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Prevention of surgical site infection and sepsis in pregnant obese women

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A B S T R A C T

Obesity is a major determinant of health outcomes and is on the increase in women worldwide. It predisposes to surgical site infection (SSI). Risk factors for the SSI include extremes of age, smoking, comorbidities such as hypertension and diabetes, inappropriate vertical abdominal and or uterine wall incisions, increased operating time, subcutaneous layer of 3 cm or more, and unnecessary use of subcutaneous drain. Most bacteria that cause SSIs are human commensals. Common organisms responsible for SSI include *Staphylococcus aureus* and coliforms such as *Proteus mirabilis*, and *Escherichia coli*. A surgeon's gloves post caesarean section in the obese has a preponderance of Firmicutes and

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Bacteroidetes, which increases SSI risk. The interaction of skin commensals and vaginal microbiome at the surgical incision site increases the risk of SSI in the obese compared to non-obese. Minimizing the risk of SSI involves modification of risk factors, timely treatment of SSI to prevent sepsis and compliance with the recommended care bundles.

Questions

Instruction: Indicate the statements that are true or false.

1. Concerning the prevalence of obesity.

a) It is decreasing in the general adult population but increasing in pregnancy
b) It is increasing in the general adult population
c) It has remained unchanged in pregnant women
d) It is decreasing in pregnancy
e) Unlike the increases in the past, it is unchanged in contemporary pregnant women.

2. According to the Centre for Disease Control (CDC) classification of Surgical Site Infection (SSI).

a Infection of the subcutaneous tissue is deep incisional SSI
b Infection of the subcutaneous tissue is superficial incisional SSI
c Infection of muscles is organ/space SSI
d Infection of muscles and fascia is superficial incisional SSI
e Deep incisional SSI is the same as organ/space SSI.

3. According to the CDC classification of wound.

a Caesarean section operative wound with no breach in sterile technique is an example of a class 1 or clean wound
b An operation wound with a breach in the sterile technique is a Class II or clean contaminated wound
c Class III or contaminated wound has non-purulent inflammation
d A fresh wound from an accident or operation that has a spillage of the gastrointestinal tract is a class IV or dirty wound
e Both Class III and Class IV wounds have pre-existing organisms.

4. Concerning obesity in pregnancy.

a Class III obesity is a body mass index (BMI) $\geq$ 40 kg/m^2
b The interaction of skin commensals and vaginal microbiome at the surgical incision site increases the *a priori* risk of SSI in the obese pregnant women.
c The commonest population of the vaginal microbiome in the obese is Actinobacteria
d The vagina of the obese compared to the non-obese, has a higher population of Firmicutes
e Bacteroidetes as a vaginal microbiome are commonly found in the obese than non-obese.

Introduction

Obesity is one of the major determinants of health outcomes and has been increasing for many decades. It is associated with poor feto-maternal outcomes, especially wound morbidities [1,2]. It is recognized by the World Health Organization (WHO) as an epidemic and has ravished beyond racial lines and age groups [3]. Despite the efforts to reduce its prevalence, it is still on a steep increase due to changes in eating habits and other lifestyles across the globe. The WHO estimates that at least 2.8 million people die yearly from overweight or obesity complications. Although once thought to be a problem only in high-income countries, it is now increasing in the low- and middle-income countries (LMIC) [4].

Among adult women, the prevalence of obesity world-wide increased from 69 million in 1975 to 390 million in 2016; while in adult males, it increased from 31 to 281 million during the same period [3,5]. A meta-analysis on maternal obesity in Africa published in 2015 showed a prevalence that varied from 6.5 to 50.7% [6]. In the UK, a review of thirty-seven health facilities providing maternity care revealed a staggering increase in obesity in the first trimester of pregnancy, which has more than doubled in the last two decades. In the antenatal period, 21.3% of the UK pregnant population are said to be obese while 47.3% have a body mass index within the normal range [7]. Furthermore, it costs the NHS twenty-seven billion pounds each year to manage the consequences of obesity [8]. In the USA, there is a rising trend of obesity in adults, and a survey between 2005 and 2014 revealed that 35.0% of men and 40.4% of women were obese and 9.9% of women and 5.5% of men were morbidly obese [9].

In pregnant women, obesity is associated with adverse maternal and perinatal outcomes including increased rates of congenital malformations, large for gestational age, small for gestational age, preterm labour and delivery, shoulder dystocia, surgical site infection, birth injuries, cerebral palsy and neonatal death [1]. Additionally, it is associated with diabetes, hypertensive disorders of pregnancy, prolonged pregnancy, anaesthetic and surgical risk, postpartum hemorrhage, operative deliveries, venous thromboembolism and postnatal depression [1,10].

Maternal infection is also on the increase worldwide. Globally, obstetric infections are the third most common cause of maternal mortality, accounting for 10.7% and 4.4% of deaths in LMIC and high-income countries respectively [2]. Although accurate evaluation of the burden of maternal infection and its consequences including sepsis is challenging due to differences in the populations studied and case definitions, the Global Burden of Disease Study estimated that in 2017, 11.9 million cases of maternal infection occurred [11]. The WHO Global Maternity Sepsis Study (GLOSS) and awareness campaign involving 52 countries under the auspices of the Global Maternity and Neonatal Sepsis Initiative reiterated the increase in maternal infections and their contribution to maternal death; these infections included surgical site infection [12–14]. Compared to normal-sized women, obese women are twice as likely to have surgical site infection (SSI), especially from a caesarean section (CS) [15]. In this article, we discuss SSI and sepsis in obese pregnant women, its prevention and clinical management.

Definitions

Obesity and body mass index (BMI)

According to the WHO, obesity is an excessive fat accumulation in adipose tissue. Different anthropometric measurements have been used to quantify adipose tissue composition [4]. Each of these tools has limitations and advantages. However, BMI is the most commonly used method in clinical practice. The classification of obesity based on BMI is shown in Table 1 [4]. This is calculated as weight in kilograms divided by height in meters squared. Body mass index has been shown to correlate with body fat and clinical outcomes. The drawback of using BMI in defining obesity is that it does not differentiate between fat and lean body mass and does not provide information on the body adipose distribution.

