg/kg of glycopyrrolate and 0.05 mg/kg of neostigmine. Standardized

criteria used for extubation included the ability to understand commands (i.e., open your eyes), a sustained head lift of 5 s, and a tidal volume of 0.5 mL/kg.

Patient-specific infection control protocol

Our institution implements a standardized protocol for prevention of surgical site infection [11]. The protocol consists of showering with chlorhexidine shampoo the night before surgery, chlorhexidine wipes over the abdomen on admission and prior to surgery, clipping the hair at the surgical site before incision, intra-operative skin preparation with 2 % chlorhexidine solution, antibiotic prophylaxis within 1 h preoperatively before the start of surgery, removing the placenta by traction rather than by manual extraction, double-layer suture closure when the depth between the skin and fascia is >2 cm, and daily evaluation of the cesarean incision site in the postoperative period. Our institution follows a general weight-based protocol for preoperative antibiotic prophylaxis for CD as outlined by the American College of Obstetricians and Gynecologists (ACOG), consisting of providing an intravenous dose of 2 g prophylactic cefazolin for women weighing up to 80 kg (175 lb), with an increase to 3 g for those who weigh >120 kg (265 lb) [12]. For patients allergic to penicillin and cephalosporin, intravenous clindamycin and gentamicin are substituted.

Statistical analysis

Normally distributed data were analyzed by the *t* test using a Welch–Satterthwaite calculation for pooled degrees of freedom [13], or analysis of variance. Non-normally distributed data were analyzed using the appropriate non-parametric equivalent (Mann–Whitney *U* or Kruskal–Wallis test). Univariate associations among categorical variables were explored using chi-squared or Fisher’s exact test for variables. Where appropriate, all results are reported as odds ratios (OR) with 95 % confidence intervals (CI). Multivariate analysis was performed on all significant univariate data using logistic regression, with data transformed to dichotomous variables where appropriate. All tests were 2-tailed, and a *P* value of <0.05 was considered significant. The statistical analyses were performed using Stata 14 (StataCorp, College Station, TX, USA).

Results

All patients included in this study were from the same institution and gave birth at the West Virginia University Hospital as described previously in the methods section. The study period covered January 1, 2009 until March 30, 2015.

We found the overall incidence of SSI after CD was 7.0 % (218/3131). Demographic, obstetric, maternal medical comorbidities, operative outcomes, and neonatal outcomes are shown in Table 1. No demographic differences were noted with respect to age and ASA Physical Status. However, the SSI group had a larger BMI (40.3 ± 10.6 vs 34.1 ± 8.2 , $P < 0.001$) with less years of education (13.3 ± 2.4 vs 14.1 ± 2.8 , $P < 0.001$) (Table 1).

No differences in obstetric data were noted with respect to prior pregnancies, prior CDs, number of prenatal care visits, GBS colonization rate, use of steroids, prior antibiotic use during pregnancy, cervical incompetence, number of vaginal examinations, use of internal fetal monitor, history or diagnosis of chorioamnionitis, and use of Foley bulb for cervical

ripening. The SSI group had more prior births (2 vs 1 median, $P < 0.001$), and a lower percent of ruptured membranes (0.5 vs 6.6 %, $P < 0.001$) (Table 1).

Regarding maternal medical comorbidities, there were no differences in patients with a diagnosis of diabetes mellitus, preeclampsia, SLE, and STD during pregnancy. The SSI group had a higher diagnosis of gestational diabetes (33.5 vs 24.1 %, $P = 0.003$), hypertension (54.5 vs 39.9 %, $P < 0.001$), and tobacco use (42.2 vs 32.9 %, $P = 0.03$) (Table 1).

Concerning operative delivery, the SSI group had a higher rate of emergency/STAT CDs (35.7 vs 25.9 %, $P = 0.01$), a lower rate of low cervical incision for CD (94.1 vs 97.2 %, $P = 0.02$), and a higher rate of classical cesarean incision for delivery (5.9 vs 2.8 %, $P = 0.02$) (Table 1).

Regarding neonatal outcome, there were no differences with respect to gestational age, child birth weight, or Apgar scores at birth (Table 1).

Multivariate logistic regression analysis of significant univariate data revealed BMI ($P < 0.001$), and number of prior births ($P < 0.001$) to be significant factors associated with SSI after CD.

