

PREVENTING SURGICAL SITE INFECTIONS

KEY CONCEPTS you will learn in this chapter include:

- What the factors that affect the risk of nosocomial surgical site infections are
- How to reduce the risk of nosocomial surgical site infections
- What the rationale for antibiotic prophylaxis is
- When the use of prophylactic antibiotics is indicated
- What the recommendations for prevention of bacterial endocarditis are

BACKGROUND

Before the work of Joseph Lister and others in the 1860s, surgical patients commonly developed postoperative fever followed by purulent drainage from their incisions, sepsis and often death. The introduction of the principles of antisepsis by Lister and the acceptance of Pasteur's germ theory in the late nineteenth century led to a marked decrease in wound infection rates. These discoveries also radically changed surgery from an activity associated with infection and death to one of preventing suffering and prolonging life. In the twentieth century, the two key factors that have enabled surgical advances, such as open heart surgery and kidney transplants, to become routinely possible and safe are improved anesthesia and scientifically sound infection prevention practices.

Despite improvements in operating room practices, instrument sterilization methods, better surgical technique and the best efforts of infection prevention practitioners, surgical site infections (SSIs) remain a major cause of nosocomial (hospital-acquired) infections—and rates are increasing globally (Alvarado 2000). Moreover, in countries where resources are limited, even basic life-saving operations, such as appendectomies and cesarean sections, are associated with high infection rates and mortality. In these countries, therefore, it makes sense to focus on preventing SSIs in those procedures most frequently performed and/or those having the highest SSI rates.

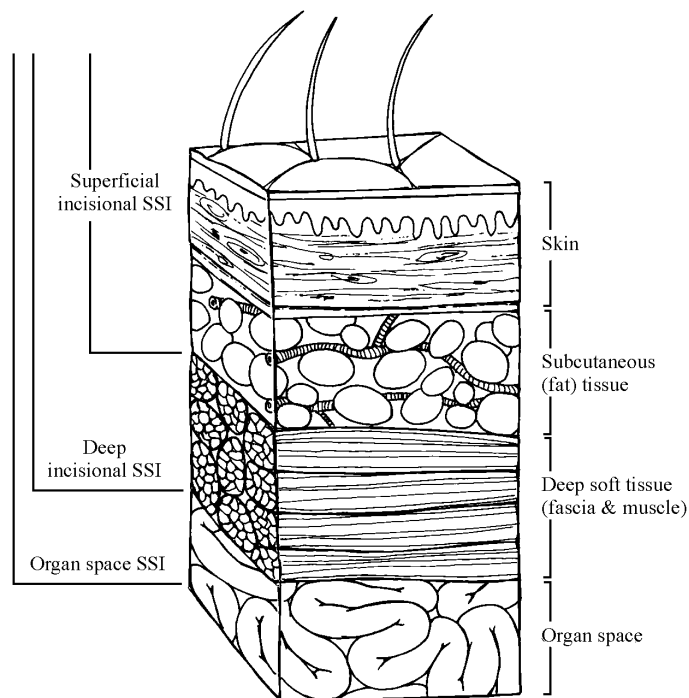
To reduce the risk of nosocomial SSIs in developing countries, a systematic but realistic approach must be applied with awareness that this risk is influenced by characteristics of the patient, the operation, the healthcare staff and the hospital. In theory, reducing risk is relatively simple and inexpensive, especially when compared to the cost of the infections themselves, but in practice it requires commitment at all levels of the healthcare system. And, as noted in **Chapter 20**, neither the basic

problems responsible for the high nosocomial rates (i.e., lack of training, supervision, infrastructure and resources) nor the recommended solutions have changed over the past 10–20 years in most developing countries.

DEFINITIONS

- **Organ/Space SSI.** Any part of the body other than the incised body wall parts that were opened or handled during an operation.
- **Surgical site infections (SSI).** Either an **incisional** or **organ/space** infection occurring within 30 days after an operation or within 1 year if an implant is present. As shown in **Figure 23-1**, incisional SSIs are further divided into **superficial incisional** (only involves skin and subcutaneous tissue)¹ and **deep incisional** (involves deeper soft tissue, including fascia and muscle layers).²

Figure 23-1. Cross-Section of Abdominal Wall Showing CDC Classifications of Surgical Site Infection



Adapted from: Horan et al 1992.

