Perioperative Strategies to Prevent Surgical-Site Infection

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Abstract

Colon and rectal resections are among the most common surgical procedures performed in the United States. Complication rates of up to 25% have been reported and result in a substantial impact on quality of life and cost of care. Recently, the Surgical Care Improvement Program (SCIP) has promoted guidelines to prevent postoperative and potentially preventable complications. A comprehensive evidenced-based review of these guidelines and other perioperative strategies for practicing colorectal surgeons is the basis of this review.

Keywords
- surgical-site infection
- colon and rectal surgery
- infection control

Objectives: On completion of this article, the reader should be able to understand and summarize evidenced-based perioperative strategies to prevent surgical-site infection in colon and rectal surgery.

According to the U.S. Centers for Disease Control and Prevention (CDC), hospital-associated infections contribute to 99,000 deaths each year. Surgical-site infections (SSIs) are the second most frequent type of nosocomial infection (20%) following urinary tract infection (36%). Among surgical patients, SSIs are the most common hospital-acquired infections accounting for 36% of nosocomial infections.[1,2] SSIs are associated with significant morbidity, mortality, and increased costs in health care.[3] SSIs significantly increase the postoperative length of the hospital stay, hospital charges, and risk of death, despite significant efforts and improvements in surgical practice, surveillance, and infection-control techniques.[4,5]

Definition

In 1992, the definition of wound infection" was revised by the CDC, creating the terminology *surgical-site infection* (SSI) to prevent confusion between the infection of a surgical incision and the infection of a traumatic wound. SSIs are defined as infections related to the operative procedure that occurs at or near the surgical incision within 30 days of an operative procedure or within one year if an implant is left in place. SSIs are divided anatomically into superficial incisional, deep incisional, and organ/space (►**Table 1**).[1,2] These criteria to define SSIs have become the national standard and are strictly followed by health care organizations, hospitals, surgical personnel, and quality and surveillance programs.[2–7]

The epidemiology of SSIs is complicated by the heterogeneous nature of these infections and varies widely between surgeons, patients, hospitals, procedures, and methods of surveillance.[8] Large (> 500 beds) teaching hospitals have the highest risk for SSIs, followed by small teaching hospitals (< 500 beds), followed by nonteaching hospitals, which have the lowest rates (8.2 vs. 6.4 vs. 4.6%).[9] The use of minimally invasive surgery has resulted in a decreased incidence of SSIs[8]; the SSI rate was significantly lower when the procedure was done laparoscopically.[10] The type of operation also affects SSI rates. Colon and rectal surgery procedures carry a risk of 4.5 to 10.5%.[11]

SSIs impose a significant clinical and financial burden. Patients affected by SSIs experience longer hospitalization, increased morbidity and mortality, and higher health care costs. A study analyzing the incidence and impact of SSIs on hospital utilization and treatment costs using the 2005 Healthcare Cost and Utilization Project National Inpatient Sample (HCUP NIS) database found that SSIs extended the length of stay by 9.7 days, while increasing costs by $20,842 per admission.[5] There is a higher risk of death in patients affected by SSIs. In a case-control study of 215 patients, the

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Table 1 Classification and definition of a surgical-site infection

Superficial incisional SSI
Infection within 30 d after the operation, only involves skin and 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 made by a surgeon or attending physician
Deep incisional SSI
Infection occurs within 30 d after the operation if no implant is left in place or within 1 y if implant is in place and the infection appears to be related to the operation and infection involves deep soft tissue (e.g., fascia, muscle) 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 incision 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 deep incisional SSI made by a surgeon or attending physician
Organ/space surgical SSI
Infection occurs within 30 d after the operation if no implant is left in place or within 1 y 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 and 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 organ/space SSI made by a surgeon or attending physician

Abbreviation: SSI, surgical-site infection.

relative risk (RR) for death associated with SSIs was 2.2 (95% confidence interval [CI], 1.1–4.5), and 5.5 (4.0–7.7) and 1.6 (1.3–2.0) for those with readmission and intensive care unit (ICU) care, respectively.[12] Furthermore, patients affected by SSIs required significantly more outpatient visits, emergency room visits, radiology services, readmissions, and home health-aide services than did controls.[13]

