Abstract

Objective: To assess the incidence, risk and associated factors that contribute to an acquired Surgical Site Infection (SSI) in emergency Caesarean Section (CS).

Design: Retrospective case-control study.

Setting: An acute District General Hospital in England.

Participants: 206 patients (101 SSI patients and 105 non-SSI patients) who had emergency CS between January-December 2017.

Methods: Grade of surgeon, smoking status, pre-operative vaginal swab status (positive or negative), diabetes status, age, body mass index (BMI), membrane rupture to delivery interval and length of surgery were recorded. Risk factors were identified using simple and multiple logistic regression.

Results: BMI (kg/m^2) was significantly associated with SSI incidence (odds ratio (OR) 1.17; 95% confidence interval (CI) 1.11 to 1.24; $p<0.001$). Substantive non-significant associations were recorded between SSI, patient age and vaginal swab status.

Conclusion: BMI was the only significant risk factor for the development of an SSI in emergency CS, possibly due to the impact of excessive adipose tissue on the immune system and reduced effectiveness of antibiotics. Diabetes status, patient age and pre-op vaginal swab status were not significantly associated with SSI in emergency CS. Improved guidelines and strategies for managing at-risk patients would enable clinicians to manage emergency CS patients better and reduce the risk of SSI development. The importance of

wound management including frequent wound cleaning, appropriate dressings, dressing changes and education is highlighted. Future research on larger samples should be conducted to validate these findings.

Key words: Caesarean section, Infectious disease: Microbiology, Risk management, Gynaecological surgery: general, Health services research, Surgical Site Infection.

Introduction

Caesarean sections (CS) occur in around 1 in 4 births in the UK [1] and are classified as elective, or emergency, where the procedure is undertaken to prevent risk to the mother and unborn child. Amongst the risks associated with a CS procedure is the development of a surgical site infection (SSI); a serious surgical complication defined as '*a type of healthcare-associated infection in which a wound infection occurs after an invasive (surgical) procedure*'. [2] The CDC (Centers for Disease Control and Prevention)[3] further define SSI as an infection that occurs after surgery in the part of the body where the surgery took place. Surgical site infections can sometimes be superficial infections involving the skin only. Other surgical site infections are more serious and can involve tissues under the skin, organs, or implanted material. The development of an SSI following CS can result in permanent injury to the bladder, uterus or rectum, as well as scarring, increased pain, a reduction in mobility [4] and extended hospital stays.[5] A severe and potentially fatal complication of developing an SSI is necrotising fasciitis (NF), a rare bacterial infection affecting the soft tissue and fascia. [6]

The World Health Organization [WHO] [7] recommended C-section rates should be between 10% and 15%. However, there has been a gradual international increase in the amount of CS being undertaken. In the United States, CS has been highlighted as a common procedure, increasing by 41% in a 13-year period to its current rate of about 32% [8] Similarly, high rates are currently observed in the UK (26.5%) [9]; in Australia (32.3%) [10]; and in China (41%). [11] In other countries both the current proportion and rate of increase are high: Zejnullahu et al. [12] report that in Kosovo, the rate of CS rose from 7.5% in 2000 to 27.3% in 2015 with 33.5% of deliveries in tertiary referral care services being C-sections.

The increase in CS risks an increase in SSI, with the WHO [13] warning that SSIs affect up to one-third of patients who have undergone a surgical procedure. Almost half of SSIs reported in the European Centres for Disease Prevention and Control surveillance system [14] were identified as superficial, with 30% being deep, and 20% extending to organ/space. However, Wilson et al. [15] reported that procedures associated with a very short post-operative stay, e.g. CS, only had infections recognised and reported following discharge from hospital. These are therefore likely to be underestimated, given that approximately 50% of SSIs become evident after discharge. [16] Incidence rates for the development of SSI in CS have been reported globally as 4.6%. [17] However, Jenks et al. [18] reporting on a multicentre English trial, concluded that SSI was estimated to be just under 10% and the readmission rate due to SSI following CS was 0.6%.

