Preventing Surgical Site Infections: A Surgeon's Perspective

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Wound site infections are a major source of postoperative illness, accounting for approximately a quarter of all nosocomial infections. National studies have defined the patients at highest risk for infection in general and in many specific operative procedures. Advances in risk assessment comparison may involve use of the standardized infection ratio, procedure-specific risk factor collection, and logistic regression models. Adherence to recommendations in the 1999 Centers for Disease Control and Prevention guidelines should reduce the incidence of infection in surgical patients.

Postoperative surgical site infections remain a major source of illness and a less frequent cause of death in the surgical patient (1). These infections number approximately 500,000 per year, among an estimated 27 million surgical procedures (2), and account for approximately one quarter of the estimated 2 million nosocomial infections in the United States each year (3). Infections result in longer hospitalization and higher costs.

The incidence of infection varies from surgeon to surgeon, from hospital to hospital, from one surgical procedure to another, and—most importantly—from one patient to another. During the mid1970s, the average hospital stay doubled, and the cost of hospitalization was correspondingly increased when postoperative infection developed after six common operations (4). These costs and the length of hospital stay are undoubtedly lower today for most surgical procedures that are done on an outpatient basis, such as laparoscopic (minimally invasive) operations or those that require only a short postoperative stay. In these cases, most infections are diagnosed and treated in the outpatient clinic or the patient's home. However, major complications such as deep sternal infections continue to have a grave impact, increasing the duration of hospitalization as much as 20-fold and the cost of hospitalization fivefold (5). Any surgical site infection after open heart surgery results in a substantial net loss of reimbursement to the hospital compared with uninfected cases, a factor that should motivate hospitals to minimize the incidence of postoperative infections (6).

Description of Surgical Site Infections

The Centers for Disease Control and Prevention (CDC) term for infections associated with surgical procedures was changed from surgical wound infection to surgical site infection in 1992 (7). These infections are classified into incisional, organ, or other organs and spaces manipulated during an operation; incisional infections are further divided into superficial (skin and subcutaneous tissue) and deep (deep soft tissue-muscle and fascia). Detailed criteria for these definitions have been described (7). These definitions should be followed universally for surveillance, prevention, and control of surgical site infections.

Microbiology of Surgical Site Infections

The pathogens isolated from infections differ, primarily depending on the type of surgical procedure. In clean surgical procedures, in which the gastrointestinal, gynecologic, and respiratory tracts have not been entered, *Staphylococcus aureus* from the exogenous environment or the patient's skin flora is the usual cause of infection. In other categories of surgical procedures, including clean-contaminated, contaminated, and dirty, the polymicrobial aerobic and anaerobic flora closely resembling the normal endogenous microflora of the surgically resected organ are the most frequently isolated pathogens (8).

According to data from the National Nosocomial Infections Surveillance System (NNIS), there has been little change in the incidence and distribution of the pathogens isolated from infections during the last decade (9). However, more of these pathogens show antimicrobial-drug resistance, especially methicillin-resistant *S. aureus* (10). Postoperative infections, including surgical site infections, were caused by multiple organisms in a multicenter outbreak due to contamination of an intravenous anesthetic, propofol (11). In this outbreak, CDC identified 62 patients at seven hospitals who had postoperative infections, primarily of the bloodstream or surgical site, after exposure to propofol. Only exposure to this anesthetic was substantially associated with these postoperative infections. In six of the seven hospitals, the same pathogen was isolated from several infected patients. The infections were due to extrinsic contamination of the propofol by the anesthesia personnel, who frequently carried the pathogens in lesions on their hands or scalp or in their nares. Lapses in aseptic technique and reuse of single-use vials for several patients were important factors in these outbreaks (11,12). This report stresses the importance of conducting a formal epidemiologic investigation when a cluster of infections involves an unusual organism such as *Moraxella osloensis* or *Serratia marcescens*.

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Prevention of Surgical Site Infections

The most critical factors in the prevention of postoperative infections, although difficult to quantify, are the sound judgment and proper technique of the surgeon and surgical team, as well as the general health and disease state of the patient (13-14). Other factors influence the development of postoperative wound infection, especially in clean surgical procedures, for which the infection rate (<3%) is generally low. Infections in these patients may be due solely to airborne exogenous microorganisms (15).

In 1999, CDC's Health Care Infection Control Practices Advisory Committee published revised guidelines for the prevention of infections (Table 1). This guideline delves extensively into the literature concerning perioperative factors associated with postoperative infections (16). The 1999 edition of the guideline has been extensively revised (Table 2).