Surgical site infection

Surgical site infection, according to the Centre for Disease Control (CDC), is defined as an infection of the skin or subcutaneous tissue (superficial incisional SSI), deep soft tissue (deep incisional SSI), and or

Table 1
World Health Organization classification of Body Mass Index.

Body Mass Index (kg/m^2)	Category
<18.5	Underweight
18.5–24.99	Normal weight
25.00–29.99	Overweight
≥30.00	Obese
30.00–34.99	Class I obesity
35.00–39.99	Class II obesity
≥40.00	Class III obesity

space/internal organs (organ/space SSI) occurring for up to thirty days after an operation if no implant was left behind or within a year if an implant was left behind (Fig. 1 and Table 2) [16].

The definitions of the various terms used in this review are:

Sepsis - a life-threatening organ dysfunction due to dysregulation of the host's response to infection [17].

Septic shock - sepsis with the persistence of tissue hypoperfusion despite adequate fluid replacement [17].

Wound - an injury to living tissue caused by a cut, blow, or other impact, typically one in which the skin is cut or broken.

Wounds can further be classified as follows [18]:

Class 1 or Clean: An operative wound in a sterile condition with no organisms and is likely to heal without complications. An example of this is a skin incision for a diagnostic laparoscopy.

Class II or Clean contaminated: An operative wound involving an organ space such as the urogenital, gastrointestinal, or respiratory systems without infection, unusual contamination, or a major breach in sterile technique. An example of this is a caesarean section (CS) wound.

Class III or Contaminated: Fresh open wounds from accidents or operations with a breach in sterile technique, spillage of the gastrointestinal tract, or incisions made in a body site that has acute or non-purulent inflammation.

Class IV or Dirty-infected: An old wound from trauma with pre-existing organisms and devitalized tissues at the wound site before surgery [18].

Epidemiology and pathophysiology of surgical site infection in the obese pregnant woman

Generally, the rate of wound complications such as separation, seroma, infection and fascial dehiscence is 3–17% [19–23]. The rate of SSI varies depending on the case definition. In general, the SSI risk in obstetrics is 6–10% [15,24]. Superficial wound infection accounts for 73.3% while deep SSI accounts for 26.1% [25].

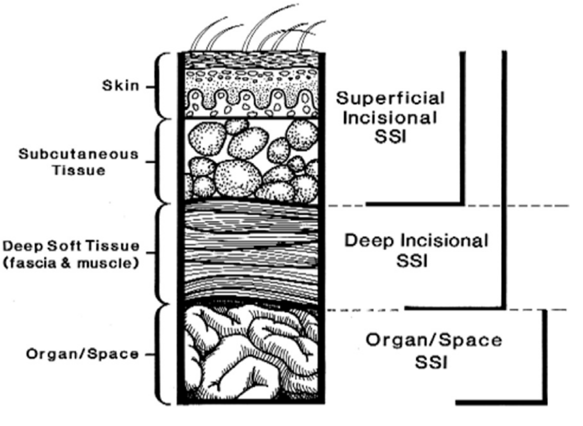

Fig. 1. Classification of SSI. Source [16]. Reproduced with permission from the publisher, Cambridge University Press.

Table 2
Criteria for defining SSI [16].

Superficial Incisional SSI	Deep Incisional SSI	Organ/space SSI
Infection occurs within 30 days after the operation, and infection involves only the skin or subcutaneous tissue of the incision and at least one of the following: 1. Purulent drainage, with or without laboratory confirmation, from the superficial incision. 2. Organisms isolated from an aseptically obtained culture of fluid or tissue from the superficial incision. 3. At least one of the following signs or symptoms of infection: pain or tenderness, localized swelling, redness, or heat and superficial incision is deliberately opened by surgeon, unless incision is culture-negative. 4. Diagnosis of superficial incisional SSI by the surgeon or attending physician. Do not report the following conditions as SSI: 1. Stitch abscess (minimal inflammation and discharge confined to the points of suture penetration). 2. Infection of an episiotomy or newborn circumcision site. 3. Infected burn wound. 4. Incisional SSI that extends into the fascial and muscle layers (see deep incisional SSI).	Infection occurs within 30 days after the operation if no implant is left in place or within 1 year if implant is in place and the infection appears to be related to the operation and infection involves deep soft tissues (e.g., fascial and muscle layers) of the incision and at least one of the following: 1. Purulent drainage from the deep incision but not from the organ/space component of the surgical site. 2. A deep incision spontaneously dehisces or is deliberately opened by a surgeon when the patient has at least one of the following signs or symptoms: fever (>38 °C), localized pain, or tenderness, unless site is culture-negative. 3. An abscess or other evidence of infection involving the deep incision is found on direct examination, during reoperation, or by histopathologic or radiologic examination. 4. Diagnosis of a deep incisional SSI by a surgeon or attending physician.	Infection occurs within 30 days after the operation if no implant is left in place or within 1 year if implant is in place and the infection appears to be related to the operation and infection involves any part of the anatomy (e.g., organs or spaces), other than the incision, which was opened or manipulated during an operation and at least one of the following: 1. Purulent drainage from a drain that is placed through a stab wound into the organ/space. 2. Organisms isolated from an aseptically obtained culture of fluid or tissue in the organ/space. 3. An abscess or other evidence of infection involving the organ/space that is found on direct examination, during reoperation, or by histopathologic or radiologic examination. 4. Diagnosis of an organ/space SSI by a surgeon or attending physician.

Estimates of wound infection in obese pregnant women differ due to variations in definition or criteria for diagnosis, methods of classification of obesity, changes in practice concerning antibiotics use, delayed wound infection and loss of follow-up [26]. The rates of SSI in obese and non-obese pregnant populations have been reported as 11.71%–19.70% and 0.06%–9.96% respectively [27,28]. Vegel et al., documented a CS-associated SSI rate of 8.1% in obese and 2.4% in non-obese ($P < 0.001$). The authors further highlighted that obesity is an independent factor in wound infection regardless of the method of wound closure [27]. Other studies have shown that obese women are 2.4 times more likely to develop SSI than overweight women (1.6 times) [29,30]. Chaboyer et al., in their study on the incidence and predictors of SSI in obese women undergoing CS, found an incidence of 8.4% [31]. Warshak and co-workers also found a similar incidence of 7.2% while evaluating the maternal and surgical factors associated with SSI in obese women after CS [32].