¹ Does not include stitch abscess, infection of episiotomy or newborn circumcision, or infected burn wound. Specific criteria are used for identifying these infections and reporting them.

² For confirmation of all SSIs, clinical findings (signs or symptoms of infections) and/or laboratory test results (organism isolated from aseptically obtained culture) are required.

The surgical wound classification system includes four categories:

- **Class I—clean.** Uninfected operative wound with no inflammation and in which the respiratory, gastrointestinal (GI), genital and urinary tracts were not entered. Clean wounds are closed at surgery and, if necessary, drained with closed drainage.
- **Class II—clean-contaminated.** Wound in which the respiratory, GI, genital or urinary tract(s) were entered under controlled conditions but without unusual contamination or spillage of contents.
- **Class III—contaminated.** Open, fresh accidental wound or an operation with a major break(s) in aseptic technique (e.g., open cardiac massage) or gross spillage from the GI tract. Also included are incisions in which acute, nonpurulent inflammation is found.
- **Class IV—dirty or infected.** Old wounds with dead tissue and those that involve existing clinical infection or a perforated bowel, suggesting that the pathogens causing the postoperative infection were present in the wound before the surgery.

EPIDEMIOLOGY AND MICROBIOLOGY

Among surgical patients, SSIs are the most common nosocomial infection, accounting for about a third of all such infections. In most studies about two thirds of these can be classified as superficial incisional, while the remaining involve either organs or spaces entered during surgery or are deep incisional SSIs. On average, having an SSI increases a patient's hospital stay by 7–10 days, with organ/space and deep incisional SSIs accounting for the longest stays and highest costs.

Organisms associated with SSIs vary with the type of procedure and the anatomic location of the operation. *Staphylococcus aureus* (coagulase-negative staphylococci), enterococcus species and *Escherichia coli* are the three most frequently isolated pathogens. An increasing number of SSIs are caused by antimicrobial-resistant pathogens, and the incidence of fungal SSIs has risen significantly in the last decade in part because of the dramatic increase in the number of HIV/AIDS patients. For most SSIs, the source of the pathogen(s) comes from the patient's skin, mucous membranes or bowel and rarely from another infected site in the body (endogenous sources). Exogenous sources of SSI pathogens are occasionally responsible. These include:

- organisms from members of the surgical team (e.g., hands, nose or other body parts);
- contaminated surfaces in the operating room, even the air; and
- contaminated instruments, surgical gloves or other items used in the surgery.

Exogenous organisms are primarily aerobic staphylococci or streptococci species (with the exception of tetanus endospores). Although fungi are widely present in the environment, they rarely cause SSIs.

The mechanisms by which microorganisms infect tissue and produce disease are complex and incompletely understood. For example, some pathogens may contain or produce toxins and other substances that increase their ability to invade a patient's tissue, produce damage or survive in the tissue.

PATHOGENESIS

By the end of an operation, bacteria and other microorganisms contaminate all surgical wounds, but only a small number of patients actually develop a clinical infection (Fry 2003). Infection does not develop in most patients because their defense mechanisms effectively eliminate the contaminating organisms at the surgical site. Whether a potential infection occurs depends on several factors, with the most important being:

- number of bacteria entering the wound;
- type and virulence (ability to cause infection) of the bacteria;
- host defense mechanisms (e.g., effectiveness of inflammatory response and status of the immune system); and
- external factors, such as being in the hospital several days before surgery or the operation lasting more than 4 hours.

Two factors that can help minimize the number of organisms entering the wound are the skill and experience of the surgeon and use of good surgical technique. Both are important because if a surgical site is contaminated with more than 10^5 (100,000) organisms per gram of tissue, the risk of SSI is markedly increased (Krizek and Robson 1975). The dose required for infection can be even lower, however, if foreign material is present at the site (e.g., only 10^2 or about 100 staphylococci are enough if silk suture is used for closure or to control bleeding) (James and MacLeod 1961).

While the type and virulence of the bacteria cannot be controlled, the other factors can to a large extent. For example, tissue injury caused by making the wound incision triggers a chain of events, called the inflammatory response, that take place even before bacterial contamination occurs. The effectiveness of the inflammatory response to mobilize patient defense mechanisms (e.g., activation of various types of white blood cells that contain and destroy the bacteria before infection can occur) depends to large extent on the patient's general health, age, obesity, smoking, some chronic diseases and the status of the immune system.

