Patient Risk Factors and Best Practices for Surgical Site Infection Prevention

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Introduction

Despite considerable research on best practices and strides in refining surgical techniques, technological advances and environmental improvements in the operating room (OR), and the use of prophylactic preoperative antibiotics, infection at the surgical site remains the second most common adverse event occurring to hospitalized patients and a major source of morbidity following surgical procedures.[1,2] Currently there are more than 40 million inpatient and 31 million outpatient surgeries performed each year in the United States, with at least 2% of these patients, or approximately 1.4 million, developing a surgical site infection (SSI) of varying severity.[3] A comparison study from Duke University conducted in 1999 estimated that a SSI doubled the patient's risk of death after surgery from 3.5% to 7.8%, increased the likelihood of an ICU stay from 18% to 29%, added 5 days to the hospital stay, doubled the cost of hospitalization from $3,844 to $7,531, and increased the probability of readmission from 7% to 41%.[4] More recent data published in November 2006 by the Pennsylvania Health Care Cost Containment Council (PHC4) revealed the astronomical increases in cost of American healthcare since then. The PHC4 reported that a commercial insurance payment for a patient with a SSI was $27,470, or 70%, greater than a case without an infection; and the actual charge for the care of patients with SSI was much higher still: $132,110 compared to $31,389 for noninfected patients.[5] However high the monetary cost to the healthcare system, the cost to the patient in terms of pain, suffering or loss of life has always been too much.

Best Practices for Surgical Site Infection Prevention

During the past decade, U.S. healthcare has entered a period of best practices bundling in which patient care actions that have been identified as improving outcomes have been grouped together. SSI reduction strategies have greatly benefited from this approach.[6,7] Elective surgery patients, who may wait days or weeks between the decision to proceed with surgery and the actual date of surgery, are the optimal candidates upon whom to focus SSI prevention strategies. Rather than consider this interval time as an unnecessary delay, it should be viewed as a window of opportunity to optimize the patient's resources and defenses against potential perioperative complications, as well as to ensure that the healthcare system is functioning at optimal level to protect the patient.

This article will review: 1) background information regarding Centers for Disease Control and Prevention (CDC) surgical wound classification,[8] 2) surgical site infection definitions, and 3) the National Nosocomial Infection Surveillance (NNIS) Risk Index. The patient-related or endogenous risk factors for the development of SSIs will also be discussed as well as patient-focused interventions that may reduce SSI incidence and severity.

Wound Classification

The risk of infection varies by type of surgical incision site. For example, invasive procedures that penetrate bacteria-laden body sites, especially the bowel, are more prone to infection. The traditional wound classification system designed by the CDC stratifies the increased likelihood and extent of bacterial contamination during the surgical procedure into four separate classes of procedures:[9]

- *Clean wounds*
  The wound is considered to be clean when the operative procedure does not enter into a normally colonized viscus or lumen of the body. SSI rates in this class of procedures are less than 2%, depending upon clinical variables, and often originate from contaminants in the OR environment, from the surgical team or most commonly from skin.

- *Clean-contaminated wounds*
  A site is considered to be clean-contaminated when the operative procedure enters into a colonized viscus or cavity of the body, but under elective and controlled circumstances. SSI rates in this class of procedures range from 4% to 10%.

- *Contaminated wounds*
  When gross contamination is present but no infection is obvious, a surgical site is considered to be contaminated. As with clean-contaminated procedures, the contaminants are bacteria that are introduced by soilage of the surgical field. SSI rates in this class of procedures can exceed 20%.

