DEPARTMENT OF HEALTH AND HUMAN SERVICES

Centers for Disease Control and Prevention

Draft Guideline for the Prevention of Surgical Site Infection, 1998

AGENCY: Centers for Disease Control and Prevention (CDC), Department of Health and Human Services (DHHS).

ACTION: Notice.

SUMMARY: This notice is a request for review of and comment on the Draft Guideline for the Prevention of Surgical Site Infection, 1998. The guideline consists of two parts: Part 1. ''Surgical Site Infection, an Overview'' and Part 2. ''Recommendations for the Prevention of Surgical Site Infections'', and was prepared by the Hospital Infection Control Practices Advisory Committee (HICPAC), the Hospital Infection Program (HIP), the National Center for Infectious Diseases (NCID), CDC.

DATES: Written comments on the draft document must be received on or before August 17, 1998.

ADDRESSES: Comments on this document should be submitted in writing to the CDC, Attention: SSI Guideline Information Center, Mailstop E–69, 1600 Clifton Road, N.E., Atlanta, Georgia 30333. To order copies of the **Federal Register** containing the document, contact the U.S. Government Printing Office, Order and Information Desk, Washington, DC 20402–9329, telephone (202) 512–1800. In addition, the **Federal Register** containing this draft document may be viewed and photocopied at most libraries designated as U.S. Government Depository Libraries and at many other public and academic libraries that receive the **Federal Register** throughout the country. Addresses and telephone numbers of the U.S. Government Depository Libraries are available by fax by calling U.S. Fax Watch at (202) 512–1716 and selecting option 5 from the main menu. The **Federal Register** is also available online at the Superintendent of Documents home page at: http://www.access.gpo.gov/su__docs, or the Hospital Infection Program Home page at: http://www.cdc.gov/ncidod/hip/hip.htm

FOR FURTHER INFORMATION CONTACT: The CDC Fax Information Center, telephone (888) 232–3299 and order document number 370160 or telephone (888) 232–3228, then press 2, 2, 3, 2, 2, 1, 5 to go directly to the guideline information.

SUPPLEMENTARY INFORMATION: This 2-part document updates and replaces the previously published CDC Guideline for the Prevention of Surgical Wound Infection. Part 1, ''Surgical Site Infection, an Overview'' serves as the background for the consensus recommendations of the Hospital Infection Control Practices Advisory Committee (HICPAC) that are contained in Part 2, ''Recommendations for Prevention of Surgical Site Infections''.

HICPAC was established in 1991 to provide advice and guidance to the Secretary and the Assistant Secretary for Health, DHHS; the Director, CDC, and the Director, NCID regarding the practice of hospital infection control and strategies for surveillance, prevention, and control of nosocomial infections in U.S. hospitals. The committee also advises CDC on periodic updating of guidelines and other policy statements regarding prevention of nosocomial infections.

The Guideline for the Prevention of Surgical Site Infection, 1998 is the third in a series of CDC guidelines being revised by HICPAC and NCID, CDC.

Dated: June 5, 1998.

Joseph R. Carter,

Acting Associate Director for Management and Operations, Centers for Disease Control and Prevention (CDC).

Executive Summary

This ''Guideline for the Prevention of Surgical Site Infection, 1998'' represents the third revision of the Centers for Disease Control and Prevention's (CDC) recommendations for the prevention of surgical site infection (SSI), formerly called surgical wound infections. This two-part guideline updates and replaces previous guidelines.[1 2]

Part I, ''Surgical Site Infection: An Overview,'' describes the epidemiology, definitions, microbiology, pathogenesis, and surveillance of SSIs. Part I also discusses SSI prevention measures such as antimicrobial prophylaxis, barrier precautions, operating room environment, sterilization practices, and surgical technique.

Recommended strategies for the prevention of SSIs are found in Part II, ''Recommendations for the Prevention of Surgical Site Infection.'' These recommendations represent the consensus of the Hospital Infection Control Practices Advisory Committee (HICPAC). This 12-member committee advises CDC on issues related to surveillance, prevention, and control of nosocomial infections in United States hospitals.[3] Whenever possible, the recommendations in Part II are based on data from well-designed scientific studies. However, it must be kept in mind that a limited number of studies establish the validation of SSI risk factors and SSI prevention measures. By necessity, available studies have often been conducted in narrowly defined patient populations or for specific kinds of operations, making generalization of their findings to all specialties and types of operations potentially problematic. This is especially true regarding the implementation of SSI prevention measures. Finally, some of the infection control practices routinely used by surgical teams cannot be rigorously studied for ethical or logistical reasons (e.g., wearing vs. not wearing gloves or masks). Thus, some of the recommendations in Part II are based on a strong theoretical rationale and suggestive evidence in the absence of confirmatory scientific knowledge.

This document does not specifically address issues unique to burns, trauma, transplant procedures, or transmission of bloodborne pathogens from health-care worker to patient. Neither does it specifically cover minimally invasive[†] (e.g., laparoscopic) procedures or procedures performed by surgeons outside of the operating room (e.g., endoscopic procedures). This document does not cover invasive procedures not performed by surgeons (e.g., cardiac catheterization, or interventional radiologic procedures). However, it is likely that many of the prevention strategies recommended in this document could be applied or adapted to prevent infections that complicate these procedures. The document does not recommend specific antiseptic agents for patient preoperative skin preparations or for health-care worker hand/forearm antisepsis. Hospitals should choose from the appropriate products categorized by the Food and Drug Administration (FDA).[4] Finally, this document is primarily intended for use in acute-care hospitals by surgeons, operating room nurses, infection control professionals, anesthesiologists, hospital epidemiologists, and other hospital personnel responsible for the prevention of nosocomial infections.

Part I. Surgical Site Infection (SSI): An Overview

Introduction

Before the mid-19th century, surgical patients commonly developed postoperative ''irritative fever,'' followed by purulent drainage from their incisions, overwhelming sepsis, and often death. It was not until the late 1860s, after Joseph Lister had introduced the principles of antisepsis, that postoperative infectious morbidity

[†] Currently, for minimally invasive and laparoscopic procedures no differences in infection control practices (preoperative, intraoperative, or postoperative) have been identified.

decreased substantially. Lister's work radically changed surgery from an activity associated with infection and death to a discipline that could eliminate suffering and prolong life.

Currently, in the United States alone, an estimated 27 million surgical procedures are performed each year, and nearly one-third of patients undergoing these operations are ≥65 years of age.[5] The CDC's National Nosocomial Infections Surveillance (NNIS) system, established in 1970, monitors reported trends in nosocomial infections in U.S. acute-care hospitals. Based on NNIS system reports, SSIs are the second most frequently reported nosocomial infection, accounting for 15% to 18% of all nosocomial infections among hospitalized patients.[6] During 1986–1996, hospitals conducting SSI surveillance in the NNIS system reported 15,523 SSIs following 593,344 operations. Among surgical patients, SSIs were the most common nosocomial infection, accounting for 38% of all nosocomial infections. Of these SSIs, 67% were incisional and 33% organ/space SSIs. Of the deaths among surgical patients with an SSI, 77% were related to the infection itself; the majority (93%) were organ/space SSIs. In 1980, Cruse showed that an SSI increased a patient's hospital stay by about 10 days, and cost an additional $2,000.[7 8] 1992 estimates suggested that each SSI resulted in 7.3 additional postoperative hospital days, adding $3,152 in extra charges.[9] Other studies corroborate that increased length of hospital stay and cost are associated with SSIs.[10 11] Deep (organ/space) SSIs, as compared to superficial (incisional) SSIs, are associated with an even greater increase in hospital cost.[12 13]

In this document, SSIs refer to infections of incisions that are closed primarily (i.e., skin edges are re-approximated at the end of the operation). SSIs are classified as incisional SSIs or organ/space SSIs. Incisional SSIs are further divided into those involving only skin and subcutaneous tissue (superficial incisional SSI) and those involving deeper soft tissues of the incision (deep incisional SSI). Organ/space SSIs involve any part of the anatomy (e.g., organs or spaces) other than incised body wall layers opened or manipulated during operations (Figure 1). Standardized criteria have been developed for defining superficial incisional, deep incisional, and organ/space SSIs are shown in Table 1. Table 2 lists specific sites used to differentiate organ/space SSIs. For example, in a patient who had an appendectomy and subsequently developed a subdiaphragmatic abscess, the infection would be reported as an organ/space SSI at the intra-abdominal specific site. Failure to use objective criteria to define SSIs has been shown to substantially impact SSI rates.[14 15] The CDC NNIS definitions of SSIs have been applied consistently by surveillance and surgical personnel in many settings and currently are a de facto national standard.[16 17]

Advances in infection control practices include improved operating room ventilation, sterilization, barriers, surgical technique, and availability of antimicrobial prophylaxis. Despite these activities, SSIs remain a substantial cause of morbidity and mortality among hospitalized patients. In part, this may be explained by the fact that many surgical patients today are of advanced age and/or have a wide variety of chronic, debilitating or immunocompromising underlying diseases. An increase in survival of low-birth-weight infants (e.g., ≤1000 g) may pose unique surgical challenges. There also are increased numbers of implants used and more organ transplants performed. Other factors include emergence of resistant pathogens, increased numbers of contaminated and dirty procedures (e.g., trauma-associated gunshot wounds and motor vehicle accidents). Thus, to reduce the risk of an SSI, a systematic but realistic approach must be applied with the awareness that this risk is influenced by characteristics of the hospital, surgical team, patient, and operation.

Microbiology of SSIs

According to the NNIS system the distribution of pathogens isolated from SSIs has not changed markedly during the last decade (Table 3).[6 18 19] Staphylococcus aureus, coagulase-negative staphylococci, Enterococcus spp., and Escherichia coli remain the most frequently isolated pathogens. However, SSIs are increasingly caused by antimicrobial-resistant pathogens, such as methicillin-resistant S. aureus (MRSA), vancomycin-resistant enterococcus, and gram negative rods.[20 21] In one 4-year study of 245 consecutive SSIs, 50% of all staphylococcal isolates were MRSA, 11% were gentamicin-resistant E. coli, and Klebsiella spp. demonstrated an increased resistance to aminoglycosides.[22]

The isolation of fungi from SSI, particularly Candida albicans, also has increased.[23] From 1991–1995, among patients at NNIS hospitals, the incidence of fungal SSIs increased from 0.1 to 0.3 per 1000 discharges.[23] The increased proportion of SSIs caused by resistant pathogens and Candida spp. may reflect an increased severity of illness of surgical patients, an increased number of surgical patients who are immunocompromised, and/or more widespread use of prophylactic and therapeutic antimicrobial agents.

