The American Society of Colon and Rectal Surgeons Clinical Practice Guidelines for Preventing Surgical Site Infection

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The American Society of Colon and Rectal Surgeons (ASCRS) is dedicated to ensuring high-quality patient care by advancing the science, prevention, and management of disorders and diseases of the colon, rectum, and anus. The Clinical Practice Guidelines (CPG) Committee is composed of society members who have been chosen because they have demonstrated expertise in the specialty of colon and rectal surgery. This committee was created to lead international efforts in defining quality care for conditions related to the colon, rectum, and anus and develop CPG based on the best available evidence. Although not proscriptive, these guidelines provide information on which decisions can be made and do not dictate a specific form of treatment. These guidelines are intended for the use of all practitioners, health care workers, and patients who desire information about the management of the conditions addressed by the topics covered in these guidelines. These guidelines should not be deemed inclusive of all proper methods of care nor exclusive of methods of care reasonably directed toward obtaining the same results. The ultimate judgment regarding the propriety of any specific procedure must be made by the physician in light of all the circumstances presented by the individual patient.

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STATEMENT OF THE PROBLEM

A surgical site infection (SSI) is defined as an infection of the incision (superficial SSI), the tissue below the incision (deep SSI), or within the abdominal cavity (organ space SSI). SSI accounts for more than 20% of all health care–associated infections and is the most common infection after surgery, affecting an estimated 300,000 patients annually.[1,2] Compared with other surgical subspecialties, patients undergoing colorectal surgery are at the highest risk for developing an SSI with an estimated incidence of 5% to 30%.[3,4] Patients undergoing emergency colorectal surgery with colon perforation have an SSI incidence as high as 80%.[5]

SSIs often have profound clinical and financial implications and are associated with significantly increased lengths of hospital stay and rates of unplanned reoperations.[6,7] An American College of Surgeons National Surgical Quality Improvement Program (NSQIP) study of nearly 500,000 patients reported that SSI was the most common cause of 30-day unplanned hospital readmissions.[8] Not surprisingly, SSI development is associated

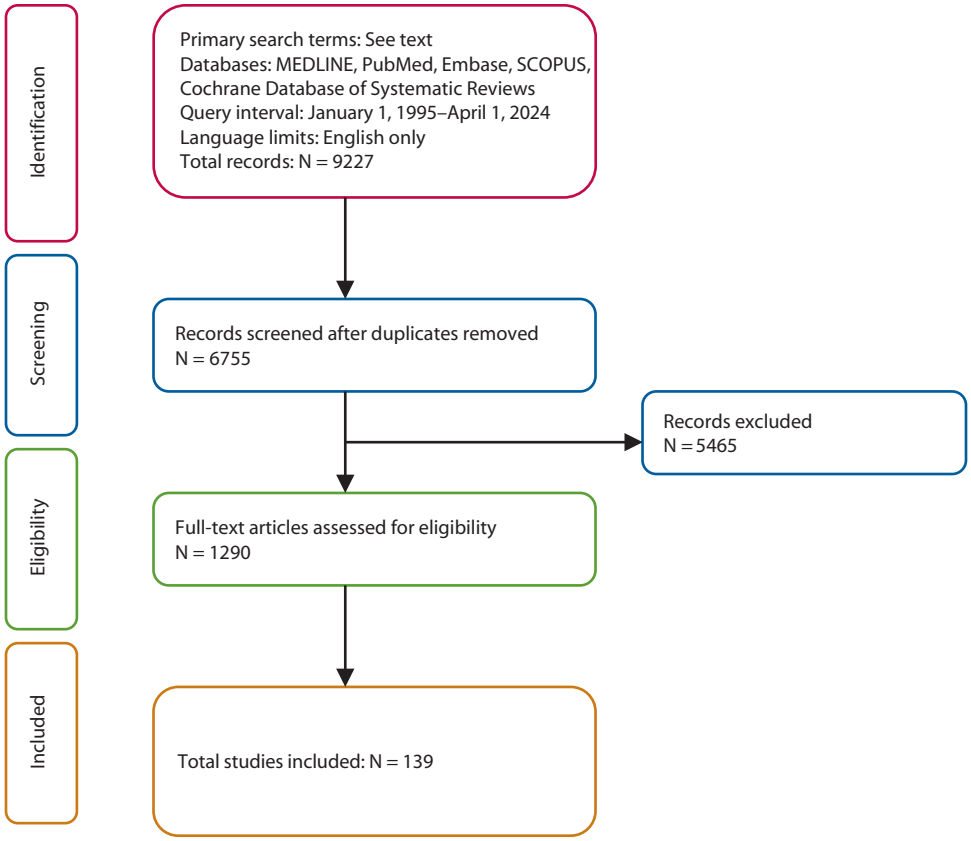

FIGURE 1. PRISMA literature search flow chart. PRISMA = Preferred Reporting Item for Systematic Reviews and Meta-Analysis.

with increased patient anxiety, worse patient-reported outcomes, and increased risk of having a subsequent SSI after unrelated reoperations.[9–11]

SSI prevention measures include institutional order sets that bundle multiple processes to help prevent SSI, preoperative optimization of high-risk patients, and perioperative interventions to reduce bacterial load and prevent contamination. The purpose of this CPG is to summarize the evidence regarding SSI prevention in the practice of colorectal surgery.

METHODOLOGY

This guideline is the first ASCRS CPG to address SSI prevention in depth and is not an update of a previously published CPG. An organized search of MEDLINE, PubMed, Embase, Scopus, and the Cochrane Database of Systematic Reviews limited to the English language was performed for relevant articles published between January 1, 1995, and February 1, 2024. The key word combinations included "surgical site infection," "SSI," "oral antibiotics," "intravenous antibiotics," "parental antibiotics," "topical antibiotics," "bowel prep," "chlorhexidine," "smoking," "hair clipping," "penicillin," "hyperglycemia," "normothermia," "high-fractionated oxygen," "FIO_2," "wound protector" "negative pressure wound therapy," "NPWT," "silver dressing," "antimicrobial dressing," "colorectal," and "abdominal." Directed searches using embedded references from primary articles were performed in selected circumstances.

A total of 9227 manuscripts were identified, and after the removal of duplicate references, a total of 6755 unique article titles were identified. A total of 1290 titles were selected for manuscript review with an emphasis placed on prospective trials, meta-analyses, systematic reviews, and practice guidelines. Peer-reviewed observational studies and retrospective studies were included when higher-quality evidence was insufficient. A final list of 139 sources was evaluated for methodologic quality, the evidence base was analyzed, and a treatment guideline was formulated by the subcommittee for this guideline (Fig. 1).