RISK FACTORS

Table 23-1 lists the most widely accepted patient and operative characteristics that may increase the risk of an SSI. What is interesting about this list is how short it is. Of the many possible human conditions and surgical practices, it is surprising how few have been proven to independently influence the risk of infection. In part this is due to the complex nature of SSIs and to the great difficulty in designing and conducting studies that accurately isolate the effect of a single factor.

Table 23-1. Patient and Operation Characteristics That May Influence the Risk of Developing a Surgical Site Infection

PATIENT

Nutritional status, poor
 Diabetes, uncontrolled
 Smoking or use of other tobacco products
 Obesity
 Coexistent infections at a remote body site
 Colonization with microorganisms
 Altered immune response (HIV/AIDS and chronic corticosteroid use)
 Length of preoperative stay

OPERATION

Preoperative shaving
 Preoperative skin prep
 Duration of operation
 Antimicrobial prophylaxis
 Operating room ventilation
 Instrument processing (cleaning, HLD or sterilization)
 Foreign material in the surgical site
 Surgical drains
 Surgical technique

- Poor hemostasis
- Failure to obliterate dead space
- Tissue trauma

Adapted from: SHEA, APIC, CDC and SIS 1990.

Patient Factors

- **Obesity** increases risk substantially when the subcutaneous abdominal fat layer exceeds 3 cm (1.5 inches) (Nyström et al 1987). The risk is increased by the need for a larger incision, decreased circulation to the fat tissue or the technical difficulty of operating through a large fat layer.
- **Infection at another site** may increase the risk of spreading infection through the bloodstream.
- **Immunocompromised patients** (e.g., those with HIV/AIDS, those with chronic corticosteroid use such as occurs with asthma and heavy

smokers or users of other tobacco products) are at significantly greater risk of SSIs.

- **Malnutrition** may or may not be a contributing factor. Unfortunately, most studies have not been conducted in developing countries where severe malnutrition is more common.
- **Age, race, socioeconomic status and chronic diseases**, such as diabetes and malignancy, are difficult to assess because they are frequently associated with other factors that independently contribute to risk. For example, age over 70 may be accompanied by decreased defense mechanisms, poor nutrition and anemia.

When possible, the effects of conditions that might complicate surgical recovery should be corrected or stabilized preoperatively. For example:

- Although diabetes and high blood pressure are not independent risk factors, they should be under control before elective surgery.
- Smoking or use of other tobacco products should be stopped at least 30 days before elective surgery if possible.
- Patients with infections remote to the surgical site should be treated if possible or their surgery postponed.
- Women using combined (estrogen- and progestogen-containing) contraceptives (oral or injectable) should be switched to a nonhormonal method at least 30 days before major elective surgery to minimize the risk of deep vein thrombophlebitis and nonfatal pulmonary embolism (Blumenthal and McIntosh 1996).

REDUCING THE RISK OF SURGICAL SITE INFECTIONS

In 1999, CDC issued guidelines for reducing the risk of SSIs based on existing scientific data, theoretical rationale and applicability. A copy of these recommendations, including the strength of the scientific information (Category I or II) on which they are based, is presented in **Appendix J**. Because these recommendations are intended to be used in US healthcare facilities, administrators and health professional staff in developing countries will need to carefully review, accept or modify them according to what is possible, practical and doable within their resource setting. While the vast majority of these recommendations are applicable and doable even in limited resource settings, some are not. For example, recommendations regarding Intraoperative Operating Room Ventilation (Section 2a) that require positive-pressure ventilation, provision of 15 air exchanges per hour and filtration of all air (fresh or recirculated)—all Category 1B recommendations—may not be financially possible. Other recommendations that may need to be modified, depending on available resources and the nature of the surgical procedure, include instrument sterilization recommendations (Section 2d) and the use of sterile surgical attire and drapes that are fluid-resistant (Section 2e).

