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REVIEW

Postoperative abdominal wound infection – epidemiology, risk factors, identification, and management

Saïd C Azoury[1]
Norma Elizabeth Farrow[2]
Qing L Hu[2]
Kevin C Soares[1]
Caitlin W Hicks[1]
Faris Azar[1]
Nelson Rodriguez-Unda[3]
Katherine E Poruk[1]
Peter Cornell[1]
Karen K Burce[1]
Carisa M Cooney[3]
Hien T Nguyen[1]
Frederic E Eckhauser[1]

[1]Department of Surgery, The Johns Hopkins Hospital, Baltimore, MD, USA; [2]School of Medicine, Johns Hopkins University, Baltimore, MD, USA; [3]Department of Plastic and Reconstructive Surgery, The Johns Hopkins Hospital, Baltimore, MD, USA

Correspondence: Frederic E Eckhauser
School of Medicine, The Johns Hopkins Hospital, The Johns Hopkins University School of Medicine, 600 N Wolfe Street, Hospital Main Entrance – Sheikh Zayed Tower, Baltimore, MD 21287, USA
Tel +1 410 502 0932
Email feckhau2@jhmi.edu

Abstract: Surgical site infections (SSIs) complicate the postoperative course of a significant proportion of general abdominal surgical patients and are associated with excessive health care costs. SSIs increase postoperative morbidity and mortality, and may require hospital admission, intravenous antibiotics, and even surgical reintervention. Risks associated with SSIs are related to both host and perioperative factors. However, a vast majority of these infections are preventable. More recently, quality initiative programs such as American College of Surgeons National Surgical Quality Improvement Program are expanding their roles to help better monitor adherence to improvement measures. Indeed, standardizing preoperative antibiotic prophylaxis timing is perhaps the most persuasive example and this has been integral to reducing postoperative SSI rates. Herein, the authors provide an update on the epidemiology, risk factors, identification, and management of wound infections following abdominal surgery.

Keywords: surgical site infection, diagnosis, treatment, prevention

Introduction

Postoperative wound infections, also known as surgical site infections (SSIs), complicate the recovery course of many patients. As defined by the Centers for Disease Control and Prevention (CDC), these infections typically occur within 30 days of an operation at the site or part of the body where the surgery took place, or within a year if an implant is left in place and the infection is thought to be secondary to surgery.[1–3] Bacterial colonization on the patient's skin and alimentary and genital tract are the principal contributing sources that lead to SSIs.[4] The organism most often isolated is *Staphylococcus aureus*.[5] Exogenous sources, such as breaches in sterile technique and operating room equipment may contribute, albeit much less frequently than endogenous flora.[6] Bacteria within the tissue or organ space hinder the postoperative healing processes, and can lead to anastomotic leaks, wound dehiscence, and superficial incisional infections.

SSIs may be classified as superficial/incisional if limited to the skin and subcutaneous tissue, deep incisional when involving the fascia and muscle, or organ space when involving a body cavity (eg, abdominal cavity following gastrointestinal surgery).[2,3] Deep tissue and organ space SSIs are less frequently encountered than superficial SSIs, but are associated with greater morbidity/mortality, readmission rates, longer hospital stay, and increased overall hospital-associated costs when compared with superficial SSIs.[7–9] Although the majority of SSIs are uncomplicated, others may be severe and more challenging to manage, such as necrotizing deep soft tissue infections.[2,8] The latter often require extensive surgical debridement, multiple reoperations, and may

even be life-threatening.[10,11] The location and extent of the infection, as well as the patient's clinical condition, guide the management approach.[2,10] For instance, in the setting of an implant, as in the case for a synthetic mesh in an infected wound, oftentimes explantation of the implant is required, which may add to the postoperative morbidity. Furthermore, appropriate antibiotic therapy is often necessary to achieve source control in such patients.

With the rising incidence and associated morbidity of SSIs, various studies have looked at ways to better optimize patients prior to surgery or improve surgical technique and management of patients during the recovery period in order to prevent SSIs.[12,13] Data regarding a hospital's rate of SSIs are becoming increasingly used as outcome measures for assessing the quality of their surgical services.[14,15] Employing methods that could reduce the incidence of SSI would significantly reduce patient morbidity and mortality while lessening the associated economic burden; this has become central to quality improvement initiatives.[16] Herein, the authors provide an update on the epidemiology, risk factors, identification, and management of wound infections following abdominal surgery.