Although there are several factors that have been shown to increase the risk of SSI, obesity on its own is a risk factor. This is based on the altered physiology in these women. For example, although there is an increase in cardiac output and stroke volume, blood flow to tissues remains unchanged and consequently the thick subcutaneous fat is underperfused and thus wound healing is poor and therefore a greater risk of infection. In addition to the thick fatty tissue, an increase in hydrostatic tissue pressure in obese women leads to leakage of intravascular fluid into the surrounding tissues, triggering an inflammatory response. Furthermore, the accumulation of protein materials in the interstitium and around the capillaries enhances clotting and fibrosis and interferes with tissue oxygenation and nutrient supply [33]. The effect of obesity on wound healing is also mediated by triggering a chronic inflammatory process through TNF-alpha, making T cells unresponsive to epithelial damage, and inhibiting the release of cytokines and growth factors that facilitate wound healing [33].

It has also been noted that accumulated fat in the neck and in the diaphragm interferes with normal breathing, thus causing a reduction in oxygen reaching the lung alveoli and the rest of the body including the wound [34]. Furthermore, the pannus could impede exposure of the wound surface to air, hence encouraging moisture formation, which propagates microorganisms and infection. Moreover, the abdominal pannus also adds stress to the wound, leading to an opening in which infection can quickly occur [27].

Microbiology

Most bacteria that cause SSIs are commensals that generally live on skin surfaces. Factors that disturb the ecology of these bacteria result in over 65% of microbial infections. In the non-obese population, the organisms responsible for SSIs are polymicrobial. The commonly isolated organisms responsible for SSI include organisms such as *Proteus mirabilis, Escherichia coli and Staphylococcus aureus* [24,29]. In obese women, the anatomical characteristics and the panniculus fold create a peculiar moist environment for developing SSIs. The surgical preparation solution, meant to provide sterility at the incision site, may uncover a unique rich bacterial diversity with decreased dominance in obese women. In some patients, the preparatory solution may interfere with the equilibrium of the individual skin commensals and propagate the growth of pathogenic bacteria [15].

In their pioneer work on skin microbiota in obese women at risk of SSI after CS, Rood and colleagues categorized microbiomes at the site of the skin incision and the vagina before and after a caesarean section. They used DNA PCR technology for bacterial biomass quantification and RNA sequencing for microbial community composition [15]. Compared to the non-obese women, the average bacterial load at the transverse suprapubic incision site was higher in the obese, (3.8-fold vs 1.8-fold) [15]. The use of surgical preparatory solutions at the Pfannenstiel site significantly reduced the bacterial load in obese pregnant women but not in non-obese controls. No difference was noted in the bacterial load vaginally and at the lower segment incision after the delivery of the baby in the two groups. Similarly, the bacterial load in the wound at the end of the surgery was similar in both groups.

Prior to skin preparation, obese patients had a preponderance of Firmicutes and Bacteroidetes with a decrease in Actinobacteria compared to the usual commensals of Staphylococcus and Propionibacterium spp. The vaginal microbiota of obese women was characterized by an increased frequency of Actinobacteria and Bacteroidetes and a reduction in Firmicutes. The surgical scrub area was associated with Fusobacteria, Firmicutes, and Bacteroidetes. Post-surgery, the incision site had a high frequency of Bacteroidetes and Proteobacteria, while the surgeon's glove in the obese had an increased proportion of Bacteroidetes and Firmicutes [15]. It was also found that at the end of the surgery, the incision site was populated by bacteria from the vagina and the surgical gloves. These findings led to the conclusion that the presence of these bacteria explains the increase in SSI among obese pregnant women [15]. Fig. 2 shows a comparison of the typical topographical distribution of microbial communities in obese and non-obese patients undergoing CS [15].

Risk factors for surgical site infections and sepsis in the obese pregnant woman

These can be grouped as pre-operative (patient factors, intraoperative and postoperative) (Table 3).

The pre-operative (patient) factors include obesity, hypertension, smoking, malnutrition, cancer, diabetes, alcoholism and immunosuppression (from HIV and other chronic infections such as Tuberculosis) [26,27,34,35]. Mejia and colleagues highlighted that obesity and hypertension were the leading risk factors for SSI in gynecological and obstetric surgery [36]. Alanis and colleagues evaluated 194 morbidly obese women undergoing CS over five years and found that 30% developed wound complications, of which 90% had wound disruption. Bivariable and multivariable analyses were used to evaluate the link between wound complications and various predictors. After controlling for confounding factors such as ruptured membranes, chorioamnionitis, prolonged labor and frequent vaginal examinations, patients with significant wound morbidity were older, smokers, diabetics, those with blood loss >1 L at surgery and having a subcutaneous drain in situ [37]. Additionally, a recent systematic review concluded that a subcutaneous drain does not reduce wound morbidities in obese pregnant women [38].

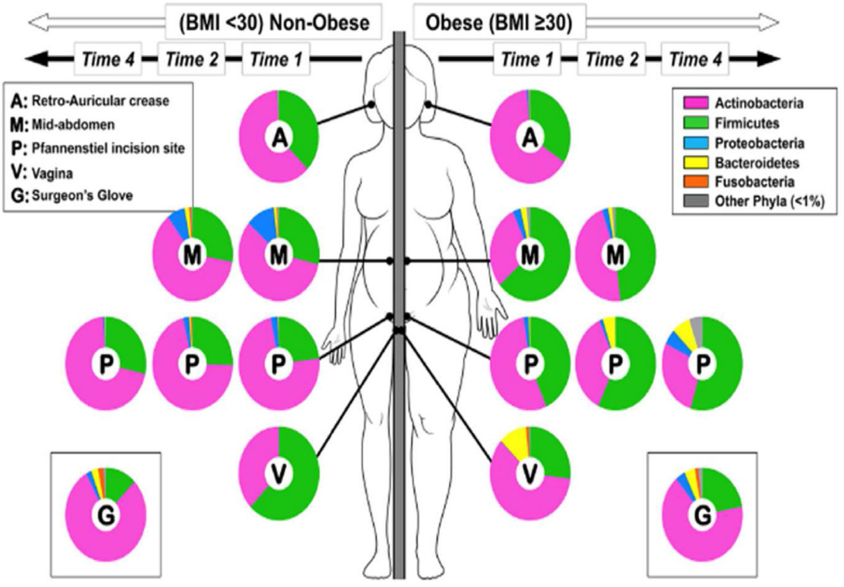

Fig. 2. Topographical distribution and biomass of microbial communities in the obese and non-obese. Source [15]. Reproduced with permission under the terms of the Creative Commons CC BY license.