CERTAINTY OF EVIDENCE

The final grade of recommendation and level of evidence for each statement were determined using the Grades of Recommendation, Assessment, Development, and Evaluation (GRADE) system. The certainty of evidence reflects the extent of our confidence in the estimates of effect. Evidence from randomized controlled trials (RCTs) starts with high certainty, and evidence derived

from observational studies starts with low certainty. The evidence is graded for each outcome as high, moderate, low, or very low (Table 1). The evidence can be rated for risk of bias, inconsistency, indirectness, imprecision, and publication bias. The certainty of evidence originating from observational studies can be rated up when there is a large magnitude of effect or dose–response relationship. As per GRADE methodology, recommendations are labeled as "strong" or "conditional." Current recommendations are stated in Table 2. When agreement regarding the evidence base or treatment guidelines was incomplete, consensus from the committee chair, vice chair, and 2 assigned reviewers determined the outcome. Recommendations formulated by the subcommittee were reviewed by the entire CPG Committee. The submission was then approved by the ASCRS Executive Council and peer-reviewed in *Diseases of the Colon & Rectum*. Each ASCRS CPG is updated approximately every 5 years. No funding was received to prepare this guideline, and the authors have declared no competing interests related to this material. This guideline conforms to the Appraisal of Guidelines for Research and Evaluation checklist.

RECOMMENDATIONS

Institutional Interventions

1. **Implementing an SSI bundle for patients undergoing colorectal surgery can decrease the incidence of SSI. Strength of recommendation: strong based on moderate-quality evidence.**

Many institutions have implemented care bundles to standardize interventions thought to decrease SSI rates. Notably, the elements included in care bundles tend to be institution specific. Most of the literature to date describe bundles as effective in reducing SSIs. A 2013 retrospective study using NSQIP data evaluated SSI rates before and after implementing a bundle in patients undergoing colorectal surgery and found that implementing a bundle significantly decreased overall and superficial SSI rates from 9.8% to 4.0% and 5.1% to 1.5% ($p = 0.01$), respectively; no difference was observed in organ space infection (5.1%–2.6%; $p = 1.0$).[12] A 2014 single-institution retrospective study of colorectal surgery patients examined SSI rates before (n = 346 patients) and after (n = 213 patients) implementation of an SSI bundle and found that superficial SSI rates decreased from 19.3% to 5.7% ($p < 0.001$) after bundle implementation; no significant difference was observed in deep or organ space infections.[13] An RCT published in 2018 randomly assigned 198 patients undergoing laparoscopic colorectal cancer surgery to either a standard bundle alone or the standard bundle with the addition of antibiotic-containing intraperitoneal irrigation, fascial closure with triclosan-coated sutures, and mupirocin ointment over the skin staples. In this study, patients treated with the augmented bundle had a significantly decreased overall SSI rate (16%–4%; $p = 0.007$) and organ space SSI rate (2%–0%; $p = 0.039$).[14]

Bundles have also been shown to be beneficial during emergency colorectal surgery.[14] A 2015 prospective observational trial compared superficial SSI rates before (n = 47) and after (n = 25) implementation of a bundle when caring for patients undergoing emergency colorectal operations requiring stoma in the setting of a perforation. They reported that an SSI bundle significantly decreased the incidence of SSI (43%–20%; $p = 0.049$).[15] The impact of SSI bundles may be augmented by the simultaneous implementation of an enhanced recovery protocol (ERP). In 2015, a single-institution retrospective study investigated SSI rates before implementing an ERP and SSI bundle (control group, n = 337), +ERP/pre-SSI bundle (n = 165), and +ERP/+SSI bundle (n = 285). There was no difference in the overall SSI incidence between the control group and the +ERP/pre-SSI bundle group, but there were statistically significant decreased rates of superficial SSI (16.1% vs 6.3%; $p < 0.01$) and postoperative sepsis

TABLE 1. Interpretation of strong and conditional recommendations using the GRADE approach

Evaluation	*Description*
Recommendation	
Strong	Most individuals should receive the intervention. Formal decision aids are not likely to be needed to help individuals make decisions consistent with their values and preferences
Conditional	Different choices will be appropriate for individual patients consistent with their values and preferences. Use shared decision-making. Decision aids may be useful in helping patients make decisions consistent with their individual risks, values, and preferences
GRADE certainty rankings	
High	The authors are confident that the true effect is similar to the estimated effect
Moderate	The authors believe that the true effect is probably close to the estimated effect
Low	The true effect might be markedly different from the estimated effect
Very low	The true effect is probably markedly different from the estimated effect

GRADE = Grading of Recommendations, Assessments, Development, and Evaluation.

TABLE 2. Summary and strength of GRADE recommendations for preventing SSIs

	Summary	*Recommendation strength*	*GRADE quality of evidence*
1	Implementing an SSI bundle for patients undergoing colorectal surgery can decrease the incidence of SSI	Strong	Moderate
2	Oral antibiotics in combination with mechanical bowel preparation have been shown to decrease the incidence of SSI after elective colorectal resection	Strong	Moderate
3	In circumstances where a mechanical bowel preparation is contraindicated or otherwise omitted, preoperative oral antibiotic preparation alone can reduce the incidence of SSI	Conditional	Moderate
4	Showering with chlorhexidine before colorectal surgery does not significantly impact SSI rates	Strong	Moderate
5	Smoking cessation before surgery may be recommended to reduce the risk of SSI	Conditional	Moderate
6	On the day of colorectal surgery, patients should have their hair removed from the surgical site using a clipper or not removed at all. Shaving with a razor before surgery is discouraged	Strong	Moderate
7	Patients undergoing colorectal resection should have parenteral antibiotics administered within 60 min of incision. Dosing and redosing should be based on the pharmacokinetic profile of the antibiotic	Strong	Low
8	Patients who report a penicillin allergy may be evaluated for having true hypersensitivity and high-risk reactions to penicillin. Delabeling a penicillin-allergic patient can facilitate the appropriate use of a preoperative prophylactic beta-lactam antibiotic and improve outcomes	Conditional	Low
9	For most clean and clean-contaminated cases, prophylactic parenteral antibiotics should be limited to the initial 24 h postoperatively	Strong	Moderate
10	Cleansing the surgical site with chlorhexidine–alcohol-based preparation is typically recommended for patients undergoing colorectal surgery	Strong	Moderate
11	Hyperglycemia on the day of surgery and in the immediate postoperative period may increase the risk of SSI after elective colorectal resection	Conditional	Moderate
12	Maintaining intraoperative normothermia may decrease the incidence of SSI in patients undergoing colorectal surgery	Conditional	Low
13	High-fractionated oxygen is not routinely recommended to prevent SSI	Conditional	Moderate
14	Wound protectors can decrease the incidence of SSI after colorectal surgery	Strong	High
15	Minimally invasive colorectal surgery can decrease the incidence of SSI compared to open surgery	Strong	High
16	Topical antimicrobial agents applied to the surgical incision are not recommended	Strong	Low
17	NPWT for primarily closed incisions may decrease the incidence of SSI	Conditional	Moderate
18	Advanced silver or antimicrobial dressings are not routinely recommended for clean or clean-contaminated wounds after colorectal surgery	Conditional	Moderate