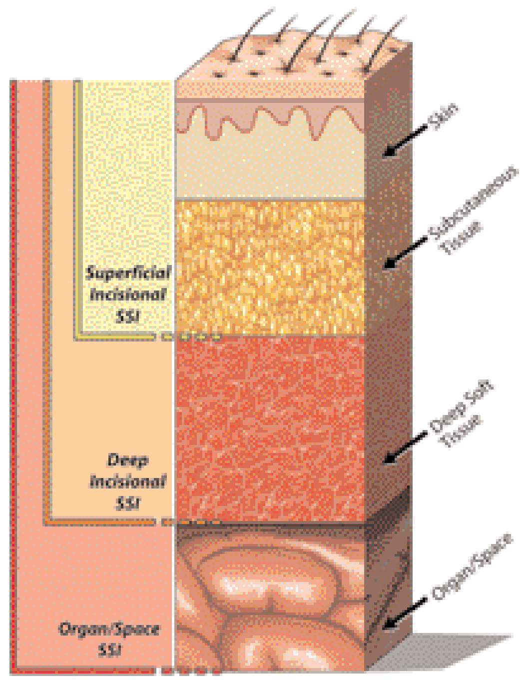
- *Dirty wounds*
  If active infection is already present in the surgical site, it is considered to be a dirty wound. Pathogens of the active infection as well as unusual pathogens will likely be encountered. SSI rates in this class of procedures can exceed 40%.

CDC Surgical Site Infection Definitions

Wound infection is most commonly characterized by the classic signs of redness (rubor), pain (dolor), swelling (tumor), elevated incisional tissue temperature (calor) and systemic fever.[10] Ultimately, the wound is filled with necrotic tissue, neutrophils, bacteria and proteinaceous fluid that together constitute pus.

It is essential for the accuracy of surgical site infection surveillance and comparison of SSI rates for there to be conformity in the definitions used to classify and categorize infections. The CDC *Guideline for prevention of surgical site infection*, published in 1999, details the criteria for defining an SSI.[8] As noted in Figure 1, SSIs are separated into three types, depending on the depth of infection penetration into the wound: superficial incisional, deep incisional and organ/space. An infection must occur within 30 days after surgery to be classified as an SSI; however, if the surgery includes an implanted device or prosthesis, then the infection window extends out to one year. Evidence of incisional pus, cellulitis, deliberate incision and drainage of surgical site and/or diagnosis of SSI by physician are also required for conformance with the definition.

Figure 1



Anticipating Risk of SSI

In order for member hospitals to report cumulative wound infection data that could be compared between facilities caring for patients with differing levels of comorbidity, the CDC developed the NNIS Risk Index[9] that applies a range from zero to three points for the absence or presence of the following three composite variables:

- 1 point—The patient has an operation that is classified as either contaminated or dirty. See wound classification discussion above.
- 1 point—The patient has an American Society of Anesthesiologists (ASA) preoperative assessment score of 3, 4, or 5.[11] See Table 1 for a description of the ASA Score's physical status classification for surgical patients.
- 1 point—The duration of the operation exceeds the 75th percentile of operation time (T point) as determined from the NNIS database. See Table 2 for the length of time in hours that represents the 75th percentile for some common surgical procedures.[9]

Table 1. ASA Score of Patient Physical Status

Class I	A patient in normal health
Class II	A patient with mild systemic disease resulting in no functional limitations
Class III	A patient with severe systemic disease that limits activity, but is not incapacitating
Class IV	A patient with severe systemic disease that is a constant threat to life
Class V	A moribund patient not likely to survive 24 hours

Table 2. The T Point for Common Surgical Procedures

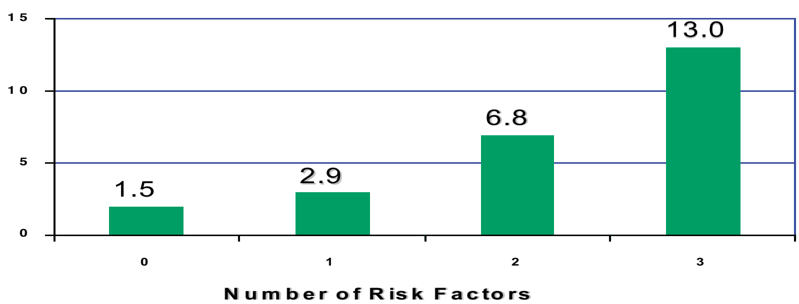
Operation	T Point (hrs)
Coronary artery bypass graft	5
Bile duct, liver or pancreatic surgery	4
Craniotomy	4
Head and neck surgery	4
Colonic surgery	3
Joint prosthesis surgery	3
Vascular surgery	3
Abdominal or vaginal hysterectomy	2
Ventricular shunt	2
Herniorrhaphy	2
Appendectomy	1
Limb amputation	1
Cesarean section	1

