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Surgical Site Infection following Emergency Caesarean Section – incidence and associated risk factors

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Abstract

Aim: The aims of this study were to 1) quantify the incidence of Surgical Site Infection (SSI) in patients who have had an emergency Caesarean Section (CS); 2) identify the risk factors and associated factors that play a major role in the development of those SSI's.

Methods: A retrospective cohort study with data collected from Mid Yorkshire Trust Pinderfields General Hospital, Wakefield. The study sample consisted of 206 patients (101 SSI patients and 105 non-SSI patients) who had emergency CSs carried out between January and December 2017. Simple logistic regression and multiple logistic regression were then carried out to determine any significant risk factors.

Results: From the period between January and December 2017 there were 105 SSIs for patients who had undergone an emergency CS. Patient BMI (kg/m^2) was a statistically significant predictor at the 5% significance level for SSI occurrence ($p<0.001$). The odds ratio of 1.17 indicated that a unit change in BMI was associated with raised odds of SSI of 17%. Other risk factors including: patient age had a P value of 0.102 and O.R. 1.05, Recoded diabetes status had a P value of 0.142 and O.R. 2.10 and Pre-operative vaginal swab taken had a P value of 0.114 and O.R. 0.594 making them all non-significant risk factors.

Conclusion: This study was carried in order to help add knowledge to an area currently lacking it, as at the time of writing there are no studies that have investigated SSI and its associated risk factors for emergency CS. Advances in this area of study would allow for the improving of guidelines and thus patient care, giving medical professionals the information they need to reduce SSI's in patients and therefore reduce patient suffering. This study identified BMI (kg/m^2) as the only significant risk factor for the development of an SSI in emergency CS. Further research will be needed to be conducted however, to strengthen this study's findings and improve upon the lack of knowledge for emergency CS and its associated risk factors.

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Abbreviations

ASA	American Society of Anesthesiologists
BMI	Body Mass Index
CS	Caesarean Section
GDPR	General Data Protection Regulation
GP	General Practice
NHS	National Health Service
NF	Necrotizing Fasciitis
O.R.	Odds Ratio
RCOG	Royal College of Obstetricians and Gynaecologists
SSI	Surgical Site Infection
UK	United Kingdom
USA	United States of America
WHO	World Health Organisation

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1.0 INTRODUCTION

1.1 Caesarean Section

A caesarean section (CS) is a surgical procedure used to deliver a baby through an incision in the mother's lower abdomen and uterus. This procedure is either planned in advance, known as an elective CS or is carried out due to unforeseen complications of normal labour, known as an emergency CS. The performing of an emergency CS occurs to protect the health of the mother and the unborn baby during labour. The performing of an emergency CS is not without its risk however, as there is the possibility that the mother can go on to develop a surgical site infection (SSI) as a complication of the surgery. An SSI as defined by NICE (National Institute for Health Care and Excellence) (2008) 'is a type of healthcare-associated infection in which a wound infection occurs after an invasive (surgical) procedure'. The development of an SSI can lead to further negative ramifications for the patient beyond that of the infection. An SSI can cause bad scarring to occur leading to significant physical and mental impact on the patient. This is due to increased pain, a poor cosmetic outcome for the scar and a reduction in the patient's mobility either through pain or recovery time (Public Health Wales, 2018). Furthermore, an SSI following a CS can lead to an extended length of stay in hospital for the patient compared to that of a patient without an SSI (Olsen *et al.* 2010). Extended length of stays can affect patients both physically and mentally as it can cause stress through unnecessary waiting, increase their risk of catching a hospital acquired infection and cause sleep deprivation (NHS Improvement, 2018). Additionally, SSI's present a real danger to patients as they can in some circumstances develop into Necrotising Fasciitis (NF). NF is a rare and potentially lethal condition defined by Public Health England (2013) as 'a bacterial infection that affects the soft tissue and fascia'. NF can occur for a multitude of reasons including minor trauma or after surgical procedures and often requires significant surgical intervention to treat and prevent the progression of the infection. SSI rates for CS are 9.6% in England as reported by Wloch *et al*. (2012). This figure is very high and double the SSI rate average for England at 4.6% when using data published by Public Health England (2019). The high rate of SSI following a CS is significant, particularly given the young age of CS patients and shows that a better understanding of the risk factors is needed to help reduced that rate.

Throughout this review there will be a critical analysis of a variety of risk factors that are thought to play a role in the occurrence of SSI after emergency CS. As well as looking at potential risk factors the review will also look at other aspects that can be affected by SSI such as the financial burden and cost to healthcare.

The search strategy for this literature review included using search engines such as Google Scholar, University of Huddersfield Summon, Web of Knowledge, Pubmed and the British Medical Journal. Key words and phrases for the literature search included: C-section infection, C-section risk factors, obesity risk factor for C-section, obesity financial implication, obesity figures UK, skin closure techniques and materials caesarean section, smoking wound healing, smoking surgical site infection, C-section NICE guidelines, SSI diabetes, economic burden SSI's.

1.2 Guidelines

1.2.1 National Guidelines

NICE are responsible for producing evidence-based guidance that is used and adhered to by the National Health Service (NHS) in order to ensure that patients are receiving the best quality of care (NICE, 2019). The NICE guidelines on CS are currently very in-depth, providing evidence-based information on the risks and benefits of planned CS, management strategies for avoiding CS, post-operative care amongst other information (NICE, 2011). The risks and benefits are presented in a table for clinicians to refer to, with the relative effect score and quality of evidence score included for extra guidance. Management strategies for the avoidance of a CS include offering induction of labour past 41 weeks to women who have an uncomplicated pregnancy and having the involvement of consultant obstetricians when deciding whether to carry out a CS. Post-operative care recommendations include the offering of non-steroidal anti-inflammatory drugs following surgery and giving the patient wound care advice (NICE, 2011). There is however, a lack of information in these guidelines that refer to the risk factors surrounding emergency CS and the implications they may have, such as the possible development of an SSI. As a result, there is limited information for the development of management and care strategies for individuals with SSI risk factors. Without sufficient management and care strategies patient care will suffer and be negatively affected. This missing guidance from the NICE guideline's could be due to there being a significant gap in knowledge for SSI in emergency CS and its associated risk factors. This research aims to address this gap in the literature by understanding the incidence and associated risk factors of SSI following emergency CS.

1.2.2 International Guidelines

The World Health Organisation (WHO) has produced many guidelines relating to the treatment and care of CS, such as recommendations to reduce unnecessary CS (WHO, 2018) as well as recommendations for use of antibiotic prophylaxis for elective and emergency CS (WHO, 2015). There is however limited information in the guidelines that discuss or highlight any significant risk factors for SSI in emergency CS. Again, this is due there being a lack research regarding these risk factors.

For example, in the United States of America (USA), there are specific guidelines relating to different aspects of CS care such as the safe prevention of the primary caesarean delivery (AJOG *et al.* 2014). However, there are currently no guidelines for the treatment and management of emergency CS and its significant SSI risk factors. In Australia, there are specific guidelines relating to CS care such as the report on early planned CS without medical or obstetrician indication (Australian Commission on Safety and Quality in Health Care, 2018), but there appears to be a lack of guidelines for managing emergency CS and the associated SSI risk factors.

The national and international guidelines for the treatment and management of CS suggest that whilst there are clear guidelines for managing CS there appears to be a lack of specific guidelines around how to manage emergency CS suggesting that there could be a lack of evidence-based knowledge on the significant risk factors that contribute to the development of an SSI and it's subsequent management. This is problematic for healthcare professionals as there is no evidence-based research that can guide them on preventing SSI in their emergency CS patients as well as being problematic for the healthcare system itself by increasing the economic burden (Troughton *et al.* 2018). In addition, and more importantly this lack of information could also have a negative impact on patients themselves by not providing recommendations that could reduce SSI frequency.

1.2.3 SSI Prevention Guidelines

NICE has developed guidelines that focus on the prevention and treatment of SSI for surgery that offer evidence-based recommendations to help reduce the frequency and severity of SSI (NICE, 2019). The guidance related to prevention of SSI includes recommendations around 3 specific phases; preoperative, intraoperative and postoperative. The preoperative phase includes recommendations such as giving patients antibiotic prophylaxis, performing nasal decolonisation to remove *staphylococcus aureus* and for specific non-sterile theatre wear to be worn by theatre staff (NICE, 2019). The intraoperative phase suggests recommendations such as using antiseptic solutions to prepare the skin and providing further guidance on what antiseptic solution to use for particular circumstances. Additional intraoperative recommendations include using appropriate wound dressings as well as ensuring that appropriate sterilisation procedures have taken place e.g. washing of hands, application of sterile gown and gloves (NICE, 2019). The recommendations for the postoperative phase include how to change dressings in a sterile manner, how to clean the surgical site and antibiotic treatment (NICE, 2019). These recommendations target surgery generally and do not provide any specific recommendations for SSI in emergency CS.

1.3 Financial Burden

As well as having a detrimental impact on an individual's quality of life, SSI's are also a financial burden for healthcare systems. An SSI can lead to an individual having an extended stay in hospital and additional medical or surgical treatment, all of which have a financial cost to healthcare (Badia *et al.* 2017).

Jenks *et al.* (2013) investigated the clinical and economic burden SSI's had on an English hospital. The study took place over a 2-year period at Plymouth hospitals NHS trust and the researchers analysed patient, SSI and costing data. Jenks *et al.* (2013) found that SSI's caused an increased cost to healthcare with SSI patients in their study being responsible for an increased cost of £2,491,424 over the 2-year period compared to that of patients with no SSI. One of the reasons for this high cost was due to increased length of stay for SSI patients with the researchers finding that 6.4 beds per day were lost as a result SSI's. The study also found that SSI infections in CS cost the hospital £97,021 with a median cost of £7,467 per patient compared to that of £3,572 for CS patient without an SSI. Although these figures are not specific for emergency CS's, they do provide a great insight into the additional costs incurred from an SSI. A limitation stated by the researchers is that their study was conducted at one hospital and it would be difficult to compare the results they obtained with those from other hospitals due to differences in data surveillance.