GRADE = Grading of Recommendations, Assessments, Development, and Evaluation; NPWT = Negative pressure wound therapy; SSI = surgical site infection.

(11.2% vs 1.8%; $p < 0.01$) between the +ERP/pre-SSI group and the +ERP/+SSI group, respectively.[16] In a subsequent 2018 Canadian study evaluating a control group before implementing an SSI bundle and ERP and the sequential impact of using an SSI bundle pre-ERP and of using both an SSI bundle and an ERP, overall SSI rates were found to be 16%, 9.5%, and 5%, respectively ($p = 0.01$). When comparing the control group and the +SSI bundle/ERP cohorts, the rate of overall wound complications significantly decreased (14.7%–6.5%; $p = 0.049$) and the rate of superficial site infection significantly decreased (8.2%–1.8%; $p = 0.047$); a statistically significant decrease in organ space infection was not observed (7.3%–4.7%; $p = 0.4$).[17]

Variable compliance across the different interventions comprising an SSI prevention bundle and the number of elements included in a particular bundle influence the overall impact of a bundle. In a large multicenter Michigan Surgical Quality Collaborative (MSQC) cohort study of 3387 patients, who underwent elective colon surgery, high compliance (eg, delivering 3–6 elements of the bundle) compared with low compliance (delivering only 1–2 elements) resulted in a significant reduction in SSI rate (16% vs 8%; $p < 0.01$).[18] In another statewide review, the Illinois Surgical Quality Improvement Collaborative, 19.5% of surgeons were compliant with at least 75% of colorectal SSI prevention bundle elements, and after embarking on a campaign to boost adoption, 49.8% of surgeons met this benchmark ($p = 0.001$).[19] In this study, enhanced protocol utilization resulted in a significant reduction in the superficial SSI rate (4.6%–1.5%; $p < 0.001$) when the lowest adherence quintile (<44.4% compliant) was compared with the highest quintile (81.4%–100%).

Finally, a 2020 systematic review and meta-analysis including 40 studies investigating patients undergoing colorectal surgery (88% were single-institution reviews with bundles ranging from 2 to 13 elements) found that bundles with greater numbers of components were associated with more significant reductions in overall SSI rates (59% reduction with 11 or more components). In this study, utilization of an SSI bundle was associated with a decreased rate of superficial, deep, and organ space infection (pooled SSI relative risk [RR] 0.56, 95% CI, 0.42–0.75;

0.67, 95% CI, 0.46–0.98; 0.63, 95% CI, 0.5–0.81, respectively).[20] Given the variability of interventions within an SSI reduction bundle, some have tried to investigate whether certain elements are more beneficial than others. A 2017 meta-analysis including 17,557 patients documented a 40% risk reduction in SSI ($p < 0.001$) and that the rate of superficial SSI was reduced by 44% ($p < 0.001$) and that of organ/space SSI was reduced by 34% ($p = 0.048$).[21] In addition, bundles that included sterile closure trays (58.6% vs 33.1%; $p = 0.019$), mechanical bowel preparation (MBP) with oral antibiotics (55.4% vs 31.8%; $p = 0.015$), and preclosure glove changes (56.9% vs 28.5%; $p = 0.002$) resulted in the greatest SSI risk reduction. A single-institution RCT comparing patients to a standard SSI bundle (n = 104) compared to an extended SSI bundle (n = 106) found that the extended bundle that contained oral mechanical and antibiotic bowel preparation, pre- and intraoperative warming, supplemental oxygen intra- and postoperatively, intraoperative fluid restriction, and use of a surgical wound protector decreased the overall SSI rate (24% vs 19%; $p = 0.003$) and superficial SSI rate (45% vs 36%; $p = 0.004$) compared with bundles without those elements.[22]

Preoperative Interventions

2. Oral antibiotics in combination with MBP have been shown to decrease the incidence of SSI after elective colorectal resection. Strength of recommendation: strong based on moderate-quality evidence.

MBP alone has been studied extensively and is not associated with SSI reduction. A 2011 Cochrane Review of 18 RCTs, including 5805 patients randomly assigned to MBP versus no bowel preparation (NBP), concluded that MBP alone does not decrease the incidence of SSI after elective colorectal surgery.[23] A 2018 meta-analysis of 23 RCTs and 13 observational studies compared MBP to NBP and showed no significant difference in SSI rates (OR 0.99; 95% CI, 0.8–1.24).[24] Similarly, another 2022 meta-analysis of 10 RCTs concluded that MBP did not reduce the incidence of SSI (OR 0.95; 95% CI, 0.74–1.22) or anastomotic leak (OR 1.08; 95% CI, 0.74–1.59) compared to NBP.[25] Conversely, the addition of nonabsorbable oral antibiotics to an MBP is associated with a significantly decreased incidence of SSI. The benefit of combining oral antibiotics with MBP was first demonstrated in 1977 by Clarke et al,[26] who randomly assigned 116 patients to MBP with or without oral antibiotics and reported a significant decrease in the SSI rate in the antibiotic cohort (35% vs 9%; $p < 0.05$). Similarly, in an RCT including 335 patients with Crohn's disease, a significantly lower incidence of SSI was identified in patients with a combined oral antibiotic and MBP preparation compared to patients who received an MBP alone (7.4% vs 16.6%; $p = 0.01$).[27] A recent RCT showed similar findings when 565 patients undergoing rectal resection were randomly assigned to the MBP plus antibiotics group or MBP plus placebo group.[28] MBP plus antibiotics were associated with a significantly lower risk of overall SSI compared to the MBP plus placebo cohort (OR 0.45; 95% CI, 0.27–0.77). Other studies evaluated MBP with oral antibiotic preparation compared with MBP with no antibiotics. A 2012 retrospective study from the Veterans Affairs Surgical Quality Improvement Program analyzed prescription data regarding 9940 patients who underwent elective colorectal resection from 2005 to 2009 and found that a combined preparation reduced the incidence of overall SSI compared to NBP (OR 0.43; 95% CI, 0.34–0.55).[29] Similarly, a retrospective study using the MSQC found a significant reduction in superficial, organ space, and overall SSI with the use of combined preparation compared to NBP (superficial SSI: 3.0% vs 6.0%, $p = 0.001$; organ/space SSI: 1.6% vs 3.1%, $p = 0.024$; overall SSI: 5.0% vs 9.7%, $p = 0.0001$).[30] A meta-analysis of retrospective studies using NSQIP data (n = 40,446 in the largest cohort) demonstrated that combined bowel preparation is superior to either MBP alone or NBP (6.5% vs 11.6% vs 14.4%; $p < 0.001$).[31]