Nobbs and colleagues confirmed that smoking and vertical abdominal incisions significantly increased the risk of SSI at CS in obese women [34], but Warshak and co-workers found that morbid obesity, diabetes, chronic hypertension, and increased blood loss were not associated with SSI in obese women with intact membranes. These findings were replicated by others [21,32,39,40]. A Pfannenstiel incision is, however, protective of SSI [32]. A recent secondary analysis of a multicenter randomized controlled trial involving women with pre-pregnancy BMI ≥30 kg/m^2 who had CS and prophylactic closed-incision negative pressure wound dressing showed that the incidence of SSI was 8.4% (122/1459). Following a logistic regression, the multiple variable-adjusted odd ratios (with 95% confidence interval) for SSI were 1.49 (1.29–1.72) for BMI ≥40.0 kg/m^2 compared to BMI 30.0–34.9 ≥ 40.0 kg/m^2; 1.48 (1.12–1.95) for parity ≥2 compared to nulliparity; and 0.55 (0.30–0.99) for pre-CS vaginal cleansing compared to no cleansing [31].

Prevention of SSI and sepsis in obstetrics: Considerations in caesarean section techniques and other intraoperative procedures

Strategies employed to reduce SSI in obstetrics vary greatly depending on the individual and setting. There are various guidelines from bodies and authorities such as NICE, WHO, and ACOG [24,41–43]. There are no strict guidelines for obese women, but prevention of SSI can be extrapolated from those of non-obese.

Table 3
Risk factors for surgical site infections in obese pregnant women [18,42].

Preoperative/patient factors	Intraoperative	Postoperative
Extremes of age	Vertical abdominal incision	Subcutaneous drain
Diabetes	Blood loss >1 L	
Smoking	Vertical hysterotomy	
Hypertension	Increased operative time	
Subcutaneous tissue ≥3 cm		
Use of systemic steroids		
Malnutrition		
Immunosuppression		

Patient factors

Gestational weight gain greater than 5–9 kg in obese women increases the risk of CS [44]. Additionally, obese women are at risk of SSI due to limitations of wound aeration by the pannus, increased local tissue trauma and ischemia, decreased immunity, and concomitant chronic conditions such as diabetes [33]. There are mixed reports on modifiable risk factors and their ability to predispose to SSI in obese patients. Nonetheless, changes such as smoking cessation, healthy eating, reduction of alcohol intake, and body weight management before surgery can significantly decrease SSI. Weight loss is essential and helps to reduce the amount of adipose tissue, as a subcutaneous thickness of ≥3 cm is a significant risk factor for SSI [45]. Bathing with antiseptic soap the night before surgery, perioperative normothermia, and adequate glycemic control (maintaining blood glucose levels between 4.4 mmol/L [80 mg/dL] and 5.6 mmol/L [100 mg/dL]) have been shown to reduce the risk of SSI [46]. Ensuring good control of hypertension before and during pregnancy should eliminate or minimize this risk of SSI and sepsis.

Skin preparations measures

There is limited evidence on the effectiveness of skin preparation in reducing the rate of SSI in the obese. Skin preparation and vaginal cleansing with chlorhexidine compared to povidone have been shown to reduce the rate of SSI in non-obese women. A Cochrane review of 30 reviews that included 349 trials with 73,053 participants on preventing SSI with preoperative antiseptics found that 0.5% of alcohol-based chlorhexidine was associated with a reduction in the risk of SSI compared to alcohol-based povidone-iodine (RR 0.47; 95% CI 0.27–0.82) [47]. Until new evidence becomes available, in the authors' opinion, skin preparation measures used for pregnant women, in general, should be applied to the obese parturient [48].

Antibiotics

Antibiotic prophylaxis has been shown to significantly reduce the rate of SSI. The American College of Obstetricians and Gynecologists (ACOG) advises doubling the dose of Cefazolin dose from 1 g to 2 g in obese women or if blood loss at surgery is > 1500 ml or if the procedure is > 3 h [33]. A second dose of prophylactic antibiotic is not required in uncomplicated routine procedures [49]. In obese women, estimating the minimum inhibitory concentration (MIC) in the adipose tissue and blood has been of great interest. MIC is said to show an inverse relationship with the level of fatty tissue [50,51]. Swank and co-workers showed that MIC was not reached at the abdominal skin incision in 44% of morbidly obese women and 20% of obese women. They found that a MIC greater than or equal to 8 μg/ml was observed in all obese women and 71% of morbidly obese women when the dose of Cefazolin was increased to 3 g [50]. Pezner and co-workers showed that the administration of 1 g of Cefazolin in obese women resulted in an SSI rate of 16% while a 2 g dose resulted in a 5.6% rate of SSI [51]. Additionally, a cohort study involving 2231 women reported a substantial reduction in SSI in obese women when Cefazolin 3 g was given (OR 0.309, $p < 0.001$) [52]. Young et al., in a double-blinded randomised trial, found that the concentration of Cefazolin was above the MIC for both Gram-positive and negative bacteria when a 2 g or 3 g dose was used for surgical prophylaxis at CS. They showed that plasma concentrations of the antibiotics were related to the BMI and the dose of the antibiotics [53]. Groff and co-workers reached similar conclusions as they observed that a dose of 2 g Cefazolin was protective of mothers and newborns against *S. aureus* and *Streptococcus group B* (GBS) infection and SSI in obese and non-obese women [54]. Interestingly, few studies failed to demonstrate significant reduction in SSI rate or a higher concentration in adipose tissue with an increased dose of Cefazolin [55,56].

Skin incision

Although the transverse suprapubic skin incision is often utilized for CS in the non-obese, the optimal incision for the obese remains controversial. It largely depends on the surgeon's experience, preferences, patient's body habitus, clinical condition, and institutional guidelines.