Discussion

We found obesity, lower education level, higher prior births, gestational diabetes, hypertension, tobacco use, and emergency/STAT operative delivery status to be independent risk factors for SSI after CD, and the presence of ruptured membranes was protective against SSI after CD. SSIs place a significant burden on the health care system, representing 21.8 % of health care-associated infections [3]. Prevention of SSIs is a key component of the Joint Commission's quality improvement initiative through the Surgical Care Improvement Project [3]. CD is one of the most common major surgical procedures performed worldwide that continues to increase in frequency, and is an important contributor to SSIs [3, 14]. In 2014, 32 % of all deliveries in the United States were CD, which accounts for approximately 1.3 million cases annually [3, 14–16].

The incidence of SSI after CD in our study was 7.0 %, which is consistent with estimates from other studies [2, 3]. The incidence of SSI after CD is higher than other types of surgeries such as cholecystectomy (1–2 %) and spine surgery (<2 %). This is because during CD, the surgical site is exposed to vaginal polymicrobial aerobic and anaerobic flora accounting for the higher incidence of infection compared to other types of surgical procedure that only break the skin surface. Hence, these operations are classified as clean-contaminated cases. Because of the polymicrobial etiology, SSIs from CDs are treated with broad-spectrum antibiotics and a wound culture is not always obtained. Certain circumstances that may require a wound culture include patient allergies to standard antimicrobial therapy, abscess formation, or lack of improvement on broad-spectrum antibiotics. In our own institution where a wound culture was obtained, 35 % were polymicrobial, 18 % were methicillin-resistant *Staphylococcus aureus*, 18 % were methicillin-sensitive *Staphylococcus aureus*, 18 % were anaerobic organisms, and 11 % of

cultures did not grow an organism. The ACOG recommends antibiotic prophylaxis during CD by receiving antibiotics within 1 h before the start of surgery. In the case of emergency CD, prophylaxis should be started as soon as possible. The prophylactic antibiotic for CD is cefazolin 1–2 g IV. For patients allergic to penicillins and cephalosporins, clindamycin with gentamicin is a reasonable alternative [17]. Studies have found a lower incidence of endometritis and wound infection with preoperative antibiotic administration compared to the previous practice of later administration after the umbilical cord has been clamped to prevent antibiotics from crossing over to the newborn [18–20]. Our institution follows a general weight-based protocol for preoperative antibiotic prophylaxis for CD as outlined by the ACOG. The protocol suggests a dose of 2 g prophylactic cephazolin for women who weigh >80 kg, with an increase to 3 g for those who weigh >120 kg [12]. In a double-blind randomized controlled trial of women with a BMI of ≥ 30 randomized to an antibiotic dosage of 2 or 3 g cefazolin, adipose tissue concentrations did not significantly differ between the two dosage strategies [21]. Therefore, conclusive recommendations for weight-based antibiotic prophylaxis are difficult to establish due to a controversial lack of evidence resulting in less SSIs with higher dosing strategies in obesity.

Recognizing SSI risk factors and targeting treatment can reduce post-cesarean complications. A multitude of risk factors for SSI after CD have been identified in previous studies including antepartum factors such as younger age, nulliparity, low socioeconomic status, limited prenatal care, obesity, tobacco use, diabetes mellitus (pre-gestational and gestational), ASA class ≥ 3 , hypertensive disorders, preeclampsia, multiple gestations, corticosteroid administration, and preoperative infection at a remote body site. Intrapartum factors include unscheduled or non-elective cesarean, length of labor, premature rupture of membranes, length of rupture of membranes, number of vaginal examinations, internal fetal monitors, chorioamnionitis, longer duration of operation, absence of antibiotic prophylaxis, management by teaching service, use of staples for skin closure, and wound length. Postpartum factors include subcutaneous drains, anemia, and postoperative hematoma [2, 3, 8–10]. Of all the risk factors mentioned above, we found obesity, lower education level, gestational diabetes, hypertension, tobacco use, and emergency/STAT operative delivery status to be independent risk factors for SSI after CD.