3. In circumstances where an MBP is contraindicated or otherwise omitted, preoperative oral antibiotic preparation alone can reduce the incidence of SSI. Strength of recommendation: conditional based on moderate-quality evidence.

A 2019 meta-analysis that combined Veterans Affairs Surgical Quality Improvement Program and NSQIP cohorts (n = 16,390) described a significant reduction in the overall incidence of SSI (RR 0.56; 95% CI, 0.38–0.83) with oral antibiotics (OAB) alone compared with NBP.[32] In contrast, a 2018 meta-analysis of RCTs found no difference in overall SSI (OR 0.62; 95% CI, 0.34–1.14) or incisional SSI (OR 0.79; 95% CI, 0.41–1.53), but it did report less organ space SSI with OAB compared to NBP (OR 0.34; 95% CI, 0.22–0.52).[33] Similarly, a retrospective before–after study of 1410 patients described that those undergoing elective colorectal resection after implementation of OAB in 2013 had a decreased incidence of deep SSI (RR 0.58; 95% CI, 0.40–0.79).[34] Several other meta-analyses have demonstrated decreased SSI rates with OAB alone compared to NBP.[35,36] There have been few RCTs that directly compare OAB alone to NBP. In an RCT of 200 patients with ulcerative colitis scheduled to undergo restorative proctocolectomy, oral antibiotics significantly decreased the incidence of SSI compared to no preparation (6.1% vs 22.4%; $p = 0.0024$).[37] Similarly, in the multicenter, single-blinded ORALEV trial, 565 patients were randomly assigned to receive either oral ciprofloxacin and metronidazole on the day before surgery or no preparation. The control group had significantly more SSIs (11% vs 5%; $p = 0.013$) and overall complications (28% vs 19%; $p = 0.017$) than those who received OAB.[36]

4. Showering with chlorhexidine before colorectal surgery does not significantly impact SSI rates. Strength of recommendation: strong based on moderate-quality evidence.

Showering with an antiseptic before surgery to decrease skin bacteria has long been postulated to prevent postoperative SSI; however, research does not support that an antiseptic wash with chlorhexidine gluconate (CHG) affects the SSI rate. Although the majority of the RCTs evaluating the utility of a chlorhexidine wash were conducted before adopting Surgical Care Improvement Project recommendations for perioperative intravenous antibiotics,[38] a meta-analyses of these data sets have shown that CHG offers no benefit over plain soap.[39–41] An updated 2015 Cochrane review, including 7 trials and more than 10,000 patients undergoing a wide range of surgical procedures, compared preoperative CHG bath with placebo and bar soap.[41] In this study, a CHG wash did not significantly decrease the SSI rate compared to placebo (RR 0.91; 95% CI, 0.80–1.04) or compared to bar soap (RR 1.02; 95% CI, 0.57–1.84). The Guidelines Development Group for the World Health Organization conducted an independent systematic review of 7 RCTs and 2 observational studies in patients undergoing abdominal, vascular, and gynecological surgery and found no significant reduction in SSIs with CHG versus plain soap (OR 0.92; 95% CI, 0.80–1.04). The Guidelines Development Group also expressed concern for patients having rare contact dermatitis and hypersensitivity reactions with the use of CHG, but they recognized that this is a potential risk of any topical soap.[42]

5. Smoking cessation before surgery may be recommended to reduce the risk of SSI. Strength of recommendation: conditional based on moderate-quality evidence.

Smoking is a significant modifiable risk factor for SSI after abdominal surgery. A retrospective NSQIP study of 72,519 laparoscopic colectomy patients from 2011 through 2017 found that smoking was a significant risk factor for superficial SSI (OR 1.29; 95% CI, 1.16–1.44).[43] Another NSQIP study of 381 patients who underwent ileal pouch excision from 2005 to 2015 found that smoking was an independent risk factor for overall SSI.[44] In a meta-analysis of 140 cohort studies and 479,150 patients undergoing a variety of surgical procedures, current smokers had a significantly increased incidence of overall SSI compared with patients who never smoked (OR 1.79; 95% CI, 1.54–2.04).[45]

Preoperative smoking cessation has been shown to decrease the incidence of SSI. In an RCT, 48 smokers were randomly assigned to continue smoking (20 cigarettes per day), smoke abstinence with a nicotine patch, or smoke abstinence with a placebo patch. Incisional wounds lateral to the sacrum were created via punch biopsy at 1, 4, 8, and 12 weeks after randomization. They found that after 4 weeks, subjects in the abstinence cohort had a lower incidence of SSI compared to the continuous smoker cohort (5.6% vs 33%; $p < 0.05$). There was no difference in the incidence of SSI between participants with transdermal nicotine patches versus abstinence with placebo (data not shown).[46] In a meta-analysis of 4 RCTs and 416 patients undergoing a variety of surgical procedures, smoking cessation significantly decreased the overall incidence of SSI (OR 0.40; 95% CI, 0.20–0.83).[45]

Intraoperative Interventions

6. On the day of colorectal surgery, patients should have their hair removed from the surgical site using a clipper or not removed at all. Shaving with a razor before surgery is discouraged. Strength of recommendation: strong based on moderate-quality evidence.

