

Surgical Site Infection and Prevention Guidelines: A Primer for Certified Registered Nurse Anesthetists

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Each year 500,000 surgical site infections occur in the US. Surgical site infections are the second most common healthcare-associated infections resulting in readmissions, prolonged hospital stays, higher medical costs, and increased morbidity and mortality. Surgical site infections are preventable in most cases by following evidence-based guidelines for hand hygiene, administration of prophylactic antibiotics, and perioperative patient temperature management. As attention to issues of healthcare quality heightens, the demands

for positive surgical patient outcomes are intensifying. The Certified Registered Nurse Anesthetist can provide transparent high-quality care by implementing evidence-based guidelines for timely and appropriate antibiotic use, maintenance of normothermia, and hand washing.

Keywords: Antibiotic prophylaxis, hand washing, hypothermia, Surgical Care Improvement Project, surgical site infection.

Objectives

At the completion of this course, the reader should be able to:

1. Define the diagnostic criteria, risk factors, and causes of surgical site infection.
2. Identify the Surgical Care Improvement Project performance measures that target prevention of postoperative infection.
3. Illustrate the appropriate antibiotic timing and dosing for general, gynecologic, orthopedic, and colorectal surgeries.
4. Describe intraoperative thermoregulation and its impact on surgical site infection.
5. Illustrate appropriate hand hygiene procedures as recommended by the World Health Organization.

Introduction

The Centers for Disease Control and Prevention (CDC) estimates that 500,000 surgical site infections (SSIs) occur annually and account for 3% of surgical mortality, prolonged lengths of hospital stay, and increased medical costs. The literature suggests that 60% of the SSIs are preventable.¹ Performance measures aimed at prevention of SSIs have been implemented nationally to enhance quality and minimize complications with respect to inpatient surgery.

This course describes SSIs epidemiology, risk factors, and clinical consequences. It concludes by discussing the contribution of Certified Registered Nurse Anesthetists (CRNAs) to preventing SSIs by implementing guidelines for timely and appropriate use of antibiotics, maintenance of normothermia, and appropriate hand hygiene techniques.

Surgical Site Infection

Surgical site infections are the second most common healthcare-associated infection. The CDC and the National Nosocomial Infection System have established criteria for defining SSIs that are widely used by SSI-surveillance and perioperative personnel.² An SSI is an infection related to an operative procedure that occurs at or near the surgical incision within 30 days of the procedure.^{3,4} The CDC and the National Nosocomial Infection System define SSIs by the following clinical criteria:

1. A purulent exudate draining from a surgical site
2. A positive culture obtained from a surgical site that was closed initially
3. A surgeon's diagnosis of infection
4. A surgical site that requires reopening due to at least one of the following signs or symptoms: tenderness, swelling, redness, or heat

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Efforts to lower the incidence of SSIs date back to the 19th century when Lister pioneered antiseptic use to prevent infection in orthopedic patients.⁵ It is estimated that SSIs develop in 2% to 5% of the more than 30 million patients who undergo surgical procedures, representing 14% to 16% of all hospital-acquired infections annually in the US.⁶ These infections account for 3% of all surgical mortality and lead to increased readmissions, increased lengths of hospital stays, and higher costs.¹ Patients who develop an SSI are 5 times more likely to be readmitted to the hospital, 60% more apt to require stay in an intensive care unit (ICU), and twice as likely to die compared with patients who are free of infection.² Evidence further suggests that patients who contract multidrug-resistant infections face worse outcomes.^{5,7}

The financial burden of SSIs is sizeable. An extensive epidemiologic review of surgical patient data revealed that lengths of hospital stay postoperatively extend 7 to 10 days, while hospital charges ranged from \$3,000 to \$29,000 per patient with a SSI diagnosis.^{3,5} Annually, hospital-acquired infections (HAIs) cost the healthcare system \$9.8 billion.⁸ Compared with all HAIs nationwide, SSIs occur most often and contribute the most to the overall cost, at 37.7% of the total cost.⁸ Death in the postoperative period was directly related to SSIs in 75% of patients in whom an SSI was diagnosed.³