According to the cumulative NNIS index summary in Table 3 below, colon surgery carries the highest risk of SSI, followed by vascular surgery, cholecystectomy and organ transplant. Following Table 3, Graph 1 depicts the general rise in SSI rates as the NNIS risk category increases.[9]

Table 3. SSI Rates by NNIS Risk Index and Surgical Procedure

	Risk Category			
Type of Operation	0	1	2	3
Colon surgery	3.2	8.5	16.0	22.0
Vascular surgery	1.6	2.1	6.1	14.8
Cholecystectomy	1.4	2.0	7.1	11.5
Organ transplant	0.0	4.4	6.7	18.0

Graph 1. Mean Surgical Site Infection Rate by NNIS Risk Index



Patient-Related Risk Factors for Surgical Site Infection

There are numerous patient-related (endogenous) and process/procedural-related (exogenous) variables that affect a patient's risk of developing an SSI. Some variables, such as age and gender, are obviously not amenable to change or improvement. Fortunately, however, a number of other potential factors, such as nutritional status, smoking, proper use of antibiotics and intraoperative technique, can be improved to bolster the likelihood of a positive surgical outcome. The remainder of this review will focus on patient-related risk factors that, with preparation, planning and methodical implementation, can be addressed and minimized. Some of the more commonly identified patient risk factors for surgical site infection to be discussed include: pre-existing diabetes and/or perioperative hyperglycemia, obesity or malnutrition, pre-existing remote body site infection, recent tobacco use, contaminated or dirty wound, colonization with microorganisms, and perioperative hypothermia.[12]

Diabetes Mellitus

Diabetes mellitus (DM), particularly adult-onset or Type 2 diabetes, has become increasingly prevalent in American society, with approximately 7%, or 20 million people, living with the disease, one-third of whom are unaware of their disease state.[13] The percentage of surgical patients with diabetes can be much higher, depending on the type of surgery being performed. One study noted that 44% of cardiac surgery patients were diabetic, with 48% of possible diabetics undiagnosed preoperatively.[14] DM is not only a well-recognized risk factor for requiring coronary artery bypass graft (CABG) surgery, with 25% to 30% of patients undergoing CABG surgery having pre-existing diabetes, but it is also one of the major predictors of post-surgery morbidity and mortality, with approximately 35% to 50% of complications occurring to patients with that co-morbidity.[15] Post-surgical adverse outcomes related to DM are believed to be related to the pre-existing complications of chronic hyperglycemia, which include vascular atherosclerotic disease and peripheral as well as autonomic neuropathies.

It is critical that all surgical patients be evaluated preoperatively for undiagnosed and/or uncontrolled diabetes. Patients facing surgery should have fasting serum glucose (FSG) as well as Hemoglobin A1c (HbA1c) drawn to evaluate the presence of pre-existing diabetes. If either or both of these tests indicate uncontrolled and/or pre-existing diabetes (FSG>110 mg/dL or HbA1c≥7%), then the patient should be set on a predetermined regimen shown to be effective in controlling serum glucose if implemented and followed.[16,17]

Perioperative Hyperglycemia

Additionally, it should be recognized that most patients undergoing major surgery experience perioperative hyperglycemia, whether or not they are insulin resistant or diabetic. Unlike DM, some scientists continue to question whether perioperative hyperglycemia is a significant risk factor for postsurgical adverse events. Perioperative hyperglycemia in nondiabetics has only recently been acknowledged as a potential risk factor for adverse outcomes following serious health events such as major surgery, myocardial infarction or stroke.[18,19] However, it appeared unclear in these studies whether those persons, classified as nondiabetic who exhibit perioperative hyperglycemia, are undiagnosed diabetics or showing evidence of long-standing insulin resistance exacerbated by the health event, or simply responding to the stress of the acute medical or surgical state. It was also unclear whether hyperglycemia is causally associated with a worse outcome or simply reflects a more severe adverse event, since serum glucose is often measured only after the fact. Another study attempted to clarify these issues by looking specifically at the infection outcomes of perioperative hyperglycemia. These researchers believed that the timing of elevated perioperative serum glucose indicated whether it was a risk factor for nosocomial postoperative infection or a harbinger of an infection.[20] The authors observed that the early postoperative period, when the patient was at greatest physiological stress, held the highest risk for development of SSI. This was also the time when serum glucose was highest in both diabetic and nondiabetic patients and when it was unlikely that patients would have pre-existing, untreated infections. They concluded that when hyperglycemia occurred during the first two postoperative days, regardless of pre-existing diabetes, the rates of nosocomial infection were higher.