Surgical site hair removal has traditionally been part of the routine preoperative preparation of patients undergoing colorectal surgery. Hair removal may be necessary to facilitate preoperative skin marking, adequate exposure, and application of wound dressings and stoma appliances. In 2021, the Cochrane Review published their second update of a review first published in 2006 and then updated in 2011 on the routine use of preoperative hair removal.[47] This most recent review included 19 RCTs and 8919 patients undergoing various surgical procedures. They found that hair removal with clippers compared to no hair removal did not reduce overall SSI incidence (RR 0.95; 95% CI, 0.65–1.39). Alternatively, hair removal with a razor increased the risk of overall SSI compared to no shaving (RR 1.82; 95% CI, 1.05–3.14) and compared to hair removal with clipping (RR 1.64; 95% CI, 1.16–2.33).

7. Patients undergoing colorectal resection should have parenteral antibiotics administered within 60 minutes of incision. Dosing and redosing should be based on the pharmacokinetic profile of the antibiotic. Strength of recommendation: strong based on low-quality evidence.

Although the recognition that parenteral antibiotics that cover both anaerobes and aerobes effectively reduce SSI rates has been acknowledged for decades,[48–51] the timing of antibiotic administration relative to incision has proven more controversial.[49,52] An RCT published in 1992, including 2847 patients undergoing various clean or clean-contaminated cases, was one of the earliest trials to demonstrate a reduction in the SSI rate when antibiotic prophylaxis was administered within 120 minutes before incision.[52] Since then, many studies have evaluated the impact of timing on surgical antimicrobial prophylaxis (SAP) with varying results. The overarching goal of antibiotic administration timing is to ensure that the appropriate and effective bactericidal concentration is established in the serum and tissues at the time of initial surgical incision.[53–55] The literature relevant to this topic is difficult to

evaluate and compare because of the heterogeneity in the surgical case mix, antimicrobial choices, and individual pharmacokinetics.

The majority of existing guidelines and literature support dosing within 60 to 120 minutes before incision.[50,53,54] Several studies have demonstrated mixed results regarding whether a tighter window (within 30 minutes) of administration relative to incision would be beneficial.[56–59] A retrospective study (n = 605) found that patients having a colorectal resection had higher rates of SSI when antibiotics were given within 30 minutes of incision compared to those in which the antibiotics were given for >30 minutes (OR 1.73; 95% CI, 1.15–2.6).[57] One of the largest meta-analyses evaluating the timing of preoperative SAP and SSI evaluated 14 studies, including 54,552 patients undergoing various general surgery procedures, and found no significant difference when SAP was administered 60 to 120 minutes before incision compared to 0 to 59 minutes (OR 1.22; 95% CI, 0.92–1.61). However, the risk was 5 times higher when administered >120 minutes before incision compared to when administered within 120 minutes (OR 5.26; 95% CI, 3.29–8.39).[60] In a study of 32,459 colorectal, vascular, and orthopedic operations within the Veterans Affairs hospital, SAP was evaluated for timing and then adjusted for patient, procedure, and antibiotic variables. This study observed no significant association between prophylactic antibiotic timing and SSI.[61] In 104 patients undergoing colorectal procedures, the incidence of SSI was significantly higher when SAP was not administered within 1 hour of incision (22% vs 3.5%; $p = 0.005$).[62]

Longer duration of surgery has been shown to be an independent risk factor for SSI,[63–65] and several studies suggest that antimicrobial redosing should be considered when the duration of the procedure exceeds 2 half-lives of the antimicrobial agent (eg, >4 hours for cefazolin) or if there is excessive blood loss (>1500 mL).[58,66–68] SAP redosing has been associated with a significant reduction in SSI incidence in a cohort of more than 9000 patients.[69] In this retrospective study of patients undergoing surgery for >240 minutes, antibiotic redosing significantly reduced the overall SSI incidence irrespective of the exact timing of the redosing (OR 0.60; 95% CI, 0.37–0.96).[69]

8. Patients who report a penicillin allergy (PA) may be evaluated for having true hypersensitivity and high-risk reactions to penicillin. Delabeling a penicillin-allergic patient can facilitate the appropriate use of a preoperative prophylactic beta-lactam antibiotic and improve outcomes. Strength of recommendation: conditional based on low-quality evidence.

It is estimated that 8% to 25% of individuals worldwide are labeled as having a PA.[70] Most of these labels are placed in childhood and are unrelated to actual allergic events. For example, in a study of 1046 patients with a reported beta-lactam allergy who received a test dose of beta-lactam, only 40 patients (3.8%) experienced a confirmed beta-lactam hypersensitivity, of which only 3 had a severe adverse reaction.[70,71] Highlighting the tolerance of beta-lactam administration in surgical patients labeled with a PA, 690 patients who underwent various surgical procedures with a reported PA were evaluated for allergy after receiving prophylactic antibiotics preoperatively. In this study, probable hypersensitivity reactions occurred in 3 patients (0.9%) in the cefazolin group, 4 (1.4%) in the clindamycin group, and 1 (1.1%) in the vancomycin group.[72]

A classification of PA may lead to the use of less effective and broader-spectrum antimicrobials for surgical prophylaxis.[73] In a retrospective study that reviewed 8385 surgical patients, 922 patients (11%) reported a PA. On multivariate logistic regression, patients reporting a PA had an increased risk of SSI (OR 1.51; 95% CI, 1.02–2.22). PA reporters were administered less cefazolin (12% vs 92%; $p < 0.001$) and more clindamycin (49% vs 3%; $p < 0.001$), vancomycin (35% vs 3%; $p < 0.001$), and gentamicin (24% vs 3%; $p < 0.001$) compared with those without a reported PA.[74] Similarly, in a retrospective study analyzing 39,972 noncolorectal procedures (eg, coronary artery bypass, craniotomy, spinal fusion, laminectomy, hip arthroplasty, knee arthroplasty), patients with a reported PA allergy were more likely to develop an SSI compared to patients who did not report an allergy to penicillin or cephalosporin (OR 3.26; 95% CI, 2.71–3.93).[75] These findings underscore the importance of delabeling patients who do not have a true allergy to penicillin.[76]

9. For most clean and clean-contaminated cases, prophylactic parenteral antibiotics should be limited to the initial 24 hours postoperatively. Strength of recommendation: strong based on moderate-quality evidence.