Microbiology and Pathogenesis

In most SSIs, the source is believed to originate from the patient's endogenous flora at the time of surgery. If the procedure involves opening a viscous organ such as in colon and rectal surgery procedures, the pathogens isolated from SSIs tend to be polymicrobial and originating from the endogenous flora of the organ affected by the procedure. A procedure that involves opening of the colon and/or rectum is considered a clean-contaminated procedure when there are no pre-existing abdominal infections and the surgery is performed with adequate technique. In colon and rectal surgery, the most common isolated pathogens from SSIs are gram-negative bacilli and anaerobes.[6] Although the species of pathogens isolated from the SSI have remained relatively stable over the last decade, there has been an increasing number of SSIs that are caused by antibiotic-resistant bacteria and fungi.[6,14–17] SSIs may also originate from exogenous sources including members of the surgical team, instruments and materials brought within the sterile field during surgery, and the operation-room environment. The most common isolates are aerobes, particularly gram-positive organisms such as staphylococci and streptococci.[18–20]

Risks Factors

Factors associated with SSIs result from the complex interaction between the health of the patient, the nature and number of organisms contaminating the surgical site, and the surgical technique.[6,20,21] A recent study concluded that most SSIs involve patient-related rather than treatment-related factors.[22] Patient-related factors implicated in the development of SSIs include advanced age, comorbidity (e.g., renal failure, cirrhosis, diabetes, coronary artery disease, chronic obstructive pulmonary disease, smoking, cancer, shock, malnutrition, obesity), pre-existing infections, preoperative hospital stay, host-defense deficiency such as immunocompromise, and colonization with *Staphylococcus aureus* or other potential pathogens.[6,8,21–23]

Procedure-related factors include surgery duration, technique, quality of preoperative skin preparation, inadequate sterilization of surgical instruments, duration of surgical scrub, preoperative shaving, antimicrobial prophylaxis, operation-room ventilation, poor hemostasis, use of surgical drains, foreign material in the surgical site, and tissue trauma.[6,8,14,21–26]

One of the first predictor models for SSI rates was the Haley model published in 1985, which uses four risk factors to create predictive values for SSI. The risk factors in Haley's model are the presence of three or more underlying diagnoses, wound classification, abdominal surgery, and surgery lasting longer than 2 hours.[27] A simplified and better predictor of SSI rates was later developed in 1990—the National Healthcare Safety Network (NHSN) Risk Index. This index has a range of 0 to 3, assigning one point for each of three variables: duration of surgery longer than 75th percentile for the specific operation, the presence of a contaminated or dirty wound, and a score of > 2 on the American Society of Anesthesiologists (ASA) Physical Status Classification.[28] The rates of SSI for the different strata were 1.5 for 0 points, 2.9 for 1 point, 6.8 for 2 points, and 13 for 3 points. The NNIS Surgical Patient Risk Index provides a system to make valid comparisons of SSI rates among surgeons and hospitals or across time.[28]

Prevention and Control Measures

Skin Antisepsis

Optimization of preoperative skin antisepsis decreases postoperative infections because the patient's skin is a major source of pathogens that may cause SSI. In a study that compared the preoperative skin preparation with either chlorhexidine alcohol, scrub or povidone-iodine scrub, and paint on 849 patients undergoing clean-contaminated surgery, the overall rate of surgical-site infection was significantly lower when compared with a povidone-iodine group (9.5% vs. 16.1%; $p = 0.004$; RR = 0.59; 95% CI, 0.41–0.85).[29] The benefit of bathing with an antiseptic preparation prior to surgery to reduce the risk of SSIs remains unclear. A recent study reviewing the evidence of preoperative bathing or showering with antiseptics for the prevention of hospital-acquired SSIs provided evidence of no benefit for preoperative showering or bathing with chlorhexidine over other wash products to reduce surgical-site infection.[30]

Surgical Hand Hygiene and Technique

In a recent review, the results of 10 trials were analyzed; only one study examined the effects of surgical hand antisepsis on the number of SSIs in patients and found a reduction in SSIs using either alcohol rubs with additional active ingredients or aqueous scrubs. It found no evidence regarding the effect of equipment such as brushes and sponges.[31–33] Although there is general agreement that good surgical technique reduces the risk of SSIs, evidence-based studies are lacking.