Epidemiology and impact
Incidence and trends
Overall, it is estimated that SSIs occur following 1%–3.1% of all surgical procedures and account for approximately 2.0% of deaths due to health care-associated infections (HAIs).[2,7,17–20] With regard to abdominal surgery, the rate of wound infection may be much higher, with several prospective studies reporting an incidence of 15%–25% depending on the level of contamination.[21–24] A recent study reviewing the reasons for hospital admissions after surgery in the USA demonstrated that SSI was the most common reason for unplanned readmission (19.5% overall, 25.8% following colectomy/proctectomy) followed by obstruction/ileus (10.3% overall).[25] When considering HAIs, survey data gathered by 183 acute-care hospitals in 2011 estimated that 157,500 of 721,800 (21.8%) cases were SSIs.[26] Compared to other common nosocomial infections, SSIs (21.8%) and pneumonia (21.8%) were the most commonly reported, followed by gastrointestinal (17.1%), urinary tract (12.9%), and bloodstream infections (10.0%).[26] The number of SSIs reported is likely an underestimate of the true incidence, as many are diagnosed in an outpatient setting or after discharge.[2]

In general, the rate of SSI for men appears to be higher than that of women across several studies.[8,27–29] Also, the topic of SSI rate in the elderly is becoming an increasingly

important area for research. As patients are living longer, the number of elderly patients undergoing general surgical procedures will certainly increase, and complications such as SSIs in patients aged ≥65 years will become a more apparent issue for general surgeons.[28,30] Although the relationship between increasing age and risk of SSI is complex, it is well known that related mortality rate, hospital stay, and health care-related costs for older patients with SSIs are greater than that for younger patients.[28] The impact of age and sex on SSI risk will be discussed later in the text.

Economic impact
Health care costs associated with treating SSIs are exceedingly high.[30–33] A study performed in Veterans Affairs Hospitals demonstrated a 1.43-fold relatively higher hospital cost for patients with an SSI ($11,876 difference) than for patients without an SSI.[32] Similar total excess costs ($10,497) have been reported for patients with SSIs from the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) when compared to those without SSIs.[29] Even more striking, data from the 2005 Healthcare Cost and Utilization Project National Inpatient Sample (HCUP NIS) highlighted that SSI extended hospital length of stay by nearly 10 days, and hospital-associated costs increased by approximately $20,842.[18] Nationally, 91,613 readmissions due to SSIs were reported in 2005, and overall associated hospital costs exceeded $900 million.[18] Furthermore, from 1993 to 2005, the number of emergency department visits in the USA for skin and soft tissue infections (SSTIs) increased from 1.2 million to 3.4 million. Of all emergency department visits, SSTIs constituted 1.35% in 1993, increasing to 2.98% in 2005.[34] A separate study demonstrated that between 2000 and 2004, total hospital admissions increased by 29% for SSTIs.[35] Similar trends are highlighted at the state level. In North Carolina, the most common HAIs are SSIs (73%), and related costs approximated 87%–91% of the total HAI-related expenditure.[36] These excess costs are largely related to antimicrobial/drug treatment, interventions, and additional nursing care.[37]

Risk factors
Understanding the multitude of variables associated with the risk of SSI following general abdominal surgery allows patients and physicians to identify modifiable risk factors and to make changes in an attempt to optimize patients prior to surgery. Several factors have been shown to be linked with SSI rate following general surgery across studies including open surgical approach, smoking status, insulin-dependent

diabetes, immunosuppression, wound contamination, American Society of Anesthesiologists (ASA) classification score >2, hypoalbuminemia, and prolonged operative time (Table 1).[13,28,30,38–44] As an example, knowing that a patient has a clean-contaminated or contaminated wound may help guide a surgeon's preference for closure with a biologic prosthesis rather than synthetic mesh when reinforcement of the abdominal wall is necessary.

The National Nosocomial Infection Surveillance (NNIS) system risk score was developed and based on three factors: 1) American Society of Anesthesiologists preoperative score of >3; 2) wound classification as contaminated or dirty; and 3) operation lasting longer than 75th percentile for that specific operation (Table 2).[44] This same study demonstrated that the rate of SSIs increases along the spectrum for clean (2.1%), clean-contaminated (3.3%), contaminated (6.4%), and dirty wound types (7.1%) (Table 2).[44] Furthermore, across all wound classification categories, the risk of postoperative SSI is greater with an increasing number of risk factors (Table 2). Broadly, the likelihood of developing a SSI depends on host and perioperative variables (Table 1).