In addition, some factors that may affect the risk of infection have either not been studied or the results of existing studies are inconclusive (e.g., members of the surgical team wearing nail polish). As a consequence, for these factors either no recommendation is provided in the guidelines or they are not dealt with at all. A few of the most notable omissions include whether or not to:

- limit traffic flow (i.e., the number of people in the operating room) during surgery;
- wear soiled surgical clothing from case to case;
- perform more than one operation in the same room, including the use of shared personnel;
- cover a clean incision closed at surgery beyond 48 hours; or
- advise the patient to bathe or shower after surgery without a dressing.

Note: Putting topical antibiotic ointments on closed skin incisions does not decrease the risk of SSIs. (Fry 2003).

For most of these, standard practice would advise against doing them. With regard to care of the incision, it is generally believed that postoperative care has only minimal effect on the risk of SSIs. This belief is based on the assumption that wounds begin to heal immediately and after 48 hours do not to require a dressing or will not become infected by showering or bathing. This assumption, however, may not be valid, especially in limited-resource settings where hygiene is poor and the quality of tap water is questionable or frankly contaminated. For example, a 1991 report by Lowry et al documented that an outbreak of Legionnaire's disease was related to contaminated tap water used for washing around surgical wounds. Thus, where the likelihood of wound contamination is high and the quality of tap water poor, it is probably advisable to keep the incision clean, dry and covered. Bathing or showering should be avoided until the incision is nearly healed (5–7 days).

Note: Healthy tissue growth is damaged when the dry gauze is removed; therefore, moisten the dry gauze with sterile normal saline before removing it.

Recommendations for postoperative care are quite different for a surgical incision that is either:

- left open at the skin level for a few days (usually 4–5 days) before it is closed (delayed primary closure); or
- left open to heal by secondary intention (i.e., healing from the base upwards until reaching the surface).

In both situations, the incision initially should be packed and covered with a sterile, moist gauze dressing and changed regularly.

Remember: Wash hands, or use an antiseptic handrub, before putting on gloves and after taking them off to avoid exposure to blood and other potentially infected body fluids and to decrease the risk of cross-contamination.

- If gauze dressings moistened with sterile normal saline are used, the dressing should be changed using aseptic technique (sterile or high-level disinfected gloves) every 8 hours to prevent the gauze from drying out.

- If sterile gauze filled with petroleum jelly or other moistening agents is used to pack and cover the incision, it can be changed less often (24–48 hours), depending on the type of wound and the manufacturer’s directions.

Unless the dressing and surrounding area can be kept dry, the patient should not bathe or shower while the incision is packed and covered with a dressing (or at least until granulation tissue is present in a wound healing by secondary intention).

Other Factors

- **Prolonged preoperative hospitalization** exposes patients to hospital flora, including multidrug-resistant organisms. Completing presurgical evaluations and correcting underlying conditions **before admission** to a hospital decreases this risk. Also, performing elective surgery, where feasible, in ambulatory surgery centers rather than acute care hospitals decreases the risk of exposure to hospital flora.
- **Preoperative hair removal** should be avoided if it is unnecessary. If hair must be removed, clip it with scissors just before the surgery. Shaving is a proven risk factor for SSIs (Cruse and Foord 1980).
- **Wide prepping of the proposed incision site** with antiseptic solution preoperatively helps keep microorganisms from migrating into the wound (breakthrough) if the site towels or drapes become wet during surgery (**Chapter 5**).
- **Good surgical technique** minimizes tissue trauma, controls bleeding, eliminates dead space, removes dead tissue and foreign bodies, uses minimal suture and maintains adequate blood supply and oxygenation. Specifically, it is important to:
 - handle soft tissue gently to avoid crushing that can result in tissue death (necrosis);
 - use electrocautery sparingly to control bleeding because it leaves behind dead tissue that is more likely to become infected;
 - use absorbable suture whenever possible because permanent suture, especially silk suture, reduces the number of bacteria necessary to cause infection (James and MacLeod 1961); and
 - use closed suction drains that exit through a separate stab wound to help prevent accumulation of tissue fluid in the dependent portion of the wound. Preventing this is especially important in obese patients and may reduce SSIs (Fry 2003). (Passive drains, such a Penrose drain, exiting through the bottom of the incision should not be used.)
- **Increased length of surgical procedures** is associated with increased risk of SSIs. It is estimated that the infection rate nearly doubles with each hour of surgery (Cruse and Foord 1980.)
- **Prompt discharge postoperatively**, provided patients are able to return to homecare, reduces the risk of infection as well.