The infection risk associated with primary hip and knee arthroplasty is approximately 1% and increases to 2% to 5% for arthroplasty revision.⁷ Compared with the infection rate for colon surgery, which is 20%, SSI rates in orthopedic surgery appear quite low. However, infection in the bones and joints is very difficult to treat and is associated with a lifelong recurrence risk of 10% to 20%.⁹ When multiresistant pathogens such as methicillin-resistant *Staphylococcus aureus* (MRSA) infect a prosthetic joint, the treatment failure rate is 20% to 40%.⁷ Surgical infections that occur after total hip and knee arthroplasty are very costly and devastating for patients.⁷ Treatment of SSIs following joint replacement often requires removal and replacement of the prosthesis, prolonged systemic antibiotic therapy, and extensive rehabilitation because of impaired mobility.

The probability of an SSI developing is dependent on both surgical procedure characteristics and patient risk factors. Surgical characteristics include the type of procedure, skill of the surgeon, use of foreign material or implantable devices, and the degree of tissue trauma.¹⁰ Evidence has documented several patient risk factors associated with higher frequency of SSIs, including diabetes, tobacco use, obesity, malnutrition, systemic steroid use or other immunosuppressive drugs, duration of the operation, and intraoperative hypothermia.¹¹⁻¹³

A study of 5,031 Veterans Administration patients with postsurgical incisions revealed that SSIs occurred in

162 cases, or 3.2% of the cohort. The highest incidence of SSIs was observed in inguinal hernia procedures, carotid endarterectomies, urologic procedures, and colon surgeries.¹³ Characteristics that were associated with the incidence of SSIs were diabetes, postoperative anemia, and weight loss greater than 10% within 6 months before surgery.¹³ Furthermore, SSIs occur with greater frequency with increasing ASA physical status classification (ASA score). An ASA score of 3, which is severe systemic but not incapacitating disease, accounted for most of the SSI cases (n = 105, 64.8%).¹³

Surgical Care Improvement Project

Current literature estimates that nearly 60% of SSIs are preventable.¹ Preventive management of SSIs is based largely on using evidence-based guidelines that support a safe patient environment during the perioperative period. The Surgical Care Improvement Project (SCIP) is a national quality partnership of organizations committed to improving patient safety by promoting evidence-based interventions as the standard of care to minimize the incidence of surgical complications.¹⁴ Six performance measures target prevention of postoperative infection. Research indicates that implementing these performance measures has a positive impact on SSI reduction.¹⁵ Efficacy and implementation of SCIP measures are supported by the literature and are nationally endorsed.¹⁵

Most SSIs result from bacterial inoculation at the time of surgery, even though infection presentation manifests several days later.³ The anesthesia provider can make a substantial contribution to prevention of SSIs during the perioperative period by implementing the SCIP guidelines for timely and appropriate use of antibiotics and maintenance of normothermia.¹

Antibiotic Timing and Selection

In 1961, Burke¹⁶ established the foundation for the current antimicrobial prophylaxis clinical guideline. Investigation of antibiotics on inflammatory response to surgical incision yielded the current recommendation to administer antibiotic prophylaxis 1 hour before incision. Burke¹⁶ concluded that bacteria were most susceptible when antibiotics were in the tissues, thus establishing timing of administration. Subsequently, Fogelberg et al¹⁷ examined the effects of prophylactic penicillin in reducing wound infections. The infection rates in the penicillin group were significantly lower than in the control group. Classen et al¹⁸ performed a retrospective study of approximately 3,000 patients undergoing various surgical procedures. The group of patients that received antimicrobial prophylaxis 1 hour before incision had the lowest rates of SSIs.