Host factors
Demographics
Male sex has been shown to be associated with an increased SSI risk,[27] particularly in the emergency setting.[45,46] It is speculated that this may be in part due to the decreased collagen deposition after surgery in men with aging compared to women, which increases the possibility for wound breakdown, dehiscence, and bacterial contamination.[47]

Table 1 Factors associated with increased surgical site infection risk

Host-related	Perioperative
Advancing age, up to 65 years	Inadequate surgical scrub/skin preparation
Diabetes mellitus	Preoperative shaving
Obesity	Inappropriate antimicrobial prophylaxis
Cancer	Prolonged operative time
Altered immune response (eg, HIV/AIDS, immunosuppressive drugs)	Poor operating room ventilation
Smoking/tobacco use	Foreign body (mesh, implants, prosthesis)
Poor nutritional status, hypoalbuminemia	Need for blood transfusion
Poor functional status	Inadequate tissue oxygenation
Coexisting infection at nonsurgical site	Open technique
Previous abdominal procedure	Poor aseptic technique
American Society of Anesthesiologists classification score >2	Tissue trauma
	Contaminated or dirty wound

Age
The reported impact of age on SSI risk has been unclear, and the relationship is complex. While some researchers have observed an increased rate of infection in older patients,[48] others have demonstrated lower associated SSI rates when compared to patients younger than 55 years.[8,49] A more recent multi-institutional study demonstrated that increasing age, up to 65 years, independently predicted an increased risk of SSI.[30] However, beyond that age, increasing age independently predicted a decreased risk of SSI.[30] It is likely that the higher rate of comorbidities in aged patients is a confounding factor in the aforementioned relationship and certainly, this topic requires ongoing investigation.

Wound classification
The risk of SSI rises with increasing wound class as defined by the CDC (Table 2).[44,50] One study observed a significantly increased risk of SSI in patients with wound class of >2 (contaminated or dirty-infected cases).[8] This is not surprising, as the probability of developing a wound infection is greater with increases in bacterial load. However, the reported quantitative bacterial load at which this risk increases has varied across studies, with several sources estimating >10^4–10^5 CFU/g.[51–55]

Functional and nutritional status
Dependent functional status has been associated with higher SSI rates when compared to independent status.[49] Furthermore, hypoalbuminemia is associated with an increased risk of postoperative SSI of any type, and therefore ensuring adequate preoperative nutritional support is essential for optimizing surgical outcomes.[38]

Immunosuppression
Use of steroids has been linked to the risk of SSI, although it is important to note that the underlying reason for which the patient is on steroid treatment may by itself increase the risk of SSI.[13] For instance, some studies have associated history of COPD with increased SSI risk and many patients with COPD are on chronic steroid treatments.[38] Additional studies are necessary to further elucidate these risk factors.

Drapeau et al reported a twofold higher rate of SSI in HIV-infected patients when compared to the general population.[12] Furthermore, patients with lower preoperative CD4 counts are more likely to develop SSIs.[56,57]

Comorbidities
Patients with a body mass index (BMI) (kg/m^2) in the normal range (18.5–24.9) have lower SSI rates when compared to

Table 2 Wound class and risk of SSI by the NNIS system risk score

Wound class	Definition[50]	Examples	Rate of SSI (%)[44]	Risk of SSI stratified by risk score[44,*]	
I: clean	An uninfected operative wound in which no inflammation is encountered and the respiratory, alimentary, and genitourinary tract is not entered.	Elective inguinal hernia, non-penetrating blunt trauma	2.1	0	1
				1	2.3
				2	5.4
				3	NA
II: clean-contaminated	An operative wound in which the respiratory, alimentary, or genitourinary tracts are entered under controlled conditions and without unusual contamination provided no evidence of infection or major break in technique is encountered.	Elective colon resection	3.3	0	2.1
				1	4
				2	9.5
				3	NA
III: contaminated	A wound in which gross contamination/ spillage and a break in sterile technique occurs, and incisions in which acute, nonpurulent inflammation is encountered.	Penetrating trauma with gross intestinal spillage	6.4	0	NA
				1	3.4
				2	6.8
				3	13.2
IV: dirty	A wound that is already considered infected, such as old traumatic wounds with retained devitalized tissue or perforated viscera.	Intra-abdominal abscess, acute bacterial peritonitis	7.1	0	NA
				1	3.1
				2	8.1
				3	12.8