There are two primary mechanisms that place patients experiencing acute perioperative hyperglycemia at increased risk for SSI. The first mechanism is the decreased vascular circulation that occurs, reducing tissue perfusion and impairing cellular-level functions. A clinical study by Akbari et al. noted that when healthy, nondiabetic subjects ingested a glucose load, the endothelial-dependent vasodilatation in both the micro and macrocirculations were impaired similar to that seen in diabetic patients.[21] The second affected mechanism is the reduced activity of the cellular immunity functions of chemotaxis, phagocytosis and killing of polymorphonuclear cells as well as monocytes/macrophages that have been shown to occur in the acute hyperglycemic state.[22] These two impairments of natural host defenses combine to increase the risk of tissue infection in both diabetic and nondiabetic surgical patients.

Controlling perioperative hyperglycemia requires a concerted, coordinated effort by anesthesia, surgery, nursing and pharmacy. Anesthesia must be ready to check the patient's FSG preoperatively and implement insulin therapy as early as indicated. The surgeon must be prepared to continue the glucose control for at least 48 hours after surgery; and the nursing staff must take special care to monitor, calibrate and finely control normoglycemia during the inpatient stay. Nursing also needs to educate patients on the potential need for postdischarge glycemic control, especially if the patient was newly noted to be hyperglycemic preoperatively. Medication reconciliation is critical for the diabetic patient during all phases of surgical care, with the pharmacist taking the lead in this effort.

Obesity

Obesity, usually defined as having a body-mass index greater than or equal to 30 kg/m,[2] is another patient risk factor for SSI that has proven difficult to pin down.[23-25] A lot of the confusion around the extent of risk caused by obesity is that its role is often difficult to extricate from the effect of severe DM, a common comorbid partner.

Often there is insufficient time prior to the surgery to significantly reduce the patient's degree of obesity. However, evaluation for the existence of diabetes and implementation of serum glucose control, if necessary, will go a long way to minimize the risk obesity may present for subsequent SSI. Additionally, major surgery is often viewed as a life-altering event and may serve to provide patients with the motivation needed to adopt healthier eating habits and other positive lifestyle changes. Personalized education and diets from nutritionists, and support from weight-loss groups have also shown positive long term effects.[26]

Malnutrition

Malnutrition has long been identified as a risk for nosocomial infections, including SSI, among patients undergoing any type of surgery.[27] Patients who are malnourished have been found to have less competent immune response to infection. Serum albumin level is the surrogate marker most commonly used to classify nutritional status, with a normal range considered to be 3.4-5.4 g/dL.

It is essential once the patient has been diagnosed as malnourished that the etiology of this comorbidity be identified. It is not uncommon for the elderly to show evidence of protein-energy malnutrition for a number of reasons: poverty and limited mobility, social isolation and depression, poor dentition, medication-related anorexia, as well as decline in cognitive and functional status.[28] Possible interventions include family-support discussions, dental consults, diet counseling and social service referrals. Depending on the surgical urgency, delay of surgery until the patient's nutritional status improves may be indicated. Preoperative and postoperative fasting should be kept at a minimum for these patients, as even short-term deprivation may exacerbate risks.