Outbreaks or clusters of SSIs have also been caused by unusual pathogens, such as Rhizopus oryzae, Clostridium perfringens, Rhodococcus bronchialis, Legionella pneumophila and dumoffii, and Pseudomonas multivorans. These rare outbreaks have been traced to contaminated adhesive dressings,[24] elastic bandages,[25] colonized health care personnel,[26] tap water,[27] or contaminated disinfection solution.[28] When a cluster of SSIs is caused by an unusual pathogen, a formal epidemiologic investigation should be conducted to determine the source of infection.

Pathogenesis of SSI

Microbial contamination of the surgical site is a necessary precursor of SSI. The risk of SSI can be conceptualized according to the following relationship [29]:

$$\frac{\text{Dose of bacterial contamination} \times \text{virulence}}{\text{Resistance of the host}} = \text{Risk of surgical site infection}$$

Quantitatively, it has been shown that if a surgical site is contaminated with $>10^5$ microorganisms per gram of tissue, the risk of SSI is markedly increased, whereas contamination with $<10^5$ microorganisms per gram of tissue usually does not produce infection.[30–32] The risk of SSI is increased when foreign material, such as sutures,[33] indwelling devices, or prostheses are placed. For example, researchers have shown that the insertion of foreign material can decrease the infecting dose of staphylococci from $>10^6$ to $<10^3$ microorganisms per gram of tissue.[34–36]

Organisms may contain or produce substances or toxins that increase their ability to invade a host, produce damage

within the host, or survive on or in colonized or infected host tissue; promoting the development of an SSI.[37–40] For example, endotoxin has numerous effects as a component of the outer membrane of gram negative bacteria, such as a stimulator of cytokine production, and as an initiator of endogenous mediator pathways with significant systemic effects (e.g., hypotension, fever).[41 42] Some bacterial surface components (notably polysaccharide extracellular capsules) inhibit phagocytosis.[43] Some bacteria, such as Clostridium spp., produce powerful cytolytic exotoxins that disrupt cell membranes or alter cellular metabolism.[32 44] Glycocalyx and the more loosely associated component, ''slime'', are produced by a variety of microorganisms, of particular significance gram-positive bacteria, and most notably coagulase negative staphylococci.[45–47] The glycocalyx material slime develops into a biofilm and can shield infecting bacteria from phagocytosis, as well as inhibit the action of antimicrobial agents.[47] Glycocalyx biofilms have been implicated as a significant contributor to infection of surgically implanted prostheses.[47–52] Despite knowledge of these and other virulence factors, in most cases the mechanistic relationship between their presence and SSI development has not yet been fully defined.

The primary reservoir for organisms causing SSI is the patient's endogenous flora. Exogenous sources of SSI pathogens include the operating room environment, hospital personnel (especially those in the operating room),[53–55] or seeding of the operative site from a distant focus of infection.[56–60] Seeding from distant foci is particularly important in patients who have prostheses or other implants placed during the operation since the device provides a nidus for attachment of the organism.[61–66] The endogenous flora causing SSIs vary according to the specific body site.[19 67–71] For example, an SSI arising from the skin is predominant due to gram-positive organisms (e.g., staphylococci). SSIs arising from the gastrointestinal system are composed of a more mixed group of organisms, including enteric, gram-negative bacilli (e.g., E. coli), anaerobes (e.g., B. fragilis), and gram-positive organisms (staphylococci and enterococci). SSIs arising from the genitourinary system are predominantly due to gram-negative organisms (e.g., E. coli, Klebsiella spp., and Pseudomonas), and enterococci. The organisms causing SSIs in the female reproductive system include enteric, gram-negative bacilli; enterococci; group B streptococci; and anaerobes. Exogenous flora are primarily gram-positive organisms (e.g., staphylococci and streptococci) and other aerobes.[19]

Fungal pathogens rarely cause SSIs, and their pathogenesis is not well understood. Factors that increase the risk of fungal infections in surgical patients include (1) fungal colonization of the upper gastrointestinal tract following exposure to broad-spectrum antimicrobials, (2) use of proton pump inhibitors or histamine-2 blockers that decrease stomach acidity and promote growth of microorganisms, including yeast, (3) disruption of the gastrointestinal mucosal barrier, (4) impaired host defenses,[53] (5) implantation of foreign bodies (e.g., prosthetic heart valves), and (6) colonized operating room personnel (e.g., fungal colonization of artificial nails).[72]

Risk and Prevention of SSIs

The term ''risk factor'' has a particular meaning in epidemiology and, in the context of SSI pathophysiology and prevention, strictly refers to a variable that has a significant, independent association with the development of SSIs. Risk factors are identified by multivariable analyses in epidemiologic studies. Unfortunately, the term risk factor often is used in the literature in a broad sense to include patient or operation features which, although associated with SSI development, are not themselves independent.[73] The literature cited in the sections that follow includes both the strict and broad definition of risk factor. Recommendations given a category ranking of IA are generally based on studies using the strict definition.

SSI risk factors (Table 4) are valuable in two ways: (1) they allow useful stratification of operations, making surveillance data more comprehensible, and (2) preoperative knowledge of risk factors may allow for targeted prevention interventions. For example, it is known that remote site infection is an independent SSI risk factor in some operations. If a patient has such an infection, the surgical team may choose to delay an elective operation until the infection resolves.

An SSI prevention measure can be defined as an action or set of actions intentionally taken by caregivers to reduce the risk of an SSI. Many such techniques, to be described subsequently, involve reducing the opportunities for microbial contamination of the patient's tissues or sterile surgical instruments. Other techniques are adjunctive, such as using antimicrobial prophylaxis or avoiding unnecessary traumatic tissue dissection. In general, SSI prevention measures have been based on direct scientific evidence, theoretical rationale, or tradition. In the discussion that follows, the foundation for each given prevention measure will be described. Optimum application of SSI prevention measures requires that a variety of patient and operation characteristics be carefully considered.

In certain kinds of operations, patient characteristics that may be associated with an increased risk of an SSI include coincident remote site infections (e.g., urinary tract, skin, or respiratory tract),[1 31 74–76] diabetes,[77–80] cigarette smoking,[78 81–85] systemic steroid use,[77 80 86] obesity (> 20% ideal body weight),[78–80 87–90] extremes of age,[85 91–95] and poor nutritional status.[78 87 91 96–98]

The contribution of diabetes to SSI risk is controversial[77–79 91 99] because the independent contribution of diabetes to SSI risk has not typically been assessed after controlling for potential confounding factors. In one prospective study of 130 pregnant women, no correlation was found between SSI risk and perioperative glycemic control, as measured by glycosylated hemoglobin (HgA1c) levels. However, the sample size in the study was small and the use of prophylactic antimicrobial agents was not assessed. More recently, the relationship between HgA1c levels and SSI risk in coronary artery bypass graft patients was assessed; a significant relationship was found between increasing levels of HbA1c and SSI rates.[100] Also, increased glucose levels (>200 mg/dl) in the immediate postoperative period (≤48 hours) were associated with increased SSI risk.[101 102] More studies are needed to assess the efficacy of perioperative blood glucose control as an adjunctive measure.

Nicotine use delays primary wound healing and may increase the risk of SSI.[78] In a large prospective study, current cigarette smoking was an independent risk factor for sternal and/or mediastinal SSI following cardiac surgery.[78] Other studies have corroborated cigarette smoking as an important SSI risk factor.[81–85] The limitation of these studies, however, is that terms like ''current cigarette smoking'' and ''active smokers'' are not always accurately defined. To appropriately determine the contribution of tobacco use to SSI risk, standardized definitions of smoking history must be adopted and used in studies designed to control for confounding variables.

Patients who are receiving steroids or other immunosuppressive drugs preoperatively also may be predisposed to developing SSI.[77 80] In a study of long-term steroid use in patients with Crohn's disease, SSI developed significantly more often in patients receiving preoperative steroids (12.5%) than in patients without steroid use (6.7%).[86] In contrast, other investigators have not found a relationship between steroid use and SSI risk.[103–105]

There may be an increased risk of SSI in patients who are malnourished, but the exact relationship between nutritional status and risk of SSI is unclear. Low serum albumin (<3.5 g/dl) has been shown to be associated with an increased risk of SSI.[78 96–98] More precise definitions of malnutrition are needed, along with prospective observational studies, to resolve this issue.

Prolonged preoperative hospital stay is frequently suggested as a patient characteristic associated with increased SSI risk. However, length of preoperative stay is likely a surrogate for severity of illness and co-morbid conditions requiring inpatient work-up and /or therapy before the operation.[8 18 19 75 93 104 106 107]

Preoperative Issues

Preoperative Antiseptic Showers

A preoperative antiseptic shower or bath will decrease the patient's skin microbial colony count. In a study of >700 patients who received preoperative antiseptic showers, chlorhexidine reduced bacterial colony counts nine-fold (2.8×10^2 to 0.3), while povidone-iodine or triclocarban-medicated soap reduced colony counts by 1.3 and 1.9-fold, respectively.[108] A smaller uncontrolled study corroborated these findings.[109] Despite the fact that preoperative showers reduce the skin's microbial colony counts, it has not definitively been shown to reduce SSI rates.[110–112]

Preoperative Shaving/Hair Removal

Preoperative shaving of the surgical site the night before an operation is associated with a significantly higher SSI risk. This risk is greater than that accompanying the use of depilatory agents or no hair removal.[8 113–115] In one study, SSI rates were 5.6% in patients who had hair removed by razor-shave compared to a 0.6% rate among those who had hair removed by depilatory or had no hair removal.[113] The increased SSI risk associated with shaving has been attributed to microscopic cuts in the skin that later serve as foci for infection. Shaving immediately before the operation compared to shaving within 24 hours or > 24 hours preoperatively is associated with decreased SSI rates (3.1% vs. 7.1% and 20% respectively).[113] Clipping hair immediately before an operation is also associated with a lower risk of SSI than shaving or clipping the night before an operation (SSI rates immediately before = 1.8% vs night before = 4.0%).[116–119] Although the use of depilatories is associated with a lower SSI risk than shaving or clipping,[113 114] depilatories sometimes produce hypersensitivity reactions.[113] Other studies show that preoperative hair removal is associated with increased SSI rates and suggest that no hair be removed.[93 120 121]

Patient Skin Preparation in the Operating Room

Several antiseptic agents are available for preoperative preparation of skin at the incision site (Table 5). The iodophors (e.g., povidone-iodine), alcohol-containing products, and chlorhexidine gluconate are the most commonly used agents.[18 31 122] No studies have adequately assessed the comparative effects of these preoperative skin antiseptics on SSI risk in well-controlled procedure-specific studies.