Notes: NNIS system risk score is the number of risk factors among these three: 1) ASA scores 3, 4, or 5; 2) either contaminated or dirty operation; and 3) duration of surgery more than 75th percentile for that specific procedure. *Note that a risk score of 0 is not possible with a contaminated or dirty wound classification.
Abbreviations: ASA, American Society of Anesthesiologists; NA, not applicable; NNIS, National Nosocomial Infection Surveillance; SSI, surgical site infection.

patients in the overweight and obese BMI categories.[49] A BMI of >30 is associated with increased likelihood of developing a SSI, and this relationship strengthens with increasing BMI.[8]

Smoking decreases tissue oxygenation, which in turn increases the risk of wound infection.[58,59] Whereas several studies have suggested that current smoking status (within a year of surgery) significantly increases the risk of all SSIs, others note an increase in deep/organ space infections, but not superficial SSIs.[8,16,49]

Preoperative sepsis is associated with developing an organ space SSI, but not superficial or deep infections.[5] This is likely explained by resultant poor tissue perfusion/oxygenation, as well as bacterial spread from the bloodstream.

Previous abdominal surgery has been shown to be associated with increased risk of any SSI, including deep or organ space infections.[24,38] For superficial SSIs, it is thought that the decreased vascularity of the prior scar and inherent problems related to prior wound healing complications may be the principle factors involved.[38]

Perioperative factors
Surgical technique
Inadequate surgical scrub or antiseptic preparation, as well as shaving hair rather than clipping at the operative site, have been associated with SSI.[5,48,60] Open surgical technique is associated with increased likelihood of developing SSI when compared to laparoscopic technique.[8,49]

Prolonged operative time increases the likelihood of developing SSI.[8,49,61] One study noted that the likelihood of developing an SSI increases by 24% for each additional hour of operation.[8] The association of prolonged operative duration and wound infection is complex and may not be entirely related to the operative time per se. Rather, this may signify a complex case or intraoperative complications, both of which have also been associated with SSI.[49] Similarly, the association of preoperative anemia and blood transfusion with risk of SSI has been previously reported, but duration of the operation was a main confounding variable in this analysis.[62]

Emergency abdominal surgery presents a greater risk of postoperative wound infection than elective general surgery.[13,45,63] Interestingly, factors contributing to the risk of SSI in elective and emergency cases are disparate.[45] Following elective surgery, perioperative blood loss, smoking, operation type (eg, hernia versus colorectal surgery), and presence of comorbidities were shown to be independent predictors of wound complications and SSI. In contrast, following emergency surgery, variables including male sex, peritonitis, and multiple operations were associated with a higher likelihood of developing a SSI.[45]

Risk factors by SSI type
Increasing efforts are being made to separate superficial, deep incisional, and organ space infections when studying risk association in order to better identify and compare risk factors

across studies and hospitals.[38] Clinically, deep and organ space infections are associated with a longer length of stay, higher readmission rates, and overall morbidity when compared to superficial incisional infections.[8] Interestingly, although some overlap exists, research has shown that the risk factors for superficial, deep, and organ space SSI may differ.[8,49] A BMI >25 kg/m^2, diabetes, alcohol use, vascular insufficiency, dyspnea and COPD increase the risk of superficial SSI.[8,24,49] Factors associated with an increased risk of deep SSI include wound class >2, BMI >25 kg/m^2, duration of operation, and ASA class >2, and those unique to organ space SSIs include weight loss >10%, disseminated cancer, prior surgery within 30 days, preoperative radiation, dialysis, and chronic steroid use.[8,49] Furthermore, patients with a diagnosis of ulcerative colitis/Crohn's disease and bowel obstruction or perforation have a greater risk of deep/organ space infection.[49] Similarly, a separate study of adults undergoing abdominal colorectal surgery also demonstrated an association of higher BMI with superficial SSI whereas preoperative radiation, postoperative hyperglycemia, and case length were associated with organ space infections.[9] Race and ethnicity has not been associated with any SSI outcome in these systems.[8]

Identification

Early identification of SSIs begins with careful history and physical examination. The majority of these, excluding SSIs involving implants, are diagnosed after discharge, but within 3 weeks from the operation.[64] For superficial SSIs, margins of the site should be marked in order to more readily observe signs of progression (Figure 1).[10] When presenting with systemic signs of infection, wound/tissue and blood samples for gram stain, culture, and susceptibility should be obtained and will help guide therapy.[2] Furthermore, any drainage should be

Figure 1 Example of a superficial site infection with necrotic margins.

