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Major Article

Risk factors for surgical site infection after cesarean delivery: A case-control study

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Background: The cesarean delivery (CD) rate is increasing worldwide. Surgical site infection (SSI) incidence is likely to follow an upward trajectory. We examined the incidence and risk factors for SSI after CD.

Methods: A case-control study of women who had a lower-segment CD during the study period was performed at Ireland's Cork University Maternity Hospital. Cases were patients who presented to the hospital with SSI and who met the criteria of the U.S. Centers for Disease Control and Prevention. Controls were randomly selected from the discharge register of CDs at a ratio of 2:1. Data were extracted from the medical records. A multivariable stepwise logistic regression model approach was used, and the results were expressed as adjusted odds ratios (aORs).

Results: The SSI rate was 2%. The greatest contribution to risk of SSI was associated with maternal obesity (aOR, 4.76; 95% confidence interval [CI], 2.00-11.32) and hypertensive disorders (aOR, 6.67; 95% CI, 1.54-28.99]. There was also an increased risk for women who underwent an emergency CD (aOR, 3.50; 95% CI, 1.09-11.30), for women who had $\geq$5 vaginal examinations (aOR, 3.24; 95% CI, 0.92-11.41), and for women without hypertensive disorders who delivered a baby weighing $<$3,500 g (aOR, 2.18; 95% CI, 1.08-4.37).

Conclusions: Obesity, hypertensive disorders, emergency CD, and multiple vaginal examinations were independent risk factors for SSI after CD.

Cesarean delivery (CD) is one of the most commonly performed major surgeries in U.S. hospitals,[1] and its incidence has increased globally in the past 3 decades.[2] Worldwide, there is considerable variation of CD rates among countries and regions, with the highest rate reported in Latin America and the Caribbean and the lowest rate reported in Africa. Higher rates were also reported in high-income countries compared with the least developed ones.[3] In Ireland, the CD rate is 26.5%, with an increase of 44% during a 12-year period.[4,5] Similar higher rates have also been reported in the United Kingdom, where 1 of every 4 births was by CD.[6] In Australia and the United States, the CD rate was 32.3% and 31.9%, respectively.[7,8]

Surgical site infection (SSI) is a common complication after CD and is increasingly used as a benchmark for quality of care by health care providers.[9] According to the World Health Organization, SSIs are among the most common causes of health care–associated infections in Europe and the United States.[10] Furthermore, SSI was the most common nosocomial infection site in reported hospital data.[11]

The incidence of SSI varies in the literature for many reasons; diagnostic criteria and reporting methodology have been linked to this variation.[12] With the trend toward early discharge after CD,[13] most SSI is diagnosed and treated in the community but may go unreported, leading to underestimation of the true incidence. There is a lack of standardized reporting of SSI, with some studies following participants up to 42 days,[14] whereas others follow strict definitions provided by the U.S. Centers for Disease Control and Prevention (CDC).[15] Researchers are currently evaluating the overall incidence of SSI in the published literature.[2] CD has been associated with a doubling of costs compared with those of vaginal delivery, both in terms

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of care around the time of delivery and postoperative care, including rehospitalization and community care during the first 2 months.[16]

Compared with women who undergo vaginal delivery, women who undergo CD have up to a 20-fold higher chance of infectious morbidity.[17] However, the independent risk factors for SSI are not well documented in the literature.[18] Reported independent risk factors for SSI include obesity and chorioamnionitis[19]; an operating time ≥ 38 minutes, which was reported as an independent risk factor by Opùien et al[13]; higher body mass index (BMI)[13,18]; hematoma after the operation[18]; a university teaching staff operator[18]; and ethnicity, although inconsistently.[20-22] The aim of this study was to identify independent risk factors for SSI after CD in an Irish tertiary care setting, in accordance with CDC criteria.[15]

METHODS

This study was conducted at Cork University Maternity Hospital, a maternity care center for the population of Cork and a tertiary referral center for high-risk obstetrics and neonatology for the South and South West Hospital Group in Ireland. The hospital obstetrics service performs 7,000-8,000 deliveries a year, of which 31% are by CD. Full-time obstetric consultants are available in-house from 8 AM to 6 PM Outside these hours, the hospital is staffed by nonconsultant hospital doctors (NCHDs) in different stages of training, and the consultant is available on call offsite. In Ireland, all pregnant women are entitled to free maternity services as public patients up to 6 weeks after delivery. Women with private health insurance may choose to receive their care directly from a consultant obstetrician. Consultants have overall responsibility for the obstetric care of public and private patients. After delivery, all mothers receive a public health nurse visit at home within 72 hours of hospital discharge, and all are entitled to 2 free visits to their family doctor.