The type of skin incision in obese pregnant women seems to correlate with wound morbidities ranging from SSI, dehiscence, hematoma to seroma [57]. A review of randomised trials has reported a greater wound infection rate with vertical incisions than with transverse suprapubic incisions [38]. Alanis et al. reported a doubling in the wound complication rate with vertical incisions compared to transverse incisions [37]. Similarly, Smid and colleagues showed that compared with nonobese women, morbidly obese women had an increased risk for any wound complication (14%, adjusted odds ratio [AOR], 1.65; 95% [CI], 1.44–1.89), endometritis (8.3%, AOR, 1.26; 95% CI, 1.07–1.49), wound infection—more in vertical than transverse wounds (2.0%, AOR, 3.77; 95% CI, 2.60–5.46), wound opening (0.0.8%, AOR, 5.47; 95% CI, 2.79–10.71), and wound infection-related hospital readmission (3.6%, AOR, 2.97; 95% CI, 2.26–3.91) [58].

Some studies have reported a reduced incidence of SSI, fascial dehiscence, hematoma and seroma with vertical compared to the horizontal incisions [40,59]. In a study of 246 obese women, the type of incision did not correlate with wound morbidities [39]. Similarly, in a recent study, Martin and colleagues found a similar wound morbidity rate between vertical and the Pfannenstiel incisions (aOR] 1.5, 95% CI 0.8–2.8). Strikingly, they noted that when skin incision was divided into infraumbilical and Pfannenstiel, the infraumbilical vertical skin incision was associated with a greater degree of wound infection and wound morbidity with an OR of 2.5 (95% CI 1.4–4.6) and 2.46 (95% CI 1.4–4.5) respectively compared with Pfannenstiel incision [60].

An additional alternative for an incision is the transverse suprapanniculus incision, which may be taken into account when the panniculus causes downward displacement of the umbilicus towards the pubic symphysis while in an upright position.

Uterine incision and closure of the peritoneum

There is no evidence that the type of uterine incision, closure or non-closure of the peritoneum increases or reduces the rate of SSI in non-obese pregnant women. To the best of our knowledge, there have been no published studies on these variables in obese parturients [61]. In non-obese women, a Cochrane review found that non-closure of the peritoneum had no effect on the development of endometritis or SSI [62]. However, careful attention should be given to maintaining hemostasis and preventing hematoma formation [24]. We believe that the type of uterine incision should be guided by the indication for surgery, ability to have uninhibited access to an operation field, and the clinical condition of the patient. Consideration must, however, be given to the increased morbidity associated with vertical uterine incisions.

Skin and subcutaneous closure

Wound closure techniques have been found to affect the development of SSI, especially when comparing subcuticular to the use of staples. The use of staples is associated with an increased risk of SSI and wound separation compared to subcuticular sutures [63]. Ibrahim et al., compared the rate of SSI in obese women after a CS where the skin incision was closed with either interrupted or subcuticular suturing. The subcuticular group had a slightly higher rate of SSI, reduced skin closure time, heightened postoperative pain and better cosmesis compared to the interrupted suture group [64].

A Cochrane review of RCT and metanalysis showed that closure of subcutaneous fat of >2 cm decreases the risk of wound complications such as SSIs, separation, seroma and hematoma formation compared to non-closure (RR 0.68; 95% CI 0.52–0.88) [65]. Closure of the subcutaneous fat layer is therefore recommended in obese women, in whom this is usually >2 cm.

Negative pressure wound management

Negative pressure wound therapy (NPWT) has received tremendous attention over the years as a credible technique for promoting better wound healing in high-risk patients such as morbidly obese women and obese women with additional risk factors for wound infection such as previous CS or diabetes. It involves the application of a vacuum wound dressing device after the closure of the transverse abdominal skin incision. The device creates a negative pressure of 80–125 mmHg by suction over a period of 5–7 days and ensures an even distribution of pressure across the wound. It also enhances fibroblast proliferation and migration to the wound edges and increases tissue perfusion. NPWT also causes a reduction in wound edema and bacterial accumulation. The commonly used NPWT is the device developed by Smith and Nephew known as PICO dressing (Fig. 3). However, in some settings such as in LMIC, NPWT is often assembled/created using an adjustable negative pressure suction device, tubing, and airtight dressing. However, the challenge is that the suction device must have an uninterrupted power supply for the set-up to remain functional.

There are studies within the literature with mixed results on the benefits of NPWT in reducing SSI in obese pregnant women. Hyldig and colleagues in a randomised controlled trial of the effect of prophylactic NPWT in obese women after CS (432 with NPWT and 444 with standard dressing) showed reported rates of SSI in the NPWT and standard dressing groups of 4.6% and 9.2% respectively (RR 0.50, 95% CI 0.30–0.84; number needed to treat 22; P-value = 0.007) [28]. A similar but recent Australian study also reported a 24% reduction in SSI rate compared to standard dressing [66]. A systematic review and meta-analysis by Słabuszewska-Jóźwiak and associates also found a reduction in SSI in women with NPWT (OR = 0.76; 95% CI 0.60–0.95, P = 0.02) [38]. However, Tuuli and colleagues did not find any statistically significant reduction in SSI when comparing NPWT (3.6%) to standard dressing (3.4%) (difference, 0.36%; 95% CI 1.46%–2.19%, P = 0.70) [67]. Also, a systematic review and metanalysis of 10 studies on the role of prophylactic NPWT in women after CS for obese women found no difference in the prevention of wound infection in the patients who had NPWT (16.8%) compared to those who had standard dressing (17.8%) [68]. We do, however, on balance believe that there are definite benefits of NPWT with regards to reducing the rate of SSI in morbidly obese women undergoing CS.