Obesity is a well-known risk factor for SSI [3, 8, 9, 22]. In addition to higher BMI and lower education level, we found tobacco use, and a diagnosis of hypertension to be other independent risk factors for SSI after CD; both of which are established correlates of obesity in the USA [22]. Possible biological explanations for the association between obesity and SSI include the relative avascularity of adipose tissue, the increase in wound area, and the poor penetration of prophylactic antibiotics in adipose tissue [2]. Reports in the literature have documented an association between obesity and the number of prior births, confirming postpartum weight retention as a significant contributor to the risk for obesity at 1 year [23] and for up to 7 years postpartum [24]. In our analysis, both BMI and the number of prior births were found to be significant in univariate and multivariate logistic regression analysis.

Diabetes mellitus is a long-recognized comorbidity associated with postoperative wound complication in the surgical literature [3]. Interestingly, we did not find diabetes to be a risk factor in our population. This may be due to better awareness and treatment in our diabetic

patient population. Although pre-existing diabetes mellitus was not found in our study to be an independent risk factor, conversely gestational diabetes was significant. This may be due to the lack of adequate blood sugar control and similar awareness in pregnant patients recently diagnosed with gestational diabetes. Poorly controlled diabetes results in advanced glycosylation end products, with impairment of the host immune response and decreased re-epithelialization of wounds [3]. An unintended side-effect of suppressing the immune system is a direct impairment of the inflammatory phase of wound closure. As a result, there is decreased fibrogenesis, macrophage response, and angiogenesis [3]. This situation may lead to delayed closure, wound breakdown, and infection [3].

Rural populations experience significant health disparities when compared to the general population. Rural adults are more likely to report a lower socioeconomic status, lower education level, poor health status, have limitations in physical activity, a higher incidence of disability, have higher rates of chronic illness, have higher rates of health risk behaviors, have poor overall health and have fewer physicians to care for them, increased mortality rates, lower life expectancies than urban residents, and have marked disparities in health care access [25, 26]. These inequalities are further intensified as rural residents are less likely to have healthcare insurance, with reduced access to and utilization of health care services [27]. A lower education level is usually an indicator of poor living conditions, failure to adequately follow medical instructions, and delay in seeking help. All these may predispose patients to increased infection risk. Most patients treated at West Virginia University Hospital are from rural West Virginia with many of the inequities associated with that population. The risk factors we found to be significant in our study namely obesity, lower education level, gestational diabetes, hypertension, and tobacco use can all be attributed to the problems of rural health disparities.

The novel point of this study is that we found the presence of ruptured membranes to be protective against SSI after CD in a rural population, which is different from the previous reports. Once the membranes are ruptured, bacteria can ascend and lead to amnionitis and fetal infection. The protective effect seen in our study may have less to do with the pathophysiology of rupture of the membranes and more to do with the timing of antibiotic prophylaxis for CD. Our database did not allow us to analyze potential differences between spontaneous rupture and artificial rupture of the membranes, as both are risk factors for chorioamnionitis. Parturients with prolonged rupture of membranes (e.g., >18 h) would have antibiotics administered long before the 30-min window required by most protocols. Some studies suggest that antibiotics administered 0–30 min prior to incision are associated with higher SSI rates compared with antibiotics given 60 min before incision [28, 29].

Limitations of this study include its retrospective nature, and the potential for outcome misclassification and information bias. By using only CPT and ICD codes to identify SSI after CD, we may have underestimated the true incidence in our population. In an effort to validate coding, our institution performs an annual audit for code selection as part of each reviewed encounter and uses a baseline of 80 % as the minimal threshold. Furthermore, we have validated the correctness of our institutional data base elements to our EMRs and found a concordance rate of >96 %, and after correcting for the apparent discordances, the database was found to be 100 % accurate [30]. Labor management guidelines that promote

vaginal delivery are intended to reduce the number of unnecessary CDs. An argument could be made that such protocols may selectively increase CDs performed on an emergency basis and thereby raise the rate of SSI. However, this will probably not be the case as labor management guidelines promoting vaginal delivery have been shown to reduce the incidence of CD overall. We are unaware of any literature to support this hypothesis. Furthermore, labor management protocols have been shown to prevent obstetric emergencies and decrease the rates of SSI accordingly [31].

In conclusion, we aimed to identify specific risk factors for SSI after CD in a rural population of women at an academic tertiary medical center. Further research to evaluate identified risk factors individually is needed to better understand the causes and the evolution of SSI after CD, especially in rural women. Benefits of this study include the potential for a future decrease in the incidence of SSI after CD. Timely feedback on SSI rates, better control of risk factors, along with active engagement of both clinicians and patients will be critical to improving SSI after CD. Reducing SSI rates after CD will in turn lead to improved patient care and reduced health care costs.