Another study conducted by Troughton *et al.* (2018) mapped out the annual incidence and economic burden of SSIs of the course of a year. The researchers gathered data from NHS hospitals across England, finding that SSI in CS caused an excess cost per operation of £3,855 compared to CSs with no SSI. Annually they caused an estimated excess cost of £7,066,826 per hospital. A limitation discussed by the researchers was that cost was estimated using only additional length of stay resulting in a possible underestimation for overall SSI cost as revision surgery cost was not included. Also, the costing for SSI in CS did not look specifically at SSI in emergency CS so no figure can be placed on the exact cost it has to healthcare.

Both studies produced by Jenks *et al.* (2013) and Troughton *et al.* (2018) indicate that SSI in CS is responsible for an increased cost to healthcare. While both studies produced different figures, they agree that there is an increase in financial burden placed on the hospitals as a result of extended stay and extra treatments. Although neither study examined the increased cost for SSI in Emergency CS on its own, the same consequence of increased economic burden to healthcare will apply as factors such as increase length of stay and additional treatment are the same.

1.4 Caesarean Section Incidence

In the United Kingdom (UK) CS's are becoming more common place. Over the past 10 years from 2008-2018 there has been a steady increase in the number of all types of CS being performed in England by the NHS. The figure has gone from 154,814 in 2008 to 177,793 in 2018, which is an increase over those 10 years of 14.8% (**Figure 1**) however, the population of England grew by 8% over the same time period (Office for National Statistics, 2019) which could the reason for most of the increase in the number of CS's being performed. When focussing on only the number of emergency CS's being performed by NHS England over the same 10-year period, it can be seen that there is a similar steady increase. In 2008 emergency CS procedures stood at 93,009 but rose to 100,048 for 2018, representing an increase of 7.6% (**Figure 2**).

Figure 1: Number of CS's performed annually:2008-2018. (NHS Digital

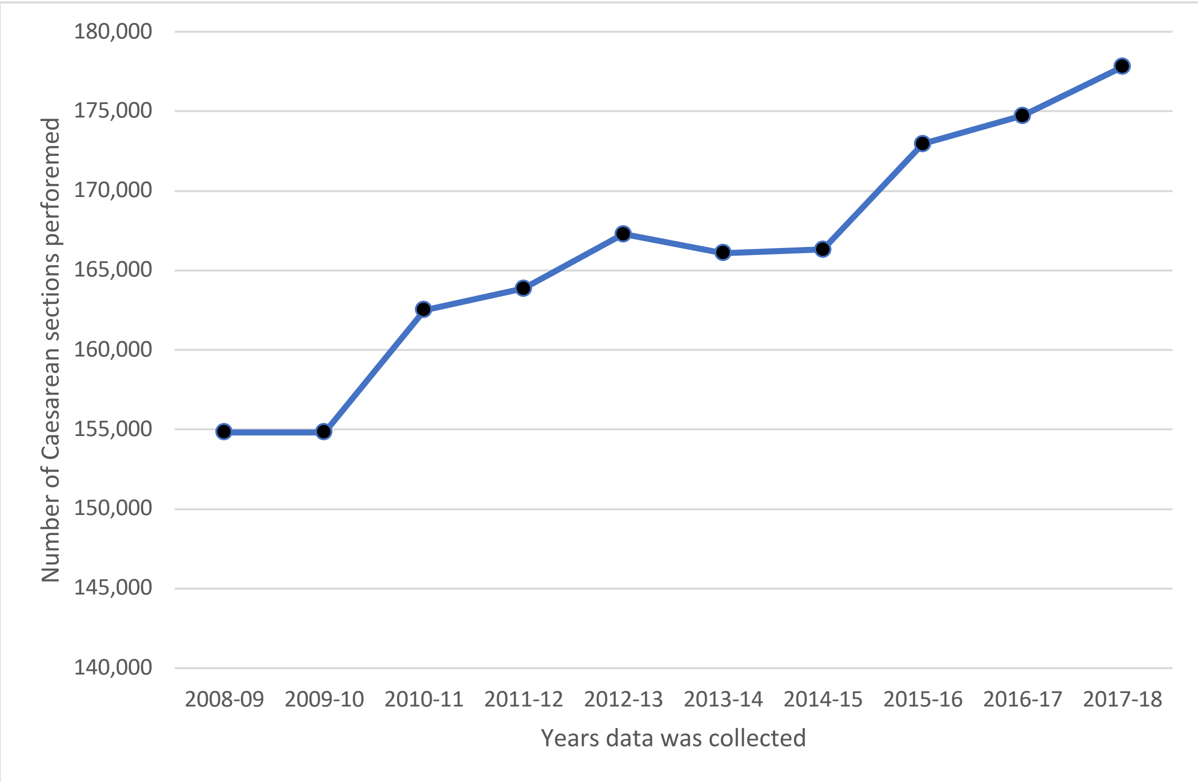
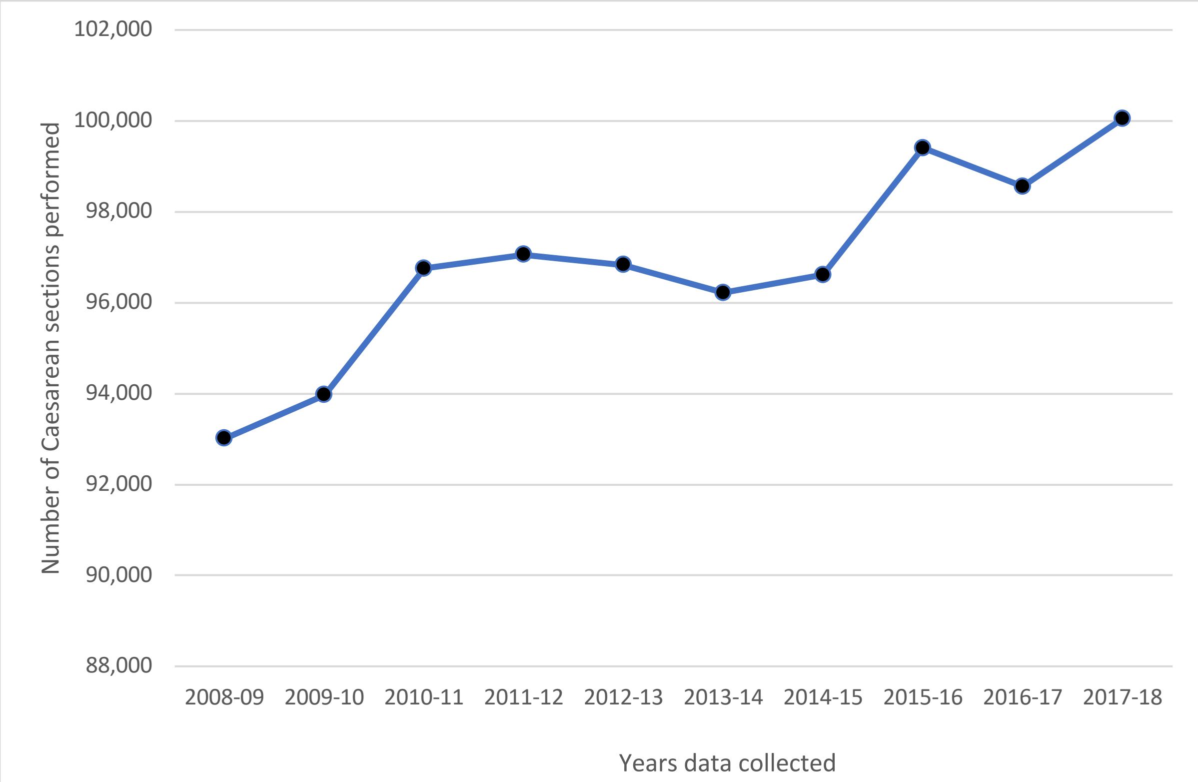


Figure 2: Number of emergency CS's performed annually: 2008-2018 (NHS digital)



When looking at the total CS figures in proportion to the total number of baby deliveries for 2008 it can be seen that CS accounted for 23.7% of all total deliveries. In 2018 CS accounted for 28.39% of all total deliveries, showing an increase of 4.66% over the 10-year period. There is no definitive answer for this rise but the President of the Royal College of Obstetricians and Gynaecologists (RCOG) suggested it could be down to the increase in the number of complex deliveries due to obesity and older mothers (RCOG, 2013). Further research would be needed however, to confirm what the President of the RCOG was suggesting.

Globally, the trend for CS's is similar with rates rising from 12.1% of all live births in 2000 to 21.1% of all live births in 2015, making NHS England's CS rates above the global average. It is worth noting however, that access and quality of healthcare differs across the world and will affect the global CS rates accordingly. In West and Central Africa for example, CS rates rose from 3.0% in 2000 to 4.1% in 2015, bringing down the global average. A more appropriate comparison for NHS England's CS rates is Western Europe where CS rates rose from 19.6% in 2000 to 26.9 % in 2015, although the authors did not give an explanation as to why this rise occurred (Boerma *et al.* 2018). The WHO (2015) stated that an increase of CS levels >10% with in a population has no effect on reducing mother and baby mortality rates and that a rise past this level cannot currently be explained.

1.5 Emergency Caesarean Section Risk Factors

As is possible with any surgery complications can arise as a result of an emergency CS being performed, for both the mother and her baby. The mother can be at risk to permanent injury to the bladder, uterus or rectum caused by the surgery, blood loss or surgical site infection (SSI), with the latter complication being the main focus of this research. Studies have been conducted to look at the risk factors associated with the development of SSI in CS in general such as Wloch *et al.* (2012), Pallasmaa *et al.* (2010), Saeed *et al.* (2019), Ghuman *et al.* (2011), (Henman *et al.* (2012), Najam and Majeed (2019) all of which will be discussed in further detail in this section.