We performed a case-control study of women who underwent lower-transverse CD between October 1, 2014, and April 30, 2016. During this time, there were 80 cases, identified by presentation with wound problems to the Cork University Maternity Hospital emergency department. The case notes of all potential wound infections were reviewed, and those meeting the CDC definition of incisional SSI within 30 days of CD were included.[15] Medical records were reviewed to confirm that the case definition criteria were met. Monthly, 2 controls per case were randomly selected from the discharge register of women who had CD. For each month of the study period, CDs were numbered from first to last. Using Statistical Package for the Social Sciences (SPSS) software (IBM, Armonk, NY), we generated random numbers within this range. CDs corresponding to these numbers were the controls if they were not cases of SSI or endometritis.

For cases and controls, data were extracted from medical records and recorded on a structured proforma devised by the research team and informed by previous relevant studies. Recorded data included maternal age (defined as the last birthday before the CD); ethnicity; type of insurance coverage (public vs private); BMI (lean if <25 kg/m^2, overweight if 25-29.9 kg/m^2, and obese if ≥ 30 kg/m^2) at the first antenatal hospital visit; number of antenatal visits (<10, 10-13, and ≥ 14); number of previous pregnancies, births, CDs, and miscarriages; and comorbidities, including hypertensive disorders (pregnancy-induced hypertension and/or preeclampsia) and diabetes (pre-pregnancy and/or gestational). Maternal age was dichotomized as <30 years and ≥ 30 years.

Labor and surgery variables included spontaneous or induced labor, spontaneous or assisted rupture of membranes (ROM), time elapsed between ROM (intact and ROM <12 hours were classified as clean contaminated, and ROM >12 hours was classified as contaminated) and delivery of the baby,[23] use of oxytocin or not, number of vaginal examinations (none, 1-4, and ≥ 5), type of procedure (elective or emergency), duration of surgery (<38 minutes, 38-45 minutes, and ≥ 46 minutes), grade of the operator, type of skin closure (staples vs sutures), and estimated blood loss during CD (<500 mL and ≥ 500 mL). Infant-related variables were gestational age (<37 weeks, 37-38 weeks, and ≥ 39 weeks), birth weight ($<3,500$ g and $\geq 3,500$ g), and sex.

CD was classified as elective or emergency by the operating team according to the standardized criteria based on clinical definitions–based classification, which was proposed by Lucas et al[24] and endorsed widely. The standard practice at our institution is that all women having CD, regardless of its urgency, receive prophylactic antibiotics within 60 minutes of the operation.[25] Our hospital policy for antibiotics choice and dosage is cefuroxime 1.5 g intravenously stat before the skin incision. Women who are allergic to penicillin or cephalosporin are treated with 900 mg of intravenous clindamycin. Our standard operative procedure after cutaneous disinfection with chlorohexidine is a low-transverse incision followed by a lower-transverse incision in the lower-uterine segment. The rest of the surgical procedure and use of surgical clips or sutures for the skin incision are at the discretion of the operator.

STATISTICAL ANALYSIS

Using the standard 5% level of statistical significance, the study sample of 80 cases and 160 controls achieved 80% power to detect an odds ratio (OR) of 2.5 for a risk factor, with a prevalence of 15% in the controls. To assess whether cases and controls differed in relation to each of the characteristics considered, χ^2 tests were used. Each characteristic associated with a difference between cases and controls at the 5% level of statistical significance was entered into univariable logistic regression models. Some pairs of characteristics associated with SSI were highly interrelated (eg, health care coverage, grade of operator, labor onset, and procedure type). The influence of these pairs of characteristics was examined separately and jointly to decide how their association with SSI should be considered in the multivariable logistic regression model. In total, 13 characteristics were considered in the multivariable analysis, which was based on 94% of the sample (n = 226/240). Considering this number of characteristics and the sample size, stepwise selection of characteristics into the model was adopted based on the Wald statistic.