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Table 1

Demographic, obstetric, and maternal medical comorbidities and operative and neonatal outcomes

	SSI (<i>n</i> = 218)	95 % CI	Control (<i>n</i> = 3131)	95 % CI	<i>P</i> value	Odds ratio (OR)
Demographic						
Age (years)	28.6 ± 6.2	(27.8–29.4)	29.0 ± 6.2	(28.8–29.2)	0.41	
BMI (kg/m ²)	40.3 ± 10.6	(38.7–38.7)	34.1 ± 8.2	(33.8–34.4)	<0.001	
Education (years)	13.3 ± 2.4	(12.9–13.7)	14.1 ± 2.8	(14.0–14.2)	<0.001	
ASA physical status	2 (1–4)		2 (1–5)		0.47	
Obstetric						
Prior pregnancies	2 (1–10)		2 (1–18)		0.73	–
Prior births	2 (1–9)		1 (1–11)		<0.001	–
Prior cesarean deliveries	1 (0–3)		1 (0–4)		0.88	–
Prenatal care visits	12 (0–30)		11 (0–44)		0.12	–
GBS colonization (%)	20.6 %		18.0 %		0.32	1.2 (0.8–1.7)
Steroid use (%)	17.9 %		19.4 %		0.59	0.9 (0.6–1.3)
Prior antibiotic use (%)	43.8 %		39.2 %		0.16	1.2 (0.9–1.6)
Cervical incompetence (%)	3.7 %		2.46 %		0.28	1.5 (0.7–3.2)
Vaginal examinations	0 (0–2)		0 (0–3)		0.64	–
Ruptured membranes (%)	0.5 %		6.6 %		<0.001	0.1 (0.0–0.5)
Internal fetal monitor (%)	68.8 %		62.73 %		0.07	1.3 (1.0–1.8)
Chorioamnionitis (%)	10.1 %		6.9 %		0.09	1.5 (1.0–2.4)
Foley bulb (%)	0.5 %		0.1 %		0.32	3.6 (0.4–32.4)
Maternal medical comorbidities						
Diabetes mellitus (%)	13.7 %		10.2 %		0.11	1.4 (0.9–2.1)
Gestational diabetes (%)	33.5 %		24.1 %		0.003	1.6 (1.2–2.1)
Hypertension (%)	54.5 %		39.9 %		<0.001	1.8 (1.3–2.4)
Preeclampsia (%)	19.3 %		15.0 %		0.10	1.3 (0.9–1.9)
Systemic lupus erythematosus (%)	0.5 %		0.5 %		0.87	0.8 (0.1–6.3)
STD during pregnancy (%)	0.0 %		0.1 %		0.64	2.0 (0.1–39.7)
Tobacco use (%)	42.2 %		32.9 %		0.03	1.5 (1.1–2.1)
Operative cesarean delivery status classification (%)						

	SSI (<i>n</i> = 218)	95 % CI	Control (<i>n</i> = 3131)	95 % CI	<i>P</i> value	Odds ratio (OR)
Elective	58.7 %		65.6 %		0.10	0.7 (0.5–1.1)
Urgent	5.6 %		8.5 %		0.22	0.6 (0.3–1.3)
Emergency/STAT	35.7 %		25.9 %		0.01	1.6 (1.1–2.3)
Cesarean delivery incision (%)						
Low cervical	94.1 %		97.2 %		0.02	0.5 (0.2–0.9)
Classical	5.9 %		2.8 %		0.02	2.1 (1.1–4.1)
Neonatal						
Gestation (weeks)	36.8 ± 3.5	(36.3–37.3)	36.7 ± 3.5	(36.6–36.8)	0.77	–
Neonatal birth weight (g)	2993.7 ± 1012.1	(2849.1–3138.3)	2914.3 ± 929.9	(2880.3–2945.5)	0.25	–
Apgar scores	8 (0–9)		8 (0–9)		0.44	–

Data are mean ± SD with 95 % CI, or median with range in parenthesis, or proportion and OR with 95 % CI. *ASA* American Society of Anesthesiologists, *BMI* body mass index, *GBS* group B streptococcus, *STD* sexually transmitted disease