SSI represents a significant financial and patient burden, with costs estimated at over £2 billion to the UK healthcare system, with a median cost of £7,467 per SSI CS patient compared to £3,572 for non-SSI CS patients. [19] Annual costs exceed US$1.6 billion in the US [20] AU$268 million in Australia, [21] and £930 million in the UK. [19] Increased financial expenditure are mainly attributable to increased length of hospital stay [18] and excess cost per operation of £3,855, with an estimated excess cost of over £7,000,000 per hospital in the UK. [22] The pain and isolation concomitant with suffering an SSI also significantly impacts on patient quality of life and experiences of care. [23] Umscheid et al. [24] argue that 60% of SSIs may be preventable and their risk minimised by applying best practice in the perioperative period.

The international literature has identified several risk factors that predispose an individual developing an SSI following a CS procedure in general, including obesity and an increased BMI, increased age, pre-eclampsia, grade of surgeon and existing comorbidities. Indeed, obesity, age and pre-eclampsia have been linked to post-surgical complications, possibly compounding wound healing and increasing the risk of infection. [25, 26] Extended labour time and the complexities surrounding an emergency CS also impact the possibility of post-surgical infection. [27, 28] However, there are some inconsistences; in a multicentre study of 4107 women who underwent a CS at 14 NHS hospitals in England, Wloch *et al.* [29] found obesity (defined as BMI>30 kg/m^2), age <20 years and grade of surgeon to be significantly associated with developing an SSI. Obesity was also found to increase the risk of SSI within 30 days after CS in a case-control study of 240 women at a hospital in Ireland. [30] However, Najm and Majeed [31] failed to find evidence to suggest that obesity was a contributing factor in SSI development in a sample of 200 women in a hospital in Iraq. Poor infection control monitoring and procedures may have limited the extent to which these findings are generalisable to the wider population.

Although there appears to be several patient-level factors that make developing an SSI following a CS more likely, the extent to which these elements increase the likelihood of infection, in emergency CS is not widely scoped out. This is problematic, as a lack of evidence-based guidelines contributes to inconsistencies in SSI prevention, treatment and management in CS, increasing the economic burden [22] and obvious detrimental effect on patient outcomes and experiences of care. Whilst evidence-based guidelines emphasise the prevention and treatment of SSI [1] there is an obvious lack of guidance for the management of SSI in emergency CS. The study objective was to quantify the incidence of Surgical Site Infection (SSI) in patients who have had an emergency Caesarean Section (CS), identifying the risk and associated factors that contribute to the development of SSI in order to develop a better understanding of the potential mechanisms that may increase the likelihood of infection.

Aim

The aim of this study was to quantify the incidence of Surgical Site Infection (SSI) in patients who have had an emergency Caesarean Section (CS), identifying the risk and associated factors that contribute to the development of SSIs.

METHODS

A retrospective case-control study (with approximately 1:1 case: control ratio) of data from individuals who had an emergency CS procedure performed between 1st January 2017 and 31st December 2017 at Pinderfields General Hospital, Wakefield; part of the Mid Yorkshire

NHS Hospitals Trust was conducted. Cases were defined to be women undergoing emergency CS who experienced an SSI within 30 days of the procedure; controls were defined to be women undergoing emergency CS who did not experience an SSI within 30 days of the procedure. Following written approval, data was collected from the electronic databases used by the Mid Yorkshire Maternity department, comprising data of all patients seen and treated by Pinderfields obstetrics department.

Inclusion criteria were:

- Women who had an emergency CS performed between 1st January 2017 and 31st December 2017
- Women with a positive wound swab indicating an infection less than 30 days after the procedure
- Women without a positive wound swab for non-SSI cases

Exclusion criteria were:

- Any women with an infection such as sepsis that could not be traced back to an SSI
- Any women who did not have an emergency CS performed between 1st January 2017 and 31st December 2017
- Patients with hypothyroidism

The following variables were collected: grade of CS (categorised as 1-4), smoking status (categorised as current smoker, ex-smoker or non-smoker), whether or not a pre-operative vaginal swab was taken, diabetes status (categorised as non-diabetic, Type I, Type II or gestational), grade of surgeon (categorised as registrar, specialist trainee, consultant, senior house officer (SHO) or associate specialist), patient age, patient BMI, membrane rupture to delivery interval and length of surgery.