Prophylactic Antibiotics in Colon and Rectal Surgery

The aim of antibiotic prophylaxis is to facilitate the function of the host immune-defense system by decreasing or suppressing bacterial growth at the surgical site. The surgical opening of the large bowel causes contamination of the surgical field by endogenous bacteria, so patients undergoing elective colon and rectal surgery are at a high risk of postoperative wound infection. Without antibiotic prophylaxis, SSIs after colon and rectal surgery can be as high as 40%.[31] This percentage decreases to ~11% with the use of prophylactic antibiotics.[32]

In response to the health and financial issues associated with SSIs, the Centers for Disease Control (CDC), the Centers for Medicare and Medicaid Services (CMS), and representatives from other established health care organizations are working together on the Surgical Care Improvement Project (SCIP) to reduce surgical morbidity and mortality by targeting several components of surgical care including antibiotic prophylaxis.[33] SCIP has an infection prevention component for elective surgical procedures that covers the administration of antibiotics within 1 hour before the surgical incision, appropriate of antibiotic selection, and the discontinuation of antibiotics within 24 hours following surgery end time. Based on these principles, hospitals and physicians are monitoring and implementing adherence with these recommendations.[34]

An ideal antibiotic regimen used for prophylaxis during elective colon and rectal surgery should provide broad suppression of fecal flora with activity against aerobic and anaerobic microorganisms. It should be cost effective, provide minimal toxicity, and avoid the emergence of resistant organisms. Furthermore, the choice of antibiotics to be used for prophylaxis should take into account both the microorganisms usually found in the surgical suite and hospital-specific microbiologic epidemiology. Currently, the recommended antibiotic regimen for elective colon and rectal surgery includes an orally administered antimicrobial with bowel preparation, a preoperative parenteral antimicrobial, or a combination of both. The regimen should include coverage against enteric gram-negative bacilli, anaerobes, and enterococci. The Surgical Care Improvement Project issued guidelines for the use of prophylactic antibiotics in colorectal surgery.[35,36] Cefotetan or cefoxitin (second-generation cephalosporins) are recommended as parenteral prophylactic antibiotic choices; however, the combination of cefazolin and metronidazole can be used as a cost-effective alternative. In cases where gram-negative bacilli have become resistant to cefoxitin, reasonable alternatives include cefazolin plus metronidazole or monotherapy with ampicillin-sulbactam. In patients with confirmed allergies or adverse reactions to β-lactams, use of clindamycin with gentamicin, aztreonam, or ciprofloxacin, or metronidazole with gentamicin or ciprofloxacin is recommended. A single dose of ertapenem is acceptable for colon and rectal surgery. However, its use should be avoided because its widespread use may result in increased rates of resistance.[35]

A systematic review of randomized controlled trials to evaluate the efficacy of antimicrobial prophylaxis and different regimens in colon and rectal surgery was conducted in 1998. It concluded that the use of prophylactic antibiotics is efficacious in the prevention of SSIs in colon and rectal surgery. With the exception of a few inadequate regimens, there is no significant difference in the rate of SSIs between the regimens studied. Moreover, the use of a multiple-dose regimen may be unnecessary for the prevention of SSIs because single-dose regimens have been demonstrated to be as efficacious as multiple dosing, and may be associated with less toxicity, fewer adverse effects, less risk of developing bacterial resistance, and lower costs. Similarly, no convincing evidence supported the idea that the new-generation cephalosporins were more efficacious than first-generation cephalosporins in preventing SSIs in colon and rectal surgery.[32] In 2009, the same group published a systematic Cochrane Review that included 182 trials (30,880 participants). The results were similar to the 1998 study in that no statistically significant differences were shown when comparing short- and long-term duration of prophylaxis or single-dose versus multiple-dose antibiotics. Statistically significant improvements in the rate of SSIs were noted with the use of combined oral and intravenous antibiotic prophylaxis when compared with intravenous alone or oral alone. It concluded that antibiotics covering aerobic and anaerobic bacteria should be delivered orally and intravenously prior to colon and rectal surgery with the resultant risk reduction of SSIs by at least 75%.[37]