Subcutaneous drains

Subcutaneous drains serve the primary purpose of reducing the risk of hematoma formation and fluid collection within the wound, as this could result in SSI with disruption of wound apposition. There are currently no studies that have shown that the routine use of subcutaneous drains prevents SSI [37,69,70]. Their use has instead been shown to increase the rate of SSI and wound dehiscence [40,71]. Słabuszewska-Jóźwiak et al., in a meta-analysis of 9 studies on the impact of drains on SSI which included 674 obese

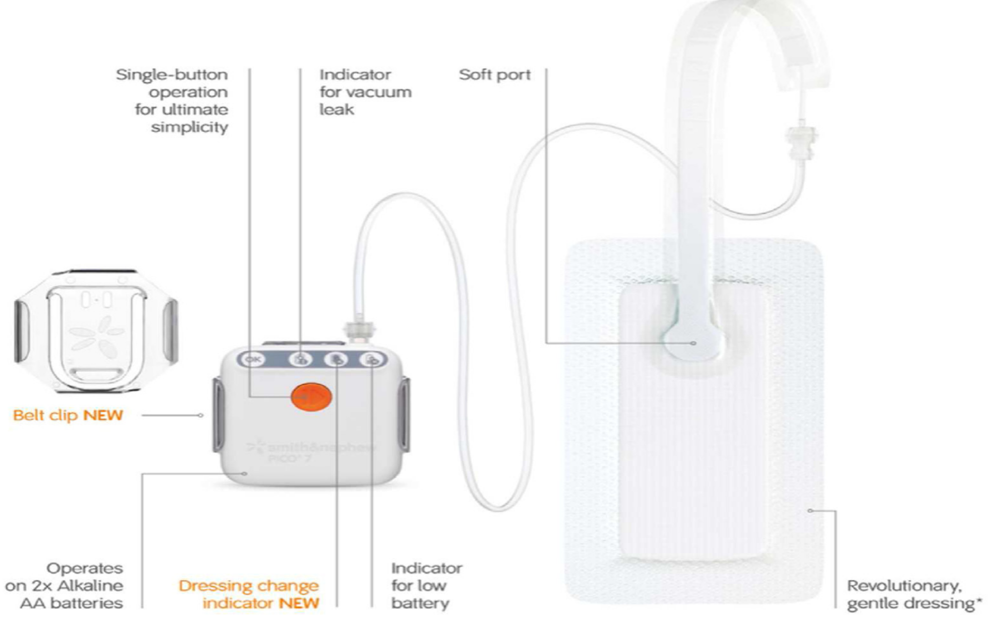

Fig. 3. Smith and Nephew PICO dressing. Reproduced with permission from Smith and Nephew UK.

women who had drains and 1718 who did not at CS showed that the percentage of wound complications was slightly higher in the women with drains (21%) than in those women without (19%), $p = 0.45$. They concluded that using a drain did not increase the risk of wound morbidities after a CS in obese women [38].

Other considerations

Cleansing of the subcutaneous layer before skin closure and or the use of post-operative dressing materials containing an antimicrobial agent have been suggested as additional steps to reduce the SSI in obese parturients. There is, however, currently no robust evidence to support these suggestions. The CDC guidelines of 2017 did not recommend topical application of any antimicrobial agent on surgical incisions [46,72]. However, the ChEETAh trial showed that change of hand gloves and instruments during abdominal wound closure reduces rate of SSI [73]. Simple steps, such as follow-up wound inspection on days 3 and 7 post-surgery for early identification and management of SSI are essential to prevent complications.

The design of the operating rooms should follow an acceptable standard. There should be a provision for materials used for surgery to be cleansed, disinfected and or sterilized (if re-useable). Non-reusable materials may in some cases increase the downstream health care cost but may obviate the need for sterilization or disinfection. Furthermore, the staff in the operation rooms should take reasonable measures to ensure that aseptic protocols are not violated. Newly employed staff or students undergoing training or assessment should be given induction training about the operating room to ensure that asepsis is maintained.

Management of surgical site infections and sepsis in the obese pregnant patient

Surgical site infection after an obstetric procedure such as a CS typically presents 48–72 h after the procedure and may even be earlier where there are multiple premorbid predisposing factors (Table 3) to SSI [22]. SSI can also progress to sepsis post-CS with distinctive presenting features of fever, offensive wound discharge with induration, and erythema at the wound. If this is not timely recognized and treated, it may result in maternal mortality. Sepsis usually presents with the features shown in Table 4 [74]. Other causes of sepsis, such as respiratory, gastrointestinal, and urinary tract infection must also be excluded.

A high index of suspicion must be maintained to reduce morbidity and mortality, and management includes early recognition or suspicion, timely commencement of treatment including resuscitation and multidisciplinary team involvement. Management of SSI historically begins with taking a history to elicit the risk factors associated with SSI, physical examination, investigations, treatment, and the preventive measures discussed in the previous sections.

Clinical monitoring in obstetrics by using the modified early warning score (MEOS) will identify early deterioration and allow for prompt intervention. A combined score of 3 or a single score of 3 from one domain raises the clinical suspicion of sepsis. Once sepsis is suspected, the sepsis survival campaign (SSC) hour-1 sepsis bundle must be activated, and this includes keeping saturation >94% with oxygen administration, taking blood cultures, commencing broad-spectrum antibiotics within 1 h of diagnosis, giving intravenous fluids if hypotensive or lactate is > 2 mmol/L, checking serum lactate and hourly monitoring of urine output [17].

If both SSI and sepsis are suspected, the initial investigations include a full blood count (FBC), C-reactive protein (CRP), blood culture, liver function test, renal function test, arterial blood gas, a clotting screen, serum lactate, urine culture, vaginal swab, and wound swab for microscopy culture and sensitivity (MCS). An abdominal ultrasound examination is also necessary to define the extent of the infection and exclude retained products of conception (RPOC) and intrabdominal fluid collection. Procalcitonin levels can be measured to determine whether a change in antibiotic therapy is required. It may also be quantified in cases where suspicion of bacterial sepsis is not clearly evident, such as in culture-negative sepsis [75]. Thus, procalcitonin is a useful tool in antibiotic stewardship. Current evidence suggests that the levels of procalcitonin in pregnant and non-pregnant populations are similar [76]. However, there is variability in the reported levels of procalcitonin used for antibiotic de-escalation [77]. The findings of an international Delphi study by Schuetz et al. showed that for many patients with mild, moderate or severe illnesses, <0.25 or <0.5 μg/L (or ng/mL) of procalcitonin, respectively, should prompt consideration for de-escalation of antibiotic therapy; however, another

Table 4
Clinical features of Surgical Site Infection and sepsis.