Alcohol is defined by the Food and Drug Administration as having one of the following active ingredients: ethyl alcohol 60–95% by volume in an aqueous solution, or isopropyl alcohol 503–91.3% by volume in an aqueous solution.[4] In this document, -propyl alcohol is included in the definition of alcohol. Alcohol is readily available, inexpensive, and remains the most effective and rapid acting skin antiseptic.[123] Aqueous 70%–92% alcohol solutions have germicidal activity against bacteria, fungi, and viruses, but spores can be resistant.[123 124] One potential disadvantage of the use of alcohol in the operating room is its flammability.[123–125]

Both chlorhexidine gluconate and iodophors have broad spectra of antimicrobial activity.[18 31 124 126] In some comparisons of the two antiseptics, chlorhexidine gluconate achieved greater reduction in skin microflora than did povidone-iodine and also had greater residual activity after a single application.[127–129] Further, chlorhexidine gluconate is not inactivated by blood or serum proteins.[18 123 130 131] Iodophors may be inactivated by blood or serum proteins, but exert a bacteriostatic effect as long as they are present on the skin.[18 125]

Before the skin preparation of a patient is initiated, the skin should be free of gross contamination (i.e., dirt, soil, or any other debris).[132] The patients skin is prepped by applying an antiseptic preparation in concentric circles, beginning in the area of the proposed incision. The prepped area should be large enough to extend the incision or create new incisions or drain sites, if necessary.[1 124 133] The application of the skin preparation may need to be modified, depending on the condition of the skin (e.g., burns) or location of the incision site (e.g., face).

Some modifications of the preoperative skin preparation process include: (1) removing, drying, or wiping off the skin prep antiseptic agent after application, (2) using an antiseptic-impregnated adhesive drape, (3) painting the skin with an antiseptic in lieu of the traditional scrub, or (4) using a ''clean'' versus a ''sterile'' surgical skin prep kit. None of these modifications adds to further reductions in bacterial colony counts at the surgical site or reduces SSI risk.[134 – 137]

Preoperative Hand/Forearm Antisepsis

Members of the surgical team universally wash their hands and forearms by performing a traditional procedure known as scrubbing (or the surgical scrub) immediately before donning sterile gowns and gloves. Ideally, the optimum antiseptic agent should have a broad spectrum of activity, be fast-acting, and have a persistent effect.[1 138 139] Antiseptic agents commercially available in the United States contain alcohol, chlorhexidine, iodine/iodophors, para-chloro-meta-xylenol, or triclosan (Table 5).[18 123 124 140 141] Alcohol is considered the ''gold standard'' for surgical hand preparation in several European countries.[142–145] Alcohol-containing preps have been used less frequently in the United States than in Europe, possibly because of concerns about flammability and skin irritation. Povidone-iodine and chlorhexidine gluconate are the current agents of choice for most U.S. surgical team members.[124] However, when 7.5% povidone-iodine or 4% chlorhexidine gluconate was compared to alcoholic chlorhexidine (60% isopropanol and 0.5% chlorhexidine gluconate in 70% isopropanol), alcoholic chlorhexidine was found to have greater residual antimicrobial activity.[138 146] No agent is ideal for every situation, and a major factor aside from the efficacy of any product is its acceptability by operating room personnel after repeated usage. Unfortunately, most studies evaluating surgical scrub antiseptics have focused on measuring hand bacterial colony counts. No clinical trials have evaluated

the impact of scrub agent choice on SSI risk.[141 147–151]

Factors other than the choice of antiseptic agent influence the effectiveness of the surgical scrub. Scrubbing technique, the duration of the scrub, the condition of the hands, or the techniques used for drying and gloving are examples of such factors. The ideal duration of scrubbing is unknown. Recent studies suggest that scrub times of 3–5 minutes are as effective as the traditional 10-minute scrub in reducing hand bacterial colony counts.[152 153]

A surgical team member who wears artificial nails may have increased hand bacterial and fungal colonization even after performing an adequate hand scrub.[154 155] Hand carriage of gram-negative organisms has been shown to be greater among wearers of artificial nails than among non-wearers.[155] An outbreak of Serratia marcescens SSIs in cardiovascular surgery patients was found to be associated with a surgical nurse who wore artificial nails.[72] Long nails, artificial or natural, may be associated with tears in gloves.[31 124 154] The influence on SSI risk of operating room team members wearing nail polish or jewelry has not been adequately studied.[140 154 156–158]

Antimicrobial Prophylaxis

Well-designed, randomized clinical trials have demonstrated the benefit of antimicrobial prophylaxis in certain kinds of operations.[12 70 159–195] Prophylaxis should not be confused with therapy. Prophylaxis is the administration of an antimicrobial agent for operations where minimal microbial contamination of the surgical site is expected (i.e., clean or clean-contaminated operations, Table 6).[47] Therapy is the administration of an antimicrobial agent in operations where substantial microbial contamination already has occurred (i.e., contaminated or dirty operations).[47 196 197] For prophylaxis to be maximally effective, an appropriate agent must be administered at the correct time to ensure microbiocidal tissue levels before the incision is made, be maintained at adequate levels for the duration of the operation, and not be continued postoperatively.[69–71 198–200] There is no evidence that antimicrobial agents given after incision closure have prophylactic effect on bacterial contamination acquired before incision closure.[47] Also, use of antimicrobial prophylaxis beyond the intraoperative period may increase the risk of toxicity and the development of antimicrobial-resistant organisms.[47 71 201]

Antimicrobial prophylaxis is reserved for clean and clean-contaminated operations. The purpose of antimicrobial prophylaxis in clean operations in which prostheses, grafts, or implants are placed in the patient is to prevent the attachment of organisms to the device since the device can serve as a nidus for infection.[47 69 197 202 203] In clean operations in which no implant or device is placed, there is controversy regarding the use of antimicrobial prophylaxis. Because the risk of developing an SSI following clean operations is generally low,[87] the risk of infection versus the risk of prophylaxis must be considered. The purpose of using antimicrobial prophylaxis in clean-contaminated operations is primarily to reduce the number of mucosal-associated organisms.[71 202]

A prophylactic antimicrobial agent should be chosen based on its efficacy against the SSI pathogens expected as contaminants for a particular operation. Table 6 lists clean and clean-contaminated operations and the most frequently isolated SSI pathogens. The most commonly used agents are cephalosporins, particularly first and second generation cephalosporins.[202] Vancomycin should not be used routinely as a prophylactic agent[69 70 197 204] However, at institutions with high numbers of infections due to (MRSA) or methicillin-resistant *Staphylococcus epidermidis*, vancomycin has been recommended as a prophylactic agent in major operations involving implantation of prosthetic materials or devices (e.g., cardiac, vascular and orthopedic operations).[69 204 205]

Intravenous administration of the prophylactic antimicrobial agent is the most commonly used route. The intravenous route produces adequate serum and tissue concentrations in a relatively short period of time.[202] A major exception to using the intravenous route is with operations involving the gastrointestinal tract, mainly colorectal operations.[71 181 182 184 202 206–213] In these operations, the antimicrobial agent is administered orally to reduce endogenous flora in the gastrointestinal tract .

Timing and duration of prophylaxis are very important issues. The objective is to administer the antimicrobial agent before the operation starts to assure adequate microbiocidal tissue levels before the skin incision is made. A large, prospective study of antimicrobial prophylaxis in surgical patients undergoing elective clean and clean-contaminated operations showed that when prophylaxis was given 0–2 hours before incision, the SSI rate was 0.59% (10/1708). If given earlier or later, the SSI rate increased (3.8 % [14/369] and 3.3% [16/488], respectively).[214] For a cesarean section, the prophylactic agent is given immediately after umbilical cord clamping to prevent the infant from being exposed to the agent.[69 70]

In modern surgical practice, the optimum strategy for most commonly used agents (first and second generation cephalosporins) entails infusion of the preoperative dose approximately 30 minutes before skin incision and administration of additional doses approximately every 2 hours intraoperatively.[18 69 71 197 202 203] Because an elective operation can be unexpectedly delayed, the practice of administering prophylactic agents ''on call'' to the operating room is not recommended.[70 215] Appropriate timing of prophylaxis may be enhanced by administering the agent as close as possible to the time of anesthetic induction. In general, the duration of an operation will dictate the necessity infusing one or more additional doses of the prophylactic agent to maintain appropriate tissue levels (i.e., for operations whose duration exceeds the estimated serum half-life). Other reasons for additional intraoperative dosing include operations with major intraoperative blood loss or operations on morbidly obese patients.[47 69 71 201 203 216–218]

Intraoperative Issues

Operating Room Environment

Air/Ventilation

Operating room air may contain microbial-laden dust, lint, skin squames, or respiratory droplets. The microbial level in operating room air is directly proportional to the number of people moving about in the room.[219] Therefore, efforts should be made to minimize personnel traffic during operations. Outbreaks of SSIs caused by group A beta-hemolytic streptococci have been traced to airborne transmission of the organism from colonized operating room personnel to patients.[220–223] In these outbreaks, the strain causing the outbreak was recovered from the air in the operating room,[220 221 224] or on settle plates in a room in which the human carrier exercised.[221–223]

Operating rooms should be maintained at positive pressure with respect to corridors and adjacent areas.[225] Positive pressure prevents air flow from less clean areas into clean areas. All ventilation or air conditioning systems in hospitals, including those in operating rooms, should have two filter beds in series with the efficiency of filter bed one ''30% and filter bed two

2'' 90%.[226] Conventional operating room ventilation systems produce a minimum of about 15 air changes of filtered air per hour. Three (20%) of these air changes/hour must be fresh air.[226 227] Air should be introduced at the ceiling and exhausted near the floor.[227 228] Recommended ventilation parameters for operating rooms have been published by the American Institute of Architects, and the U.S. Department of Health and Human Service (Table 7).[226]