Wloch *et al.* (2012) conducted a multicentre study which examined 4107 women who underwent a CS at 14 NHS hospitals in England in order to assess the frequency and risk factors of SSI after a CS. SSI was defined in this study as a wound infection that occurs within 30 days of the operation. Furthermore, the authors investigated a variety of different SSI risk factors, the main ones of which included: age, BMI, pregnancy gestation, surgeon grade and antimicrobial prophylaxis. The researchers came to the conclusion that obesity (defined in the study as a Body Mass Index (BMI) of >30 kg/m^2) along with age <20 years and operations performed by associate specialist or staff grade surgeons were significant risk factors for SSI following a CS. The study suggests that the significance of grade of surgeon could have been caused by confounding as a result of other SSI risk factors that were not taken into account when they conducted their study. The researchers also note that due to the study being conducted across different hospitals there is the chance that the detection and reporting of SSI was varied. This variation however, was taken into account and the researchers ensured that the necessary checks were put in place in order to accurately verify any SSI.

Saeed *et al.* (2019) also found obesity to a significant risk factor for the development of SSI after CS. Saeed *et al.* (2019) conducted a case control study of 240 women who had a CS at the Cork University Maternity Hospital in Ireland during the study period of between 1st October 2014 and 30th April 2016. Again, SSI was defined in this study as a wound infection that occurs within 30 days after the operation took place. The authors were able to successfully identify 80 SSI cases and using data obtained from the SSI patients records conducted a statistical analysis of potential risk factors for SSI; including: BMI, ethnicity, hypertensive disorders, diabetes, type of CS and age. The researchers in this study came to the conclusion that the main significant risk factor for SSI following CS was obesity, but also found hypertension, emergency CS and women who had ≥5 vaginal examinations to be significant risk factors. The study may have been limited by its design as the researchers noted that the rate of SSI may have been underestimated in their research. Although more SSI's recorded would have allowed for a stronger analysis it cannot be said that it has significantly affected the results of this study.

Pallasmaa *et al.* (2010) focussed on comparing the morbidity between elective, emergency and crash-emergency CS whilst also assessing possible associated risk factors that could play a role in increased morbidity. The study was a prospective multicentre cohort study that took place across a 6-month period in 12 delivery units throughout Finland, with a sample size of 2,496 women. The study found that there was a greater chance of complication in women who underwent emergency CS and crash-emergency CS compared to those who had an elective CS. Pallasma *et al.* (2010) also found obesity, increased age and pre-eclampsia to be significant risk factors for increasing the rate of complications. Although this study highlights the increased risk of emergency CS and the significant risk factors for complications, it does not however, look at the risk factors at play for specifically emergency CS nor for SSI. The researchers also add that the results could be susceptible to some bias due to the differences in data coverage between the hospitals they collected data from.

Consistently, Ghuman *et al.* (2011) aimed to identify the incidence of SSI along with any associated risk factors by undertaking a retrospective analysis of 526 CS patients identifying cases that resulted in an SSI. The study was conducted at Waikato Hospital in New Zealand and the researchers' results showed that an elevated BMI, an emergency CS and increased labour time were significant risk factors in the development of an SSI. These findings concur with all the previous studies discussed in this section that identify obesity or elevated BMI as a significant risk factor for SSI. The study, again like the ones previously discussed, highlighted emergency CS as a risk factor for SSI following CS but did not look at any risk factors for increased SSI in emergency CS. The researchers did note in their discussion however, that their analysis was limited by a number of factors: small sample size, data collected from only one site, missing data in patient charts and possibly by their case finding methodology.

Henman *et al.* (2012) investigated the incidence and risk factors for SSI following CS. The study was conducted in two parts with the researchers first carrying out a retrospective study on SSI cases over a 14-month period and then secondly collecting prospective data on CS over a 6-month period, comparing women who developed an SSI post CS to those who did not. The study took place at the Royal Darwin Hospital in Australia and included a sample size of 583 women. The statistical analysis performed by the researchers showed that diabetes mellitus, a high American Society of Anesthesiologists (ASA) score (a physical status classification system used by anaesthetists to predict operative risk (Doyle & Garmon, 2019) and the use of staples were significant risk factors for the development of SSI. These significant risk factors do differ from the ones suggested by the other studies, particularly the absence of obesity, but the researchers did not include obesity as a potential risk factor when conducting their study. The study also did not look at smoking as a risk factor which again was seen by other studies as a potential risk factor for SSI in CS. The researchers do note in their discussion that due to their small sample size they were not able to carry out multivariate analysis for the SSI risk factor group.

Additionally, Najm and Majeed (2019) also conducted a study investigating the associated risk factors for SSI following CS. The study was a prospective one that had a sample size of 200 women that underwent a CS. The researchers carried out their study at AL-Krkh hospital in Iraq and collected data by interviewing and examining each patient in the study. They concluded that emergency CS, membrane rupture and vertical incision were significant risk factors for the development of SSI in CS. The researchers also found obesity not be a significant risk factor for SSI in CS which contradicts most of the research that is currently available. The researchers do however state that this finding could be down to their study design or small sample size. The study also states that infection control in the Iraq health care system is very poor, so this is likely to have an effect on SSI outcome. Again, like previous papers have discussed in this section it identifies the significant risk emergency CS poses to the development of SSI without looking at the risk factors for emergency CS.

Another study, conducted by Gelaw *et al.* (2017) researched the incidence and risk factors associated with SSI following a CS. The study was a cross-sectional study that took place at Lemlem Karl public hospital in Ethiopia, Africa over a 3-year period from 2013 to 2016. The researchers retrospectively gathered data on 364 women who had received a CS and statistically analysed the data, looking for any significant associations. The study showed 3 significant risk factors associated with development of an SSI following CS; type of abdominal incision (Midline incisions giving the greater risk), duration of labour and membrane rupture time. Gelaw *et al.* did not however investigate obesity or smoking status as potential risk factors, so their significance cannot be obtained from this study. No limitations were noted by the researchers regarding their study although with it being conducted in a developing country there will be differences in the standard of care compared to that of a developed country. The researchers do state that the incidence of SSI following CS is lower than that of other developing nations but not as low as developed ones, indicating that quality of care could still impact the difference in significant risk factors. The paper also focussed on CS generally making no distinction between elective and emergency CS, making the significant risk factors they found non-specific to emergency CS. This again highlights the gap in research there is regarding significant risk factors associated with SSI following emergency CS.

Furthermore, Newlin *et al.* (2015) investigated the risk factors for wound complications as well as specific SSI analysis in a retrospective analysis of 559 women who had undergone a CS between July 2012 and June 2013. The study showed that the most significant risk factors for developing an SSI following CS were a BMI > 33.45 kg/m^2 and the patient having pre-eclampsia during pregnancy. The rationale for such an arbitrary cut off in BMI was that the researchers carried out receiver operator curve analysis and found the risk threshold to be 33.45kg/m^2. The researchers identified the lack of randomisation of patients for comparison of treatment outcomes as a limitation of their study. It is also worth noting that the study does not specifically specify where the research was carried out so it is difficult to say what other factors could have had an impact on the study such as quality of healthcare. The research also investigates the SSI risk factors associated with all CS's rather than just emergency CS making the significant risk factors found non-specific for emergency CS.

The literature suggests there is no one risk factor that can be claimed as the sole causative factor in the development of SSI in CS, but rather the authors all came to the conclusion that there is a multitude of factors that can lead to the development of SSI including: obesity, age, diabetes, pre-eclampsia, membrane rupture time, staples for wound closure, emergency CS, type of abdominal incision, high ASA score, ≥ 5 vaginal examinations, grade of surgeon and duration of labour. It also important to note that the research discussed in this section is both national and international, showing that given the different health care systems each country may have there is still a similarity in the significant risk factors that could cause an SSI in CS. It is also worth mentioning that there was no standard set of risk factors tested across all of the papers, with different studies investigating different risk factors. This will have led to the different outcomes the studies had regarding the significant risk factors. Furthermore, although most of the research papers discussed highlight the significant risk posed by emergency CS for the development of SSI following CS, none of these research papers look specifically at the risk factors for SSI in emergency CS. This study aims to fill that gap by focussing on the associated risk factors for SSI in emergency CS. These studies are however, good sources for comparison of SSI risk factors, given some of the similarities between elective CS and emergency CS. The potential role and significance of these risk factors will be discussed in further detail in the next section.

Table 1:

Authors	Study Design	Sample Size	Risk Factor (Significance)
Wloch *et al.*	Prospective multicentre cohort	4107	BMI (P< 0.0001) Age < 20 years (P=0.04) Operations performed by Associate specialist or staff grade surgeon (P<0.01)
Saeed *et al.*	Case control	240	Obesity (P< 0.001) Hypertension (P=0.005) Emergency CS (P=0.004) ≥5 vaginal examinations (P=0.004)
Pallasmaa *et al.*	Prospective multicentre cohort	2496	Emergency CS (CI=1.5-2.2) Obesity (CI= 1.1-1.8) Increased age (CI=1.03-1.2) Pre-eclampsia (CI=1.1-2.0)
Ghuman *et at.*	Retrospective	526	Elevated BMI (P=0.0002) Emergency CS (P=0.0243) Increased labour time (P=0.0019)
Henmann *et al.*	Retrospective	583	Diabetes Mellitus (P=0.02) ASA score (P=0.003) Staples (P=0.002)
Najm and Majeed	Prospective	200	Emergency CS (P=0.005) Membrane rupture (P=0.020) Vertical incision (P=0.001)
Gelaw *et al.*	Cross sectional	364	Type of abdominal incision (P<0.05) Duration of labour (P<0.05) Membrane rupture time (P<0.05)
Newlin *et al.*	Retrospective	559	BMI > 33.45kg/m^2 (P=0.03) Pre-eclampsia (P=0.02)

1.5.1 Obesity

The WHO defines obesity as 'abnormal or excessive fat accumulation that may impair health' and states that individuals that are classed as obese have 'a BMI greater than or equal to 30 kg/m^2' (WHO, 2018). Obesity is one of the biggest health problems for society at this current moment in time with the NHS using resources to create adverts tackling the matter. The time and effort invested by the NHS to try and reduce obesity shows the importance of the issue, particularly given the wide range of comorbidities that can occur as a result of an individual being obese. In 2018 the UK government released national statistics for obesity in England which showed levels at 26% of the population for 2016, this an increase of 11% from 1993 (House of Commons Library, 2018). This figure of 26% is 13 percentage points higher than the WHO global estimates for 2016 which found that 13% of the global adult population were obese, with figures expected to rise year upon year (WHO, 2018).