Symptoms	Signs
Fever	Pyrexia
Rigor	Tachypnoea
Offensive wound discharge	Tachycardia
Offensive vaginal discharge	Hypotension
Heavy lochia	Hypothermia
Urinary symptoms	Hypoxia
Bowel symptoms such as vomiting and diarrhoea	Oliguria
Abdominal pain	Delayed uterine involution
	Impaired consciousness

criterion is a >80% decrease in procalcitonin level [78]. It is recommended that procalcitonin levels should be repeated within 6–24 h or 24–48 h in mild, moderate or severe illnesses respectively [78]. Other investigations, such as a Computed Tomography (CT) or a Magnetic Resonance Imaging (MRI), may be needed to assess the extent of wound morbidities, such as intraabdominal collection, hematoma, seroma, or dehiscence. Early presentation of sepsis within 12 h of delivery indicates streptococcal infection, particularly Group A Streptococcus (GAS), and severe pain may be a pointer to necrotizing fasciitis [79,80]. The initial goal in the management of sepsis is the administration of antibiotics against the likely organisms and maintaining hemodynamic stability. Empirical broad-spectrum antibiotics are usually commenced while awaiting the sensitivity pattern. The commonly used combination includes metronidazole and penicillin such as Amoxicillin and Clavulanic acid (Augmentin) or a cephalosporin (Cefuroxime) and Metronidazole in patients with mild penicillin allergy. Clindamycin or Vancomycin may be used in those with severe penicillin allergies as they cover the usual organisms. In patients with swinging continuous pyrexia, Gentamycin may be added. For SSI following CS, Flucloxacillin and Clindamycin may also be used [23]. In the presence of red flag symptoms and severe sepsis (Box 1), Piperacillin/Tazobactam or a carbapenem such as Meropenem may also be considered [74,81].

Specimens for cultures, such as blood, must be taken before the administration of antibiotics, and once the results are available, the choice should be modified based on the sensitivity profile [74].

Pain arising from the wound and erythema may be a sign of superficial SSI, whereas offensive lochia and/or discharge may signify endometritis. In these situations, an initial ultrasound scan to confirm or exclude diagnosis, culture of the offensive discharge, antibiotics therapy and wound care may be appropriate. In some women, conservative measures may not resolve the infection, and these women may require surgical intervention, including radiologically-guided aspiration, pelvic lavage and insertion of a drain [22,82].

Small hematomas may reabsorb, while large ones may require evacuation and sometimes ligation of bleeding vessels [22]. Seromas may increase the risk of SSI and can be evacuated by needle aspiration. An application of a firm dressing immediately after the evacuation may prevent reformation. Large seromas may require open exploration and evacuation [22].

A deep incisional SSI may require debridement and secondary wound closure. This is crucial in the obese, where there is a significant risk of poor wound healing, especially if other risk factors such as immunosuppression and diabetes are present. In this situation, a tissue viability team and/or vascular surgeons may be required for wound management during debridement and secondary closure [24]. In some cases, infected wounds may be packed and left open to heal by secondary intention [22]. In these circumstances, guidance should be obtained from the tissue viability team.

Organ/space SSI with pelvic cellulitis and abscess may need surgical intervention with an exploratory laparotomy, abscess drainage and saline lavage with the insertion of an abdominal drain. Radiological intervention may also be considered for obese women with comorbidity unsuitable for repeat surgery [23,83,84]. In cases of puerperal sepsis, hysterectomy is indicated if the patient develops septic shock, a necrotic cervix, persistent failure of greater than one body organ (despite adequate resuscitation), or a uterus that does not blanch at laparotomy.

Necrotizing fasciitis (cellulitis, fasciitis, and myositis) is a rare, rapidly progressive complication of wounds involving the superficial and subcutaneous tissue. It is less likely to develop from an obstetric procedure and more likely to follow trauma. It can have a fulminating course and a high mortality rate

Box 1
Red flag signs of sepsis.

Red flag features of sepsis.

GCS <15 or VPU (not alert).

Acute confusional state.

Mottled skin, cyanosis, non-blanching rash, and ashen.

Heart rate of >130 beats per minute (bpm)

RR $\geq$ 25 bpm Systolic BP $\leq$ 90 mmHg (or drop >40 from normal)

Needs oxygen to keep SpO 2 $\geq$92%

Lactate $\geq$2 mmol/L.

Anuric in the last 18 h/urine output <0.5 ml/kg/h.

due to systemic toxicity [85]. The obese patient with poor wound care and peculiar characteristics of the panniculus is at a greater risk of necrotizing fasciitis (NF) [86]. Other risk factors that can complicate healing with a predisposition to NF include diabetes, anemia, immunosuppression, and malnutrition. Organisms implicated usually include Gram-negatives, positives, and anaerobes ranging from *Clostridium* spp, *Bacteroides, Peptostreptococcus, Proteus Sp, Pseudomonas and* methicillin-resistant *S. aureus* (MRSA) [86,87]. It could be polymicrobial or solely due to Group A streptococcus (GAS) and clostridial myonecrosis, also known as gas gangrene. In obstetric patients, GAS is the most common organism associated with NF. Management involves a high index of suspicion, as GAS should be suspected if sepsis begins within 12 h of delivery. Early NF occurs deep in the tissues and may not present with visible skin changes [80]. Clinical features include agonizing pain requiring an increasing amount of analgesia, erythema, cellulitis, ecchymosis and the presence of crepitus in the tissue demonstrated through palpation [22]. The diagnosis is usually clinical, but ancillary imaging modalities may include plain X-ray showing gas in the tissues. CT and MRI findings may complement or support the diagnosis [22]. Treatment is with a combination of penicillin G; Clindamycin (which suppresses Gram-negative bacilli, streptococcus, staphylococcus, and anaerobic cover); and Gentamycin (in the presence of a normal renal function). Early and aggressive wound debridement is necessary until viable and healthy tissue is reached [22,83,86,88].

Patients with severe sepsis or septic shock may need admission to the intensive care unit (ITU or ICU), and the indications for admission are shown in Table 5 [89]. In patients with sepsis or septic shock who require ICU, the admission should occur within 6 h [17].

While investigating pre-admission avoidable factors associated with pregnant and postpartum patients admitted to ICU, Ngene et al., in 2016 recommended 6 h as being a pragmatic time interval to arrange and provide an ICU bed in a South African setting [90]. Nonetheless, it is preferable for an ICU admission to occur as soon as the ICU admission criteria are met. This is because the time lag between the decision for ICU admission and patients' arrival to ICU may influence outcomes. When there is a delay, adequate ongoing organ support and monitoring should be provided at the site of interim admission. This may be achieved by redeploying health care professionals including nursing staff to provide one-to-one nursing. The preferred site for the interim admission is an obstetric high-

Table 5
Indications for intensive care unit admission.