The multivariable logistic regression analysis considered the following factors: age group, combined health care coverage and operator variable, BMI, parity, antenatal care visits, combined birth weight and hypertension variable, gestational age at CD, procedure type, ROM lapse time, number of vaginal examinations, oxytocin use, fever during labor, and procedure duration. The derived multivariable model included the same characteristics irrespective of whether forward or backward stepwise approaches were used. Fourteen records (5.8%) were excluded from the analysis owing to missing data on at least 1 variable. To address this, a final logistic regression model was estimated considering only those variables selected by the stepwise approach. This model used 238 of the 240 study sample (99.2%). The model's goodness of fit was assessed by the Omnibus tests of coefficients, the Nagelkerke R-square test, and the Hosmer and Lemeshow test. Statistical analyses were performed using SPSS version 24(IBM).

Ethical approval was sought and granted by the Clinical Research Ethics Committee of the Cork Teaching Hospitals: ECM 4 (k) 9/05/15.

RESULTS

During the 19-month study period, 3,948 patients underwent lower-segment CD. Of these, 80 (2.0%; 95% exact Poisson confidence interval [CI], 1.6%-2.5%) re-presented to the hospital with incisional SSIs within 30 days of delivery. Only 1 case was a deep incisional SSI (1.2%).

Cases and controls differed in relation to a wide range of characteristics (Table 1). Among cases, there was an overrepresentation of women who were public patients, obese, and primiparous; who had

Table 1
Characteristics associated with differences between cases of cesarean delivery incisional surgical site infection and controls

Characteristic	Category	Cases (n = 80), n (%)	Controls (n = 160), n (%)	OR (95% CI)	*P* value
Age group	<30 y	24 (30)	28 (17.5)	2.02 (1.08-3.79)	.028
	≥30 y	56 (70)	132 (82.5)	1	(ref grp)
Health care coverage	Public	71 (88.8)	116 (72.5)	2.99 (1.38-6.5)	.006
	Private	9 (11.3)	44 (27.5)	1	(ref grp)
BMI	Lean (<25)	29 (36.3)	80 (50)	1	(ref grp)
	Overweight	24 (30)	58 (36.3)	1.14 (0.6-2.16)	.68
	Obese (≥30)	27 (33.8)	22 (13.8)	3.39 (1.67-6.85)	.001
Parity	Primiparous	46 (57.5)	65 (40.6)	1	(ref grp)
	Multiparous	34 (42.5)	95 (59.4)	0.51 (0.29-0.87)	.014
Antenatal care	10-13 visits	31 (38.8)	97 (60.6)	1	(ref grp)
	<10 visits	23 (28.8)	29 (18.1)	2.48 (1.26-4.9)	.009
	≥14 visits	26 (32.5)	34 (21.3)	2.39 (1.25-4.59)	.009
HTN disorders	No	68 (85)	154 (96.3)	1	(ref grp)
	Yes	12 (15)	6 (3.8)	4.53 (1.63-12.57)	.004
Gestational age	≥39 wk	49 (61.3)	93 (58.1)	1	(ref grp)
	<37 wk	18 (22.5)	15 (9.4)	2.28 (1.06-4.91)	.036
	37-38 wk	13 (16.3)	52 (32.5)	0.47 (0.24-0.96)	.037
BWT	>3,500 g	28 (35)	86 (53.8)	1	(ref grp)
	<3,500 g	52 (65)	74 (46.3)	2.16 (1.24-3.76)	.007
Onset of labor	Spontaneous	25 (31.3)	23 (14.4)	1	(ref grp)
	Induced	23 (28.8)	33 (20.6)	0.64 (0.3-1.4)	.26
	No labor	32 (40)	104 (65)	0.28 (0.14-0.57)	<.001
ROM lapse time	Membranes intact	36 (46.8)	106 (69.3)	1	(ref grp)
	ROM <12 h	24 (31.2)	32 (20.9)	2.21 (1.15-4.23)	.017
	ROM >12 h	17 (22.1)	15 (9.8)	3.34 (1.51-7.36)	.003
Vaginal examinations	None	32 (40.5)	104 (65.4)	1	(ref grp)
	1-4 examinations	17 (21.5)	38 (23.9)	1.45 (0.73-2.92)	.29
	≥5 examinations	30 (38)	17 (10.7)	5.74 (2.81-11.72)	<.001
Oxytocin use	No	52 (65)	125 (78.1)	1	(ref grp)
	Yes	28 (35)	35 (21.9)	1.92 (1.06-3.48)	.031
Fever during labor	No	73 (91.3)	156 (97.5)	1	(ref grp)
	Yes	7 (8.8)	4 (2.5)	3.74 (1.06-13.18)	.040
Operator	Consultant	16 (20)	59 (36.9)	1	(ref grp)
	NCHD	64 (80)	101 (63.1)	2.34 (1.24-4.41)	.009
Procedure type	Elective	20 (25)	94 (58.8)	1	(ref grp)
	Emergency	60 (75)	66 (41.3)	4.27 (2.35-7.75)	<.001
Procedure duration	<38 min	15 (19.5)	57 (39.6)	1	(ref grp)
	38-45 min	29 (37.7)	53 (36.8)	2.08 (1.01-4.30)	.048
	≥46 min	33 (42.9)	34 (23.6)	3.69 (1.75-7.76)	<.001