Evidence suggests that effective prevention of SSIs is achieved through implementation of prophylactic anti-

Surgical procedure	Appropriate antibiotic
Cardiothoracic and vascular surgery	Cefazolin, cefuroxime, or vancomycin If β -lactam allergy: vancomycin or clindamycin
Hysterectomy	Cefotetan, cefazolin, cefoxitin, cefuroxime, or ampicillin/sulbactam If β -lactam allergy: clindamycin + gentamycin (or ciprofloxacin or aztreonam) or metronidazole + gentamycin (or ciprofloxacin) or clindamycin monotherapy
Hip or knee arthroplasty	Cefazolin or cefuroxime If β -lactam allergy: vancomycin or clindamycin
Colon	Cefotetan, cefoxitin, cefazolin + metronidazole, or ampicillin/sulbactam If β -lactam allergy: clindamycin + gentamycin (or ciprofloxacin or aztreonam) or metronidazole + gentamycin (or ciprofloxacin)

Table. Surgical Care Improvement Project Guidelines for Appropriate Antibiotic Selection for Selected Procedures

Abbreviation: +, plus.
(Adapted from Bratzler et al²³)

biotic guidelines to reduce the presence of microorganisms during the operative procedure.^{6,9,14,19} A consensus distinguishes timely antibiotic prophylaxis as essential in infection prevention, suggesting 30 minutes to 1 hour before incision as the ideal window for drug administration.^{9,20} Merollini and colleagues²⁰ determined through structured interviews with infectious disease physicians and orthopedic surgeons that antimicrobial prophylaxis is a relevant clinical practice for SSI prevention recommended by all participants. Uçkay et al⁹ conducted a comprehensive literature search using National Library of Medicine Medical Subject Headings (MeSH) terms *infection*, *orthopedic*, and *prevention*. They identified peer-reviewed literature, which revealed that antibiotic prophylaxis for patients undergoing orthopedic joint surgery, when administered within 30 to 60 minutes before incision, helps to reduce SSI rates to 1% to 3% compared with 4% to 8% without preoperative antibiotic administration.⁹

Based on published evidence, the SCIP established that an antibiotic received prophylactically within 1 hour before incision reduces the risk of infection.^{6,16,18,21,22} When a fluoroquinolone or vancomycin is the indicated antibiotic, administration should occur within 120 minutes before incision to avoid an adverse reaction associated with rapid infusion.⁶ Appropriate antibiotic selection is based on recommended guidelines for procedures targeted for national surveillance.²³ Although research demonstrates that many antibiotic regimens are effective preventive agents, the professional consensus supports using narrow-spectrum, first- and second generation cephalosporins, which are inexpensive, safe to use, and bactericidal, and have long half-lives.²² The Table summarizes SCIP guidelines for appropriate antibiotic selection.²³

Hypothermia

Mild hypothermia, a body temperature of 34°C to 36°C,

is a common phenomenon during surgery. Contributing factors include low ambient temperatures in the surgical suite, use of cold skin preparatory agents, exposed open wounds, cool fluid administration, and the anesthetic effects on a patient's ability to control and conserve heat.^{24,25} The body's core temperature is controlled by the hypothalamus, or the thermoregulation center of the brain. When a difference between core and skin temperature is detected, the thermoregulation threshold triggers autonomic defense mechanisms to produce heat through vasoconstriction and shivering.²⁶ Anesthetic inhalation agents, propofol, and opioids impair thermoregulatory control by decreasing heat production and increasing cutaneous heat loss through vasodilation. Muscle relaxants also compromise thermoregulatory control by preventing shivering.²⁵

The deleterious effects of hypothermia are well documented. Adverse outcomes of hypothermia include increased blood loss and transfusion requirements, prolonged postoperative recovery times, heightened postoperative pain, and impaired immune function.²⁵ Hypothermia compromises neutrophil function and promotes vasoconstriction, which leads to tissue hypoxia and increased incidence of SSIs.²⁷ Numerous studies have demonstrated the impact of hypothermia on SSIs. Kurz et al¹² studied patients undergoing colorectal surgery who were randomly assigned to a hypothermic and a normothermic group. Rates of infection were 3 times higher in the hypothermic group.¹² Patients in the hypothermic group had hospital stays nearly 1 week longer than did normothermic patients.¹² In a 1999 meta-analysis, Mahoney and Odom²⁴ reported a 64% increased rate of SSIs in hypothermic patients. Conversely, when normothermia was maintained, a cost savings of up to \$7,000 per patient was realized.