The sample was summarised descriptively. A series of uni-variable logistic regression screening analyses were conducted on the outcome of SSI status to identify variables substantively associated with the outcome ($p<0.200$); with low-frequency categories of certain variables combined where appropriate. All such variables were carried forward into a corresponding multiple logistic regression analysis. All analyses reported unadjusted or adjusted odds ratios with associated 95% confidence intervals, *p*-values and the percentage of correct classifications.

For inferential analysis, CS grades were merged into G1 and G2 (reference category); and G3 and G4. Smoking status was merged into non-smoker (reference category); and current/ex-smoker. Diabetes status was merged into no diabetes (reference category); and any kind of diabetes. Grade of surgeon was merged into registrar (reference category) and Other.

Results

Data was obtained from 206 emergency CS patients for the study; including 101 who had an SSI and 105 who did not have an SSI. The sample is summarised in Table 1 below.

INSERT TABLE ONE HERE

Regression parameters from a series of uni-variable binary logistic regression analyses conducted on all included variables are summarised in Table 2.

INSERT TABLE 2 HERE

According to the level of substantive association with the outcome, BMI, age, diabetes status and pre-operative vaginal swab status were carried forward for inclusion in the multiple model. Parameters from this model are summarised in Table 3.

INSERT TABLE 3 HERE

DISCUSSION

Findings from this study identified BMI as the only significant risk factor from a range of patient-level factors for the development of an SSI in emergency CS. Interestingly, for every increase in unit of BMI kg/m^2, the risk of SSI increased by 17%. Patient age, diabetes status and pre-operative vaginal swab status were not found to be significantly associated with an increased risk of SSI.

BMI and obesity

The finding that BMI poses a significant risk factor for developing an SSI following emergency CS is consistent with previous research demonstrating the negative impact on post-surgical infection risk [29, 30, 25, 27, 26,] Wloch *et al.* [29] and Ghuman *et al.* [27] both cited impaired immune response, larger wound area size and poor perfusion of prophylactic antibiotics in obese individuals as possible reasons for this increased risk. One possible explanation is the pathophysiological role that BMI plays in emergency CS due to the decreased efficacy of excess adipose tissue on the immune system and a decrease in perioperative tissue deoxygenation. [32] There is evidence to support this; in a meta-analysis of the use of perioperative supplemental oxygen therapy on the rate of SSI, Qadan *et al.* [33] found that administering supplemental oxygen following an operation had a significant effect in preventing the development of an SSI, possibly due to 'oxidative killing', which requires sufficient oxygen partial pressures in order to function. Metabolic and hormonal changes attributable to obesity have been cited as increasing the risk of infection [34] and impaired wound healing [35, 36, 37] suggesting that the physiological impact of an increased body mass compounds the body's ability to recover following a surgical procedure. However, other studies have failed to substantiate these findings or indeed identify possible causes for the increased risk of infection in obese patients. [25, 30] The impact of BMI on post-surgical outcomes has been recognised more widely in general surgery as a possible consequence of impaired wound healing due to increased volume of subcutaneous fat, increased tension on surgical incision and elevated blood glucose levels. [38] Impaired antibiotic performances and altered immune cell function [39, 40] as well as a larger surgical incision and more complex surgical procedure [41] have also been cited as explanations for the increased risk of infection in obesity.

