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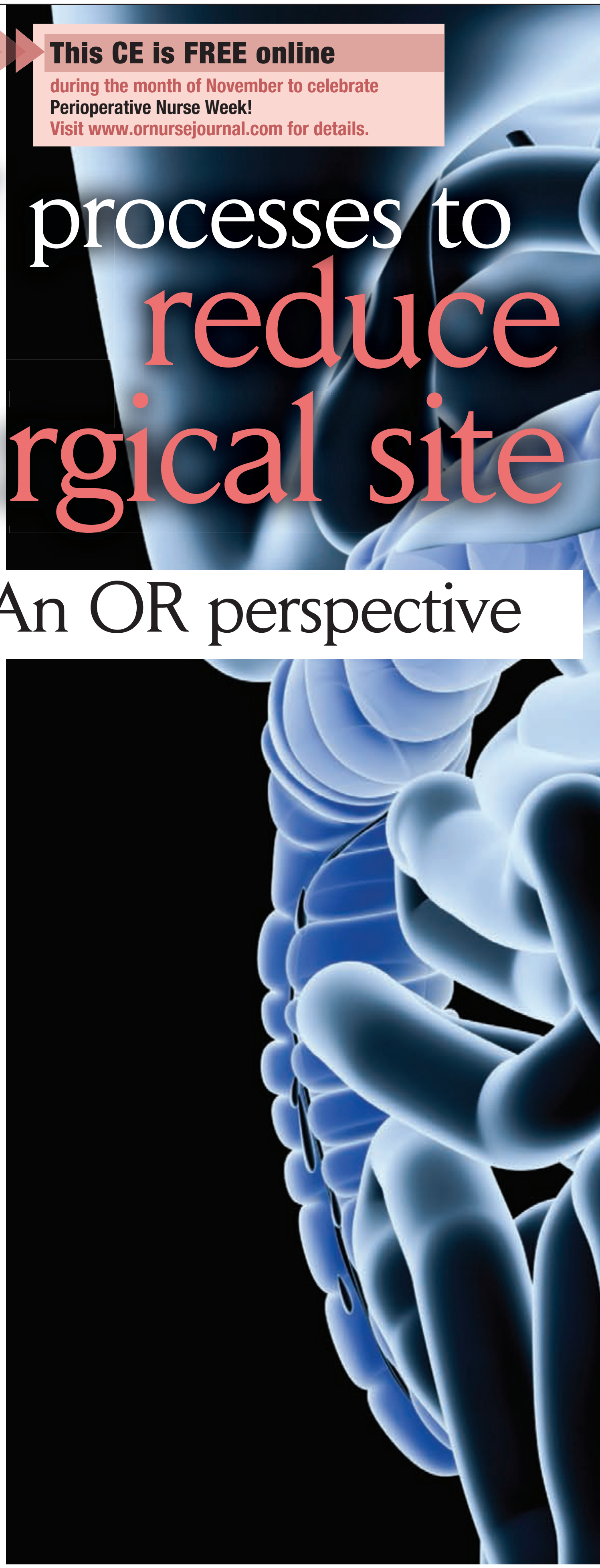
Review of processes to reduce surgical site infections



An OR perspective

By Robert Cima, MD, MA and Lynn Quast, RN

According to the CDC, of the approximately 16 million surgeries performed in the United States in 2010, the overall rate of surgical site infections (SSIs) is 1.9%.[1] This might be a significant underestimate, as it relies upon a voluntary, national hospital-based reporting system. In a recent prevalence study of hospital-acquired infections (HAIs)—a 1-day survey of hospitalized patients in nine acute care hospitals in Florida—SSIs were the most frequent HAIs requiring hospitalization, representing 31% of infections.[2] SSIs contribute to significant patient morbidity, increased mortality, prolonged hospital stays, hospital readmissions, and the need for subsequent procedures.[3,4] Since SSIs result in increased healthcare utilization, they represent a major driver of healthcare costs. In seven major categories of surgical procedures performed in the United States, the associated SSIs are responsible for $1.6 billion in additional direct costs and nearly 1 million excess hospital days.[3] The profound negative impact SSIs have on individual patients, their families, and society in resource and economic factors provide the rationale for national efforts to reduce SSIs.