Laminar air flow is designed to move particle-free air (called ''ultraclean air'') over the aseptic operating field at a uniform velocity (0.3 to 0.5 µm/sec), sweeping away particles in its path. This air flow can be directed vertically or horizontally, and recirculated air is usually passed through a high efficiency particulate air (HEPA) filter.[229 230] HEPA filters, commonly used in hospitals, remove particles 0.3µm in diameter with an efficiency of 99.97%.[74 227 229 231] Ultraviolet (UV) light has been used as an infection control measure to reduce SSI risk. However, neither laminar flow nor UV light has been conclusively shown to decrease overall SSI risk.[87 225 232–237]

Environmental Surfaces

Environmental surfaces in U.S. operating rooms (e.g., tables, floors, walls, ceilings, lights, and the like) are rarely implicated as the sources of pathogens important in the development of SSIs. Nevertheless, it is important to perform routine cleaning of environmental surfaces to reestablish a clean environment after each operation.[31 154 227 229] There are no data to support routine disinfecting of environmental surfaces or equipment between operations in the absence of contamination or visible soiling. When visible soiling of surfaces or equipment occurs during an operation, an Environmental Protection Agency (EPA)-approved hospital disinfectant should be used to decontaminate the affected areas before the next operation.[31 154 227 229 238–240] This is in keeping with the Occupational Safety and Health Administration (OSHA) requirement that all equipment and environmental surfaces be cleaned and decontaminated after contact with blood or other potentially infectious materials.[240] Wet-vacuuming with an EPA-approved hospital disinfectant is performed routinely after the last operation of the day or night. Care should be taken to insure that medical equipment is covered and that solutions used for cleaning and disinfecting do not contact sterile devices or equipment. There are no data to support special cleaning procedures or closing an operating room after a contaminated or dirty operation has been performed.[227 228]

Tacky mats placed outside the entrance to an operating room/suite have not been shown to reduce the number of organisms on shoes or stretcher wheels, nor do they reduce the risk of SSI.[1 18 219 228]

Microbiologic Sampling

Because there are no standards or acceptable parameters for comparison of microbial levels for ambient air or environmental surfaces in the operating room, routine microbiologic sampling cannot be justified. Such environmental sampling should only be performed as part of an epidemiologic investigation.

Conventional Sterilization of Surgical Instruments

Inadequate sterilization of surgical instruments has resulted in SSI outbreaks.[229 241 242] Surgical instruments can be sterilized by steam under pressure, by dry heat, by ethylene oxide, or other approved methods. The importance of monitoring the quality of sterilization procedures has been established.[1 31 154 226] Microbial monitoring of steam autoclaves performance is necessary and can be accomplished by use of a biological indicator.[154 239 243] Detailed recommendations for sterilization of surgical instruments have been published.[154 239 244 245]

Flash Sterilization of Surgical Instruments

The Association for the Advancement of Medical Instruments (AAMI) defines flash sterilization as ''the process designated for the steam sterilization of patient care items for immediate use''.[245] During any operation, the need for emergency sterilization of equipment may arise (e.g., to reprocess an inadvertently dropped instrument). Flash sterilization is intended to be used for emergent sterilization of surgical instruments and other items and is never used for reasons of convenience such as an alternative to purchasing additional instrument sets and as a general time-saver. Some of the reasons that flash sterilization has not been recommended as a routine sterilization method include lack of timely biologic indicators to monitor performance, absence of protective packaging following sterilization, possible contamination during transportation to the operating rooms, and use of minimal cycle parameters (i.e., time, temperature, pressure).[243] The AAMI has published sterilization cycle parameters for flash sterilization (Table 8).

Until studies are performed to demonstrate that routine flashing for purposes other than emergencies does not increase SSI risk, flash sterilization should be restricted to its intended purpose. Also, flash sterilization is not recommended for implantable devices†† because of the potential for serious infections.[239 244–246]

Surgical Attire and Drapes

In this section the term ''surgical attire'' refers to scrub suits, caps/hoods, shoe covers, masks, gloves, and gowns. Although experimental data show that live microorganisms are shed from hair, exposed skin, and mucous membranes of operating room personnel,[126 247–252] few controlled clinical studies have evaluated the relationship between the use of surgical attire and the risk of SSI. Nevertheless, the use of barriers seems prudent to minimize exposure of a patient to the skin, mucous membranes, or hair of surgical team members and operating room personnel, and to protect operating room personnel from bloodborne pathogens (e.g., human immunodeficiency virus and hepatitis virus).

Scrub Suits

Hospital personnel, especially operating room nurses, surgeons, and anesthesiologists, often wear a uniform throughout the day that consists of pants and top/shirt and is called a ''scrub suit.'' Procedures for laundering, wearing, covering, and changing scrub suits vary greatly. In some facilities, scrub suits are laundered only by the hospital, while in others, scrub suits also may be laundered at the health-care worker's home. Although, there are no well-controlled studies evaluating SSIs risk among hospital-versus home-laundered scrub suits,[253] the Association of Operating Room Nurses (AORN) recommend scrub suits only be laundered in an approved and monitored laundry facility.[154] Some facilities require that scrub suits be worn only in operating room suites, while others allow the wearing of cover gowns over scrub suits when personnel leave the operating room suites. AORN recommends changing scrub suits when they are visibly soiled.[154] OSHA requires that ''if a garment(s) is penetrated by blood or other potentially infectious materials, the garment(s) shall

†† According to the FDA, an implantable device is a ''device that is placed into a surgically or naturally formed cavity of the human body if it is intended to remain there for a period of 30 days or more''.[245]

be removed immediately or as soon as feasible.'' [240]

Masks

Data regarding the possible effect of using surgical masks on SSI risk are limited. However, there is a strong theoretical rationale for wearing surgical masks during all operations. Some studies have evaluated the efficacy of surgical masks in reducing SSI risk and have raised issues regarding cost vs benefit.[254–258] Although surgical masks are effective at filtering out some bacteria, they may not completely prevent passage of organisms around the sides and edges of the mask.[250, 259, 260] Nevertheless, masks protect the surgical team from inadvertent exposures to blood (i.e., splashes) and other body fluids. OSHA requires that masks in combination with eye protection devices, such as goggles or glasses with solid shields, or chin-length face shields be worn whenever splashes, spray, spatter, or droplets of blood or other potentially infectious material may be generated and eye, nose, or mouth contamination can be reasonably anticipated.[240]

Surgical Caps/Hoods and Shoe Covers

Surgical caps/hoods are inexpensive and reduce the shedding of hair and scalp organisms. Rarely, SSI outbreaks have been traced to organisms isolated from the hair or scalp (S. aureus and Group A Streptococcus),[248 261] even when caps were worn by personnel during the operation and in the operating suites.

The use of shoe covers has never been shown to decrease SSI risk or decrease floor bacterial counts.[262 263] Shoe covers may protect a health care worker from exposures to blood and other body fluids during an operation. OSHA stipulates that surgical caps or hoods and/or shoe covers or boots shall be worn in instances when gross contamination can reasonably be anticipated (e.g., autopsies, orthopaedic surgery).[240]

Sterile Gloves

There is a strong theoretical rationale for the use of sterile gloves by all members of the surgical team. Sterile gloves are worn to minimize transmission of microorganisms from the hands of operating room personnel to patient's and to prevent contamination of personnel hands with blood and body fluids. If the integrity of a glove is compromised (e.g., punctured) it should be changed as promptly as safety permits.[240 264–266] Double gloving (i.e., wearing two pairs of gloves) has been shown to reduce bloodborne pathogen contamination of surgical team members' hands.[267–270] Sterile gloves are put on after donning sterile gowns.

Gowns and Drapes

Both sterile surgical gowns and drapes are used to create an aseptic barrier between the surgical site incision and possible sources of bacteria. Gowns are worn by operating room personnel and drapes are laid over the patient. There are limited data to substantiate the impact of surgical gowns and drapes on reducing SSI risk. The wide variation in the products studied and the study designs make available data difficult to evaluate.[251 271–275]

Gowns and drapes are classified as disposable (single use) or reusable (multiple use). Regardless of the material used to manufacture gowns and drapes, these items should be impermeable to liquids and viruses [276 277] and effective when wet.[1] In general, only gowns reinforced with films, coatings, or membranes appear to meet standards developed by the American Society for Testing and Material (ASTM).[276–278] However, the gowns that do meet these standards ''liquid proof'' gowns may be uncomfortable because they also inhibit the evaporation of sweat and heat loss from the wearer's body. These factors should be considered when selecting gowns.[278]

Practice of Anesthesiology

Anesthesiologists and nurse anesthetists perform invasive procedures (e.g., placement of intravascular devices, endotracheal intubation, administering intravenous solutions) and work in close proximity to sterile surgical fields, thus it is imperative that they strictly adhere to recommended infection control practices.[154 279–281] Breaks in aseptic technique,282 including use of common syringes,[283 284] contaminated infusion pumps,[282 285–287] and the assembly of equipment in advance of procedures,[283 288] have been associated with SSI outbreaks. Although a barrier (i.e., sterile drape) is placed between the anesthesiologist's work area and the surgical field, SSIs have occurred in which the source of the pathogen was the anesthesiologist or a member of the anesthesia team (e.g., anesthesia technician).[289–293] Continued efforts must be undertaken to educate and reinforce the importance of good infection control practices in preventing SSIs, not only to surgeons and operating room nurses but to all members of the surgical team.[282 294]

Hypothermia in surgical patients, defined as a core body temperature below 36°C, may result from general anesthesia, exposure to cold, or intentional cooling such as, in cardiac procedures to protect the myocardium or central nervous systems.[295–297] In one study of patients undergoing colorectal operations hypothermia was associated with an increased risk of SSI.[298] However, since any alteration in normal homeostasis alters normal host responses, more studies are needed to establish a relationship between hypothermia and SSI risk.

Surgical Technique

Excellent surgical technique can reduce SSI risk. Maintaining effective hemostasis while preserving adequate blood supply, gently handling tissues, avoiding inadvertent entries into a viscus, removing devitalized (e.g., necrotic or charred) tissues, using drains and suture material appropriately, eradicating dead space, and appropriate post-operative incision management are widely believed to reduce the risk of SSI.[18 19 31 32 299 300]

Any foreign body, including suture material or drains, may promote inflammation at the surgical site [87] and may increase the probability of infection for some levels of tissue contamination. There are two types of suture material: absorbable and non-absorbable. There is extensive literature comparing different types of suture material and their presumed relationships to SSI risk.[301–310] In general, monofilament sutures appear to have the lowest infection-promoting effects.[3 18 31 87]

While appropriate decisions regarding drain placement are beyond the scope of this document, general points should be briefly noted. Drains placed through an operative incision increase SSI risk.[67] Many researchers suggest placing drains through a separate incision distant from the operating incision.[67 197 311] It appears that SSI risk decreases when closed suction drains are used in comparison to open drains. [312 313] Closed suction drains are useful in evacuating postoperative hematomas, seromas, and purulent material. Also, the timing of drain removal is important; bacterial colonization of drains tracts may increase as the duration of drainage increases.[314]

Postoperative Issues

Postoperative Incision Care

Whether the incision is closed primarily (i.e., the skin edges are re-approximated at the end of the operation), left open to be closed later, or left open to heal by secondary

intention determines the details of postoperative incision care.