sampled and sent off for gram stain and culture. Laboratory testing that may be necessary depending on the clinical presentation of the patient includes complete blood cell count with differential, C-reactive protein, creatine phosphokinase, and basic metabolic panel to assess for creatinine/renal insufficiency and any metabolic/electrolyte abnormalities.[2,6,10] These values may help in the diagnosis, but none are specific for SSI. Additionally, it is important to note that SSIs may present without laboratory abnormalities. When working up deep and organ space SSIs, computed tomography is particularly useful and more reliable in detecting free air in soft tissues than plain abdominal radiograph. Furthermore, computed tomography imaging helps guide procedural intervention (eg, interventional radiology percutaneous drainage).[6]

Superficial/incisional

Superficial SSI (Table 3) is defined as an infection involving only the skin or subcutaneous tissue occurring within 30 days of an operation (Figure 1).[1] Additionally, at least one of the following must be present: 1) diagnosis by the surgeon or attending physician; 2) purulent drainage with or without laboratory confirmation from the surgical site; 3) aseptically obtained culture (tissue or fluid) demonstrating causative organisms; 4) presence of symptoms such as pain/tenderness, redness, localized swelling, or heat and the site opened by the surgeon if the culture is positive.[1]

Deep tissue

Deep incisional SSIs involve the deep soft tissues (Table 3) including the fascia and muscle layers of the incision and occurs within 30 days after the operation or within 1 year if an implant is in place and the infection appears to be associated with the surgery.[1] Additionally, one of the following must be present: 1) diagnosis by an attending physician or surgeon; 2) purulent drainage from the deep tissue site but not from a deeper source (organ space); 3) the deep incision is either

Table 3 Surgical site infection categories and management

Type of wound	Definition[1]	Management
Superficial incisional	Involves skin or subcutaneous tissue of the incision and rarely leads to systemic toxicity	Oral antibiotics in the case of uncomplicated superficial (eg, cellulitis); incision and drainage for complicated infections
Deep incisional	Includes tissues down to and including fascia and muscle	Anatomic source control plus appropriate antibiotics
Organ space	Involves any body cavity that was opened or manipulated during surgery	Anatomic source control plus appropriate antibiotics

opened by the surgeon in the setting of signs and symptoms of infection (eg, fever >38°C, tenderness, pain) or dehisces spontaneously; 4) evidence of infection (eg, abscess) is identified during the work-up, management, or by histopathologic or radiologic examination.[1]

Organ space

Organ space SSI (Table 3) involves the abdominal cavity that was manipulated during the surgery and occurs within 30 days after the operation or within 1 year if an implant is left in place. Furthermore, the infection appears to be related to the surgery but does not involve the superficial incision. One of the following must also be present: 1) diagnosis by an attending or surgeon; 2) evidence of infection (eg, abscess) is identified during the work-up, management, or by histopathologic or radiologic examination; 3) aseptically obtained culture (tissue or fluid) demonstrating causative organisms; 4) purulent drainage from the cavity, as from a percutaneously placed drain or during reoperation.[1]

Management

In order to effectively treat a SSI, antibiotics and anatomical source control may be necessary.[2,10,65–67] Source control is achieved through surgical (eg, operative debridement) or procedural (eg, interventional percutaneous drainage) intervention. Inpatient hospital admission should be sought when the infection and resultant clinical sequelae are concerning. Supportive care and resuscitation is necessary for patients with hemodynamic changes and/or systemic inflammatory response syndrome.

Uncomplicated superficial SSIs, such as cellulitis, may be effectively managed with oral antibiotics without surgical intervention and debridement (Table 3).[6] Antimicrobial therapy is recommended for 5 days and extended if clinical signs of infection persist or worsen.[10] If physical exam (eg, purulent drainage) and imaging suggests a deeper infection (ie, deep or organ space), then suture removal, incision and drainage, and debridement of necrotic tissue should be performed.[6,10] Furthermore, deep and organ space SSIs require surgical debridement and operative or interventional drainage of the infected fluid collection.[6,49,68] Empiric systemic antibiotics should be started as soon as a deep or organ space SSI is suspected and when clinical signs of infection are present (ie, fever >38.5°C, abnormal vital signs, erythema and induration extending >5 cm from the wound edge, white blood cell count >12,000/μL).[10] Type and duration of empiric antimicrobial therapy is based upon expected pathogens which is determined by clinical presentation, anatomic site, comorbidities, and physical exam.[69] The antibiotics are then tailored to culture results as soon as that data become available.[1]