Prophylactic Antibiotic Use in the Surgical Patient

The use of antibiotic prophylaxis before surgery has evolved greatly in the last 20 years (17). Improvements in the timing of initial administration, the appropriate choice of antibiotic agents, and shorter durations of administration have defined more clearly the value of this technique in reducing postoperative wound infections. Some historical milestones of the last 4 decades shed light on the current situation.

Historical Aspects

Confusing and heated debate concerning the efficacy of prophylactic antibiotics in surgery followed the publication of clinical trials during the 1950s. Errors in study design of these early efforts included nonrandomization, lack of blinding, faulty timing of initial antibiotic administration, prolonged antibiotic use, incorrect choices of antimicrobial agents, and inappropriate choices of control agents.

Experimental studies published during the early 1960s helped clarify many of these problems and resulted in a more scientifically accurate approach to antimicrobial prophylaxis. Most important was the report by Burke (18), which demonstrated the crucial relationship between timing of antibiotic administration and its prophylactic efficacy. His experimental studies showed that to greatly reduce experimental skin infection produced by penicillin-sensitive *S. aureus*, the penicillin had to be in the skin shortly before or at the time of bacterial exposure. This study and others fostered the attitude that to prevent subsequent infection the antibiotic must be in the tissues before or at the time of bacterial contamination. This important change in strategy helped correct the common error of first administering the prophylactic antibiotic in the recovery room.

As early as 1964, Bernard and Cole (19) reported on the successful use of prophylactic antibiotics in a randomized, prospective, placebo-controlled clinical study of abdominal operations on the gastrointestinal tract. The success of antibiotic prophylaxis noted in this early study was clearly due to the authors' appropriate patient selection and wise choice of available agents, as well as the timing of administration. Further advances in understanding of antibiotic prophylaxis in abdominal surgery occurred in the 1970s. During this decade, the qualitative and quantitative nature of the endogenous gastrointestinal flora in health and disease was appropriately defined (20). Many prospective, blinded clinical studies in the 1980s and 1990s prompted

Table 1. Hospital Infection Control Practices Advisory Committee partial recommendations for the prevention of surgical site infection,1999 (16)

Rankings	
Category 1A	Strongly recommended for implementation and supported by well-designed experimental, clinical, or epidemiologic studies
Category 1B	Strongly recommended for implementation and supported by some experimental, clinical, or epidemiologic studies and strong theoretical rationale
Category II	Suggested for implementation and supported by suggestive clinical or epidemiologic studies or theoretical rationale
No recommendation; unresolved issue.	Practices for which insufficient evidence or no consensus regarding efficacy exists
Recommendations—Preoperative—partial and modified	
A. Preparation of the patient	
Category 1A	Treat remote infection before elective operation; postpone surgery until treated; Do not remove hair from operative site unless necessary to facilitate surgery; If hair is removed, do immediately before surgery, preferably with electric clippers
Category 1B	Control serum blood glucose perioperatively; Cessation of tobacco use 30 days before surgery; Do not withhold necessary blood products to prevent SSIs; Shower or bath on night before operative procedure; Wash incision site before performing antiseptic skin preparation with approved agent
Category II	Prepare skin in concentric circles from incision site; Keep preoperative stay in hospital as short as possible
Unresolved	Improve nutritional status; Use of mupirocin in nares; Improve oxygenation of wound space; Taper or discontinue systemic steroid use before elective surgery
B. Antimicrobial prophylaxis	
Category 1A	Select (if indicated) an antimicrobial agent with efficacy against expected pathogen; Intravenous route used to ascertain adequate serum levels during operation and for at most a few hours after incision closed; Before elective colorectal operations, in addition to parenteral agent, mechanically prepare the colon by use of enemas and cathartics. Administer nonabsorbable oral antimicrobial agents in divided doses on the day before the operation
Category 1B	Do not routinely use vancomycin for antimicrobial prophylaxis

SSI = surgical site infections

Table 2. Changes in CDC surgical site infections prevention guidelines, 1999 (16)