Obesity is a risk factor in the occurrence of SSI's in CS as identified in **section 1.3**, but there are studies and reviews that go further into describing the relationship between obesity and infection such as the review by Genoni *et al.* (2014) which discusses the biological mechanisms at play in obese individuals giving them a greater chance of developing an infection. Genoni *et al.* (2014) explain in their review that in obese individuals there is a variety of complicated metabolic and hormonal changes that take place, all of which interact with the immune system leading to negative consequences in relation to infection. Furthermore, obesity can also lead to a greater chance of SSI due to its ability to impair wound healing (Avishai *et al.* 2017) (Guo and DiPierto, 2010) (Pierpont *et al.* 2014). Wound healing is an integral part of any post-operative recovery and its failure to occur can lead to serious complications for the individual. Wound healing is best explained by Guo and DiPietro (2010) in their review as 'a dynamic process consisting of four continuous, overlapping, and precisely programmed phases' all of which need to occur without interruption in order for wound healing to be successful.

Tissue hypoxia is another factor at play in obese individuals with it having an effect on the body's ability to heal following surgery, hampering the wound healing process (Guo and DiPierto, 2010) as well as effecting oxidative killing (Kabon *et al.* 2004). In a study conducted by Kabon *et al.* (2004) they investigated the effect of obesity on perioperative tissue oxygenation by comparing the tissue oxygen levels of 46 patients split into two equal groups, those with a BMI <30 kg/m^2 and those with a BMI ≥30 kg/m^2. The patients then received intraoperative oxygen to the arterial oxygen tension of either 150 mmHg or 300 mmHg and had their tissue oxygen tension measured during the operation and after. The authors found that in the obese individuals their oxygen tension was significantly lower than that of non-obese individuals, making them hypoxic. The hypoxic environment that occurs in obese individuals has a negative impact on the oxygen dependant processes such as angiogenesis, cell motility and phagocytosis (Guo and DiPierto, 2010) (Harper *et al.* 2014). Sufficient oxygen is also required by the body for an effective immune response as it plays a crucial role in the oxidative killing of invasive microbes (Guo and DiPierto, 2010).

Thelwall *et al.* (2015) investigated the effect of BMI on the risk of SSI following a number of different types of surgeries, including hip replacement, large bowel and abdominal hysterectomy. The study was a prospective cohort study and analysed the data for 159 720 operations that took place across 206 NHS England hospitals between 2007 and 2011. The researchers found that having a BMI ≥35 kg/m^2 significantly increased the risk of an individual developing an SSI following surgery. The authors discuss that the possible reasons for a BMI ≥35 kg/m^2 significance may be multifactorial, with a decrease in tissue oxygenation leading to impaired wound healing, impaired immune cell function and poor diffusion of prophylactic antibiotics. The study does state that diabetes status was not collected for the patients despite it being a known risk factor for infection, so it is possible that the inclusion of this risk factor could have a bearing on the results. Furthermore, the procedures investigated do not include emergency CS's so it cannot be concluded from this study the impact that a raised BMI has on risk of SSI in emergency CS.

As cited by Thelwall *et al.* (2015) one potential reason for obesity being a risk factor for SSI is the poor perfusion of antibiotics in obese patients. Antibiotics that are hydrophilic have a decreased serum concentration in obese individuals due to their reduced ability to dissolve in adipose tissue (Falagas and Karageorgopoulos, 2010). In addition, obese individuals have changes to their liver and kidneys that increases the rate of clearance for antibiotics from the patient's body reducing the drug's effectiveness (Falagas and Karageorgopoulos, 2010) (Janson and Thursky, 2012). A study conducted by Toma *et al.* (2011) investigated whether the tissue penetration of the antibiotic cefoxitin was reduced in obese individuals. The researchers found that there was a reduced tissue concentration of the prophylactic cefoxitin in obese individuals. Furthermore, there is a lack of understanding and research into the effectiveness of other antibiotics and their correct dosage when treating obese individuals with a study conducted by Boyd *et al.* (2016) identifying this lack of knowledge.

The financial burden of obesity to the NHS is also of an increasing concern as obesity becomes more prevalent in society. In 2014/15 overweight and obesity-related ill health was estimated to have cost the NHS £6.1 billion and that figure is expected to rise to around £9.7 billion for the year 2050 (Public Health England, 2017). Furthermore, a study conducted by Wang *et al.* (2011) looked at the projected economic burden of obesity in both the USA and UK. The researchers concluded from their study that the number of obese individuals will continue to rise and along with it the healthcare costs as well. For an already financial stretched healthcare system these figures will be unsustainable so there will be a greater need for a better management of patients and their conditions. Although none of these studies can highlight the specific economic cost obesity might play with regards to SSI following emergency CS, it is clear that there is an economic burden associated with obese patients. As such identifying obesity as a possible risk factor may lead to the better management of patients with obesity, as patients at a greater risk of SSI will be more readily identified and appropriate preventative measures could be taken to limit the impact the risk factor will have on the outcome of the patient.

1.5.2 Smoking

Smoking is still one of the biggest health concerns that the NHS faces due it being a risk factor for many diseases and health conditions such as cancer, cardiovascular disease and lung cancer among other respiratory conditions (NHS, 2018). In 2018 NHS digitals smoking statistics stated that 14.9% of the adult population in England were classed as current smokers and that 10.8% of expectant mothers were smokers at the time of delivery. Smoking is known to have adverse effects on both the mother and child during pregnancy such as an increased risk of postneonatal mortality and increased risk of upper a lower respiratory tract infection (Lawder *et al.* 2019). In relation to the mother and infection, smoking has also been identified as having a detrimental impact on wound healing itself leading to the development of an SSI (Nolan *et al*. 2017). As discussed in **section 1.4.1** it is crucial that all four phases are carried out to their entirety without interruption in order for successful wound healing to occur. Oxygen is a vital element in this wound healing process, as it plays an integral role in cell metabolism. The toxic compounds found in cigarette smoke, such as carbon monoxide and nicotine help to create a hypoxic environment within an individual, which in turn interrupts the necessary process for wound healing. As well as interrupting those wound healing processes, hypoxia also reduces the response of neutrophils and other bacterial defences the body has. This all together creates a more bacteria-friendly environment leading to a greater chance of an SSI occurring (Bishop, 2008). In the study conducted by Nolan *et al.* (2017) they investigated whether smoking and its associated carbon monoxide levels had any significant effect on the frequency of SSI following elective surgery. The study conducted was a matched case-control study, matching on age, sex and type of surgery and analysed 2452 patients who had an SSI. The study found that being a current smoker had a statistically significant impact on increasing the likelihood of developing an SSI, as well as also finding that smoking on the day of surgery increased the likelihood of developing an SSI. Although the study did not directly investigate the relation of SSI to CS, it is still an important study to consider when looking at potential risk factors for SSI following emergency CS.

1.5.3 Diabetes

Diabetes is a disease in which the body's ability to produce or respond to the hormone insulin is impaired, resulting in abnormal metabolism of carbohydrates and elevated levels of glucose in the blood. There are 3 types of diabetes; type 1, type 2 and gestational diabetes. Diabetes can have a detrimental effect on the development of infection, due to the negative role it can play in wound healing.

As identified earlier in **section 1.4** in the study conducted by Henman *et al* (2012) they found Diabetes Miletus to be a significant risk factor for the development of an SSI in CS, however there was no rationale given as to why this was the case.

In a study conducted by Muller *et al.* (2005) they investigated the risks of individuals with type 1 and type 2 diabetes developing a common infection. The study was a prospective cohort study that spanned the course of a year. The sample size was 26,328 patients of whom 7417 had either type 1 or type 2 diabetes; and 18,911 patients who did not have diabetes but did have hypertension and were used as the control in the study. The study took place across the Netherlands and the infections investigated were urinary tract, skin and mucous membrane and respiratory tract. The researchers found that type 1 diabetes and type 2 diabetes increased the risk of an individual developing a common infection. Although this study did not investigate the association of diabetes and risk of SSI in individuals who had undergone an emergency CS, it does however show the impact that diabetes can have on skin infections making it an important study to consider when considering risk factors for SSI infection following emergency CS.

Furthermore, a study conducted by Shah and Hux (2003) quantified the risk of infectious diseases in diabetic patients. The retrospective cohort study had a sample size of 1,027,498 with half the patients being diabetic and the other half being matched non-diabetic patients with the data for all patients collected from hospitals across Ontario, Canada. The researchers found that diabetic patients had a risk ratio of 1.21 compared to that of non-diabetic patients when it came to hospitalisation due to an infectious disease.

1.5.4 Skin closure techniques

Skin closure is a necessary part of an emergency CS, but can be done in a variety of ways using different types of sutures and material leading to different outcomes.

Hasdemir *et al.* (2015) conducted a randomised prospective study comparing the use of different subcuticular suture materials in CS patients at Celal Bayar University hospital in Turkey. The study had a sample size of 250 women who underwent a CS, with 108 patients having their wound closed with absorbable polylactin and 142 having their wound closed with nonabsorbable polypropylene. The researchers found that there was no significant difference between the two types of suture for the rate of wound infection. One limitation for the study, noted by the researchers in their discussion, was the difference in sample size between the groups as this could have had an effect on their analysis and results. Although this study did not focus on emergency CS, the closure of the skin is the same for an emergency CS as it is for an elective CS, but it cannot be said for certain whether these results would be the same for emergency CS's.