Associated risk factors

Smoking status, existing health conditions such as diabetes, age, or skin closure techniques were not found to contribute to an increased risk of infection in this study. This is in contrast to other research which has found significant relationships for smoking and delayed wound healing, [42] diabetes [28, 43, 44] and skin closure techniques. [45] Indeed Henman *et al.* [28] found age was not associated with SSI in CS; however, other evidence suggests that up to the age of 65 years, there is an increased risk of SSI more generally, [46] possibly due to an impaired immune system. [47] An increase in age-related comorbidities could also increase the risk of developing an SSI following emergency CS. [48] One possible reason for age being unrelated to SSI in this study is the small age range within an already young sample. In addition, the risk factor of diabetes has been identified in the literature as a risk factor for SSI due to a reduction in the body's immune response to defending against microbes as well as impairing wound healing [49] and it is likely that hyperglycaemia, hypoxia and chronic inflammation all playing a role in interrupting the different crucial stages of wound healing. [50]

Limitations

This study used BMI to calculate body composition, however, the accuracy of BMI to diagnose obesity has been questioned, with misclassifications evidence in the literature. [53] More recently, the Edmonton obesity staging system (EOSS) [55] has been proposed as an alternative to the simplistic measurements of BMI in guiding clinical decisions in obesity assessment and management through a five-stage classification structure, accounting for the metabolic, physical and psychological individual differences in adiposity-related complications. However, BMI currently remains one of the most commonly used methods of body composition measurement and is the rationale for its use in this study. A further limitation of the findings from this study is the potential for stigmatisation by healthcare professionals (HCPs) working in reproductive care, of pregnant women considered obese, [56] particularly with the over-emphasis on risks associated with being overweight pre and post pregnancy that has been identified in the literature. [57] Indeed, Ward and McPhail [58] outline the importance of educating HCPs to reduce stigmatising attitudes and beliefs about being overweight in pregnancy through the adoption of a health, rather than weight focused approach to maternal care. In addition, the literature suggests SSI rates are higher for repeated rather than primary CS. [59] Due to the relatively small sample size it was not possible to collect sufficient data relating to this variable although it is possible this variable may have had an impact.

This study utilised data collected from a single hospital in an NHS Trust and a relatively small sample size may have contributed to the finding that certain patient-related factors were not associated with an increased risk of SSI following CS. It was also difficult to capture data on certain variables due to missing or inaccurate data recording. In addition, the identification of patients with SSIs relied on wound swabs; use of swabs to identify an infection can lead to both false negative results (due to decreased volume of bacteria collected by the swab, as identified by Aggarwal *et al.*[54]; and false positive results (when the swab becomes contaminated by commensal organisms). However, alternatives such as the use of tissue cultures to increase sensitivity and specificity would be more invasive for the patient, therefore swabs were considered the most accurate method of identifying infection in this study.

Implications for Clinical Practice

The possible negative effect of excessive adipose tissue on the body's immune system as well as the reduced effectiveness of antibiotics in individuals with an increased BMI suggests that patients in this group are most at risk of developing an SSI, possibly highlighting the need for increased monitoring and surveillance of this patient group to mitigate the potential development of SSI. This could be achieved through increasing the patient's awareness of their increased risk and ensuring they are provided with the appropriate education about possible signs and symptoms of SSI following discharge.

Conclusion

This study found that BMI was significantly associated with an increased risk of developing an SSI in patients undergoing emergency CS. Other potential risk factors such as diabetes status, patient age and pre-op vaginal swab status did not reach statistical significance in this study. Future research on larger samples should be conducted to validate these findings to substantially improve the knowledge and evidence base on the treatment and management of SSI and associated risk factors following emergency CS.

Contribution of authorship:

All authors made significant contribution to the manuscript. KO was responsible for study design and conception. TS, JB, JS and KO wrote the manuscript, which was developed from an MRes thesis submitted to the University of Huddersfield by TS; supervised by JB and JS. JS and TS conducted the statistical analysis. JB, JS and KO provided critical feedback. All authors approved the final manuscript for submission.

Ethical approval

Ethical approval for this retrospective study was received from The University of Huddersfield's School Research Ethics Panel: Reference: SREP-2019-061, 25th July 2019. Written consent was also obtained from the maternity department at Mid Yorkshire Hospital NHS Trust and approval from occupational health at Pinderfields General Hospital.

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