As mentioned previously, the most commonly implicated pathogens in superficial SSIs include gram-positive bacteria, mainly *S. aureus*, and coagulase-negative staphylococci.[50,69–74] Antimicrobial therapy should target these organisms as well as methicillin-resistant *S. aureus* (MRSA) in patients with specific risk factors (eg, presence of non-penetrating trauma, positive MRSA nasal swab or MRSA infection elsewhere, and history of intravenous drug abuse).[73] First line empiric therapy consists of a first-generation cephalosporin (eg, cefazolin) or an anti-staphylococcal penicillin (for methicillin-sensitive *S. aureus*).[69] Vancomycin, daptomycin, linezolid, or an equivalent antibiotic are appropriate when targeting MRSA.[69] In penicillin-allergic patients, clindamycin rather than a macrolide is the recommended antimicrobial agent. Gram-negatives and mixed organisms, such as *Pseudomonas aeruginosa*, *Enterococcus* spp., *Escherichia coli*, and other Enterobacteriaceae are often present in wound infections that follow gastrointestinal/genitourinary surgery. Therefore, broad-spectrum antimicrobial coverage active against gram-negatives and anaerobes should be used in these cases.[10] Examples include vancomycin plus piperacillin/tazobactam or imipenem/meropenem, and cephalosporin or fluoroquinolone in combination with metronidazole.[10] A recent prospective evaluation of antimicrobial therapy duration for intra-abdominal infection in patients who had undergone adequate source-control procedures demonstrated similar outcomes in fixed-duration antibiotic therapy (4 days) when compared to patients treated with a longer time duration (8 days) that extended beyond resolution of symptoms.[66]

Necrotizing fasciitis is a more severe infection that is often grouped among SSIs and requires immediate surgical consultation and intervention.[10] Dish-water pus from a wound postoperatively has been described as one of the clinical presentations, along with leukocytosis >15,000/mm³ in the setting of hyponatremia (sodium <135 meq/L).[75] Necrotizing fasciitis is often polymicrobial and, therefore, broad-spectrum empiric antibiotic treatment should be initiated. Examples of proper antibiotic coverage include vancomycin or linezolid plus piperacillin/tazobactam, or a carbapenem. For documented group A streptococcal necrotizing fasciitis, penicillin plus clindamycin is an appropriate treatment regimen.[10]

Prevention

It is estimated that approximately half of SSIs are preventable.[76–80] Common practices that have been shown to reduce

the incidence of SSIs include administering prophylactic antibiotics prior to incision, clipping rather than shaving the operative site, maintaining normal body temperature and oxygen supplementation perioperatively, and achieving adequate glycemic control (Table 4).[60,81–90] Simply introducing a surgical safety checklist has even been shown to reduce morbidity and mortality in noncardiac surgery patients.[91] Advances in surgical approach, including laparoscopy, intraoperative wound irrigation, the use of wound protectors during an operation, and negative pressure wound therapy (NPWT) systems afterward have also been shown to reduce wound morbidity at follow-up.[22,92–95]

NPWT (Figure 2) is a technique often employed at the abdominal incision/wound following a general surgery operation that incorporates a foam dressing and suction pump that provides an airtight seal to the wound. NPWT has also been used for the management of ulcers, skin flaps, grafts, and burns. Following placement, an adjustable negative pressure is applied to the dressing, which helps to provide a sterile airtight seal to the wound in the initial postoperative period until the initial dressing change by the surgical team. The technique used most often at our institution has been previously described and shown to reduce wound morbidity postoperatively when compared to standard dressings.[92]

This observation was also reported in other series, with a decrease in the incidence of SSI and other occurrences (eg, seroma) following abdominal surgery.[96,97] Furthermore, a reduction in overall mortality and improvement in primary fascial closure rates has been observed with the use of variations of NPWT in patients requiring open abdomen following trauma or general surgery.[98] Methods by which the vacuum-assisted closure (VAC) therapy is thought to lessen wound morbidity include increased microvascular blood flow to the wound margins and tissue bed as well as enhanced removal of excessive edema while maintaining adequate wound moisture for healing.[92,99] Furthermore, significantly decreased bacterial counts and increased rates of granulation tissue have been observed in animal models using NPWT.[96]