Furthermore, a study conducted by Figueroa *et al.* (2013) investigated the risk of using surgical staples compared to subcuticular sutures for the development of a wound infection or wound disruption. The study took place at University Hospital, Birmingham, Alabama and had a sample size of 398 patients. The patients were randomized into two groups: those who received an absorbable suture and those who received surgical staples. The researchers found that using surgical staples to close wounds following a CS, compared to using sutures increased the chance of wound morbidity significantly. A limitation recognised by the researchers was that for some of the patients (12%) there was no follow-up information, although it is stipulated that this would not have affected the final results. This study outlines the difference between the sutures and staples for CS, but does not look at association these risk factors may have for SSI in emergency CS as there could be other factors that affect the outcome.

1.6 Project Aims and Objectives

The aims of this research are to quantify the incidence of SSI in patients who have had an emergency CS and then to identify the risk factors and associated factors that play a major role in the development of those SSI's.

The Objectives for the project included:

- The creation of an appropriate data collection database
- The collection and inputting of the required data into the database
- The statistically analysis of the data collected
- The identification of SSI incidence for emergency CS
- The identification of statistically significant risk factors and associated factors for SSI in emergency CS
- The presentation of risk factors and discussion of their significance

1.7 Ethical Considerations

The dissertation received ethical approval from The University of Huddersfield's School Research Ethics Panel. Patient confidentiality is of highest importance with no patient identifiable data being collected during the project. Ethical considerations for the project included:

- Acquiring an honorary contract from the Mid Yorks Hospital NHS Trust for the duration of the project to allow access to patient data
- Written consent from the maternity department at Mid Yorks Hospital NHS Trust
- Approval from occupational health at Pinderfields General Hospital
- Completing both the introduction to good clinical practice eLearning (primary care) and introduction to good clinical practice eLearning (secondary care)

2.0 METHODOLOGY

2.1 Study Design

The study carried out was a retrospective cohort study. This design was chosen in preference over a prospective cohort study due to the 12-month time constraint of the masters.

2.2 Study Setting

The study was conducted at Pinderfields General Hospital, Wakefield; part of the Mid Yorkshire NHS Hospitals Trust. Data was collected from the electronic databases used by the Mid Yorkshire Maternity department. Written approval was obtained from the maternity department before the auditing of any patient data took place.

2.3 Sample

The study sample was made up of individuals of whom had an emergency CS procedure performed between 1st January 2017 and 31st December 2017 at Pinderfields General Hospital. The study sample was obtained through the use of one of the obstetric departments databases, Euroking. The database contains all patients seen and treated by Pinderfields obstetrics department. The database was searched using date and delivery parameters to show patients who had an emergency CS for the whole of 2017. All the hospital numbers of identified patients were then exported to a password-protected Excel spreadsheet.

2.4 Inclusion and Exclusion Criteria

Inclusion criteria:

- 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:

- 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

2.5 SSI Definition

SSI was defined in this study as any infection that occurred to the surgical incision site within 30 days post-operation as identified by a positive wound swab. Any infections found and recorded on the NHS databases after that time period were not included in this study.

2.6 SSI Identification

To identify emergency CS patients who acquired an SSI each patient's hospital number was inputted in the Sunquest ICE database. Sunquest ICE is an electronic database used by the NHS to record the outcomes of any laboratory tests that occur within the hospital or local community. Any patients who had a positive CS wound swab 30 days post-operation were marked as having an SSI on the spreadsheet, and those who had a negative wound swab within 30 days post-operation were marked as not having an SSI on the spreadsheet.

2.7 Data Collection

Data collection started with the drawing up of the data collection spreadsheet. This was done in conjunction with experienced healthcare professionals, along with the use of relevant research papers in order to obtain appropriate data headings. The paper notes for all of the identified SSI cases were requested from the offsite storage facility and upon arrival were stored in a locked filing cabinet. With the use of the paper notes, Euroking and Sunquest ICE the potential risk factors for each patient were filled in on the data collection spreadsheet. Once the spreadsheet had been completed for SSI cases the same process was repeated for non-SSI cases.

2.8 Data Cleaning

Before any statistical analysis could be performed the data needed to be cleaned so that it could be exported to SPSS, the software being used to analyse the data. Cleaning the data included changing any text recorded data to a number code for better analysis, as well as removing any patients who were missing SSI data as they would not be able to be analysed successfully. Missing data occurred as a result of the information not being filled out or due to physical copies of the information being missing from the patients file. In addition, some risk factors had to be removed from the data collected due to there being too many for the sample size or due to missing data exceeding 10% of the sample size for that variable, which would lead to unsuccessful analysis. This removal of risk factors was done with the guidance of previous research and with the help of health care professionals.

As well as removing data, there were also instances where data was missing and the substituting of data needed to occur to allow for successful analysis. The mean substitution of data only occurred when the frequency of missing data for a particular risk factor did not exceed 10% of the total sample size.

2.9 Statistical Analysis

The statistical analysis of all the data was performed using SPSS software. A descriptive summary of all the variables was conducted. Categories with similar qualities were combined into larger groups to allow for analysis as this prevented data being spread to thinly over a large number of categories. Any variable that was revealed to be statistically significant at the 5% significance level was carried forward for inclusion in a subsequent multiple logistic regression model. Additionally, any variables with a $p<0.15$ were also carried through for analysis to avoid the overlooking of a variable with some importance. Odds ratio, 95% confidence intervals, P-value and % correct classifications were all being recorded following the multiple logistic regression analysis.

3.0 RESULTS

There was a total sample size of 206 emergency CS patients for the study, 105 of which did not have an SSI and a 101 of which did have an SSI.

The initial analysis of the data collected included performing a descriptive analysis on all the variables, with the results recorded in the table below.

Table 2: Descriptive summary of categorical variables.

Variable	SSI frequency (%)	No SSI frequency (%)	Overall frequency (%)
*Grade of CS:			
G1	20 (19.8)	19 (18.1)	39 (18.9)
G2	37 (36.6)	48 (45.7)	85 (41.3)
G3	39 (38.6)	36 (34.3)	75 (36.4)
G4	5 (5.0)	2 (1.9)	7 (3.4)
Smoking status:			
Non-smoker	63 (62.4)	65 (61.9)	128 (62.1)
Smoker at time of booking	22 (21.8)	23 (21.9)	45 (21.8)
Stopped smoking before booking	16 (15.8)	17 (16.2)	33 (15.8)
Pre-operative vaginal swab taken:			
No	61 (60.4)	52 (49.5)	113 (54.9)
Yes	40 (39.6)	53 (50.5)	93 (45.1)
Diabetes status:			
No Diabetes	83 (82.2)	98 (93.3)	181 (87.9)
Type 1	2 (2.0)	1 (1.0)	3 (1.5)
Type 2	2 (2.0)	1 (1.0)	3 (1.5)
Gestational	14 (13.9)	5 (4.8)	19 (9.2)
Grade of Surgeon:			
Registrar	58 (57.4)	55 (52.4)	113 (54.9)
Specialist trainee	5 (5.0)	7 (6.7)	12 (5.8)
Consultant	11 (10.9)	21 (20)	32 (15.5)
SHO	6 (5.9)	3 (2.9)	9 (4.4)
Associate Specialist	21 (20.8)	19 (18.1)	40 (19.4)

*grading of CS used to classify urgency: G1= immediate threat to foetus or mother's life, G2= no immediate threat to foetus or mother's life, G3= early delivery needed, G4= delivery when suits maternity services or mother (rcog, 2010).

Table 2 shows that for the variable grade of CS, G4 has a very low frequency making the data impossible to analyse leading to the recoding of this variable into 2 groups; G1 + G2 and G3 + G4. Smoking status also saw a heavily uneven distribution across the data and was recoded into 2 groups: non-smoker and smoker at time of booking + stopped smoking before booking.

Diabetes status had a very uneven distribution and was recoded into 2 groups: No diabetes and Type 1 + Type2 + gestational. Grade of surgeon had an uneven distribution, particularly for specialist trainee and SHO, so was recoded into 2 groups; registrar + specialist trainee + SHO and Consultant + Associate specialist. Recoding was done to allow the data to be meaningfully analysed.

A descriptive summary of all the continuous variables was completed.

Table 3: Descriptive summary of continuous variables

Variable	Mean	Std. deviation	Median	Range			
				Interquartile	Full	Minimum	Maximum
Patient age	28.7	5.51	29	9	23	18	41
Patient BMI (kg/m^2)	29.1	6.72	29	10	33	16	49
Membrane rupture to delivery interval time (min)	841	1,730	701	909	23,400 (6.5 days)	0	23,400 (6.5 days)
Length of surgery (min)	47.2	20.1	45	21	197	19	216

In **table 3** membrane rupture to delivery time had interquartile range of 909 and a full range 23,400. This positive skew is down to one patient having a membrane rupture to delivery interval time of 23,400 mins and this skew can be seen more clearly in **Figure 3**.