Evidence-based practices to prevent perioperative hypothermia include identifying risk factors, measur-

ing temperature, and initiating preventive and active warming measures.²⁸ Risk factors are independent predictors used to determine the potential for developing hypothermia. They include extremes of age, female gender, length and type of procedure, administration of general and spinal anesthesia, ambient temperature of the operating room (OR), and preexisting conditions (extensive burns, endocrine disorders, pregnancy, and large open wounds).²⁷ No single method of measuring temperature is deemed the gold standard. Core temperature may be measured in the distal esophagus, pulmonary artery, nasopharynx, or adjacent to the tympanic membrane.²⁵ Use of an esophageal temperature probe in the intubated patient is the most reliable method. Skin temperature is approximately 2°C less than core temperature; thus, forehead skin temperature measurement only estimates core temperature. Clinical research suggests that rectal temperature lags behind temperature measured in the esophagus and the pulmonary artery. Moreover, rectal temperature measurement fails to appropriately rise during malignant hyperthermia and therefore must be used with caution.²⁵

The American Association of Nurse Anesthetists *Standards for Nurse Anesthesia Practice*²⁹ requires temperature monitoring of all patients receiving anesthesia for whom large temperature changes are intended, anticipated, or suspected. Therefore, patient temperature should be monitored at no less than 15-minute intervals during all general and regional anesthetic procedures of more than 60-minute duration and during all pediatric procedures that are 30 minutes or longer.²⁵

The greatest decline in patient temperature occurs during the first hour of surgery.²⁷ The CRNA should intervene immediately on entering the surgical suite by applying warm blankets to limit the patient's skin exposure to low ambient temperature. The Association of Operating Room Nurses recommends ambient temperatures between 20°C and 25°C. On induction of anesthesia, forced-air warming should be initiated using the manufacturer's guidelines for use. The literature supports the use of forced air as the best warming approach because of its ease of use, efficacy, safety, and price.^{25,30} The use of warmed intravenous fluids in combination with forced-air warming has been shown to positively impact core temperature.²⁷

Hand Hygiene

In 1825, a French pharmacist published an article recommending that physicians and healthcare workers would benefit from moistening their hands with liquid chloride solutions when caring for patients with contagious diseases.³¹ In 1846, an obstetrician and surgeon by the name of Semmelweis encouraged healthcare workers to incorporate hand washing into their practice as a means to prevent HAIs. Semmelweis observed that women who de-

livered in the hospital setting were dying of febrile illness at much higher rates, compared with women who delivered at home. He discovered that the hands of healthcare workers were transmitting the toxins that were causing the febrile illness from patient to patient.³¹ After his discovery, he demanded that his nurses and physicians wash their hands with a chlorine solution before caring for a patient. This intervention by Semmelweis was the first evidence of preventing HAIs by adhering to strict hand hygiene practices. Semmelweis would be disappointed in our progress of reducing HAIs, because they continue to occur at a rate of 10% of hospitalized patients.³² Many of these infections have been attributed to the lack of hand washing by healthcare providers.

Numerous studies have proved that healthcare workers' hands transmit microorganisms to patients.³³ Evidence proves that effective hand washing is the cornerstone for preventing healthcare-associated infections. It is also important in preventing specific site infections such as catheter-related bloodstream infections, catheter-related urinary tract infections, ventilator-associated pneumonia, and SSIs.³³