The duration of postoperative SAP to prevent SSI has been extensively studied. A meta-analysis evaluating 34 studies (n = 5123) demonstrated no difference in SSI comparing "short duration" of SAP (24 hours) versus "longer duration" (>24 hours) in patients undergoing colorectal surgery (RR 1.10; 95% CI, 0.93–1.29).[50] The same analysis evaluated 11 studies (n = 2005) examining a single dose (SD) of SAP versus multiple doses and found no difference in the SSI rate (OR 1.21; 95% CI, 0.82–1.8).[50] In an RCT comparing an SD of SAP (n = 48) versus 3 doses (n = 45) in patients undergoing elective colorectal surgery, it found that overall SSI rates (6.3% vs 4.4%; $p = 0.59$) and organ/space SSIs were similar between the 2 groups (2 patients in the SD group and 3 patients in the 3-dose group; $p = 0.593$).[77] Another retrospective study evaluating 90,725 patients who underwent open colectomy found an overall SSI prevalence of 5.2%. Patients were given antibiotic prophylaxis for <24 hours (51.6%), 24 to 48 hours (28.5%), and >48 hours (19.9%); there was no difference in SSI rate related to the duration of SAP.[78] In contrast, an RCT randomly assigned 384 patients undergoing colorectal surgery to

either SD (n = 190) or 3 doses of cefmetazole (n = 187) and found that the incidence of incisional SSI was higher in the SD group than in the 3-dose group (14.2% vs 4.3%, $p = 0.009$). The incidence of organ/deep space SSI did not significantly differ between the 2 groups. On multivariable analysis, antibiotic dose was the only significant factor related to the incidence of incisional SSI.[79]

10. Cleansing the surgical site with chlorhexidine–alcohol-based preparation is typically recommended for patients undergoing colorectal surgery. Strength of recommendation: strong based on moderate-quality evidence.

Multiple solutions are available to cleanse the surgical site before incision. In a retrospective study of 500 patients undergoing a laparotomy, chlorhexidine with isopropanol was associated with a decreased incidence of overall SSI compared to isopropanol alone (6.6% vs 12.3%; $p = 0.038$).[80] In a 2010 RCT, patients undergoing clean-contaminated surgery were randomly assigned to the chlorhexidine–alcohol group (n = 409) or the povidone–iodine group (n = 440). In this study, the overall incidence of SSI was significantly lower in the chlorhexidine–alcohol group than in the povidone–iodine group (9.5% vs 16.1%; $p = 0.004$; RR 0.59; 95% CI, 0.41–0.85).[81] Other RCTs investigating a variety of surgical procedures have also shown a significant benefit in using chlorhexidine–alcohol-based solutions compared to aqueous povidone–iodine for the reduction of SSI rates.[81–86] In contrast, SKINFECT, a cluster-randomized crossover trial in which 3665 patients were randomly assigned (n = 656 colorectal surgery patients) to receive chlorhexidine–alcohol (n = 1835) or iodine–alcohol skin antiseptic (n = 1830), showed differing results. The overall incidence of SSI was 3.8% in the chlorhexidine–alcohol group and 4.0% in the iodine–alcohol group.[87]

11. Hyperglycemia on the day of surgery and in the immediate postoperative period may increase the risk of SSI after elective colorectal resection. Strength of recommendation: conditional based on moderate-quality evidence.

In a multicenter retrospective study of patients with and without diabetes who underwent colorectal surgery (n = 6273) or bariatric surgery (n = 5360), hyperglycemia (>180 mg/dL) on postoperative day 0, 1, or 2 was independently associated with an increased risk of overall SSI (OR 2.0; 95% CI, 1.63–2.44), reoperative intervention (OR 1.8; 95% CI, 1.41–2.3), anastomotic failure (OR 2.43; 95% CI, 1.38–4.28), and mortality (OR 2.71; 95% CI, 1.72–4.28).[88] In colorectal surgery patients specifically, hyperglycemia was associated with in-hospital mortality (3.1% vs 1.0%, $p < 0.001$), reoperative intervention (5.9% vs 4.3%, $p < 0.001$), and composite infections (14.8% vs 9.6%, $p < 0.001$) compared with normoglycemia.

Another retrospective review of 2447 patients with no diabetes who underwent elective colorectal surgery reported a significant increase in superficial and deep SSI among patients who had hyperglycemia within 48 hours of their operation.[89] A retrospective review of 4073 patients with no diabetes who underwent colorectal surgery from the MSQC database identified a blood glucose of >180 mg/dL as an independent risk factor for superficial SSI (OR 1.53, $p = 0.03$), sepsis (OR 1.61, $p < 0.01$), and mortality (OR 2.26, $p < 0.01$).[90] Alternatively, in patients with diabetes, high blood glucose was not associated with an increased incidence of superficial SSI (OR 1.35, $p = 0.39$). In a prospective cohort study of 484 patients who underwent open abdominal surgery (two-thirds of which were clean-contaminated and one-third contaminated), hyperglycemia (≥200 mg/dL) at the end of surgery (OR 1.56; 95% CI, 1.01–2.42) and 12 hours after surgery (OR 2.17; 95% CI, 1.43–3.29) was independently associated with having an SSI.[91] Two studies observed a dose–response effect; as blood glucose levels increased, the risk of SSI also increased.[88,91]

12. Maintaining intraoperative normothermia may decrease the incidence of SSI in patients undergoing colorectal surgery. Strength of recommendation: conditional based on low-quality evidence.

Hypothermia is defined as a core body temperature of ≤36.4°C.[92] In 1996, an RCT demonstrated that maintaining normothermia during open colorectal surgery (n = 200) was associated with a significant reduction in overall SSI rate compared with permitting hypothermia (6% vs 19%, $p = 0.009$).[93] The length of stay was also decreased in the normothermia group (11.8 vs 13.5 days, $p = 0.01$). In 2007, a similar RCT of 103 patients (71 with colorectal cancer, 15 with IBD, and 7 with diverticular disease), comparing warming only during surgery versus warming during surgery plus 2 hours before and after surgery, found that the extended warming resulted in fewer postoperative complications (32% vs 54%, $p = 0.027$) and SSIs (13% vs 27%; p value not provided).[94] In a 2012 retrospective review of 524 patients who underwent trauma laparotomy, an intraoperative core body temperature of <35°C was independently associated with an increased risk of overall SSI, and incremental decreases in intraoperative temperature were associated with incremental increases in the risk of SSI.[95]

Meanwhile, other reports have not supported an independent association between hypothermia and SSI. A 2013 single-center retrospective study of 1008 patients who underwent colorectal surgery (7% emergent, 72% open) that analyzed ACS-NSQIP data reported that maximum, minimum, ending, and median body temperatures were similar for those with and without SSI.[96] Similarly, another large, multicenter retrospective review of 2040 patients who underwent colorectal operations reported a lack of association between body temperature and SSI.[97] Despite the conflicting data, in 2016, the American

College of Surgeons and the Surgical Infection Society recommended intraoperative maintenance of normothermia to reduce the risk of SSI.[98]

13. High-fractionated oxygen (FiO_2) is not routinely recommended to prevent SSI. Strength of recommendation: conditional based on moderate-quality evidence.