When a surgical incision is closed primarily, as most are, the surgeon has determined that it is relatively free of microbial contamination (i.e., clean or clean-contaminated). The primarily closed incision is covered with a sterile dressing for 24–48 hours until the incision edges are sealed.[315 316] Beyond 48 hours, it is unclear whether an incision must be covered by a dressing or whether showering or bathing is detrimental.

When a surgical incision is left open for a few days before it is closed (delayed primary closure), a surgeon has determined that it is likely to be contaminated, or that the patient's condition prevents primary closure (e.g., edema at the site). At the end of the operation, such an incision is packed with a sterile dressing (usually moist) and is inspected daily during dressing changes until the decision is made to close it. When a surgical incision is left open to heal by secondary intention, it is also packed with sterile moist gauze and covered with a sterile dressing. For wounds healing by secondary intention, there is no consensus on the benefit of using sterile technique (i.e., using sterile gloves and dressings) vs clean technique during dressing changes. The American College of Surgeons, CDC, and others have described changing dressings with sterile gloves and equipment.[31 317–320] However, a pilot study of 30 patients examined the difference between sterile vs clean technique for dressing changes of surgical incisions left open. No difference was found in SSI rates and the clean technique was less expensive. However, larger studies are needed to confirm these preliminary findings.[321]

Discharge Planning: Care of the Surgical Site

Today, many patients are discharged soon after their operation, with surgical incisions in the early process of healing.[322] There are no set, specific protocols for home incision care, and much of what is done at home by the patient, family, or home care agency has to be individualized for each patient. The intent of discharge planning is to maintain integrity of the healing incision, educate the patient about the signs and symptoms of infection, and inform the patient about whom to contact to report any problems. Written instructions and repeated demonstrations may help reinforce consistency in following verbal directions. It is the responsibility of the surgeon, nurse, discharge planners, and home health agencies to educate the patient and family in a uniform, concise, and coordinated fashion.

SSI Surveillance

Surveillance of SSI with feedback of appropriate data to surgeons has been shown to be an important component of strategies to reduce SSI risk.[8, 323, 324] A successful surveillance program includes epidemiologically sound infection definitions (Tables 1 and 2), effective surveillance methods, and stratification of SSI rates according to risk factors associated with SSI development.[17]

SSI Risk Stratification

Concepts

From the factors found to be associated with SSI, three categories of variables have emerged as good predictors: (1) those that estimate the intrinsic degree of microbial contamination of the surgical site, (2) those that measure the duration of an operation, and (3) those that serve as markers for host susceptibility.[17] The probability of developing an SSI depends upon the interaction of these variables in a given patient.

A widely accepted scheme for classifying the degree of intrinsic microbial contamination of a surgical site was developed by the 1964 National Academy of Sciences/National Research Council cooperative research study and modified in 1982 by CDC for use in SSI surveillance (Table 9).[2, 87] In this scheme, a member of the surgical team classifies the patient's wound at the completion of the operation. Because of its ease and wide availability, the surgical wound classification has been used to predict the risk of SSI.[8, 87, 325–330] Some researchers have suggested that surgeons compare clean wound SSI rates with those of other surgeons.[8, 323] However, two CDC efforts—the Study on the Efficacy of Nosocomial Infection Control (SENIC) Project and the NNIS system—incorporated other predictor variables into SSI risk indices. These showed that even within the category of clean wounds, the risk of SSI varied from 1.1% to 15.8% and from 1.0% to 5.4%, respectively.[328,331] In addition, sometimes the incision is neither classified at the time of surgery nor assigned by a member of the surgical team, calling into question the reliability of the classification. Therefore, reporting SSI rates stratified by wound class alone is not recommended.

Data on 10 variables collected in the SENIC Project were analyzed by using logistic regression modeling to develop a simple additive SSI risk index.[331] Four of these were found to be independently associated with the risk of SSI: (1) an abdominal operation, (2) an operation lasting >2 hours, (3) a surgical site with a wound classification of either contaminated or dirty/infected, and (4) an operation performed on a patient having ≥3 discharge diagnoses. Each of these equally weighted factors contributes a point when present, such that the risk index values range from 0 to 4. By using these factors, the SENIC index was able to predict the risk of SSI twice as well as the traditional wound classification scheme alone.

The NNIS risk index is operation specific and applied to prospectively collected surveillance data. The index can range from 0 to 3 points and is defined by three independent and equally weighted variables. A surgical patient scores one point when any of the following are present: (1) American Society of Anesthesiologists (ASA) class is ≥3 (Table 10), (2) wound classification is either contaminated or dirty/infected, and (3) operation lasts >T hours, where T is the approximate 75th percentile of the duration of the specific operation being performed.[328] The ASA class replaced discharge diagnoses of the SENIC risk index as a proxy for the patient's underlying severity of illness (host susceptibility)[332 333] and is readily available in the chart during the patient's hospital stay (Table 10). Unlike SENIC's constant 2 hour cut-point for duration of operation, the operation-specific cut-points used in the NNIS risk index have been shown to increase discriminatory power.[328]

Issues

Adjustment for variables known to confound rate estimates is critical if valid comparisons of SSI rates are to be made between surgeons or hospitals.[334] Risk stratification, as described above, has proven useful for this purpose, but relies on the ability of surveillance personnel to consistently and correctly find and record the data. For the three variables used in the NNIS risk index, only one study has focused on how accurately any of them are recorded. Cardo et al. found that surgical team members' accuracy in assessing wound classification for general and trauma surgery was 88% (95% CI: 82%–94%).[335] However, there are sufficient ambiguities in the wound class definitions themselves to warrant concern about the reproducibility of Cardo's results. The accuracy of recording the duration of operation (i.e., time from skin incision to skin closure) and the ASA class has not been studied. In an unpublished report from the NNIS system, there was some evidence that

over-reporting of high ASA class existed in some hospitals (Emori TG, personal communication). Further validation of how well the risk index variables are recorded is needed.

Additionally, NNIS data show that the NNIS risk index does not adequately discriminate the risk of SSI for all types of operations.[336 337] It seems likely that a combination of risk factors specific to patients undergoing an operation will be more predictive. A few studies have been performed to develop procedure-specific risk indices [338–342] and the NNIS system continues research in this area.

SSI Surveillance Methods

SSI surveillance methods used in both the SENIC Project and the NNIS system were designed for monitoring inpatients at acute-care hospitals. Over the past decade, the shift from inpatient to outpatient surgical care (also called ambulatory or day surgery) has been dramatic. It has been estimated that 75% of all operations in the United States will be performed in outpatient settings by the year 2000.[343] While it may be appropriate to use common definitions of SSI for inpatients and outpatients, [344] the types of operations monitored, the risk factors assessed, and the case-finding methods used may differ. New predictor variables may emerge from analyses of SSIs among outpatient surgery patients, which may lead to different ways of estimating SSI risk in this population.

Deciding upon which operations to monitor should be done jointly by surgeons and infection control personnel. Rarely do hospitals have the resources to monitor all surgical patients all the time, nor is that level of surveillance intensity probably necessary for certain low-risk procedures. Instead, hospitals should target surveillance efforts towards high-risk procedures.[345]

Inpatient SSI Surveillance

Two methods, alone or together, have been used to identify inpatients with SSIs: (1) direct observation of the surgical site by the surgeon, trained nurse surveyor, or infection control personnel [8 90 323 326 346–350] and (2) indirect detection by infection control personnel through review of laboratory reports, patient records, and discussions with primary care providers.[7 77 323 326 329 346 348 351–357] The surgical literature suggests that direct observation of surgical sites is the most accurate method to detect SSIs, although sensitivity data are lacking.[8 323 326 347 348] Much of the SSI data reported in the infection control literature have relied on indirect case-finding methods,[328 331 352 355 356 358–360] but some studies of direct methods also have been conducted.[90, 346] Some studies use both methods of detection.[77 325 346 354 357 361] A study that focused solely on the sensitivity and specificity of SSIs detected by indirect methods found a sensitivity of 83.8% (95% CI: 75.7%–91.9%) and a specificity of 99.8% (95% CI: 99%–100%).[346] Another study showed that chart review triggered by a computer-generated report of antibiotic orders for post-cesarean section patients had a sensitivity of 89% for detecting endometritis.[362] It is recommended that hospitals use direct, indirect, or a combination of both methods for detecting SSI in postoperative inpatients.

Indirect SSI detection can readily be performed by infection control personnel during surveillance rounds. The work includes gathering demographic, infection, surgical, and laboratory data on patients who have undergone operations of interest to the investigator.[224] These data can be obtained from patients' medical records, including microbiology and histopathology laboratory data and radiology reports, and records from the operating room. Pharmacy records may be useful if data on prophylactic antimicrobial use are to be collected. Additionally, hospital admissions, emergency room, and clinic visit records are sources of data for those postdischarge surgical patients who re-admitted or seek follow-up care.

The optimum frequency of case-finding by either method is unknown and varies from daily to ≤3 times per week, continuing until the patient is discharged from the hospital. Because duration of hospitalization is now so short, postdischarge SSI surveillance has become increasingly important to obtain accurate SSI rates (see ''Postdischarge SSI Surveillance'' section).

To calculate meaningful SSI rates, data must be collected on all patients undergoing the operations of interest (i.e., the population at risk). In the NNIS system, because one of its purposes is to develop strategies for risk stratification, the following data are collected on all surgical patients surveyed: operation date; NNIS operative procedure category; [363] surgeon identifier; patient identifier, age, and sex; duration of operation; wound class; general anesthesia; ASA class; emergency; trauma; multiple procedures; endoscopic approach; and discharge date.[224] With the exception of discharge date, these data can be obtained manually from operating room logs or be electronically downloaded into surveillance software, thereby substantially reducing manual transcription and data entry errors.[224] Depending on the needs for risk-stratified SSI rates by infection control, surgery, and quality assurance, not all data elements may be pertinent for every type of operation. At minimum, however, variables found to be predictive of increased SSI risk should be collected (see ''SSI Risk Stratification'' section).