BMI, body mass index; *BWT*, birth weight; *CI*, confidence interval; *HTN*, hypertensive disorders; *NCHD*, nonconsultant hospital doctor; *OR*, odds ratio; *ref grp*, reference group; *ROM*, rupture of membranes.

fewer than or more than the usual number of antenatal care visits; and who had hypertensive disorders, preterm deliveries, below-average-birth-weight babies, ≥5 vaginal examinations during labor, and procedures performed by an NCHD that were emergency CD and of longer duration.

Cases and controls did not differ in relation to skin closure method (sutures were used for 80.0% of cases and 82.4% of controls; OR, 1.17; 95% CI, 0.59-2.32), patient ethnicity, history of previous CD, diabetes, antepartum hemorrhage, sex of the baby, or estimated blood loss during CD >500 mL (Supplementary Table S1).

Some pairs of characteristics associated with SSI were highly interrelated and were examined in greater detail to ascertain which was contributing to risk of the outcome. For example, health care coverage and grade of operator were interrelated because consultants perform CD for all private patients, whereas consultants and NCHDs operate on public patients. Labor onset and procedure type were interrelated because elective CD is always before labor onset, which is not the case for emergency CD. Hypertension and birth weight were also interrelated because the former is associated with low birth weight, and, in this study, all women with hypertension delivered a baby weighing <3,500 g.

Table 2 details the association between combined pairs of interrelated variables and SSI after CD. The combined health care coverage and operator variable demonstrated that public patient operations by NCHDs had a higher risk of SSI. Therefore, the combined variable was considered in the multivariable analysis. The combined procedure type and labor onset variable showed that emergency CD was associated with increased risk of SSI irrespective of labor onset. Therefore, the original procedure type variable was considered in the multivariable analysis. The combined birth weight and maternal hypertension variable demonstrated that hypertension was associated with a marked increased risk of SSI, but women without hypertension who delivered a baby weighing <3,500 g also had an increased risk but to a lesser extent. Therefore, the combined variable was considered in the multivariable analysis.

The stepwise process selected 4 variables into the final multivariable model (Table 3). Goodness of fit of the model was supported, as the Omnibus test of model coefficients was highly statistically significant ($P < .001$), the Nagelkerke R-square test was 0.31, and the Hosmer and Lemeshow test yielded a P value close to 1 ($P = .89$).

The greatest contribution to risk of SSI was associated with maternal obesity (adjusted odds ratio [aOR], 4.23; 95% CI, 1.87-9.56) and hypertension (aOR, 6.00; 95% CI, 1.74-20.72). There was also an increased risk for women who underwent an emergency CD (aOR, 2.99; 95% CI, 1.42-6.31), for women who had ≥5 vaginal examinations (aOR, 3.39; 95% CI, 1.49-7.70), and for women without hypertension who delivered a baby weighing <3,500 g (aOR, 2.24; 95% CI, 1.16-4.34).