colorectal surgery infections

The risk of an SSI is related to a number of factors. In broad terms, SSI risk can be considered a function of patients' health, the underlying disease, the urgency of the operation, and care received during the surgical episode.[5,6] The surgical episode of care is comprised of a number of different elements, which can influence the patient's risk of a postoperative SSI and other important clinical outcomes. These elements include the surgical technique, the proficiency of the surgeon, the functioning of the surgical team, and specific perioperative care processes.[5] Colorectal surgery (CRS) SSI rates range from 5% to 45%.[7-9] Since colon and rectal surgery is commonly performed in the United States and is associated with a high SSI rate, it has frequently been used to assess different approaches to SSI reduction. All the SSI risk factors previously mentioned have been identified as contributing to CRS SSI. However, it's important to note that across the literature investigating CRS SSI risk factors, not all the same risk factors are consistently identified as being significant contributors to SSI development. This speaks to the complexity of the problem. Thus, the absence of easily modifiable, highly-consistent risk factors for the development of CRS SSI means that successful reduction efforts will not be achieved with implementation of an individual or small set of interventions.

Reducing SSIs is an important goal for all surgical personnel because it's the right thing to do for all patients. Additionally, institutional SSI rates for a number of different surgical procedures, including CRS, are being reported publically to better inform patients about the expected quality outcomes for hospitals as well as being tied to reimbursement. In this review, perioperative interventions that have been demonstrated to be effective in reducing SSIs (broadly) as well as in CRS (specifically) will be discussed. Some interventions will be reviewed that have conflicting data in the literature, but when applied consistently, are associated with improved surgical outcomes. Given the breadth of the literature on this subject matter, the discussion will be, by necessity, focused and brief. A strategy utilized at the Mayo Clinic in Rochester, Minn., to reduce CRS SSI rates will also be presented.

Role of prophylactic antibiotics

The increased availability of antibiotics in the mid-20th century saw a significant increase in their use as prophylaxis against common infections after surgery. By the 1970s and 1980s, antibiotic surgical prophylaxis accounted for almost 50% of all hospital antibiotic use.[10] In the 1980s and 1990s, numerous studies demonstrated that antibiotic prophylaxis given prior to incision reduced postoperative SSIs.[11,12] The theory behind prophylactic antibiotics is to ensure therapeutic tissue levels of antibiotic(s) appropriate for the expected variety of microbes that might contact the open wound during the procedure. In the majority of surgeries, this requires antibiotic coverage for skin flora. Additionally, in clean-contaminated cases such as CRS, coverage for aerobic and anaerobic bowel organisms is required. In the latter half of the 20th century, there were few detailed guidelines for the most appropriate and effective antibiotic combinations or parameters for administration timing. This led to wide variation in practices within institutions and SSI outcomes, making analysis of SSI rates and SSI reduction efforts hard to implement.[13] Furthermore, the variety of practices complicated comparisons within and between individuals and institutions.

Based upon a number of seminal studies from the 1980s and 1990s that addressed appropriate antibiotic selection for specific surgery types, timing of antibiotic administration, and early postoperative antibiotic discontinuation, a large-scale demonstration project to reduce SSIs by standardizing prophylactic antibiotic administration was performed in Washington State with support from the Centers for Medicare and Medicaid Services and the CDC.[14] Conducted in 56 hospitals using a standardized approach to surgical antibiotic prophylaxis, SSIs were reduced by 27% from an overall of 2.3% to 1.7% after 1 year. Based on this study, the broader Surgical Care Improvement Program (SCIP) was implemented nationally as a series of quality process measures. Despite the success of the original study, subsequent studies have not shown the same level of SSI reduction despite high adherence to the antibiotic management elements of the SCIP bundle.[15,16]

An essential element of antibiotic prophylaxis is ensuring adequate tissue level of the antibiotic in the wound, not just at the time of incision, but perhaps more importantly near the time of wound closure. Two modern trends affecting inpatient surgical practices (especially CRS) that need to be considered are the obesity epidemic and increased duration of surgical cases. Both of these factors influence how antibiotics should be dosed and re-dosed during surgery; neither of these are considered in the SCIP guidelines.

Primary prophylaxis regimen

The primary prophylaxis regimen* for the colorectal surgery patient is SCIP compliant but is enhanced to include the recommended weight-based dosing and intraoperative redosing.[17]

Antimicrobial agent	Initial dose within 60 minutes prior to incision	Intraoperative redosing
Metronidazole	500 mg I.V.	500 mg I.V. at 6 hours
Cefazolin		
Patient less than 154.3 lbs (70 kg)	1 g I.V.	1 g I.V. at 3 hours; repeat as required
Patient 154.3 lbs (70 kg) or greater, but less than 264.6 lbs (120 kg)	2 g I.V.	2 g I.V. at 3 hours; repeat as required
Patient 264.6 lbs (120 kg) or greater	3 g I.V.	2 g I.V. at 3 hours (do not repeat 3-g dose); repeat as required

*The regimen is for the nonpenicillin allergic patient. Consult the manufacturer's prescribing label for complete information for dosage adjustments, contraindications, and precautions for each drug.