Postdischarge SSI Surveillance

Between 12% and 84% of SSIs are detected after patients are discharged from the hospital. [91 259 326 358 364–383] At least two investigators have shown that most SSIs become evident within 21 days after operation.[360 376] Since the length of postoperative hospitalization continues to decrease, true estimates of SSI risk will only be possible by performing a combination of inpatient and postdischarge surveillance.

Postdischarge surveillance methods have been used with varying degrees of success for different procedures and among hospitals and include (1) direct examination of patients' wounds during follow-up visits to either surgery clinics or physicians' offices,[323 326 329 360 365 369 370 376 381 384 385]

(2) review of medical records of surgery clinic patients,[329, 360, 368] (3) questionnaire administration to patients by mail or telephone,[364 366 367 370 371 374 375 377 378 384 386 388] or

(4) questionnaire administration to surgeons by mail or telephone.[91 358 360 366 368 372 373 375 377 379 380 384] One study found that patients have difficulty assessing their own wounds for infection (52% specificity, 26% positive predictive value),[389] suggesting that data obtained by patient questionnaire may inaccurately represent actual SSI rates.

Recently, Sands et al. performed a computerized search of three data bases—ambulatory encounter records for diagnostic, testing, and treatment codes; pharmacy records for specific antimicrobial prescriptions; and administrative records for rehospitalizations and emergency room visits. The purpose of the search was to determine which best identified SSIs.[375] These researchers found that pharmacy records indicating a patient had received antimicrobial agents commonly used to treat soft tissue infections had the highest sensitivity (50%) and positive predictive value (19%).

As integrated health information systems expand, tracking surgical patients through the course of their care may become more feasible, practical, and effective. Until then, there is no

consensus on which postdischarge surveillance methods are the most sensitive, specific, and practical. Infection control and surgery personnel must choose from a variety of methods to find those that work for their unique mix of operations, personnel resources, and data needs.

Outpatient SSI Surveillance

Both direct and indirect methods have been used to detect SSIs that complicate outpatient operations. One study used home visits by district health nurses combined with a questionnaire completed by the surgeon at the patient's 2-week postoperative clinic visit to identify SSIs in an 8-year study of operations for hernia and varicose veins.[390] While ascertainment was very high, essentially 100%, this method is impractical for widespread implementation. High response rates have been obtained from questionnaires mailed to surgeons (72%–>90%).[372 373 375 384 391 393] Response rates from telephone questionnaires administered to patients were more variable (38%,[386] 81%,[388] and 85% [384]), and response rates from questionnaires mailed to patients were quite low (15% [384] and 33% [375]). At this time, no single detection method can be recommended. Available resources and data needs determine which method(s) should be used and which operations should be monitored. It is recommended that the CDC NNIS definitions of SSI (Tables 1 and 2) be used without modification in the outpatient setting.

Guideline Evaluation Process

Users of the HICPAC guidelines determine their value. To help assess that value, HICPAC is developing an evaluation tool to learn how guidelines meet user expectations, and how and when these guidelines are disseminated and implemented.

Part II—Recommendations for the Prevention of Surgical Site Infections (SSIs)

Introduction

As in previous CDC guidelines, each recommendation is categorized on the basis of existing scientific data, theoretical rationale, applicability, and possible economic impact. However, the previous CDC system for categorizing recommendations has been modified to include a designation of those recommendations that are required by federal regulations. The document does not recommend specific antiseptic agents for patient preoperative skin preparations or for health-care worker hand/forearm antisepsis. Hospitals should choose from the appropriate products categorized by the Food and Drug Administration (FDA).[4]

Category IA. Strongly recommended for all hospitals and strongly supported by well-designed experimental or epidemiological studies.

Category IB. Strongly recommended for all hospitals and viewed as effective by experts in the field and a consensus of Hospital Infection Control Practices Advisory Committee (HICPAC), based on strong rationale and suggestive evidence, even though definitive scientific studies may not have been done.

Category II. Suggested for implementation in many hospitals. Recommendations may be supported by suggestive clinical or epidemiological studies, a strong theoretical rationale, or definitive studies applicable to some, but not all hospitals.

No recommendation; unresolved issue. Practices for which insufficient evidence or no consensus regarding efficacy exists.

Recommendations

1. Preoperative preparation of the patient

a. Adequately control serum blood glucose level in all diabetic patients before elective operation and maintain blood glucose level <200 mg/dl during the operation and in the immediate postoperative period (48 hours).[77–79 100–102] Category IB

b. Always encourage tobacco cessation. At minimum, instruct patients to abstain for at least 30 days before elective operation from smoking cigarettes, cigars, pipes or any other form of tobacco consumption (e.g., chewing/dipping).[78 81 83–85] Category IB

c. No recommendation to taper or discontinue steroid use (when medically permissible) before elective operation.[77 80 86 103–105] Unresolved issue

d. Consider delaying an elective operation in a severely malnourished patient. A good predictor of nutritional status is serum albumin.[78 96–98] Category II

e. Attempt weight reduction in obese patients before elective operation.[78 79 89 90] Category II

f. Identify and treat all infections remote to the surgical site before elective operation.[31 74–76] Do not perform elective operations in patients with remote site infections. Category IA

g. Keep preoperative hospital stay as short as possible.[18 75 93 104 106] Category IA

h. Prescribe preoperative showers/baths with an antiseptic agent the night before and the morning of the operation.[108 109] Category IB

i. Do not remove hair preoperatively unless the hair at or around the incision site will interfere with the operation.[8 93 113 114 120 121] Category IA

j. If hair is removed, it should be removed immediately before the operation using electric clippers rather than razors or depilatories.[115 117 119] Category IA

k. Thoroughly wash and clean at and around the incision site to remove gross contamination before performing antiseptic skin preparation.[154] Category IB

l. Use an acceptable antiseptic agent for skin preparation, such as alcohol (usually 70%–92%), chlorhexidine (4%, 2%, or 0.5% in alcohol base), or iodine/iodophors (usually 10% aqueous with 1% iodine or formulation with 7.5%) (Table 5).[123 124] Category IB

m. Apply preoperative antiseptic skin preparation in concentric circles moving out toward the periphery. The prepped area must be large enough to extend the incision or create new incisions or drain sites, if necessary.[31 124 154] Category IB

2. Preoperative Hand/Forearm Antisepsis

All members of the surgical team:

a. Keep nails short and do not wear artificial nails.[31 72 124 154 155] Category IB

b. No recommendation on wearing nail polish. Unresolved Issue

c. Do not wear hand/arm jewelry. Category II

d. Perform a preoperative surgical scrub that includes hands and forearms up to the elbows before the sterile field, sterile instruments, or the patient's prepped skin is touched. Category IB

e. Clean underneath each fingernail prior to performing the surgical scrub.[31 140 154] Category IB

f. Perform the surgical scrub for a duration of 3–5 minutes [124 152 153] with an appropriate antiseptic (see Table 5).[123 124–140] Category IB

g. After performing the surgical scrub, keep hands up and away from the body (elbows in flexed position) so that water runs from the tips of the fingers toward the elbows. Dry hands with a sterile towel and don a sterile gown and gloves.[154] Category IB

3. Antimicrobial Prophylaxis

a. Select a prophylactic antimicrobial agent based on its efficacy against the most common pathogens causing SSI for a specific operation (Table 6). Category IA

b. Administer the antimicrobial prophylactic agent by the intravenous route except for colorectal operations.[202] In colorectal operations the antimicrobial agent is administered orally, or a combination of oral and intravenous route is used. Category IA

c. Administer the antimicrobial agent before the operation starts to assure adequate microbiocidal tissue levels before the skin incision is made, ideally antimicrobial prophylaxis should be administered within 30 minutes before, but not longer than 2 hours before, the initial incision.[69 71 202 203 214] Category IA

d. For cesarean section, administer prophylaxis immediately after the umbilical cord is clamped.[69 70] Category IA

e. Administer prophylactic antimicrobial agent as close as possible to the time of induction of anesthesia. Category II

f. Do not extend prophylaxis postoperatively.[47 71 199 – 201] Category IB

g. Consider additional intraoperative doses under the following circumstances: (1) operations whose duration exceeds the estimated serum half-life of the agent, (2) operations with major intraoperative blood loss, and (3) operations on morbidly obese patients.[47 69 71 201 203 216 – 218] Category IB

h. Do not routinely use vancomycin for prophylaxis.[204 205] Category IB

4. Intraoperative Issues

4–1. Operating Room Environment

A. Ventilation

a. Maintain positive-pressure ventilation in the operating room with respect to the corridors and adjacent areas.[226] Category IB

b. Maintain a minimum of 15 air changes per hour, of which at least 3 should be fresh air.[226] Category IB

c. Filter all air, recirculated and fresh, through the appropriate filters per the American Institute of Architects recommendations.[226] Category IB

d. Introduce all air at the ceiling and exhaust near the floor.[227 228] Category IB

e. No recommendation for the use of laminar flow ventilation or ultraviolet lights in the operating room to prevent SSI.[87 225 232 – 237] Unresolved issue

f. Keep operating room doors closed except as needed for passage of equipment, personnel, and the patient.[219] Category IB

g. Limit the number of personnel entering the operating room to necessary personnel.[219] Category IB

B. Cleaning and Disinfection of Environmental Surfaces

a. No recommendation on disinfecting operating rooms between operations in the absence of visible soiling of surfaces or equipment. Unresolved issue

b. When visible soiling or contamination, with blood or other body fluids, of surfaces or equipment occurs during an operation, use an EPA-approved hospital disinfectant to clean the affected areas before the next operation.[31 154 227 – 229 238 – 240] Category IB*

c. Wet vacuum the operating room floor after the last operation of the day or night with an EPA-approved hospital disinfectant.[154] Category IB

d. Do not perform special cleaning or disinfection of operating rooms after contaminated or dirty operations.[227 228] Category IA

e. Do not use tacky mats at the entrance to the operating room suite for infection control; this is not proven to decrease SSI risk.[1 18 219 228] Category 1A

C. Microbiologic Sampling

Do not perform routine environmental sampling of the operating room. Perform microbiologic sampling of operating room environmental surfaces or air only as part of an epidemiologic investigation. Category IB