System	Indication
Respiratory	Airway protection, pulmonary edema, mechanical ventilation
Cardiovascular	Increased serum lactate levels or hypotension persisting despite adequate fluid replacement suggesting the need for ionotropic support
Renal	Dialysis
Neurological	Significant impaired level of consciousness
Miscellaneous	Hypothermia, multiorgan failure, uncorrected acidosis

dependency care unit. Therefore, all level II hospitals particularly those in LMIC are urged to establish such a unit using acceptable standards [91–93]. This is of particular importance given that there is insufficient ICU capacity in many settings limiting the number of patients that may be managed at a time [90]. It is also crucial to improve critical care by providing functional imaging and laboratory services (including point-of-care services) to reduce the turnaround time for investigation results/reports as any delay may compromise patients' care [90,94]. Furthermore, having a referral pathway and criteria (including those based on BMI) for referring pregnant patients are important.

Summary

The impact of obesity continues to be a substantial public health problem with far-reaching implications for patients, their families, and the overall healthcare system. The surge in maternal infection remains a major concern in obstetrics because of associated increased morbidity and mortality. Obesity is a major risk factor for the development of SSI and sepsis. In the obese, anatomical characteristics such as the panniculus fold create a peculiar moist environment for developing SSI. The thick subcutaneous fat also leads to wound disruption and reduced blood flow, resulting in poor wound healing and increased risk of infection. Contamination of the incision site by bacteria, such as Fusobacteria, Firmicutes, Bacteroidetes and Proteobacteria, from the skin, vagina, and surgical gloves in obese pregnant women may increase their rate of SSI. Management of SSI and sepsis requires a high index of suspicion and a multidisciplinary team that should include an obstetrician, surgeons, infectious disease specialists, tissue viability specialists and physicians. Strategies to reduce SSI in obese women include lifestyle modifications, intra- and post-operative preventive measures, and case management of sepsis with the sepsis survival campaign hour-1 bundle recommendations (including prompt administration of antibiotics), appropriate wound management, and early recourse to laparotomy and drainage of abscesses. These may reduce the burden of morbidity and mortality caused by maternal infection.

Practice points

- Obesity is a risk factor for surgical site infection and sepsis.
- Preventive measures that include adequate pre-, intra- and post-operative measures should be employed to prevent infection in obese pregnant women.
- All maternity units should have an established referral route to ensure that women with various classes of obesity are managed at appropriate levels of health care.
- Planned or emergency caesarean sections must be with appropriate prophylactic precautions to minimise the risk of SSI. These include doubling the dose of prophylactic antibiotics, closing the subcutaneous fat layer, avoiding the use of unnecessary drains, consideration to the use of NPWT and early vigilance for signs and symptoms of infection.
- Timely and proper management of SSI and sepsis that includes the use of bundles of care, and quality improvement projects will prevent the morbidity and mortality associated with obesity in pregnancy.

Research agenda

- The preferred abdominal wall incision during CS in the obese remains controversial. A robust and pragmatic multicenter study is required to further investigate this concept.
- The preferred uterine incision and whether the peritoneum should be closed in obese patients of various BMI classes need further evaluation to find out if there is an increased risk associated with a particular option.
- A multicenter study is required to further investigate the optimal wound dressing to be applied to obese women. This will help resolve the mixed results associated with the use of NPWT compared to standard dressing.

Answers

Answers to question 1

(a) F (b) T (c) F (d) F (e) F.

Explanation: The prevalence of obesity is increasing in both the general adult population and pregnant women due to changes in eating habits and other lifestyles.

Answers to question 2

(a) F (b) T (c) F (d) F (e) F.

Explanation: CDC classifies SSIs into three categories based on the structures infected/affected. In superficial incisional SSI, the tissues affected are skin or subcutaneous tissue. In deep incisional SSI, the deep soft tissues such as the fascia and muscles are affected. In organ/space SSI, the spaces and or internal organs are affected.Therefore, infection of the subcutaneous tissue qualifies as superficial incisional SSI; while infection of muscles is deep incisional SSI. Infection of muscles and fascia is deep incisional SSI. Deep incisional SSI is not the same as organ/space SSI.

Answers to question 3

(a) F (b) F (c) T (d) F (e) F.

Explanation: CDC classified wounds into four categories, namely: Class 1 or Clean, Class II or Clean contaminated, Class III or Contaminated, and Class IV or Dirty-infected.

Class 1 or Clean is an operative wound in a sterile condition with no organisms and is likely to heal without complications. An example of this is a skin incision for a diagnostic laparoscopy. However, Class II or Clean contaminated wound is an operative wound involving an organ space such as the urogenital, gastrointestinal, or respiratory systems without infection, unusual contamination, or a major breach in sterile technique. An example of this is a CS wound. An operation wound with a breach in the sterile technique is a Class III or Contaminated wound and has non-purulent inflammation. A fresh wound from an accident or operation that has a spillage of the gastrointestinal tract is an example of a Class III or Contaminated wound. Class III wounds have no pre-existing organism. However, a Class IV or Dirty-infected wound is an old wound from trauma with pre-existing organisms and devitalized tissues at the wound site before surgery.

Answers to question 4

(a) T (b) T (c) T (d) F (e) T.

Explanation: Categories of BMI (kg/m^2) are underweight <18.5; normal weight $18.5 - 24.99$; overweight $25 - 29.99$; class 1 obesity $30 - 34.99$; class II obesity $35 - 39.99$; and class III obesity ≥ 40. At the end of surgery in obese women, the incision site gets populated by bacteria from the vagina and the surgical gloves, and the presence of these bacteria explains the increased risk of SSI among obese pregnant women. The vaginal microbiome in decreasing order of frequency of occurrence in obese are Actinobacteria, Firmicutes, Bacteroidetes, and Fusobacteria; and in non-obese Firmicutes, and Actinobacteria. Therefore, Firmicutes is higher in proportion in the non-obese than the obese. Additionally, Bacteroidetes are commoner in the obese than non-obese.

Declaration of competing interest

The authors report no conflict of interest.

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