However, in the recent *Clinical Practice Guidelines for* Antimicrobial *Prophylaxis in Surgery*, the major emphasis is focused on weight-based dosing and the re-dosing interval for cases anticipated to last three hours or longer.[17] In the Mayo Clinic CRS practice, the SCIP elements have been enhanced with these guideline recommendations for primary antibiotic regimen for colorectal cases (*see Primary prophylaxis regimen*).

Skin preparation

Ever since Joseph Lister introduced the practice of preparing skin prior to surgery with either carbolic or phenolic acid in his seminal paper, *On the Antiseptic Principle in the Practice of Surgery*, in 1867, surgeons have been searching for the most effective skin preparation.[18] The goal of the preoperative skin preparation is to clean the skin of particulate matter, both organic and inorganic, and to significantly reduce the burden of skin organisms to avoid inoculation of the sterile tissues below the skin surface. In the early part of the 20th century, numerous agents (predominantly organic acids) were used. However, these agents were quite caustic, namely after repeated exposure for OR staff. Alcohol became the major form of skin antisepsis in the mid-portion of the last century but fell out of favor because of the high risk of OR fires. Eventually, iodophors (iodine preparations) became the favored approach for surgical skin preparations because of their effectiveness at reducing bacterial load, sustained duration of activity when dry, low incidence of skin irritation when applied and removed properly, and low cost.

Recently, the primacy of water-based iodine preparations as the standard skin preparation has been challenged, particularly for clean-contaminated procedures (type II surgical wounds). Darouiche and colleagues conducted a multi-institution, randomized, controlled trial evaluating the use of chlorhexidine-alcohol versus povidone-iodine as the skin preparation for clean-contaminated procedures.[19] The use of chlorhexidine-alcohol was associated with a significant reduction in both superficial and deep wound infections. Although chlorhexidine-alcohol preparations have recently received much of the focus, there is a considerable body of literature describing the efficacy of iodine-alcohol preparations. In a large, single-center study of povidone-iodine-alcohol use in over 1,000 cases, the superficial SSI rate was 4%.[20] In another single-center trial that used a prospective sequenced design, different skin preparations were used for a defined period of time, and the SSI rates during the periods were compared.[21] The iodine-alcohol preparations were associated with a lower rate of SSI than the chlorhexidine-alcohol preparation. Interestingly, there have been no major randomized trials directly comparing chlorhexidine-alcohol to iodine-alcohol skin preparations. The real confounder in all of these studies is the presence of alcohol. In a recent systemic review and meta-analysis of the chlorhexidine skin preparation, the authors found that only the combination of chlorhexidine-alcohol was associated with improved outcomes (as measured by lower infection rates) as compared to chlorhexidine or an iodine preparation alone.[22]

Skin preparation clearly remains of vital importance in mitigating the risk of SSIs. The literature strongly supports the use of a skin preparation that includes alcohol as component of the preparation. It's essential that the user closely follow the application instructions for any alcohol-containing preparation because of the fire risk. In addition, proper application method, according to the manufacturer's instructions, is essential for the effectiveness and includes the following: recognizing the differences in effective coverage area between the chlorhexidine and iodine alcohol preparations and the use of appropriate application technique, which involves a linear scrubbing motion (for chlorhexidine and alcohol) rather than a gentle circular "painting" motion working away from the area of the proposed incision.

Surgical wound dressings

The advantages to applying a covering on wounds were first described in Sumerian cuneiform stone tablets dating from 3000 B.C.[23] Furthermore, detailed descriptions of organic materials and various ointments used on both traumatic and surgical wounds were described in numerous Egyptian papyruses dated to 2000 B.C.[24] Modern history saw the expanded use of cloth dressings that continues

Elements of the Mayo Clinic, Rochester, colorectal surgery SSI reduction bundle

Preoperative outpatient phase

- The perioperative nurse explains to the patient the importance of preventing SSIs and gives the patient the "Reducing surgical site infections" patient education pamphlet.
- The perioperative nurse explains to the patient the importance of the preoperative shower and gives the patient the 4% chlorhexidine shower packet with two soap envelops and the educational material.

Preoperative morning of admission phase

- Patients who did not shower with the chlorhexidine packet or those with a BMI greater than 30 are washed with 2% chlorhexidine impregnated cloths.
- Hair removal at the surgical site is performed using hair clippers and is done outside of OR by a gender appropriate surgical technician.
- Prepare active warming measures if the patient is hypothermic. If the patient is hypothermic upon arrival in the pre-op area, the perioperative nurse will provide warmed blankets or apply a forced-air warming device.