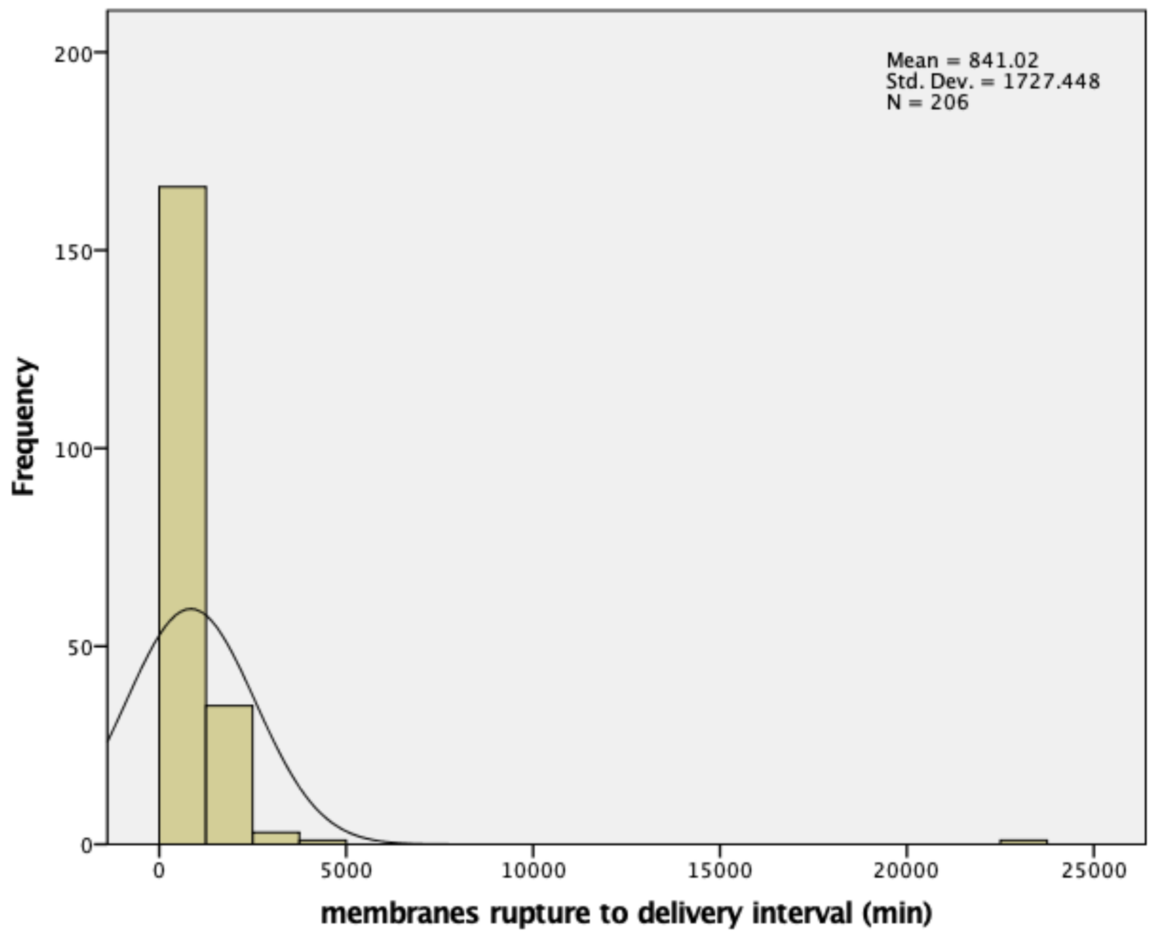


Figure 3: Positive skew of membrane rupture to delivery interval time

Following the descriptive analysis of the data, a simple binary logistic regression was completed.

Table 4: Binary logistic regression results of all variables

Variable	O.R.	95% C. I		P-Value	% correct classification
		Lower	Upper		
Patient age	1.05	1.00	1.11	0.044	58.7
Patient BMI (kg/m^{2})	1.17	1.11	1.24	< 0.001	68.4
Membrane rupture to delivery interval time (min)	1.00	1.00	1.00	0.597	53.4
Length of surgery (min)	1.01	0.991	1.02	0.455	51.9
Pre-operative vaginal swab taken	0.643	0.370	1.12	0.118	55.3
Recoded grade of CS	1.36	0.778	2.38	0.280	53.9
Recoded grade of surgeon	0.754	0.424	1.34	0.335	52.9
Recoded diabetes status	3.04	1.21	7.62	0.018	56.3
Recoded smoking status	0.980	0.558	1.72	0.944	51.0

After the simple binary logistic regression analysis was completed, any variable with a P value < 0.200 was included in the next stage of analysis where a multiple logistic regression analysis was performed.

Table 5: Multiple logistic regression analysis

Variable	O.R.	95% C. I		P-Value	% correct classification
		Lower	Upper		
Patient BMI (kg/m^2)	1.17	1.11	1.24	< 0.001	70.4
Patient age	1.05	0.990	1.12	0.102	
Recoded Diabetes status	2.10	0.780	5.66	0.142	
Pre-operative vaginal swab taken	0.594	0.311	1.13	0.114	

In **Table 4** the pre-operative vaginal swab variable had a P value of 0.118 and therefore deemed to possibly have an effect on the outcome so was included in the final analysis. In **Table 5** Patient BMI had a P-value < 0.001 making it a very significant risk factor and had an O.R. of 1.17. Patient age had a P-value of 0.102 making it now a non-significant risk factor, but still having an O.R. of 1.05. Recoded diabetes status recorded a P-value of 0.142 making it a non-significant risk factor and its O.R. decreased to 2.10, which decrease in odds by over 50%. Pre-op vaginal swap remained a non-significant risk factor with a P-value of 0.114.

The only risk factor that had a statistically significant association with an increased chance of acquiring an SSI following an emergency CS was Patient BMI with a P value < 0.001. The O.R. shows that for every increase in unit of BMI the odds of an individual acquiring an SSI increase by 17 % when controlling for BMI, age, diabetes status and vaginal swab taken. The classification rate for BMI on its own was 68.4% however, with the inclusion of age, diabetes status and vaginal swab taken the classification rate has risen to 70.4%, only improving predictability by 2%.

4.0 Discussion

4.1 Main findings

The main aims of this research were to quantify the incidence of SSI in patients who have had an emergency CS and then identify any risk factors and associated factors that play a major role in the development of those SSIs. The major findings of this study show that between January 2017 - December 2017 105 patients were diagnosed with an SSI. Importantly, BMI (kg/m^2) was identified as a significant risk factor in the development of SSIs in individuals who had undergone an emergency CS and for every increase in one unit of BMI kg/m^2 the odds of an individual developing an SSI following an emergency CS increased by 17%.

Whilst some research has focused on investigating risk factors of developing and SSI in CS, no study has previously distinguished between the different CS procedures, emergency and elective. At the time of writing there is no study that has investigated SSI risk factors for Emergency CS's and the findings from this study go some way towards filling that gap in the literature.

4.2 Risk Factors

The finding that BMI is a significant risk factor for developing an SSI following emergency CS suggests that individuals classed as obese are at the greatest risk of such an event occurring. One possible reason for this increased risk is the role that excess adipose tissue can play on the immune system causing its efficacy to be decreased as well as the negative affect obesity can have on tissue oxygenation. This decrease in perioperative tissue deoxygenation could potentially be one reason for BMI being a significant risk factor for SSI in emergency CS, although further research would need to be done to outline the pathophysiological role BMI plays in emergency CS SSIs (Kabon *et al.* 2004). In a meta-analysis investigating the use of perioperative supplemental oxygen therapy had on the rate of SSI, Qadan *et al.* (2009) evaluated the results of 5 randomised controlled trials and found that giving supplemental oxygen following an operation had a significant effect in preventing the development of an SSI. The authors suggest that this prevention could be due to one of the bodies defence mechanisms, oxidative killing, which requires sufficient oxygen partial pressures in order to function (Qadan *et al.* 2009). This research shows the effect that obesity and the subsequent tissue hypoxia can have on the development of SSIs and particularly in relation to SSIs in emergency CS's.

The finding of BMI as a significant risk factor for the development of an SSI following emergency CS is consistent with previous research conducted by Wloch *et al.* (2012), Saeed *et al.* (2019), Pallasmaa *et al.* (2010), Ghuman *et al.* (2011) and Newlin *et al.* (2015). Wloch *et al.* and Ghuman *et al.* both cited impaired immune response, larger wound area size and poor perfusion of prophylactic antibiotics in obese individuals as possible reasons for BMI being a significant risk factor for developing an SSI. Newlin *et al.* also cited poor perfusion of prophylactic antibiotics and Pallasmaa *et al.* and Saeed *et al.* gave no rationale for BMI's significance. Najm and Majeed (2019) found BMI to be a non-significant risk factor citing a different study sample and design as the reason for difference with other studies. Henmen *et al.* 2012 and Gelaw *et al.* 2017 both did not investigate BMI in their studies with no rationale given as to its lack of inclusion. Other research looking into obesity as a risk factor for infection yield the same results with studies conducted by Tjeertes *et al.* (2015), Namba *et al.* (2012) and Serrano *et al.* (2010) finding obesity to be a risk factor for the development of an infection. Tjeertes *et al.* (2015) investigated the role obesity can play in postoperative complications following general surgery in a study population 4293 patients. The researchers found that an increase in BMI led to an increase risk in the development of an SSI, consistent with the findings of this thesis. The authors stated possible reasons for this increased risk could be: impaired healing due to increased volume of subcutaneous fat, increased tension on surgical incision and elevated blood glucose levels. Although this was not a study specifically on emergency CS it still highlights the effect obesity can have on the development of an infection. Namba *et al.* (2012) investigated the influential risk factors for the development of an SSI following primary total hip replacements in a population size of 30,491 patients and concluded that having an elevated BMI of ≥ 30 kg/m^2 significantly increased an individual's risk of developing an SSI. Despite the authors not specifically investigating the relationship between obesity and SSI in emergency CS, it does acknowledge the role obesity can play in the development of an SSI. The mechanisms behind why obesity can play a role in SSI development are multifactorial, with obesity having an effect on antibiotic performance as well as impairing the individual's immune system. Antibiotics can have a reduced effect in obese individuals, as often the same standard dosage is given irrespective of BMI and body size (Falagas and Karageorgopoulos, 2010). This in turn makes the individual more susceptible to a microbial invasion and the development of an infection. This study identified BMI (kg/m^2) as a significant risk factor for SSI in emergency CS with possible reasons for this being altered immune cell function and reduced antibiotic effect however, further research will need to be conducted to identify the specific mechanisms responsible for this increased risk.

Furthermore, individuals with high BMI such as those classed as obese will require a larger surgical incision compared to those with a lower BMI (Corneille *et al.* 2007). A larger incision may result a greater operation complexity which in turn may increase the procedure time and the number theatre staff that need to be present, both potentially increasing SSI risk. A larger surgical incision may also damage more subcutaneous fat leading to greater tissue hypoxia. As discussed, tissue hypoxia can increase the risk of a patient developing an SSI following a surgical procedure. More research will need to be done however to identify whether a larger incision has any significance on the development of SSI following an emergency CS.

4.3 Additional Risk factors

Other risk factors investigated in this study include patient age and diabetes status, both of which when statistically analysed individually were significant having P values of 0.044 and 0.018 respectively, although when analysed along with other risk factors they lost their significance.