Studies continue to demonstrate that hand hygiene practices among healthcare workers is at an abysmally low rate. An observational study of the hand hygiene practices of anesthesia providers was performed at a major metropolitan medical center. The study observed the hand hygiene practices of anesthesia providers following the World Health Organization (WHO) Guidelines on Hand Hygiene in Health Care over a 4-week period. The results were daunting: "[T]he overall failure of hand hygiene ranged from 64% to 93% by provider group with a mean aggregate failure rate of 82%".³² The major categories where hand hygiene failures occurred were moving between patients in the preoperative phase, performing pain service interventions, using the keyboard when documenting in an electronic medical record, placing intravenous catheters and blood draws, preparing drugs and equipment for the following case, leaving soiled gloves on after airway manipulation, Foley catheter insertion or central or arterial line manipulation, and picking up something from the floor and using it.³²

An academic hospital in the Netherlands also reported results of poor hand hygiene, when an observer evaluated the hand hygiene practices in an OR. This study used an observational scoring tool that documented the hand hygiene practices of the staff members who touched patients without the application of hand hygiene.³⁴ The OR staff was categorized by profession, and staff members who were considered sterile were excluded. The observer evaluated 28 surgical procedures for more than 60 hours in a variety of surgical specialties. The results of this study revealed that the OR staff was observed participating in hand hygiene in 7 of 363 opportunities (2%) and in 28 of 333 opportunities on leaving the OR (8.4%).³⁴ This

study also revealed that compliance with gloving guidelines varied from 0% to 87%.³⁴ Many providers donned gloves when performing invasive procedures such as intubation/extubation of the trachea, but the providers wore the gloves for long periods without appropriate hand hygiene.³⁴

A tertiary care hospital in Argentina revealed that with education and improved hand hygiene practices, there could possibly be a reduction in nosocomial infections. This study was conducted in 2 ICUs in a 180-bed teaching hospital in Buenos Aires over a 2-year period. An intervention, which included educational classes on hand hygiene, the distribution of an infection control manual, and guidelines for appropriate hand hygiene practices, was provided to all healthcare providers.³⁵ A trained nurse observed the hand hygiene practices of the healthcare practitioners. The observed hand hygiene practices were discussed at monthly meetings and posted in the ICUs. Nosocomial infections that occurred in the ICUs were recorded according to the CDC definitions of such infections. Baseline and postintervention data of hand hygiene practices were collected by trained infection control practitioners. The overall compliance of hand hygiene improved from baseline (23.1%) to the postintervention phase (64.5%).³⁵

Hand hygiene is a simple measure that when implemented in the everyday care of patients can reduce SSIs and improve patient safety.³⁶ Hand hygiene practices should always be a priority when participating in patient care. The 2009 WHO Guidelines on Hand Hygiene³⁶ recommend that the healthcare provider engage in hand hygiene in the following situations:

1. When the hands are visibly dirty or visibly soiled with blood or body fluids or after using the toilet
2. If there is exposure to potential spore-forming pathogens, including outbreaks of *Clostridium difficile*
3. Before and after touching a patient, before handling an invasive device for patient care, regardless of whether or not gloves are used; after contact with body fluids or excretions, mucous membranes, nonintact skin, or wound dressings; if moving from a contaminated body site to another body site during the care of the same patient; after contact with inanimate surfaces and objects (including medical equipment) in the immediate vicinity of the patient; and after removing sterile or nonsterile gloves
4. Before handling medications or preparing food

Conclusion

The Institute of Medicine has galvanized attention to issues of quality and medical error as they pertain to healthcare delivery in the US.³⁷ Policymakers, healthcare stakeholders, and professional organizations have launched initiatives targeted at improving hospital quality regarding inpatient surgery by minimizing com-

plications, reducing medical expenses, and increasing favorable outcomes. As the need for transparency in healthcare heightens, the demand for positive surgical patient outcomes will intensify. The anesthesia provider can deliver transparent high-quality care by implementing timely and appropriate antibiotic use, maintenance of normothermia, and hand hygiene practices in accordance with evidence-based guidelines.

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ACKNOWLEDGMENT

Thank you to our families and the faculty of the Florida International University Nicole Wertheim College of Nursing and Health Sciences, Miami, Florida, for their support and encouragement.