Hypoxia can slow the healing of surgical incisions and can increase the risk of SSI.[99] The utility of high-fractionated oxygen in the perioperative period to mitigate the risk of an SSI is controversial. Meta-analyses regarding perioperative hyperoxygenation should be viewed with caution because of the significant heterogeneity in the RCTs evaluating perioperative hyperoxygenation (variability in the use of prophylactic antibiotics, the definition of SSI, fluid management strategy, postoperative oxygen supplementation, patient population, use of nitrous oxide or neuraxial anesthesia, and the operations performed). A 2007 meta-analysis of 4 RCTs comparing colorectal surgery patients who received supplemental oxygen (n = 477) compared to those who did not (n = 466) showed that the perioperative use of high-fractionated oxygen decreased the incidence of SSI (RR 0.68; 95% CI, 0.49–0.94).[100] Another meta-analysis published 2 years later also reported a significant reduction in SSI rates associated with the administration of supplemental oxygen.[101] A double-blinded case-controlled study of 80 patients undergoing emergency colorectal surgery compared hyperoxygenation after induction (80% oxygen) to control (30% oxygen), finding that hyperoxygenation decreases overall SSI (5% vs 15%, $p < 0.05$).[102]

However, more recent RCTs have not found a significant SSI benefit associated with high FiO_2. The PROXI trial evaluated the effect of 80% oxygen during surgery on the 14-day SSI rate and randomly assigned 1400 patients undergoing laparotomy and found no difference in SSI rates or secondary outcomes, such as atelectasis or pneumonia. In this study, the 0.80 FiO_2 group had increased respiratory failure and mortality rates, but these comparisons did not meet significance.[103] In the iPROVE-O2 multicenter RCT, 740 patients undergoing abdominal surgery were randomly assigned to receive high (0.8) or conventional (0.3) FiO_2 during the intraoperative period and during the first 3 postoperative hours. Results demonstrated no difference in overall SSI rates between the 2 cohorts (RR 0.94; 95% CI, 0.59–1.5).[104] Similarly, another RCT on 5749 abdominal surgeries found that 30% oxygen compared to 80% oxygen did not affect a composite of deep-tissue or organ space SSI, healing-related wound complications, or mortality (RR 0.99; 95% CI, 0.85–1.14).[105] A systematic review of 11 studies and 8245 patients undergoing colorectal surgery found that 80% FiO_2 did not reduce overall SSI (RR 0.91; 95% CI, 0.74–1.13).[106] Given these mixed results, routine use of perioperative hyperoxia is not recommended.

14. Wound protectors can decrease the incidence of SSI after colorectal surgery. Strength of recommendation: strong based on high-quality evidence.

Several RCTs have investigated the use of a wound protector to prevent SSI. A 2012 meta-analysis of 6 RCTs, including 1008 patients undergoing abdominal surgery, found that the use of a wound protector was associated with a significant decrease in SSI (RR 0.55; 95% CI, 0.31–0.98).[107] A subsequent meta-analysis in 2015 of 16 RCTs, including 3695 patients undergoing a laparotomy, found that wound protectors significantly reduced the rate of SSI (RR 0.65; 95% CI, 0.51–0.83).[108] A similar finding was described in the subgroup of 1525 patients undergoing colorectal surgery (RR 0.65; 95% CI, 0.44–0.97). In a second subgroup analysis of the 2 common types of wound protectors, double-ring devices were found to exhibit a greater protective effect (RR 0.29; 95% CI, 0.15–0.55) than single-ring devices (RR 0.71; 95% CI, 0.54–0.92).[108] A more recent systematic review of 14 RCTs, including 2684 patients undergoing abdominal surgery, found significant benefits from impervious plastic wound protector use (RR 0.70; 95% CI, 0.51–0.96).[109]

15. Minimally invasive colorectal surgery can decrease the incidence of SSI compared to open surgery. Strength of recommendation: strong based on high-quality evidence.

Pooled data from 16 RCTs comprising 5797 patients (55.1% laparoscopic and 44.9% open) found that overall SSI rates were significantly lower after laparoscopic colorectal surgery compared to open surgery (RR 0.72; 95% CI, 0.60–0.88; 184 events of laparoscopic surgery vs 209 open surgery).[110] Two NSQIP studies have also reported that laparoscopy significantly reduces SSI rates after colorectal procedures. One study compared 30-day SSI rates among patients who underwent open or MIS appendectomy (n = 97,780) or colectomy (n = 118,407) using propensity score matching.[111] In this study, MIS was associated with significantly lower rates of SSI after appendectomy (7.0% vs 3.8%, $p < 0.001$) and after colectomy (15.0% vs 9.3%, $p < 0.001$) compared with open surgery. MIS had lower odds of SSI after both appendectomy (OR 0.52; 95% CI, 0.48–0.58) and colectomy (OR 0.58; 95% CI, 0.55–0.61) according to logistic regression analysis. The second NSQIP study compared SSI rates after laparoscopic (n = 3414) and open (n = 7565) colorectal surgery and found that the laparoscopic approach was associated with a significantly lower SSI rate and a lower unadjusted rate of SSI compared to the open approach (9.5% vs 16.1%, $p < 0.001$).[112] An analysis of 229,726 Medicare beneficiaries found that laparoscopy was associated with a significantly lower rate of overall SSI (OR 0.43; 95% CI, 0.41–0.46) when stratified by colorectal surgical procedures. In this study, the mean SSI rates were 4.1% (procedure-specific range, 3.9%–5.1%) for the laparoscopic approach and 7.9% (procedure-specific range, 7.4%–10.2%) for the open approach.[113]

An NSQIP study of patients who underwent robotic (n = 472) or laparoscopic (n = 8392) colorectal surgery found no significant difference in SSI rates between the 2 approaches.[114] Another NSQIP review of 11,477 colorectal patients, including 7790 laparoscopic and 299 robotic abdominal cases and 2057 laparoscopic and 331 robotic pelvic cases, found no significant difference in superficial SSI or organ/space SSI rates.[115]

Wound Care

16. Topical antimicrobial agents applied to the surgical incision are not recommended. Strength of recommendation: strong based on low-quality evidence.