Table 2
Association between combined pairs of interrelated variables and cesarean delivery incisional surgical site infection

Characteristic	Category	Cases (n = 80), n (%)	Controls (n = 160), n (%)	OR (95% CI)	*P* value
Health care coverage and operator	Private patient, Consultant	9 (11.3)	44 (27.5)	1	(ref grp)
	Public patient, Consultant	7 (8.8)	15 (9.4)	2.28 (0.72-7.19)	.16
	Public patient, NCHD	64 (80)	101 (63.1)	3.10 (1.42-6.77)	.005
Procedure type and labor onset	Elective, no labor	20 (25)	94 (58.8)	1	(ref grp)
	Emergency, no labor	12 (15)	10 (6.3)	5.64 (2.14-14.85)	<.001
	Emergency, IOL	23 (28.8)	33 (20.6)	3.28 (1.6-6.72)	.001
	Emergency, SOL	25 (31.3)	23 (14.4)	5.11 (2.43-10.75)	<.001
BWT and HTN disorder	>3,500 g, no HTN	28 (35)	86 (53.8)	1	(ref grp)
	<3,500 g, no HTN	40 (50)	68 (42.5)	1.81 (1.01-3.22)	.045
	<3,500 g, HTN	12 (15)	6 (3.8)	6.14 (2.11-17.89)	.001

BWT, birth weight; *CI*, confidence interval; *HTN*, hypertensive disorder; *IOL*, induction of labor; *NCHD*, nonconsultant hospital doctor; *OR*, odds ratio; *ref grp*, reference group; *SOL*, spontaneous onset of labor.

DISCUSSION

To our knowledge, this study is the largest of its type in an Irish setting examining the rate and independent risk factors of SSI after CD using the criteria set out by the CDC and within 30 days after surgery. The independent risk factors identified were obesity at first antenatal hospital visit (BMI >30 kg/m^2), multiple vaginal examinations during labor, emergency procedure, and hypertensive disorder. In this study, we found an SSI rate of 2% when the maximum period for diagnosis was 30 days. In a collaborative multicenter study from the United Kingdom[26] using CDC definitions for SSI and active community surveillance with a follow-up of 15 days, only 16% were diagnosed during the inpatient stay; 84% were diagnosed after discharge. In 2006, Johnson et al[27] concluded that >70% of SSIs were diagnosed in the community. The actual incidence in our study might be underestimated because case ascertainment was dependent on re-presentation at the hospital, in addition to missing SSI diagnosed and treated in the community. Our study could be considered as a passive form of surveillance because we included only cases who re-presented to the hospital within 30 days with a diagnosis of SSI. However, our case ascertainment was based on the presentation problem documented in the Emergency Room Register, using subsequent medical notes to identify cases meeting the definition.

Risk factors for SSI after CD have been getting the attention of the research community recently, partly because of some amenable risk factors, such as obesity (which could be ameliorated through public health approaches); because of the psychological consequences of SSIs on mothers; and because of the financial impact that SSIs have on health systems. Obesity as a potential risk for post-CD wound infection has been discussed previously[28-30]; moreover, in a recent US publication, Olsen et al[18] concluded that obesity was an independent risk factor for SSI. The presence of obesity was significantly associated with SSI, and the association remained significant even after multivariate logistics regression.[27,31] A similar conclusion was reached in a well-designed multicenter cohort study from England, published in 2012,[23] in which after controlling for other factors in a multivariate analysis, the authors found that only BMI was significantly associated with developing SSI. When investigated by Beattie et al,[20] increasing maternal weight was reported to be significantly associated with incisional SSI.

We found that having multiple vaginal examinations (≥5) during labor was significantly associated with the development of SSI. The odds increased >3 times compared with women who had no or <5 vaginal examinations during labor. In a recently published study, in an attempt to predict risk factors of SSI in Tanzania,[32] multiple vaginal examinations (>4) were statistically significant when applying multivariate logistic regression. The risk of developing SSI increased 3-fold compared with women who had <3 examinations. It is worth noting that the Tanzanian study is from a developing country where perioperative and operation standards may be different from practices in Ireland. However, the concept of amniotic fluid contamination from multiple vaginal examinations seems plausible in both settings. Furthermore, in a study published in 2005, Mitt et al[33] concluded that, among other factors, internal fetal monitoring was independently associated with increased risk of developing SSI.