D. Sterilization of Surgical Instruments

a. Sterilize all surgical instruments according to published guidelines.[154 226 239 245] Category IB

b. Perform flash sterilization only in emergency situations.[239 244 – 246] Category IB

c. Do not use flash sterilization for routine reprocessing of surgical instruments. Category IB

4–2. Surgical Attire and Drapes

a. No recommendations on how or where to launder scrub suits, on restricting use of scrub suits to the operating suite or for covering scrub suits when out of the operating suite.[154 277] Unresolved issue

b. Change scrub suits when visibly soiled, contaminated and/or penetrated by blood or other potentially infectious materials.[154 240] Category IB *

c. Wear a surgical mask that fully covers the mouth and nose when entering the operating room if sterile instruments are exposed, or if an operation is about to begin or already under way. Wear the mask throughout the entire operation.[154 240] Category IB *

d. Wear a cap or hood to fully cover hair on the head and face when entering the operating room suite.[154 240 248 261] Category IB *

e. Do not wear shoe covers for the prevention of SSI.[262 263] Category IA

f. Wear shoe covers when gross contamination can reasonable be anticipated.[240] Category II *

g. The surgical team must wear sterile gloves, which are put on after donning a sterile gown.[240 264–266] Category IB *

h. Use materials for surgical gowns and drapes that are effective barriers when wet.[1 154 169 277] Category IB

4–3. Practice of Anesthesiology

Anesthesia team members must adhere to recommended infection control practices during operations.[154 279–281] Category IA

4–4. Surgical Technique

a. Handle tissue gently, maintain effective hemostasis, minimize devitalized tissue and foreign bodies (i.e., sutures, charred tissues, necrotic debris), and eradicate dead space at the surgical site.[18 19 31 32] Category IB

b. Use delayed primary closure or leave incision open to close by secondary intention, if the surgical site is heavily contaminated (e.g., Class III and Class IV). Category IB

c. If drainage is deemed necessary, use a closed suction drain. Place the drain through a separate incision, rather than the main surgical incision. Remove the drain as soon as possible.[312 313] Category IB

5. Postoperative Surgical Incision Care

a. Protect an incision closed primarily with a sterile dressing for 24–48 hours postoperatively. Also ensure that the dressing remains dry and that it is not removed bathing.[315 316] Category IA

b. No recommendation on whether or not to cover an incision closed primarily beyond 48 hours, nor on the appropriate time to shower/bathe with an uncovered incision. Unresolved Issue

c. Wash hands with an antiseptic agent before and after dressing changes, or any contact with the surgical site. Category IA

d. For incisions left open postoperatively, no recommendation for dressing changes using a sterile technique vs. clean technique. Unresolved Issue

e. Educate the patient and family using a coordinated team approach on how to perform proper incision care, identify signs and symptoms of infection, and where to report any signs and symptoms of infection. Category II

6. Surveillance

a. Use CDC definitions of SSI [16] without modification for identifying SSI among surgical inpatients and outpatients. Category IB

b. For inpatient case-finding, use direct prospective observation, indirect prospective detection, or a combination of both direct and indirect methods for the duration of the patient's hospitalization, and include a method of postdischarge surveillance that accommodates available resources and data needs. Category IB

*Federal regulation—Occupational Safety and Health Administration

c. For outpatient case-finding, use a method that accommodates available resources and data needs. Category IB

d. For each patient undergoing an operation chosen for surveillance, record those variables shown to be associated with increased SSI risk (e.g., surgical wound class, ASA class, and duration of operation). Category IB

e. Upon completion of the operation, a surgical team member assigns the surgical wound classification. Category IB

f. Periodically calculate operation-specific SSI rates stratified by variables shown to be predictive of SSI risk. Category IB

g. Report appropriately stratified, operation-specific SSI rates to surgical team members. The optimum frequency and format for such rate computations will be determined by stratified case-load sizes and the objectives of local, continuous, quality improvement initiatives. Category IB

h. No recommendation to make available to the infection control committee coded surgeon-specific data. Unresolved issue

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Appendix

Figure1. Schematic of abdominal wall in cross section depicting appropriate surgical site infection classification.

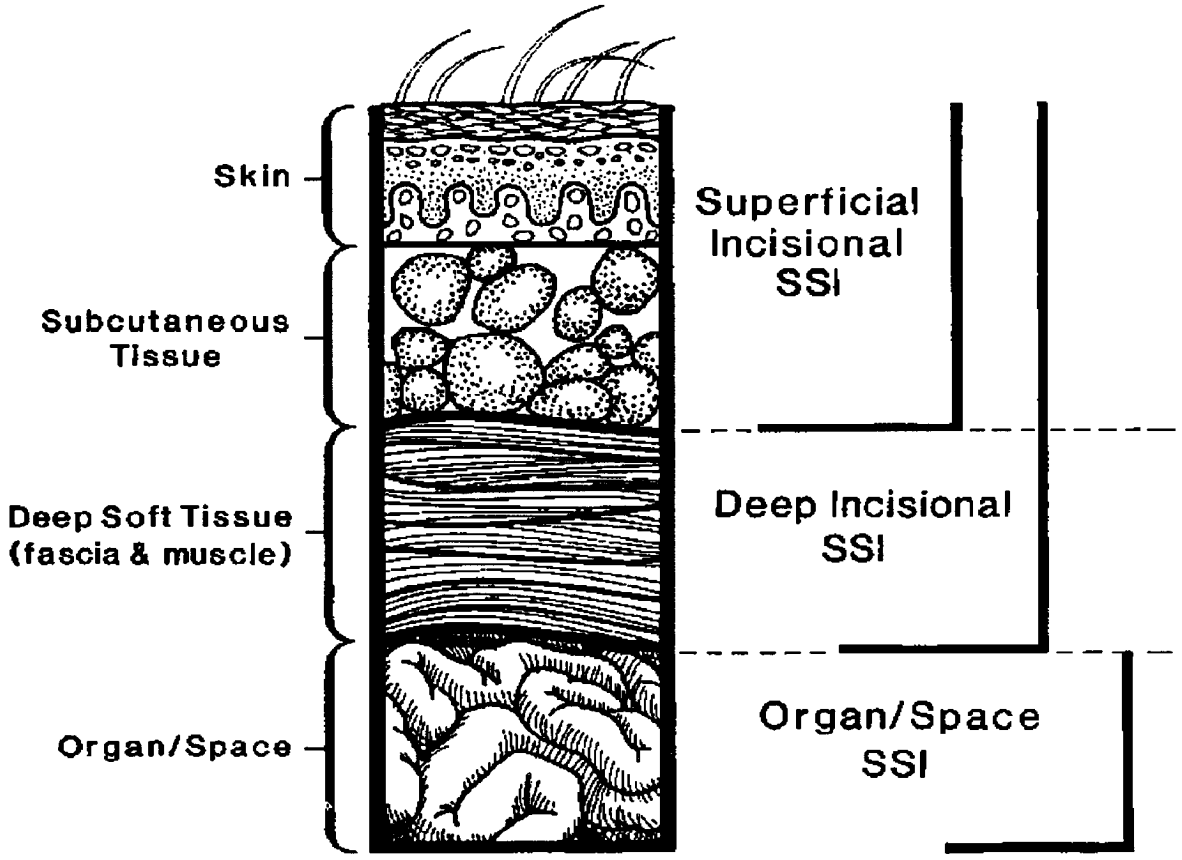

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TABLE 1.—CRITERIA FOR DEFINING SURGICAL SITE INFECTION (SSI).[16]

SUPERFICIAL INCISIONAL SSI

Infection occurs within 30 days after the operation *and* infection involves only skin or subcutaneous tissue of the incision *and* at least *one* of the following:

1. Purulent drainage, with or without laboratory confirmation, from the superficial incision.
2. Organisms isolated from an aseptically obtained culture of fluid or tissue from the superficial incision.
3. At least one of the following signs or symptoms of infection: pain or tenderness, localized swelling, redness, or heat *and* superficial incision is deliberately opened by surgeon, *unless* incision is culture-negative.
4. Diagnosis of superficial incisional SSI by the surgeon or attending physician.

Do *not* report the following conditions as SSI:

1. Stitch abscess (minimal inflammation and discharge confined to the points of suture penetration).
2. Infection of an episiotomy or newborn circumcision site.[3]
3. Infected burn wound.[3]
4. Incisional SSI that extends into the fascial and muscle layers (see deep incisional SSI).

DEEP INCISIONAL SSI

Infection occurs within 30 days after the operation if no implant[4] is left in place or within 1 year if implant is in place and the infection appears to be related to the operation *and*

Infection involves deep soft tissues (e.g., fascial and muscle layers) of the incision *and* at least *one* of the following:

1. Purulent drainage from the deep incision but not from the organ/space component of the surgical site.
2. A deep incision spontaneously dehisces or is deliberately opened by a surgeon when the patient has at least one of the following signs or symptoms: fever (>38°C), localized pain, or tenderness, unless site is culture negative.
3. An abscess or other evidence of infection involving the deep incision is found on direct examination, during reoperation, or by histopathologic or radiologic examination.
4. Diagnosis of a deep incisional SSI by a surgeon or attending physician.

Notes:

1. Report infection that involves both superficial and deep incision sites as deep incisional SSI.
2. Report an organ/space SSI that drains through the incision as a deep incisional SSI.

ORGAN/SPACE SSI

Infection occurs within 30 days after the operation if no implant is left in place or within 1 year if implant is in place and the infection appears to be related to the operation *and*

Infection involves any part of the anatomy (e.g., organs or spaces), other than the incision, that was opened or manipulated during the operative procedure *and* at least *one* of the following:

1. Purulent drainage from a drain that is placed through a stab wound[5] into the organ/space.
2. Organisms isolated from an aseptically obtained culture of fluid or tissue in the organ/space.
3. An abscess or other evidence of infection involving the organ/space that is found on direct examination, during reoperation, or by histopathologic or radiologic examination.
4. Diagnosis of an organ/space SSI by a surgeon or attending physician.

[3] Specific criteria are used for infected episiotomy and circumcision sites and burn wounds.

[4] NNIS definition—A nonhuman-derived implantable foreign body (e.g., prosthetic heart valve, nonhuman vascular graft, mechanical heart, or hip prosthesis) that is permanently placed in a patient during surgery.

[5] If the area around a stab wound becomes infected, it is not an SSI[1]. It is considered a skin or soft tissue infection, depending on its depth.