Other approaches that have been used in the past in an attempt to reduce the incidence of postoperative SSIs include covering surgical wounds with sterile dressings for up to 48 hours postoperatively. However, there is insufficient evidence to show that such a practice reduces SSI rate at this point.[50,100,101] Additionally, there has been much interest in the use of antibiotic coated sutures for abdominal wall closure for the reduction of SSIs. Despite prior meta-analyses, the recent PROUD trial demonstrated no benefit in triclosan-coated polydioxanone (PDS) closure compared to control/

Table 4 Recommendations for the prevention of postoperative abdominal wound infections

Preoperative prevention	
Checklists	Use a World Health Organization-based checklist to increase compliance with best practices[115]
Smoking cessation	Encourage smoking cessation for at least 30 days prior to procedure[50]
Blood glucose control	Attempt to control blood glucose levels in diabetic patients and avoid hyperglycemia perioperatively[50,81]
Skin preparation	Clear skin of gross contamination[50]
	Perform prep in concentric circles, beginning with area of incision[50]
	Use alcohol-containing antisepsis agents unless contraindicated, combined with chlorhexidine gluconate or an iodophor (eg, povidone-iodine)[50]
Hair removal	Do not remove hair unless necessary[50,60,104,115]
	When hair is to be removed, use electric clippers with a single-use head; do not use razors[50,60,81]
Antimicrobial prophylaxis	Administer antimicrobial prophylaxis only when indicated, and according to evidence-based guidelines[105–114]
	With few exceptions, administer within 1 hour prior to incision, preferably within 30 minutes[108,112,116]
	Discontinue within 24 hours after surgery (up to 72 hours for cardiothoracic procedures in adults)[50,104,112]
	Adjust dosing for patient weight and redose for longer cases or in cases of excessive blood loss[50,107,115]
	Use a combination of parenteral and oral antimicrobials with mechanical bowel preparations prior to colorectal procedures[50,103,112,114]
Intraoperative prevention	
Maintenance of normothermia	Maintain perioperative normothermia ($\geq$35.5 degrees)[85]
Maximize tissue oxygenation	Administer supplemental oxygen during and after surgical procedures with general anesthesia and mechanical ventilation[90,115]
Wound protectors	Use wound protectors for open abdominal surgery[23]
Postoperative prevention	
Blood glucose control	Maintain immediate postoperative glucose at 180 mg/dL or lower, particularly for cardiac surgery patients[50,81,104]
Wound dressings	Protect primarily closed wounds with sterile dressings for 24–48 hours postoperatively[50,100,101]

Note: These recommendations are based largely from expert opinion, retrospective case series, systematic/meta-analysis reviews, and prospective studies, and further studies are necessary to further explore and validate these recommendations.
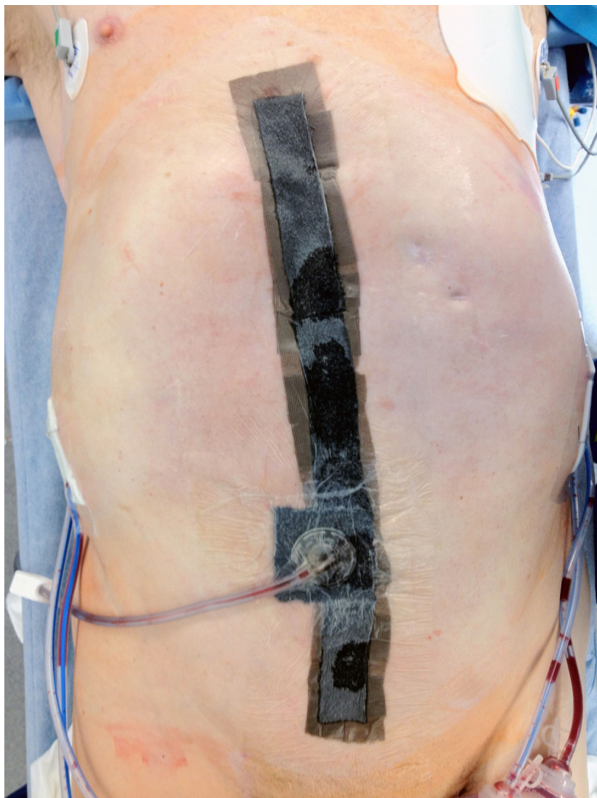
Figure 2 Examples of negative pressure wound therapy system previously shown to reduce the risk of surgical site infection.

uncoated closure.[21,102,103] Finally, closed suction drainage, whether placed in a subcutaneous or intra-abdominal location, should be used judiciously as regular use may be associated with an increased risk of infection.[40,68]