These factors, coupled with the experience and skill of the surgeon and assistant, are known to reduce the risk of SSIs.

ANTIBIOTIC PROPHYLAXIS IN SURGERY

The use of antibiotics preoperatively can reduce the rate of infection, particularly wound infections, after certain operations. The benefit, however, must be weighed against the risks of toxic and allergic reactions, the emergence of resistant bacteria, drug interactions, superinfection and cost (Nichols 2001). For example, it is estimated that 5% of patients receiving an antibiotic will have a serious reaction to the drug. In general, antibiotic prophylaxis is recommended only for procedures with high infection rates and those in which the consequences of infection are especially serious. The recommendations for when to consider prophylactic antibiotics in general surgical, gynecologic and obstetric patients are outlined in **Table 23-2**.

Guidelines for Choosing a Prophylactic Antibiotic

Ideally the prophylactic drug(s) should be directed against the most likely infecting organisms, but need not kill or inactivate all pathogens. For most procedures, an inexpensive, first- or second-generation cephalosporin, such as cefazolin (Ancef[®]), which has a moderately long half-life and is active against staphylococci and streptococci, has been effective when given intravenously (IV) 30 minutes before surgery. Exceptions are for an appendectomy, where cefoxitin (Mefoxin[®]) or cefotetan (Cefotan[®]) is preferred because they are more active than cefazolin against bowel anaerobic organisms.

Where methicillin-resistant staphylococci are important postoperative pathogens, vancomycin (Vancocin[®]) can be used, but routine use for prophylaxis should be avoided because it may promote the emergence of resistant organisms. Also, third- and fourth-generation cephalosporins (e.g., ceftaxime or cefepime) should not be used for routine surgical prophylaxis because:

- they are expensive, some are less active than cefazolin against staphylococci;
- their spectrum of activity includes organisms rarely encountered in elective surgery; and
- their widespread use may promote the emergence of resistance.

Table 23-2. Prevention of Wound Infection and Sepsis in Surgical Patients

NATURE OF OPERATION	LIKELY PATHOGENS	RECOMMENDED DRUGS	ADULT DOSAGE BEFORE SURGERY
Gastrointestinal			
Colorectal	Enteric gram-negative bacilli, anaerobes, enterococci	<i>Oral:</i> neomycin plus erythromycin base ¹ <i>IV:</i> cefoxitin or cefotetan OR cefazolin plus metronidazole	1–2 grams IV 1–2 grams IV 1–2 grams IV 0.5 grams IV
Appendectomy	Enteric gram-negative bacilli, anaerobes, enterococci	cefoxitin or cefotetan	1–2 grams IV 1–2 grams IV
Genitourinary			
	Enteric gram-negative bacilli, enterococci	<i>High risk</i> ² only: ciprofloxacin	500 mg PO or 400 mg IV
Gynecologic and Obstetric			
Vaginal or abdominal hysterectomy	Enteric gram-negative, anaerobes, group B strep, enterococci	cefazolin or cefotetan or cefoxitin	1–2 grams IV 1–2 grams IV 1 gram IV
Cesarean section	same as for hysterectomy	<i>High risk</i> ³ only: cefazolin	1 gram IV after cord clamping
Abortion	same as for hysterectomy	<i>First trimester, high risk</i> ⁴ : aqueous penicillin G OR doxycycline <i>Second trimester:</i> cefazolin	2 million units IV 300 mg PO ⁵ 1 gram IV
Contaminated Surgery ⁶			
Ruptured viscus	Enteric gram-negative bacilli, anaerobes, enterococci	cefoxitin or cefotetan plus or minus gentamicin OR clindamycin plus gentamicin	1–2 grams IV q6h 1–2 grams IV q12h 1.5 mg/kg IV q8h 600 mg IV q6h 1.5 mg/kg IV q8h
Traumatic wound	<i>S. aureus</i> , group A strep, clostridia	cefazolin ⁷	1–2 grams IV q8h

¹ After appropriate diet and enemas, one gram of each at 1 pm, 2 pm and 11 pm the day before an 8 am operation.

² Urine culture positive or unavailable, preoperative catheter, transrectal prostatic biopsy.