When considering the emergency nature of the operation, we found that emergency CD was an independent risk factor for SSI; however, in a similar setting,[34] other authors did not find a statistically significant increase in SSI rate after emergency CD. In a study from Brazil,[35] when the nature of the operation was studied, the results demonstrated a significant association between post-CD SSI and emergency CD; however, this finding did not hold after applying a regression model. Similarly, in a study from Norway,[13] no significant difference in SSI rate was found in elective or emergency CD, nor was there a significant association between emergency CD and SSI after logistic modeling. However, consistent with our findings, Ward et al[26] found that having an emergency procedure was significantly associated with the development of an SSI. One possible explanation of this association is that the emergency nature to expedite delivery by CD may affect the skin cleansing and decontamination procedure. There may also be an unrecognized risk of bacterial contamination in labor and ROM.

In this study, we combined and analyzed birth weight and maternal hypertension as a single variable. Hypertensive disorders in pregnancy are well known to be associated with low birth weight.[36] When birth weight was <3,500 g and there was no maternal hypertensive disorder, the risk of developing SSI was double compared

Table 3
Independent risk factors for cesarean delivery incisional surgical site infection derived from multivariable logistic regression

Characteristic	Category	aOR (95% CI)	*P* value
BMI	Lean (<25)	1.00 (ref grp)	
	Overweight	1.05 (0.51-2.16)	.89
	Obese (≥30)	4.23 (1.87-9.56)	<.001
Vaginal examinations	None/<5 examinations	1.00 (ref grp)	
	≥5 examinations	3.39 (1.49-7.70)	.004
Procedure type	Elective	1.00 (ref grp)	
	Emergency	2.99 (1.42-6.31)	.004
BWT and HTN disorder	>3,500 g, no HTN	1.00 (ref grp)	
	<3,500 g, no HTN	2.24 (1.16-4.34)	.017
	<3,500 g, HTN	6.00 (1.74-20.72)	.005

aOR, adjusted odds ratio; *BMI*, body mass index; *BWT*, birth weight; *CI*, confidence interval; *HTN*, hypertensive disorders.

with when birth weight was >3,500 g. However, when considering birth weight <3,500 g coupled with maternal hypertensive disorder, the odds of developing SSI were 6 times higher. Consistent with our findings, in a study published in 2005,[37] hypertensive disorder was an independent risk factor for wound infection after CD. Tran et al[38] also found that preeclampsia was an independent risk factor after accounting for other confounding factors. Maternal hypertensive disorders have a greater effect on the risk of developing SSI; however, low birth weight has an association to a lesser extent. This increased risk of infection in women with hypertensive disorder could be explained by the alteration of peripheral blood supply owing to the increased vascular resistance, which in turn leads to reduction in the blood supply to skin and subcutaneous tissue, rendering it prone to infection. The optimal treatment of hypertension during pregnancy may itself affect the microcirculation and the peripheral vascular blood supply, which may lead to a reduction in perfusion in the skin and subcutaneous tissues and postpone wound healing, increasing the risk of SSI. The reason for an increased risk of infection when birth weight is <3,500 g is not clear. One possibility could be subclinical hypertension that was not diagnosed during the antenatal or perinatal period; another consideration is the association of low birth weight and maternal smoking. Smoking status during pregnancy is poorly recorded in our health care records. Notably, in a study published in 2010,[39] smoking was regarded as an independent risk factor for wound complication after CD in massively obese patients.

Given the nature of our institution as a tertiary referral center for the South and South West Hospital Group, results of this study might not be generalizable. However, the primary strength that this study holds is the independent risk factors established after studying a wide range of host-related pregnancy, labor, and intraoperative potential risk factors. We evaluated >20 potential risk factors and accounted for confounding using multivariate logistic regression. We acknowledge the limitation posed by the nature of follow-up, yet the active community-hospital referral pathway would ensure that most of the incisional SSIs were accounted for. By the nature of the study design, we believe that the rate of SSI may be underestimated. However, the identified independent risk factors remain valid.

Given the substantial implications of SSIs, recognizing the risk factors and building strategies to prevent and treat SSIs are essential for reducing post-CD maternal morbidity and mortality. Furthermore, recognizing independent risk factors, particularly modifiable ones (eg, BMI), and implementing strategies to prevent, diagnose, and treat infections in time, are all vital steps for reducing the occurrence of SSI and its consequences. Similarly, health care practitioners should be familiar with aspects of the procedure that are amenable to intervention, which could be targeted during the antenatal period at preconception visits in the community. An increased understanding of the risk factors will ensure better counseling for women, enhancing informed decision making with respect to mode of delivery. Additionally, incorporating assessment of risk factors preoperatively could improve the likelihood of minimizing maternal and perinatal morbidity and mortality from SSI.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found at https://doi.org/10.1016/j.ajic.2018.07.023.