In this study patient age was found not to be a significant risk factor when analysed in a multiple logistic regression with BMI (kg/m^2), Diabetes status and Pre-operative vaginal swab. When assuming the linear effect of age the odds ratio was 1.05 giving a 5% increase in the odds of acquiring an SSI with every increase in unit of age. This finding of non-significance is in disagreement with Wloch *et al.* (2012) and Pallasmaa *et al.* (2010) who found it to be a significant risk factor for SSI in CS. Both these studies however came to opposing conclusions with Wloch *et al.* finding that an age of >20 had a significantly increased the risk of an SSI compared to Pallasmaa *et al.* found that increasing age significantly increased the risk of an SSI. Neither study however, was able to explain their contrasting results or possible rationale for these outcomes. Furthermore, it is also unclear as to why patient age was not a significant risk factor in this thesis, although there are studies that support this result. Both Henman *et al.*

(2012) and Khalid *et al.* (2019) found age not to be a significant risk factor for the development of an SSI in CS. One possible reason for its non-significance could be due the small age range within an already young sample population. There is research that suggests age could play a role in increasing the risk of infection with a study conducted by Kaye *et al.* (2005) showed that increasing age up to the age of 65 increased the risk of an SSI developing. As people get older their immune system becomes less effective and as a result individuals can become more susceptible to infectious diseases (Valiathan *et al.* 2016). Another possible reason could be that as people age, they are more likely to have comorbid conditions that increase their risk of developing an SSI following emergency CS (Agodi *et al.* 2015). However, further research would need to be done in order to determine if age has any significance on the development of an SSI in emergency CS.

In this study, diabetes was found not to be a significant risk factor. Individuals with diabetes mellitus were found in the Henman *et al.* (2012) study to be at a significant risk of developing an SSI following CS, differing from the findings of this study. However, it is worth noting that Henman *et al.* had small variable sample size of 30 diabetic patients decreasing the strength of the analysis. In addition, one reason for the difference in findings may be again the small variable group size of patients with diabetes in this thesis, making it difficult to analyse the effect that diabetes may have on the development of an SSI. In contrast to Henman *et al.* and in agreeance with the findings in this study, Wloch *et al.* (2012) analysed 218 diabetic patients and found that it was not a significant risk factor in the development of an SSI in CS. Wloch et al. do state however, that this finding could be down to the adjusting by BMI category in the analysis. It is thought that diabetes has the potential to be a risk factor for SSI as it has a negative effect on the hosts immune system, reducing its response to defending against microbes as well as impairing wound healing (Brem and Tomic-Canic, 2007). The mechanisms that make diabetic patients more susceptible to infection are complex and multi-layered with hyperglycaemia, hypoxia and chronic inflammation all playing a role in interrupting the different crucial stages of wound healing (Baltzis *et al.* 2014).

Smoking status was identified in this study as not being a significant risk factor in the development of an SSI following an emergency CS which is in agreement with the study performed by Pallasmaa *et al.* (2010) however, no rationale for this finding was given for their finding. There are currently no studies that investigate SSI risk factors for CS or emergency CS that identify smoking as a significant risk factor, but there are however, studies that do identify smoking as risk factor for SSI following surgery (Nolan *et al.* 2017). Smoking is thought to be a potential risk factor for SSI following emergency CS due to the negative effect it can have on the body's wound healing process (McDaniel and Browning, 2014). The toxins found in cigarette smoke such as nicotine, carbon monoxide and hydrogen cyanide are thought to be responsible for creating a hypoxic environment within the body's tissues (Guo and DiPierto, 2010). It has been suggested that nicotine given its vasoconstrictive nature, reduces blood flow and perfusion to tissues causing hypoxia however, the significance of its effect is disputed (Sorensen *et al.* 2009). Carbon monoxides role in tissue hypoxia occurs due to its haemoglobin binding qualities, restricting the amount of oxygen that can reach the tissues (McDaniel and Browning, 2014). Hydrogen cyanide plays a more inhibitory role by inhibiting the enzyme system responsible for cellular oxygen metabolism, therefore adding to the hypoxic environment (McDaniel and Browning, 2014). Given the evidence to suggest a potential role smoking could play in the development of an SSI following emergency CS, further research will need to be done to fully establish its effect.

Membrane rupture time was identified in this study as a non-significant risk factor for SSI in emergency CS, which is in agreement with studies conducted by Saeed *et al.* (2019) and Ghuman *et al.* (2011) however, neither gave a rationale for its lack of significance. Studies conducted by Gelaw *et al.* (2017) and Najm and Majeed (2019) found the rupturing of membranes to be a significant risk factor in the development of an SSI following CS. The authors for both studies suggested one reason for its significance is that once the membranes rupture the amniotic fluid loses its sterility and could become contaminated with bacteria that then comes into contact with the surgical incision risking infection.

4.4 Clinical Relevance

One of the aims of this study was to identify the significant factors at associated with an SSI in emergency CS. The understanding of any significant risk factors allows for more timely SSI intervention and gives the ability to identify those patients at the greatest risk of SSI. Knowing the most significant risk factors would help with the development of effective strategies that would reduce the frequency and escalation of SSI's. The finding of obesity to be a significant risk factor in the development of an SSI following CS from this study will help to contribute towards the very limited evidence base for risk factors associated with SSI in emergency CS and along with the addition of potential future studies will help improve the current guidelines and best practices. Improved guidelines and strategies would allow clinicians to manage emergency CS patients better and reduce the risk of SSI development. Better delivery planning would allow at risk individuals to undergo an elective CS rather than an emergency one. However, as already discussed BMI is a significant risk factor for SSI in elective CS so undergoing an elective CS rather than an emergency one may make no difference to the risk of SSI following surgery. Improved wound management could also help to reduce the risk of an SSI through frequent cleaning of the wound and use of appropriate dressings, along with regular changing of dressings. The prevention of wound ischemia could also help to reduce the risk of SSI as fat necrosis can lead to the development of an infection (Rangaswamy, 2013). Surgical wound irrigation could also help to lower the risk of an SSI developing following an emergency CS, with surgeons using antibacterial solutions to flush out the wound site in order to remove any contaminants (Barnes *et al.* 2014). The implementation of improved and targeted weight management for individuals with a higher BMI could help to reduce the risk of an SSI. This could be done through stricter dietary advice, although this would be hard to achieve given the nutritional needs of the foetus and is strongly advised against by the NHS (NHS, 2020).

The impact of identifying significant risk factors will also be felt by patients who will receive a better quality of care and surgical outcome due to a potentially reduced risk of SSI development. Reduced risk of SSI would mean less patients would suffer the pain and discomfort associated with infections as well as reducing the time some individuals would spend in hospital for more serious infections. An extended hospital stay could result in the mother spending time away from her new born baby in what is a critical time for the baby's development. Furthermore, the mental health of the individual suffering from an SSI is also a concern with a study conducted by Andersson *et al.* (2010) reporting that they endure significant pain and isolation as a result of their infection. The physical changes that can occur as a consequence of infection as well as the negative economic ramifications were also cited in the study with all aspects adding up to have a detrimental effect on the patient's well-being. The identification of risk factors for SSI following emergency CS will help to have a positive impact on the patient's quality of care and life, reducing hospital stay and reducing the psychological and sociological effects caused by SSI.

Furthermore, the reduction of SSI's would help to relieve the economic burden placed upon the healthcare system as a result of their occurrence. As stated by Troughton *et al.* (2018) the financial implications of the SSI's following CS's is £7,066,826 a year per hospital. Although this figure does not specifically relate to emergency CS, the treatment and care for emergency CS wound infections will be the same as that of CS wound infections. Strategies that identify patients most at risk of an SSI will result in a decreased demand on NHS services through a reduction in treatment cost and patient stay time. The decline in frequency of SSI's overall would reduce the economic burden for treating those patients.

4.5 BMI

BMI was used in this study to identify individuals who were obese as it is a widely used standard of measurement in hospitals and was the choice of measurement used by the obstetrics department at Pinderfields Hospital. The accuracy of BMI however, is often questioned with a study conducted by Romero-Corral *et al.* (2008) finding that the use of BMI to diagnose obesity was not completely accurate, especially in those individuals with a BMI <30 kg/m^2. The researchers state that for individuals with a BMI ≥ 30 kg/m^2 the measurement method has greater specificity and also for women in general, BMI has a greater correlation with body fat % compared to that of men. With that said there are still inaccuracies when using BMI with 12% of women being misclassified as being obese (Romero-Corral *et al.* 2008). Other measurement methods for body composition exist with varying accuracy such as bioelectrical impedance analysis (BIA), skin fold measuring, hydrostatic weighing, dual energy x-ray absorptiometry and air displacement plethysmography. BIA is an easy and non-invasive technique that can be used to measure body composition and body fat percentage through the introduction of an electrical current to the body (Foster and Lukaski, 1996). BIA, although practical, is not a standardised technique currently used by the NHS to measure for obesity, so could not be used for this study. A limitation of BIA is that it uses the body's total water in order to make a measurement on the individuals total body fat percentage so can be affected by the amount of water an individual drinks before being analysed (Nagy *et al.* 2008). Skin fold measuring is a potential technique that could be used to determine body composition and fat distribution on an individual however, it requires training of staff to allow for accurate measurements (Stomfai *et al.* 2011). Skin fold measuring was also not performed by the hospital on any of the patients in this retrospective cohort study so could not be used. Hydrostatic weighing, dual energy x-ray absorptiometry and air displacement plethysmography are all costly and impractical for use in the NHS (Nagy *et al.* 2008).

4.6 Limitations

One of the main limitations of this study is the missing information when filling out the data collection spreadsheet. Data for different variables were on occasion not available for some patients due to the information not being filled out or due to the information being missing from the patients file. In a few cases where the missing data was too great it led to the exclusion of that patient's data from the study as it would have been unable to be statistically analysed. In cases where the missing data for a particular risk factor exceeded 10% of the total sample size, the risk factor was then excluded from the study as the missing data could no longer be replaced via mean substitution and the data for that risk factor could no longer be analysed. It is possible that some significant risk factors were lost before they could be statistically analysed due to the missing data. A solution for this would be to conduct the study at hospital where all the data set is electronically stored as this would allow for easier preliminary checks to be done on the expected data to be collected. Electronically stored data also reduces the risk of information getting lost and is also easier and quicker for busy staff to fill in, reducing the likelihood of missing data.