Tobacco Use

Not unexpectedly, malnutrition and cigarette smoking have shown evidence of interaction. Cigarette smoking has been associated with inhibited wound healing and decreased circulation to the skin due to microvascular obstruction from platelet aggregation and increased nonfunctioning hemoglobin.[29] In addition, smoking has been found to compromise the immune system and respiratory system. Cigarette smoking as a host risk factor has had conflicting reports, and that may be partly due to the fact that some studies that evaluate this factor consider only current smoking to increase risk of SSI.[30] A percentage of patients quit smoking immediately before the surgery, and then may signify themselves as nonsmokers at the time of surgery, which may be performed within days or weeks of smoking cessation. The conflicting results may be dependent on how distant prior smoking must be before there is a significant difference between the groups in terms of outcome.

Cigarette smoking may also be one of the pre-existing patient factors amenable to intervention, especially with the relatively new smoking cessation supports now available, such as the nicotine patch or bupropion hydrochloride. At least one month prior to surgery, patients should be encouraged to cease tobacco use. Patients should also adhere to nutrition and physical status guidelines including the intake of vitamins such as A, B, C, D, E and K and supplements of zinc, manganese, magnesium, copper and iron.[31]

Pre-existing Remote Body Site Infection

Not infrequently, patients harbor indolent dental, urinary or skin soft tissue infections at the time of surgery. The major concerns about the presence of a pre-existing infection are that it may: 1) be the source for hematogenous spread, causing late infections to joint prostheses or cardiac valves, or 2) be a contiguous site for bacterial transfer.[32-34] These infections at a site remote from the wound have been linked to increasing SSI rates three- to five-fold.[35]

Any remote infections should be identified and treated prior to the operation. It is not uncommon for multiple dental extractions to be required in order for oral infections to be eliminated preoperatively. Certain surgical cases, especially those requiring implanted devices, may demand that the operation be postponed until the infection is resolved.[1]

Colonization with Microorganisms

The primary source of infection for most surgical sites is the patient's endogenous microorganisms.[23,24] All patients are colonized with bacteria, fungi and viruses—up to 3 million germs per square centimeter of skin.[36] However, not all patients, bacteria, fungi and viruses are created equal. Patients with a history of diabetes mellitus (DM), chronic obstructive pulmonary disease (COPD) necessitating long-term steroid use, or other chronic illness who have had repeated hospitalizations and/or courses of antibiotics tend to be more heavily colonized with bacteria, especially with antibiotic-resistant bacteria such as methicillin-resistant *Staphylococcus aureus* (MRSA). All surgical wounds will be contaminated with bacteria during surgery, but only a small percentage becomes infected.[10] This is because most patients' host defenses are capable of controlling and eliminating the offending organisms when the wound inoculum is small, the bacterial contaminants are not overwhelmingly virulent, the wound microenvironment is healthy,

Surgical site infections (SSIs) result in up to $10 billion in costs every year.[4] Compared to an uninfected patient, the patient with an SSI:

- Stays hospitalized 7 days longer;
- Is 60% more likely to spend time in the ICU;
- Is 5 times more likely to be readmitted within 30 days of discharge;
- Is twice as likely to die.[48]

and the host defenses are intact. The patient-related surgical site infection risk equation drawn below in Figure 2 models this concept, where the outcome calculation is a hoped for risk of SSI less than one or a nonevent.

Figure 2. Patient-Related Surgical Site Infection Risk Equation

$$\frac{\text{Dose of Bacterial Contamination} \times \text{Virulence of Microorganism}}{\text{Resistance of Patient to Infection}} = \text{Risk of SSI}$$

Staphylococcus aureus nasal carriage, noted in 30% of most healthy populations, and especially methicillin-resistant *staph aureus* (MRSA), predisposes patients to have higher risk of SSI.[10] Having an endogenous source for the bacterium that may be responsible for as many as one out of three wounds can increase the likelihood of infection ten-fold.[27,38] However, most surgical settings have not yet instituted routine active surveillance for this common carrier state, so decolonization strategies are infrequently implemented.