References

1. Pfuntner A, Wier LM, Stocks C. Most frequent procedures performed in U.S. hospitals, 2010. HCUP Statistical Brief #149. Washington, DC: Agency for Healthcare Research and Quality; 2013.
2. Saeed KBM, Greene RA, Corcoran P, Neill SM. Incidence of surgical site infection following caesarean section: a systematic review and meta-analysis protocol. BMJ Open 2017;7:e013037.
3. Betran AP, Merialdi M, Lauer JA, Bing-Shun W, Thomas J, Van Look P, et al. Rates of caesarean section: analysis of global, regional and national estimates. Paediatr Perinat Epidemiol 2007;21:98-113.
4. Sinnott SJ, Brick A, Layte R, Cunningham N, Turner MJ. National variation in caesarean section rates: a cross sectional study in Ireland. PLoS One 2016;11:e0156172.
5. Farah N, Geary M, Connolly G, McKenna P. The caesarean section rate in the Republic of Ireland in 1998. Irish Med J 2003;96:242-3.
6. Hospital Episode Statistics Analysis HaSCIC. NHS maternity statistics—England, 2014-15. Available from: http://www.hscic.gov.uk2015. Accessed September 10, 2018.
7. Li Z ZR, Hilder L, Sullivan EA. Australia's mothers and babies 2011. Perinatal Statistics Series No. 28. Canberra, Australia: Australian Institute of Health and Welfare; 2013.
8. Martin JA, Hamilton BE, Osterman MJK, Driscoll AK, Drake P. Births: final data for 2016. Available from: https://www.cdc.gov/nchs/data/nvsr/nvsr67/nvsr67_01.pdf. Accessed September 10, 2018.
9. Humphreys H. Preventing surgical site infection. Where now? J Hosp Infect 2009;73:316-22.
10. Allegranzi B, Bischoff P, de Jonge S, Kubilay NZ, Zayed B, Gomes SM, et al. New WHO recommendations on preoperative measures for surgical site infection prevention: an evidence-based global perspective. Lancet Infect Dis 2016;16, e276-87.
11. Horan TC, Culver DH, Gaynes RP, Jarvis WR, Edwards JR, Reid CR. Nosocomial infections in surgical patients in the United States, January 1986-June 1992. National Nosocomial Infections Surveillance (NNIS) System. Infect Control Hosp Epidemiol 1993;14:73-80.
12. Bruce J, Russell EM, Mollison J, Krukowski ZH. The measurement and monitoring of surgical adverse events. Health Technol Assess 2001;5:1-194.
13. Opøien HK, Valbø A, Grinde-Andersen A, Walberg M. Post-cesarean surgical site infections according to CDC standards: rates and risk factors. A prospective cohort study. Acta Obstet Gynecol Scand 2007;86:1097-102.
14. Duggal N, Poddatorri V, Noroozkhani S, Siddik-Ahmad RI, Caughey AB. Perioperative oxygen supplementation and surgical site infection after cesarean delivery: a randomized trial. Obstet Gynecol 2013;122:79-84.
15. Horan TC, Andrus M, Dudeck MA. CDC/NHSN surveillance definition of health care-associated infection and criteria for specific types of infections in the acute care setting. Am J Infect Control 2008;36:309-32.
16. Petrou S, Glazener C. The economic costs of alternative modes of delivery during the first two months postpartum: results from a Scottish observational study. BJOG 2002;109:214-7.
17. Smaill FM, Grivell RM. Antibiotic prophylaxis versus no prophylaxis for preventing infection after cesarean section. Cochrane Database Syst Rev 2014;(8):CD007482.
18. Olsen MA, Butler AM, Willers DM, Devkota P, Gross GA, Fraser VJ. Risk factors for surgical site infection after low transverse cesarean section. Infect Control Hosp Epidemiol 2008;29:477-84, discussion 85-6.
19. Lakhan PD, Jones M, Clements A. A systematic review of maternal intrinsic risk factors associated with surgical site infection following caesarean sections. Healthc Infect 2010;15:34-41.
20. Beattie PG, Rings TR, Hunter MF, Lake Y. Risk factors for wound infection following caesarean section. Aust N Z J Obstet Gynaecol 1994;34:398-402.
21. Noyes N, Berkeley AS, Freedman K, Ledger W. Incidence of postpartum endomyometritis following single-dose antibiotic prophylaxis with either ampicillin/sulbactam, cefazolin, or cefotetan in high-risk cesarean section patients. Infect Dis Obstet Gynecol 1998;6:220-3.
22. Assawapalanggool S, Kasatpibal N, Sirichotiyakul S, Arora R, Suntornlimsiri W. Risk factors for cesarean surgical site infections at a Thai-Myanmar border hospital. Am J Infect Control 2016;44:990-5.
23. Wloch C, Wilson J, Lamagni T, Harrington P, Charlett A, Sheridan E. Risk factors for surgical site infection following caesarean section in England: results from a multicentre cohort study. BJOG 2012;119:1324-33.
24. Lucas DN, Yentis SM, Kinsella SM, Holdcroft A, May AE, Wee M, et al. Urgency of caesarean section: a new classification. J R Soc Med 2000;93:346-50.
25. Health Service Executive. Royal College of Surgeons, College of Anaesthetists, Patient Safety First. National policy and procedure for safe surgery. Dublin: Health Service Executive; 2013.
26. Ward VP, Charlett A, Fagan J, Crawshaw SC. Enhanced surgical site infection surveillance following caesarean section: experience of a multicentre collaborative post-discharge system. J Hosp Infect 2008;70:166-73.
27. Johnson A, Young D, Reilly J. Caesarean section surgical site infection surveillance. J Hosp Infect 2006;64:30-5.
28. Nielsen TF, Hokegard KH. Postoperative cesarean section morbidity: a prospective study. Am J Obstet Gynecol 1983;146:911-6.
29. Pelle H, Jepsen OB, Larsen SO, Bo J, Christensen F, Dreisler A, et al. Wound infection after cesarean section. Infect Contr 1986;7:456-61.
30. Martens MG, Kolrud BL, Faro S, Maccato M, Hammill H. Development of wound infection or separation after cesarean delivery. Prospective evaluation of 2,431 cases. J Reprod Med 1995;40:171-5.
31. Tran TS, Jamulitrat S, Chongsuvivatwong V, Geater A. Risk factors for postcesarean surgical site infection. Obstet Gynecol 2000;95:367-71.
32. Mpogoro FJ, Mshana SE, Mirambo MM, Kidenya BR, Gumodoka B, Imirzalioglu C. Incidence and predictors of surgical site infections following caesarean sections at Bugando Medical Centre, Mwanza, Tanzania. Antimicrob Resist Infect Contr 2014;3:25.