A further limitation of this study is the small sample size. The sample size was restricted due to the length of time it took to collect the data from the different systems and notes. This small sample size led to some categories in variables being too small to analyse on their own resulting in them being combined. Although this combining was only done when appropriate it is possible that it had an effect on the outcome of the analysis. A solution for this issue would have been to increase the sample size of the study as this would allow for a greater volume of data to be collected, reducing the negative effect of missing data as well as providing greater reliability for results produced. Another solution given time constraints of the study would be to allow more time for the study to be conducted, giving sufficient time for data collection.

Another limitation for this study is that it was conducted at one hospital rather than collecting and using data from multiple NHS England hospitals. This means the study could be limited in terms of representing the wider population as different parts of England have different levels of diversity. It is also difficult to compare data collected from one hospital with another as data is often recorded differently at different NHS trusts and hospitals as well as there being contrasting methods of care. A solution would be to conduct the study at multiple hospitals that have a similar data recording process making data comparisons much easier. There is however, no evidence to suggest that the diversity in patient population at Pinderfields Hospital is any different from the rest of the UK.

Moreover, identifying patients with SSIs was also a limitation as the method used relied on patients having their wound swab uploaded to the ICE database. It is therefore possible that the total figure for SSIs is lower than it should be, as patients could have had their infections diagnosed by hospitals or GP practices outside of the Mid Yorkshire trust catchment area. This would mean that any positive wound swabs would not have appeared on the ICE database. A possible solution for this would be to contact the GP surgery for each patient in order to better identify any positive wound swab. This however, is not an entirely practical solution as it would be very time consuming and difficult to carry out from GDPR stand point. In addition, the use of swabs to identify an infection has the limitations of providing false negatives and false positives, both affecting the accuracy of SSI diagnosis. A false negative swab can occur due there being a decreased volume of bacteria collected by the swab (Aggarwal *et al.* 2013). A false positive can occur when the swab becomes contaminated by commensal organisms. A solution would be to use tissue cultures as they provide more accurate results however, this would be more invasive for the patient (Aggarwal *et al.* 2013). It is also worth noting that wounds swabs are only taken if an SSI is suspected and is not something that is done on a routine basis which, could lead to some SSI to go undiagnosed. This could be resolved through routine swabbing of patient's wounds after an operation, although this would be costly and time consuming.

4.7 Future Studies

In order to support this study, further research will need to be done to add knowledge and further insight into an area where it is lacking. Any future research on this topic would benefit from a larger sample size to allow for greater data collection and therefore stronger statistical analysis as a result. Additionally, a larger sample size would allow for the analysis of a greater number of variables to be analysed adding further validity to the study.

2.0 Conclusion

This study investigated the incidence and associated risk factors for SSI following emergency CS with the underlying rationale being to add knowledge and input to an unstudied area. The studying of risk factors is of particular importance as this would allow for the identification of patients most at risk of an SSI and as a result preventative strategies could be developed and put in place to reduce the risk of SSI following emergency CS. Knowledge obtained from research would allow for the altering of guidelines and give healthcare professionals the information they need to reduce patient suffering. This study identified BMI (kg/m^2) as a significant risk factor associated with the development of an SSI in emergency CS's. Possible reasons for BMI's (kg/m^2) significance could be the negative effect of excessive adipose tissue on the body's immune system as well as the reduced effectiveness of antibiotics in individuals with an obese BMI (kg/m^2). Other potential risk factors such as diabetes status, patient age and pre-op vaginal swab did not reach statistical significance in this study. Future research 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.

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Appendix 1- Occupational Health approval

The Mid Yorkshire Hospitals **NHS**
NHS Trust

Occupational Health Services
Pinderfields General Hospital
Aberford Road
Wakefield
WF1 4DG
Tel: 01924 543585

To: Recruitment:	Line Manager:	Work Area: **Plastics Pinderfields Hospital**
Candidates Name: **Tom Southern**	D.O.B:**12/Mar/1996**	Occupation: **Research Fellow**

The above named candidate has completed a confidential work health assessment. **Results are below.** ✓ where appropriate

1. ON HOLD – awaiting further information	Health information missing	
	Additional information needed	

NON EPP ROLES

2. FIT for the post with no restrictions	✓	**3.** Fit for the post with restrictions		
Adjustments/restrictions recommended:				
Disability element of the Equality Act 2010 may apply to this candidate			Yes	No
Required **to attend OH in first working week** for routine vaccine/ health surveillance update – **Line Manager to organise during induction week**			✓	

EPP ROLES (EXPOSURE PRONE PROCEDURES) = hands/fingers out of site within a body cavity where there is potential for transfer of body fluids if skin punctured during procedures e.g. Surgeons, midwives, ED clinical staff)

4. Fit for the EPP post/role with no Restrictions (this includes **all rotations** for medical staff)		**5. Not fit for full EPP role/post** May work with restrictions i.e. NON-EPP until seen and cleared		
	Adjustments/restrictions recommended:			
Disability element of the Equality Act 2010 may apply to this candidate			Yes	No
****Required to attend OH in first working week for routine vaccine/ health surveillance update – Line Manager to organise during induction week****				
6. NOT FIT FOR ROLE		The individual has been assessed and further information gained. The opinion is that they are not fit for the role for which they have applied.		

Name of OH&WBs Assessor **Tracey Gillott**	Job Title: **Advanced HCA**	Date signed:14/5/2018

Appendix 2- Approval letter from obstetrics department to carry out research

The Mid Yorkshire Hospitals NHS
NHS Trust

Women's Health Directorate
Dewsbury & District Hospital
Halifax Road
DEWSBURY
West Yorkshire
WF13 4HS

Department of Gynaecology & Obstetrics
Miss S Dhingra

Date: 2nd of April 2019

Miss Dhingra's Secretary
Tele - 01924 319217
Fax - 01924 512372

To whom it may concern

Re - Tom Southern - Study of post caesarean section infections

Please accept this letter as confirmation that the Maternity Department at Midyorks agreed and were happy for Tom Southern who is a Huddersfield University Research student to access the maternity notes to undertake a study of post caesarean sections infections. This was discussed in the maternity Governance meeting in June 2018.

Please do not hesitate to contact me if you have any further queries.

Yours sincerely

Miss Simi Dhingra
Consultant Obstetrician & Gynaecologist

Appendix 3- Honourary contract approval

NHS
The Mid Yorkshire Hospitals
NHS Trust

Medical Staffing Dept
Gate 47, Level E
Pinderfields General Hospital
Aberford Road
Wakefield
WF1 4AD
Tel: 01924 542282
Email: joanne.freeman@midyorks.nhs.uk

Our Ref: JMF/ts

5th July 2019

TO WHOM IT MAY CONCERN

Dear Sir/Madam

Re: TOM SOUTHERN

I am writing to confirm that the above named person received an honorary contract from the Mid Yorkshire Hospitals NHS Trust as a Clinical Research Fellow in Plastic Surgery from 17th September 2018 until 16th September 2019.

During this period he has access to all databases in order to help with his project.

Should you require any further information please do not hesitate to contact me.

Yours faithfully

Freeman

Mrs Joanne Freeman, Assoc (CIPD)
Medical Staffing Officer
Surgical Specialities, Anaesthetics, Radiology and Pathology

Appendix 4- Introduction to good clinical practice eLearning (primary care) certificate.

NHS
National Institute for Health Research

CERTIFICATE of ACHIEVEMENT

This is to certify that

Tom southern

has completed the course

Introduction to Good Clinical Practice eLearning (Primary Care)

October 18, 2017

A practical guide to ethical and scientific quality standards in clinical research

Including EU Directives, Medicines for Human Use (Clinical Trials) Regulations & the Department of Health Research Governance Framework for Health & Social Care, as applied to the conduct of Clinical Trials & other studies conducted in the NHS

Modules completed:

Introduction to Research and the GCP standards
Preparing to deliver your study
Identifying and recruiting participants: eligibility and informed consent
Ongoing study delivery and data collection
Safety Reporting
Study closure

This course is worth 4 CPD credits

CPD
The CPD Certification Service

Delivering research to make patients, and the NHS, better

Appendix 5- Introduction to good clinical practice eLearning (secondary care) certificate.

NHS
National Institute for Health Research

CERTIFICATE of ACHIEVEMENT

This is to certify that

Tom southern

has completed the course

Introduction to Good Clinical Practice eLearning (Secondary Care)

October 19, 2017

A practical guide to ethical and scientific quality standards in clinical research

Including EU Directives, Medicines for Human Use (Clinical Trials) Regulations & the Department of Health Research Governance Framework for Health & Social Care, as applied to the conduct of Clinical Trials & other studies conducted in the NHS

Modules completed:

Introduction to Research and the GCP standards
Preparing to deliver your study
Identifying and recruiting participants: eligibility and informed consent
Ongoing study delivery and data collection
Safety Reporting
Study closure

This course is worth 4 CPD credits

CPD
The CPD Certification Service

Delivering research to make patients, and the NHS, better

Appendix 6- SREP approval email

SE

SHUM Research Ethics
Thu 25/07/2019 14:56
Tom Southern (Researcher); Joanna Blackburn

Dear Tom,

The panel reviewers have confirmed that you have addressed the issues raised to their satisfaction and your SREP Application has now been **approved outright.**
With best wishes for the success of your research project.

Regards,

Kirsty
(on behalf of SREP)

Kirsty Thomson
Research Administrator

: hhs_srep@hud.ac.uk
: www.hud.ac.uk

School of Human and Health Sciences R&E Office - R1/17
University of Huddersfield I Queensgate I Huddersfield I HD1 3DH

Appendix 7- Link to data collection spreadsheet to show data points collected

https://drive.google.com/file/d/1IIOWce2i4eFlwWZmwO5l90b-KpWdHgCN/view?usp=sharing