TABLE 2.—SPECIFIC SITES OF ORGAN/SPACE SURGICAL SITE INFECTION[16]

Arterial or venous infection
Breast abscess or mastitis
Disc space
Ear, mastoid
Endocarditis
Endometritis
Eye, other than conjunctivitis
Gastrointestinal tract

TABLE 2.—SPECIFIC SITES OF ORGAN/SPACE SURGICAL SITE INFECTION[16]—Continued

Intraabdominal, not specified elsewhere
Intracranial, brain abscess or dura
Joint or bursa
Mediastinitis
Meningitis or ventriculitis
Myocarditis or pericarditis
Oral cavity (mouth, tongue, or gums)
Osteomyelitis

TABLE 2.—SPECIFIC SITES OF ORGAN/SPACE SURGICAL SITE INFECTION[16]—Continued

Other infections of the lower respiratory tract (e.g., abscess or empyema)
Other male or female reproductive tract
Sinusitis
Spinal abscess without meningitis
Upper respiratory tract, pharyngitis
Vaginal cuff

TABLE 3.—DISTRIBUTION OF PATHOGENS ISOLATED* FROM SURGICAL SITE INFECTIONS, NATIONAL NOSOCOMIAL INFECTIONS SURVEILLANCE SYSTEM, 1986–1996.[6 18 19]

	Percent of isolates	
	1986–1989	1990–1996
Pathogen	(N=16,727)	(N=17,671)
Staphylococcus aureus	17	20
Coagulase-negative staphylococci	12	14
Escherichia coli	10	8
Enterococcus spp.	8	12

TABLE 3.—DISTRIBUTION OF PATHOGENS ISOLATED * FROM SURGICAL SITE INFECTIONS, NATIONAL NOSOCOMIAL INFECTIONS SURVEILLANCE SYSTEM, 1986–1996.[6 18 19]—Continued

	Percent of isolates	
	1986–1989	1990–1996
Pseudomonas aeruginosa	8	8
Enterobacter spp.	8	7
Proteus mirabilis	4	3
Klebsiella pneumoniae	3	3
Other Streptococcus spp.	3	3
Candida albicans	2	3
Group D streptococci		2
Other gram-positive aerobes		2
Bacteroides fragilis		2

* Pathogens representing less than 2% of isolates are excluded.

TABLE 4.—FACTORS THAT INFLUENCE SURGICAL SITE INFECTION RISK

INTRINSIC—Patient-Related Risk Factors
- Age
- Nutritional status
- Diabetes
- Smoking
- Obesity
- Remote infections
- Endogenous mucosal microorganisms
- Altered immune response
- Preoperative stay—severity of illness

EXTRINSIC—Operation-Related Risk Factors

TABLE 4.—FACTORS THAT INFLUENCE SURGICAL SITE INFECTION RISK—Continued

- Duration of surgical scrub
- Skin antisepsis
- Preoperative shaving
- Preoperative skin prep
- Surgical attire
- Sterile draping
- Duration of operation
- Antimicrobial prophylaxis
- Ventilation
- Sterilization of instruments

TABLE 4.—FACTORS THAT INFLUENCE SURGICAL SITE INFECTION RISK—Continued

- Wound class
- Foreign material
- Surgical drains
- Exogenous microorganisms
- Surgical technique
  - Poor hemostasis
  - Failure to obliterate dead space
  - Tissue trauma

This table has been adopted from references.[17 and 29]

TABLE 5.—MECHANISM AND SPECTRUM OF ACTIVITY FOR COMMONLY USED ANTISEPTICS FOR PREOPERATIVE SKIN PREPARATION AND SURGICAL SCRUBS.[123]

Agent	Mechanism of action	Gram-positive bacteria *	Gram-negative bacteria *	*Mycobacterium tuberculosis* *	Fungi *	Virus *	Rapidity of action	Residual activity *	Toxicity
Alcohol	Denature proteins	E	E	G	G	G	Most rapid	None	Drying, volatile.
Chlorhexidine	Disrupt cell wall	E	G	P	F	G	Intermediate	E	Ototoxicity, Keratitis.
Iodine/Iodophors	Oxidation/substitution by free iodine.	E	G	G	G	G	Intermediate	Minimal	Absorption from skin with possible toxicity, skin irritation.
** PCMX	Disrupt cell wall	G	F	F	F	F	Intermediate	Good	More data needed.
Triclosan	Disrupt cell wall	G	G†	G	P	U	Intermediate	E	More data needed.

** Para-chloro-meta-xylenol
† Good except for Pseudomonas
* E—excellent. G—good. F—fair. P—poor. U—unknown.

TABLE 6.—OPERATIONS, LIKELY SURGICAL SITE INFECTION PATHOGENS, AND REFERENCES REGARDING USAGE OF ANTIMICROBIAL PROPHYLAXIS

Operations	Likely pathogens
Clean—Class I	Endogenous and Exogenous
Placement of all grafts, prostheses, or implants [47 69 197 202 203]	*S. aureus, S. epidermidis.*
Cardiac [190 192–194 205]	*S. aureus, S. epidermidis.*
Neurosurgery [170–174 394 395]	*S. aureus, S. epidermidis.*
If approach through nasopharynx or transphenoid sinus are Class II.	
Ophthalmology [396 397]	*S. aureus; S. epidermidis;* streptococci; enteric, gram-negative bacilli.
—Limited data.	
—However, commonly used in procedures such as anterior segment resection, vitrectomy, and scleral buckles.	

TABLE 6.—OPERATIONS, LIKELY SURGICAL SITE INFECTION PATHOGENS, AND REFERENCES REGARDING USAGE OF ANTIMICROBIAL PROPHYLAXIS—Continued

Operations	Likely pathogens
Orthopedic [57 69 175–180 398–404]	*S. aureus, S. epidermidis.*
—Total joint replacement.	
—Closed fractures/use of nails, bone plates, other internal fixation devices.	
—Functional repair without implant/device.	
—Trauma	
Pulmonary (noncardiac thoracic) [188 191 405 406]	*S. aureus; S. epidermidis; Streptococcus pneumoniae;* enteric, gram-negative bacilli.
—Thoracic (lobectomy, pneumonectomy, wedge resection, other non-cardiac mediastinal procedures)	
—Closed tube thoracostomy	
Vascular [69 189 197 205 407 408]	*S. aureus, S. epidermidis.*
Clean—Contaminated—Class II *	
Appendectomy [185 409 410]	Enteric, gram-negative bacilli, anaerobes.
Biliary (cholecystectomy) [186 187 411–416]	Enteric, gram-negative bacilli, anaerobes.
—For high risk (e.g., age >65, jaundice, acute cholecystitis, choledocholithiasis, or prior biliary surgery) and low-risk patients.	
Colorectal	Enteric, gram-negative bacilli, anaerobes.
—Oral. [71 181 182 184 202 206–213]	
—Oral and IV. [184 211 417–419]	
Gastroduodenal [183 184 420–422]	Enteric, gram-negative bacilli, enterococci.
Head and neck (major procedures with incision through oral or pharyngeal mucosa [423–426].	*S. aureus,* streptococci, oral anaerobes (e.g., peptostreptococci).
Obstetric and gynecologic [159–168 203 364]	Enteric, gram-negative bacilli; enterococci; group B streptococci; anaerobes.
—Cesarean section.	
Low risk and high risk (high risk = prolonged rupture of membranes, no prenatal care, multiple vaginal examines, emergency cesarean, frequent invasive monitoring).	
—Hysterectomy.	
Vaginal and abdominal	
Urology—prostate [68 69 198 203]	*Escherichia coli, Klebsiella spp. Pseudomonas.*
May not be beneficial if urine is sterile.	
Exploratory laparotomy.	Aerobic coliforms Bacteroides fragilis and other anaerobes.
Penetrating abdominal trauma. [193 338 339 427 428]	

* Staphylococci will cause a certain amount of infections in all procedures.

TABLE 7.—DEPARTMENT OF HEALTH AND HUMAN SERVICES' PARAMETERS FOR OPERATING ROOM VENTILATION, AMERICAN INSTITUTE OF ARCHITECTS, 1996.[226]

Normal temperature	68–73°F depending on normal ambient temperatures.
Relative humidity	30%–60%.
Air movement	Out ''clean to less clean'' areas.
Air Changes	Minimum 15 total air changes per hour. Minimum 3 air changes of outdoor air per hour.

TABLE 8.—ASSOCIATION FOR THE ADVANCEMENT OF MEDICAL INSTRUMENTS FLASH STERILIZATION CYCLE PARAMETERS.[245]

Gravity-displacement cycles	*Minimum exposure time and temperature*
Porous and nonporous items	Nonporous items—3 min at 132°C (270°F) Nonporous and porous items—10 min at 132°C (270°F)
Prevacuum cycles	*Minimum exposure time and temperature*
Porous and nonporous items	Nonporous items (270°F)—3 min at 132°C Nonporous and porous items (270°F)—4 min at 132°C

TABLE 9.—SURGICAL WOUND CLASSIFICATION.[1 2]

Class I/Clean: An uninfected operative wound in which no inflammation is encountered and the respiratory, alimentary, genital, or uninfected urinary tract is not entered. In addition, clean wounds are primarily closed and, if necessary, drained with closed drainage. Operative incisional wounds that follow nonpenetrating (blunt) trauma should be included in this category if they meet the criteria.

Class II/Clean-Contaminated: An operative wound in which the respiratory, alimentary, genital, or urinary tracts are entered under controlled conditions and without unusual contamination. Specifically, operations involving the biliary tract, appendix, vagina, and oropharynx are included in this category, provided no evidence of infection or major break in technique is encountered.

Class III/Contaminated: Open, fresh, accidental wounds. In addition, operations with major breaks in sterile technique (e.g., open cardiac massage) or gross spillage from the gastrointestinal tract, and incisions in which acute, nonpurulent inflammation is encountered are included in this category.

Class IV/Dirty-Infected: Old traumatic wounds with retained devitalized tissue and those that involve existing clinical infection or perforated viscera. This definition suggests that the organisms causing postoperative infection were present in the operative field before the operation.

TABLE 10.—AMERICAN SOCIETY OF ANESTHESIOLOGISTS' (ASA) PHYSICAL STATUS CLASSIFICATION

Code	Patient's preoperative physical status
1	Normally healthy patient.
2	Patient with mild systemic disease.
3	Patient with severe systemic disease that is not incapacitating.
4	Patient with an incapacitating systemic disease that is a constant threat to life.
5	Moribund patient who is not expected to survive for 24 hours with or without operation.

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