33. Mitt P, Lang K, Peri A, Maimets M. Surgical-site infections following cesarean section in an Estonian university hospital: postdischarge surveillance and analysis of risk factors. Infect Contr Hosp Epidemiol 2005;26:449-54.
34. Corcoran S, Jackson V, Coulter-Smith S, Loughrey J, McKenna P, Cafferkey M. Surgical site infection after cesarean section: implementing 3 changes to improve the quality of patient care. Am J Infect Contr 2013;41:1258-63.
35. Farret TCF, Dallé J, da Silva Monteiro V, Riche CVW, Antonello VS. Risk factors for surgical site infection following cesarean section in a Brazilian Women's hospital: a case-control study. Braz J Infect Dis 2015;19:113-7.
36. National Collaborating Centre for Women's and Children's Health. Hypertension in pregnancy: the management of hypertensive disorders during pregnancy. London, England: RCOG Press; 2010.
37. Schneid-Kofman N, Sheiner E, Levy A, Holcberg G. Risk factors for wound infection following cesarean deliveries. Int J Gynecol Obstet 2005;90:10-5.
38. Tran TS, Jamulitrat S, Chongsuvivatwong V, Geater A. Risk factors for postcesarean surgical site infection. Obstet Gynecol 2000;95:367-71.
39. Alanis MC, Villers MS, Law TL, Steadman EM, Robinson CJ. Complications of cesarean delivery in the massively obese parturient. Am J Obstet Gynecol 2010;203;271.e1-7.