Intraoperative phase

- Implement the active warming and room temperature protocol. If the patient is hypothermic, the circulating nurse adjust the OR room temperature according to the protocol and a forced-air warming blanket is applied, if not initiated in the pre-op area. The patient's temperature is monitored every 15 minutes until >96° F, then the room temperature is reduced according to protocol.
- The weight-based SCIP antibiotic is infused within 60 minutes prior to incision.
- Chlorhexidine-alcohol skin preparation is performed by the surgical assistant with a 3-minute dry time.
- Redose weight-based cefazolin at 3 hours and metronidazole at 6 hours.
- At incision closure, all staff change to new surgical gloves. Gowns are changed if soiled.
- All instruments are removed by the certified surgical technician (CST). The Mayo stand is recovered with sterile towels and the operative field reblocked with a sterile towel. The sterile closing instrument tray is brought up to the field by the CST for fascia and skin closure.

Postoperative phase

- The sterile dressing is removed on the morning of postoperative day 2 by the surgeon.
- Once the dressing is removed, the patient showers with 4% chlorhexidine, or if unable to shower, the patient bathes with 2% chlorhexidine cloths daily and is instructed to continue for two weeks after discharge.
- Strict hand hygiene is followed by providers, patients, and visitors.

to this day. Wound dressings are thought to serve a number of purposes, including acting as a barrier to contamination by organisms, wound drainage and management, and protection from environmental exposures. Although the exact role of wound dressings in mitigating SSIs is unclear, the CDC has recommended that surgical wounds closed primarily should be dressed under sterile condition and remain covered for 24-to-48 hours.[25]

Although there is some literature questioning the need for routine dressing coverage after a primary wound closure without increasing the risk of SSI, dressing of the wound under sterile conditions at the completion of a surgical procedure remains the standard of care. Modern dressings fall into two major categories: basic wound contact dressings (BWCDs) and advanced wound dressing. BWCDs are commonly cotton-based, absorbent dressings that are either secured by separate adhesive materials or as combined absorbent/adhesive dressing. Recently, BWCDs have expanded to include impregnation with antimicrobial materials, including silver and antibiotics. Advanced wound dressings include hydrogels, hydrocolloids, complex films, and even vacuum-assisted devices. Despite the variety of dressing materials available and range of costs, there is little evidence that one type of dressing material is superior to another for a clean, primarily closed, surgical incision. A recent meta-analysis of available randomized trials of wound dressings for primarily closed surgical incisions demonstrated that there is no evidence that one type of dressing material is superior to another or even that a dressing is required to minimize SSI risks.[26]

Closing instrument tray

The closing instrument tray is used after all the surgical instruments used during the case have been removed from the Mayo stand by the certified surgical technician (CST) and the perioperative team members have changed their gloves. The circulating nurse brings the closing instrument set to the CST to place on the freshly draped Mayo stand.

Preoperative skin cleansing

While the need for skin preparation and decontamination just prior to surgical incision is well established and strongly supported in the literature, the utility of extended periods of skin cleansing prior to the day of surgery is uncertain. The use of antimicrobial soaps for whole body cleansing in preparation for surgery had been a common practice in the 1950s through the 1970s when patients were routinely admitted to hospitals prior to surgery, but this practice fell out of favor, as same-day surgery admissions became the norm. Across the SSI literature, there is conflicting evidence on the effectiveness of this practice of preoperative skin disinfection on reducing SSIs. However, there are some recent studies discussing the impact of whole body cleansing in reducing skin colonization and HAIs that might complement other perioperative practices to reduce SSIs.[27] The available literature clearly demonstrates that preoperative bathing with either a chlorhexidine or povidone-iodine solution significantly reduces the skin microbial load at the time of surgery.[28] However, how this impacts SSIs is less clear, as the studies are often underpowered and confounded by design limitations. Recently, studies in the orthopedic literature have found that the use of preoperative cleansing with chlorhexidine cloths prior to joint replacement surgery results in a significant reduction in SSIs, leading to the national consensus expert guidelines recommending this practice to reduce orthopedic joint replacement SSIs.[29]

Normothermia

The importance of maintaining patient normothermia (patient core temperature greater than 96.8° F [36° C]) with active warming (forced-air warming and fluid warming) during an abdominal colorectal procedure was reported by Kurz et al. in 1996.[30]

They demonstrated a significant reduction in SSIs and hospital length of stay in the actively warmed patients (normothermic group) compared to those without active warming (hypothermic group). Subsequent studies in different abdominal surgeries have found a similar association between patient temperature and SSIs.[31] However, not all surgical specialities have seen this correlation between normothermia and reduced SSI.