No matter what the intervention, the patient's skin will never be sterile, but a number of strategies can be employed to reduce the bioburden. Patients should bathe or shower with an antiseptic such as chlorhexidine at least once before the operation.[8] If there is any indication that physical debris has not been adequately removed, another supervised shower and shampoo should be performed on the day of surgery. Hair in the surgical incision area should be left unless removal is necessary for the procedure. If removed, caregivers should do so with clippers immediately prior to surgery. Intraoperative skin preparation is of critical importance, not only that the antibacterial solution used has broad spectrum properties, but also that the product be properly applied. Additional strategies used to reduce bacterial migration into the surgical incision include the use of antiseptic-impregnated adhesive drapes and/or novel cyanoacrylate-based skin sealants that are applied over the skin prep to immobilize residual skin flora, including those imbedded in hair follicles.

Perioperative Hypothermia

Hypothermia, a reduction in core body temperature below 36ºC/96.8ºF, is one of the most common patient risk factors for perioperative complications and surgical site infection.[39,40] One out of every two surgical patients has been noted to have temperatures below 36ºC, and one out of three surgical patients incur core body temperatures below 35ºC/95.0ºF during the perioperative interval.[41] Just 1.5°C below normal may result in: increased wound infections (SSI), decreased oxygen tension in tissues, cardiac dysfunction, coagulopathy evidenced as increased blood loss, altered drug metabolism, delayed recovery of normothermia and increased mortality.[42,43] The loss of body heat is the result of a combination of factors and heat loss mechanisms commonly occurring in the perioperative setting. Patient-related risk factors include: cachexia or general ill health, female gender, extremes of age as well as type of anesthesia, and type and length of surgical procedure.[44] Contributing factors involve presurgery fasting, low ambient temperatures in the preoperative and surgical areas, and the use of cold skin prepping solutions, cold operating table, and cold IV fluids. General anesthesia results in vasodilation with a rapid redistribution of warmer core blood being shunted to cooler extremities, reduction in metabolic heat generation and loss of shivering response.[45] Major surgeries resulting in large thorax and/or abdominal incisions also expedite core heat loss and impede most warming strategies.

The best way to treat hypothermia is to prevent heat loss from occurring. Noninvasive strategies noted to have increasing effectiveness include the routine use of warmed IV fluids and skin prep solutions, warmed blankets, thermal lamps, hot water mattresses, forced-air warming systems and direct conduction thermal pads.

Post-Procedure Prevention Strategies

The risk of infection continues even after the patient leaves the hospital. Caregivers should educate the patient and relatives regarding proper incision care, how to recognize signs of SSI and the importance of reporting symptoms to their surgeons as well as primary care providers. Take-home materials should be easy-to-read and available in multiple languages.

It is also important to coordinate postdischarge SSI surveillance activities between the facility's infection prevention program, the surgeon, the surgical unit, and possible referral or readmission centers so that accurate statistics can be collected on the incidence of SSI by types of patients, surgeries and surgeons. Considering that more than half of all surgeries are performed in outpatient settings and more than 65% of all inpatient surgery SSIs are identified after the patient leaves the facility, it is very easy to significantly underestimate SSI rates and miss serious infection issues.[46,47] Most importantly, the outcome data and data analysis should be shared with all stakeholders so that there is agreement on the data validity and universal involvement in ongoing and episodic improvement activities.

Conclusion

Surgical site infection risk depends upon a number of patient factors, including pre-existing medical conditions, amount and type of resident skin bacteria, perioperative glucose levels, core body temperature fluctuations, and preoperative, intraoperative and postoperative care. Therefore, it is difficult to predict which wounds will become infected. For that reason, caregivers should strive for early identification of patients with risk factors amenable to intervention to minimize the risk of wound contamination in all surgical cases and to support host defenses throughout the continuum of care. These and other well-researched interventions should be bundled together and considered integral components of the best practices care we must provide our patients every day. ✛

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Dr. Pear is a registered nurse and obtained her bachelor's degree in Nursing from Long Island University in New York. She also holds a master's degree in Medical-Surgical Nursing with an education concentration from the University of Arizona. Her thesis work investigated nurses' self-perception of hand hygiene behavior. She subsequently obtained a Doctorate in Epidemiology from the College of Public Health at the same institution. Her dissertation work focused on the role of hyperglycemia in post-cardiac surgery infections. She has been certified in Infection Control and Epidemiology (CIC) for more than 15 years.