Prophylactic antibiotic timing is a nationally mandated quality metric and the timing of administration of preincision antibiotics has been well studied.[104–108] The utility of prophylactic antibiotics in clean cases remains controversial.[100] Prophylaxis is most appropriate in any case where contamination is evident or expected. Historic data suggests that the efficacy of prophylactic antibiotics is reduced when they are administered too early prior to incision or after the start of the operation.[109–111] Antibiotic prophylaxis should be administered <1 hour prior to incision; evidence in support of this measure is primarily based off of a large multicenter prospective study.[108,112] The type of antibiotic administered does appear to affect SSI following gastrointestinal surgery and ensuring the appropriate selection of coverage is crucial. For instance, SSI outcomes following colorectal surgery are improved when using cefazolin/metronidazole, ciprofloxacin/metronidazole, and ertapenem.[82,107,108,113] Furthermore, the use of parenteral and oral antimicrobials with mechanical bowel preparations has been shown to reduce SSIs following colorectal surgery.[114] Prophylactic antibiotics duration should not exceed 24 hours after surgery.[50,104,112,115,116] Furthermore, redosing of antibiotics is important, particularly during long cases, and is based on blood loss and antibiotic half-life.[107]

The impact of skin decontamination on reducing the rate of SSIs has been well studied.[117–120] Investigators have evaluated the use of nasal mupirocin/chlorhexidine as part of a decolonization program for MRSA in an attempt to prevent spread and ultimately reduce SSIs.[121] Results on its use have been inconsistent and such a practice has been criticized by many, given the potential for increased resistance in these offending bacteria and concern over the cost-effectiveness of this approach.[120,121] More persuasive evidence supports the use of alcohol-based chlorhexidine products compared to povidone–iodine, with the potential for reduced postoperative SSI even for clean cases.[100,119,122,123]

Collaborative initiatives to reduce the incidence of SSIs are expanding. The CDC established the National Nosocomial Infections Surveillance system in the 1970s as a way to monitor infection rates at acute care hospitals in the USA. Today, this system is known as the National Healthcare Safety Network (NHSN).[80] Other similar programs include the ACS-NSQIP and the Veterans Affairs Surgical Quality Improvement Program.[80] The CDC and Centers for Medicare and Medicaid Services implemented the National Surgical Infection Prevention Project in 2002, with the aim to decrease morbidity and mortality associated with postoperative SSI.[104,124] Performance measures for national surveillance and quality improvement for antimicrobial prophylaxis included proportion of patients who are given prophylactic antibiotics consistent with published guidelines, within 1 hour prior to incision (within 2 hours for vancomycin or fluoroquinolones), and whose prophylactic regimen is discontinued within 24 hours after surgery.[104,124] In adherence to these three measures, 56 hospitals were able to reduce their SSI rate by 27% (from 2.3% to 1.7%) over a 3 month period.[125] Similarly, the Surgical Care Improvement Project (SCIP) is a national quality partnership of organizations committed to improving safety of surgical care through the prevention of SSIs, as well as other complications (ie, venous thromboembolism, adverse cardiac events, etc).[104] Despite a high compliance rate with SCIP measures, there has not been a significant reduction in the observed SSI rate.[126] A recent study by Wick et al highlights that the implementation of a surgery-based comprehensive unit-based safety program is a safe and effective way to improve the quality of care for patients through the implementation of evidence-based

standardized interventions.[127] After demonstrating a nearly one-third reduction of colorectal SSI rate at the Johns Hopkins Hospital, Baltimore, MD, USA, such an approach is now being employed at many other health care facilities around the USA.

Conclusion

SSIs complicate the recovery course of a significant proportion of general abdominal surgical patients and are associated with excessive health care costs. SSIs increase postoperative morbidity and mortality, and may require hospital admission, intravenous antibiotics, and even surgical reintervention. Risks associated with SSIs are both related to host and perioperative factors. However, many of these are modifiable and a concerted effort by the patient and physician surgeon to make changes can improve outcomes. As it has been shown that a vast majority of these infections are preventable, quality initiative programs such as ACS-NSQIP are expanding their roles to help better monitor adherence to improvement measures. Indeed, standardizing preoperative antibiotic prophylaxis timing is perhaps the most persuasive example and this has been integral to reducing postoperative SSI rate. Additional studies are necessary to further evaluate other areas that can be improved upon to reduce SSI rate and ultimately improve the delivery of care to surgical patients.

Disclosure

The authors report no conflicts of interest in this work.

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