³ Active labor or premature rupture of membranes.

⁴ Patients with previous pelvic inflammatory disease, previous gonorrhea or multiple sex partners.

⁵ Divided into 100 mg 1 hour before the abortion and 200 mg one half hour after.

⁶ For contaminated or “dirty” surgery, therapy should usually be continued for about 5 days. Ruptured viscus in postoperative setting (dehiscence) requires antibacterials to include coverage of nosocomial pathogens.

⁷ For bite wounds in which likely pathogens may also include oral anaerobic organisms, such as *Eikenella corrodens* (human) or *Pasteruella multocida* (dog and cat), use ampicillin/sulbactam (*Unsayn*[®]). This antibiotic can also be used for penetrating intracranial wounds, including gunshot injuries.

Adapted with special permission from: *The Medical Letter* 2001.

Number of Doses In most instances, a single intravenous (IV) dose of an antibiotic completed 30 minutes or less before the skin incision provides adequate tissue levels throughout the operation. (If vancomycin is used, at least 1 hour is required.) Clearly the concept of “on call” infusion of prophylactic antibiotics is not acceptable because delays in starting the operation can occur, resulting in ineffective tissue levels when the surgery actually does start. If surgery is prolonged (more than 4 hours), major blood loss occurs or an antibiotic with a short half-life such as cefoxitin is used, one or more additional doses should be given during the procedure.

PREVENTION OF BACTERIAL ENDOCARDITIS

The risk of endocarditis is considered high in patients with previous endocarditis, prosthetic heart valves, complex congenital heart disease such as tetralogy of Fallot or surgically constructed pulmonary shunts or tubing (conduits). Viridans streptococci are the most common cause of endocarditis after dental or upper respiratory procedures, while enterococci are most frequently found following GI or genitourinary procedures.

Although the effectiveness of antimicrobial prophylaxis in preventing endocarditis has never been established by controlled clinical trials in humans (Level 1 evidence), many physicians believe their use before procedures that may cause brief periods of bacteremia is protective. The drugs and dosages in **Table 23-3** are based on those recommended by the American Heart Association (Dajani et al 1997).

Table 23-3. Endocarditis Prophylaxis

	DOSAGE FOR ADULTS	DOSAGE FOR CHILDREN*
DENTAL AND UPPER RESPIRATORY PROCEDURES		
Oral		
Amoxicillin (Amoxi [®])	2 grams 1 hour before procedure	50 mg/kg 1 hour before procedure
Penicillin allergy:		
Clindamycin (Cleocin [®])	600 mg 1 hour before procedure	20 mg/kg 1 hour before procedure
OR		
Azithromycin (Zithromax [®])	500 mg 1 hour before procedure	15 mg/kg 1 hour before procedure
Parenteral (for patients unable to take oral drugs)		
Ampicillin (Omnipen [®])	2 grams IM or IV within 30 minutes before procedure	50 mg/kg IM or IV within 30 minutes before procedure
Penicillin allergy:		
Clindamycin	600 mg IV within 30 minutes before procedure	20 mg/kg IV within 30 minutes before procedure
GASTROINTESTINAL AND GENITOURINARY PROCEDURES		
Oral		
Amoxicillin	2 grams 1 hour before procedure	50 mg/kg 1 hour before procedure
Parenteral		
Ampicillin ¹	2 grams IM or IV within 30 minutes before procedure	50 mg/kg IM or IV within 30 minutes before procedure
Penicillin allergy:		
Vancomycin (Vancocin [®])	1 gram IV infused <i>slowly over 1 hour</i> beginning 1 hour before procedure	20 mg/kg IV infused <i>slowly over 1 hour</i> beginning 1 hour before procedure
± Gentamicin ² (Garamycin [®])	1.5 mg/kg (120 mg max.) IM or IV within 30 minutes before procedure	1.5 mg/kg IM or IV within 30 minutes before procedure

* Should not exceed adult dosage.

¹ High-risk patients given parenteral ampicillin before the procedure should receive a dose of ampicillin 1 gram IM or IV or a dose of amoxicillin 1 gram orally 6 hours afterwards.

² Gentamicin should be added for patients with a high risk of endocarditis.

Adapted with special permission from: The Medical Letter 2001, citing recommendations by Dajani et al 1997.

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