There is a lack of high-quality evidence regarding the application of topical antimicrobials after the closure of incisions in colorectal surgery. An RCT in 2017 of 198 colorectal surgery patients compared a standard infection bundle to one including intraperitoneal lavage with antibiotic solution, fascial closure with triclosan-coated sutures, and use of mupirocin ointment on the skin staples after laparoscopic colorectal surgery and reported a significantly lower superficial SSI rate in the study arm (16% vs 2%, $p = 0.007$).[14] However, which specific intervention had the most impact on the SSI rate could not be determined. In another RCT that compared a standard gauze dressing (n = 75) to a 2% mupirocin ointment dressing (n = 75), no difference in SSI rate was identified (3% vs 1%, $p = 0.56$).[116]

SC placement of a gentamicin-containing collagen implant before the closure of the incision has also been evaluated as a potential technique to reduce SSI. A 2010 multicenter RCT of 602 open and laparoscopic-assisted colorectal procedures randomly assigned patients to either placement of gentamicin-containing collagen sponges above the fascia before skin closure versus no intervention and reported a higher rate of SSI in the treatment group than in the control group (30% vs 20.9%; $p = 0.01$).[117] A 2015 meta-analysis of 8 RCTs (n = 1685) regarding the use of locally applied gentamicin in the closure of incisions after colorectal surgery reported that there was no significant difference in overall SSI (RR 0.73; 95% CI, 0.47–1.12) or organ space infection (RR 0.90; 95% CI, 0.51–1.59).[118] Another randomized double-blinded 3-arm trial compared no sponge, collagen sponge, and gentamicin-containing collagen sponge in 291 patients undergoing colorectal surgery and found no significant difference in SSI rates between the groups (8.2%, 13.5%, and 11.3%, respectively, $p > 0.05$).[119]

17. Negative pressure wound therapy (NPWT) for primarily closed incisions may decrease the incidence of SSI. Strength of recommendation: conditional based on moderate-quality evidence.

NPWT can potentially improve wound healing by promoting angiogenesis and reducing edema.[120] Whether NPWT influences SSI rates remains controversial. A 2017 phase II RCT including patients undergoing surgery for GI (n = 57), pancreas (n = 73), and peritoneal surface (n = 135) malignancies showed no difference between NPWT and standard surgical dressings in terms of superficial SSI rate (12.8% vs 12.9%; $p > 0.99$) or deep SSI rate (3.0% vs 3.0%; $p > 0.99$).[121] Subsequently, in 2019, the NEPTUNE (NPWT used to decrease surgical nosocomial events in colorectal resections; n = 300) RCT also found no statistically significant difference in SSI rate between NPWT versus standard gauze dressing (32% vs 34% respectively; $p = 0.68$).[122]

Similarly, a more recent systematic review and meta-analysis, including 5 RCTs and 16 observational studies evaluating the utility of NPWT after abdominal operations, reported a reduction in the SSI rate associated with NPWT (RR 0.53; $p < 0.0001$).[123] The SSI difference attributed to NPWT was more evident in studies where the incidence of SSI in the control arm was 20% or more, but statistical significance was lost when only high-quality observational studies and RCTs were evaluated. When only colorectal studies (1134 patients) were considered, the RR for SSI was 0.35 ($p = 0.008$). This article recommended the use of NPWT in patients undergoing abdominal surgery.[123] However, another meta-analysis in 2020, including 5 RCTs and 792 patients using NPWT versus standard dressing after abdominal surgery, found that there was no significant difference in SSI with a RR of 0.56 (95% CI, 0.30–1.03; $p = 0.064$).[124]

In 2021, 2 small RCTs (n = 148 and 124) evaluated the use of NPWT after colorectal procedures and reported no significant differences in SSI rates (13.3% vs 23.3%, $p > 0.05$; 9.8% vs 20.6%, $p > 0.05$).[125,126] However, a 2021 prospective cohort study evaluating the utility of NPWT after elective colorectal surgery (n = 200) reported a statistically significant decrease in SSI associated with NPWT (19% vs 9%, $p = 0.02$).[127] In addition, a 2021 RCT evaluating 71 patients undergoing ileostomy closure after colon cancer surgery showed a statistically significant improvement in SSI in the NPWT group (5.7% vs 22.2%, $p = 0.046$).[128] A 2022 RCT of 149 patients undergoing high-risk reoperative colorectal procedures found no significant difference in the superficial SSI rate between standard dressing or NPWT (9.4% vs 14.1%, $p = 0.28$).[129]

18. Advanced silver or antimicrobial dressings are not routinely recommended for clean or clean-contaminated wounds after colorectal surgery. Strength of recommendation: conditional based on moderate-quality evidence.

Various dressing materials can be used to cover wounds postoperatively including plain gauze and silver-impregnated and antimicrobial dressings. An RCT comparing gauze (n = 106) versus 2 different types of silver-impregnated dressing (n = 211) in patients undergoing cardiac surgery

reported that silver-impregnated dressings did not decrease the incidence of SSI.[130] Similarly, a 2016 Cochrane review of 29 trials compared 11 dressings, including film, hydrocolloid, and silver-containing dressings, and concluded that no particular dressing influenced SSI rates.[131] Of note, the trials included in this review included clean and clean-contaminated wounds after various surgical procedures.

Silver-impregnated dressings have been evaluated after colorectal procedures. In an early RCT of 55 patients undergoing colorectal resection with an incision >3 cm, there was no difference in SSI rate between silver nylon dressings compared to plain gauze (13% vs 33%, $p = 0.11$).[132] Two additional RCTs, including colorectal surgery patients (n = 112 and 147), showed no influence of silver dressings on the incidence of SSI.[133,134] When these trials were combined and analyzed in a meta-analysis, silver-impregnated dressing again did significantly decrease the incidence of SSI (RR 0.55; 95% CI, 0.35–0.85), but the authors noted that the quality of evidence for the included studies was very low to moderate.[135]

The use of mupirocin gauze has produced mixed results in preventing SSI in colorectal-specific patients in multiple RCTs. In an RCT that compared standard gauze dressing (n = 75) to a 2% mupirocin ointment dressing (n = 75), the antibiotic ointment did not reduce the overall SSI rate (3% vs 1%, $p = 0.56$).[116] Alternatively, in an RCT of colorectal patients comparing silver-impregnated dressings (n = 49) versus mupirocin ointment (n = 49) versus a standard dressing (n = 49), the incidence of overall SSI was most reduced with the mupirocin dressing (silver-impregnated 9%, mupirocin 2%, standard 10%, $p = 0.031$).[134]

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