SSI reduction bundles

With the rare exception of appropriate and timely antibiotic administration, there are very few interventions reported to reduce SSIs that are consistently found to be efficacious across surgery. This finding speaks to the multifactorial nature of SSI development and the futility of searching for a single or small handful of interventions that will eliminate SSIs. However, as demonstrated by the near elimination of central line-associated bloodstream infections and the marked reduction in ventilator-associated pneumonias, through the introduction of care "bundles," HAIs can be markedly reduced. These bundles are comprised of multiple elements that are each directed at a different contributing factor development of the adverse outcome. A key to success in the use of bundles is ensuring that there is a very high level of adherence when performing each element of the bundle every time it's used. A number of successful colorectal SSI reduction bundles have been reported in the literature.[32-35] Interestingly, while they frequently share some elements, there are many different components reported. Furthermore, many of the reported bundles include elements that have not

The multidisciplinary team

A multidisciplinary quality improvement team allowed design of the process across the episode of surgical care was a key to success in both implementation and sustaining the effort.

Role	Department
Surgeon, Project Leader	Surgery, Division of Colon and Rectal Surgery
Quality Advisor	Systems and Procedures
Infection Preventionist	Nursing
Nurse Managers on Colon and Rectal Surgery Patient Care Units	Nursing
Clinical Administrator	Nursing
Clinical Nurse Specialist	Nursing
Wound, Ostomy, Continence Nurse	Nursing
Operating Room Nursing Managers supporting Colon and Rectal Surgery	Nursing—Hospital Surgical Services
Quality Improvement Advisor	Nursing—Hospital Surgical Services
American College of Surgeons – National Surgical Quality Improvement Project (ACS-NSQIP) Data Abstraction and Analysis	Surgery Clinical Research Office
Pharmacist	Pharmacy
Process Engineer	Systems and Procedures
Hospital Service Nurse Practitioner	Colon and Rectal Surgery
Research Fellow	Surgery, Division of Colon and Rectal Surgery

been demonstrated as a value in a randomized control trial, which is often a criticism of the bundle approach to quality improvement in healthcare.

The Mayo Clinic colorectal SSI reduction bundle was introduced in January 2011, resulting in a 50% reduction in SSIs that was sustained for more than a year (see *Elements of the Mayo Clinic, Rochester, colorectal surgery SSI reduction bundle*).[32] In designing the bundle, the multidisciplinary team incorporated evidence-based interventions (hair clipping outside of the OR, chlorhexidine-alcohol-based skin preparation, appropriate antibiotic selection, antibiotic administration within 60 minutes prior to incision, weight-based dosing, and intraoperative redosing of antibiotics) while also including less rigorously tested interventions that were easy to implement and monitor. Additional interventions included preoperative showers with chlorhexidine; use of high-concentration chlorhexidine cloths the morning of surgery for patients with a BMI greater than 30 kg/m^2; use of a closing process with required glove changes and use of a closing instrument tray; and removal of the surgical dressing on the morning of postoperative day 2 (see *Closing instrument tray*). Furthermore, the team designed system improvements into the electronic medical record to ensure an extremely high level of adherence to each step with every patient. The bundle interventions were implemented across the entire surgical episode starting with the preoperative consultation to wound care after discharge.

A key factor in the design and success of the bundle was the design and implementation by a multidisciplinary team (see *Multidisciplinary team*). Meeting twice a month, members discussed the improvement elements that they were accountable for designing and implementing, but also ensuring they understood processes both upstream and downstream to complement them, and design appropriate streamlined protocols and information exchange. Using this bundle approach, the colorectal SSI rate (as measured through the American College of Surgeon's National Surgical Quality Improvement Program)[36] went from a 2-year average of 10.5% to 4.6% for over a year of follow up.

Summary

SSIs are the most common HAIs in surgical patients. They're associated with major morbidity, increased mortality, and significant economic burden. Abdominal gastrointestinal surgery is associated with a high incidence of SSI, and colorectal surgery, in particular, is responsible for a significant proportion of those SSIs. There are only a few interventions that have been demonstrated to decrease SSI rates after colorectal surgery. Given the multiple contributing factors for SSI development, use of a bundle of interventions across the surgical episode of care, both inside and outside of the OR, has been shown to further reduce SSI rates after colorectal surgery. The key to success with these bundles is engagement of all staff to ensure a high level of adherence when performing all the bundle elements on every patient. Monitoring of adherence and outcomes reporting to staff are essential to sustaining performance. **OR**

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