The most recent questionnaire regarding the use of prophylactic antibiotics before colon and rectal surgery showed that the use of oral antibiotic prophylaxis was still practiced by 75% of surgeons. Intravenous antibiotic prophylaxis was almost invariably used (98% of the respondents).[38]

Prophylactic antibiotics should be administered within 60 minutes of incision to ensure adequate drug tissue levels at the time of the initial incision. If vancomycin or a fluoroquinolone is used, they should be administered within 120 minutes before incision. This timing of administration also reduces the likelihood of antibiotic-associated reactions during induction of anesthesia.[35,37,39,40]

In regards to redosing of prophylactic antibiotics during surgery, for procedures lasting less than 4 hours, a single dose of intravenous antibiotics is appropriate.[36] For procedures lasting more than 4 hours or in the setting of major blood loss, repeating dosing is indicated every one to two halflives of the drug in patients with normal renal function. This recommendation is supported by a retrospective study in 1,548 patients who underwent cardiac surgery lasting more than 240 minutes after preoperative administration of cefazolin. Intraoperative redosing of cefazolin was associated with a 16% reduction in the overall risk for surgical-site infection after cardiac surgery, including procedures lasting less than 240 minutes.[41]

There has been no evidence that a continuous administration of antibiotics for more than 24 hours after elective colon and rectal surgery decreases the risk of wound infection and that extended dosing may increase the risk of resistant organisms and development of *Clostridium difficile* colitis.[36,37,42]

Preservation of Normothermia

SSI rates in patients undergoing surgery are significantly decreased when operative normothermia is maintained to a temperature less than 36°C. In a study that included 200 patients undergoing colon and rectal surgery, SSIs were found in 19% of patients assigned to hypothermia, but in only 6% of patients assigned to normothermia intraoperatively ($p = 0.009$).[43] Another study involving 421 patients evaluated whether warming patients before short-duration clean surgery would reduce the rate of SSIs. They identified 19 wound infections in 139 nonwarmed patients (14%), but only 13 in 277 patients who received warming (5%; $p = 0.001$).[44]

Hair Removal

Most studies studying the subject have shown an increased risk of SSI in patients undergoing hair removal with the highest risk present when shaving with razors. Furthermore, the lowest rates of SSIs were seen when hair was removed just prior to incision.[45–47] In a meta-analysis studying hair removal prior to surgery, the authors found no difference in SSIs among patients who had their hair removed prior to surgery and those who had not. They concluded that if hair needs to be removed, it should be clipped rather than shaved.[48]

Increased Oxygen Delivery

Several studies have addressed the potential favorable impact in the prevention of wound infection by increasing oxygen delivery.[49] In a prospective randomized trial that assigned 500 patients undergoing colorectal surgery to receive 30% or 80% inspired oxygen during the operation and for 2 hours afterward along with prophylactic antibiotics, rates of SSIs were compared between groups. Among the patients who received 80% oxygen, 13 (5.2%; 95% CI, 2.4–8.0% had surgical-wound infections, compared with 28 patients given 30% oxygen (11.2%; 95% CI, 7.3–15.1%; $p = 0.01$).[50] However, the optimal inspired oxygen concentration still needs to be evaluated.[51]

Wound Protectors

Wound protectors are devices that have been used during laparotomy to protect the abdominal wound edges from contamination. The evidence for the efficacy in reducing SSI rates has been discrepant.[52] A recent meta-analysis of randomized controlled trials evaluating the use of wound protectors in gastrointestinal and biliary surgical procedures and the impact on SSIs, the researchers found that the use of a wound protector was associated with nearly a 50% decrease in SSIs (RR = 0.55; 95% CI, 0.31–0.98; $p = 0.04$).[53]

Summary

SSI remains the most common complication following colon and rectal surgery procedures and is associated with significant morbidity, mortality, and increased costs in health care.

Prevention of SSIs can be achieved by several methods, which include better preoperative preparation of the surgical site, sound infection control practice while performing operations, and strict adherence to prophylaxis antibiotic therapy. New areas that have the potential to even further reduce the incidence of SSIs include glucose-level control, increased oxygen delivery, and maintenance of normothermia. Continuous research in understanding the biology of SSIs and strict adherence to the application of evidence-based proven methods to reduce SSIs is instrumental to further reduce the health and financial consequences associated with SSIs.

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