1985	1999
Category 1	Category 1A
Category II	Category 1B
Category III	Category II or no recommendation; unresolved
Preoperative hair removal	
Do not remove hair unless it will interfere with the operation Category II	Recommendation unchanged Category 1A
If removed, remove by clipping or use of a depilatory, not by shaving Category II	If removed, preferably remove immediately before the operation with electric clippers Category 1A
Preoperative shower or bath	
Patient should bathe with antimicrobial soap the night before an elective operation Category III	Require patients to shower or bathe with an antiseptic agent at least the night before surgery Category 1B
Preoperative hand and forearm antisepsis	
Perform surgical scrub for at least 5 minutes before first operation of day Category 1	Perform surgical scrub for at least 2-5 minutes with an appropriate antiseptic Category 1B
Between consecutive operations perform surgical scrub 2 to 5 minutes Category II	
After scrub, dry hands with sterile towel, don sterile gown and gloves Category 1	After scrub, keep hands up and away from body; dry hands with sterile towel; don sterile gown and gloves Category 1B
Preoperative patient preparation	
Treat and control all bacterial infections before operation Category 1	Identify and treat all remote infections before elective operation Category 1A
The hospital stay should be as short as possible Category II	Keep hospital stay as short as possible Category II
If patient is malnourished, enteral or parenteral nutrition should be given Category II	No recommendation to use nutritional support solely to prevent surgical site infection Unresolved
Preoperative antimicrobial prophylaxis	
Use for operations with high infection rate or for those with severe or life-threatening consequences if infection occurs Category 1	Administer antimicrobial agent only when indicated and select based on published recommendations for a specific operation and efficacy against most common pathogens Category 1A
Select antimicrobial agents that are safe and effective Category 1	
Start parenteral IV antimicrobial agents shortly before operation and discontinue shortly afterward Category 1	Administer antimicrobial agents by IV timed to ensure bactericidal serum and tissue levels when incision made Category 1A
	Maintain therapeutic levels during operation and, at most, a few hours after closure Category 1A
	Before colorectal elective operations, in addition to IV antimicrobial drugs, mechanically prepare the colon with enemas and cathartic agents; administer nonabsorbable oral antimicrobial agents in individual doses the day before surgery Category 1A
	For cesarean sections in patients at high risk administer IV antimicrobial agent immediately after cord is clamped Category 1A
	Do not routinely use vancomycin for prophylaxis Category 1B

definitive recommendations concerning the proper approaches to antibiotic prophylaxis in surgery (21).

Current Use of Parenteral Antibiotic Agents in Surgical Prophylaxis

The choice of parenteral prophylactic antibiotic agents and the timing and route of administration have become standardized on the basis of well-planned prospective clinical studies (21). It is generally recommended in elective clean surgical procedures using a foreign body and in clean-contaminated procedures that a single dose of cephalosporin, such as cefazolin, be administered intravenously by anesthesia personnel in the operative suite just before incision. Additional doses are generally recommended only when the operation lasts longer than 2 to 3 hours. Other controversial areas include the routine use of antibiotic prophylaxis in clean surgical procedures, such as hernia repair or breast surgery (21,22). This subject has been summarized in a published review (23), and some specific situations will be described.

Antibiotic Prophylaxis before Elective Colon Resection

The human colon and distal small intestine contain an enormous reservoir of facultative and anaerobic bacteria, separated from the rest of the body by the mucous membrane. A reliable method of sterilizing the colonic contents has been a goal of surgeons throughout this century (24). In the past 25 years, clinical trials have demonstrated that to substantially reduce septic complications after elective colon surgery, antibiotics must have activity against both colonic aerobes (e.g., *Escherichia coli*) and anaerobes (e.g., *Bacteroides fragilis*), a finding we reported over 25 years ago (25). Today, approaches to mechanical cleansing differ widely (26). Modern approaches include standard outpatient mechanical cleansing with dietary restriction, cathartics, and enemas for a 2-day period, or whole-gut lavage with an electrolyte solution of 10% mannitol, Fleet's phospho-soda, or polyethylene glycol, done the day before the operation.

Most surgeons use both antibiotics and mechanical cleansing for preoperative preparation before elective colon resection (26). Three regimens of oral agents combine neomycin with erythromycin base, metronidazole, or tetracycline. The most popular regimen in the United States has been the neomycin-erythromycin base preparation, which was introduced in 1972 (27).

In a survey published in 1997, 471 (58%) of 808 board-certified colorectal surgeons described their bowel preparation practices before elective procedures (26). All respondents used mechanical preparation: oral polyethylene glycol solution (70.9% of respondents), oral sodium phosphate solution with or without bisacodyl (28.4%), and accepted methods of dietary restriction, cathartics, and enemas (28.4%). Most (86.5%) surgeons added both oral and parenteral antibiotics to the regimen; 11.5% added only parenteral antibiotics, 1.1% added only oral antibiotics, and 0.9% did not add antibiotics. Oral neomycin and erythromycin or metronidazole were combined with a perioperative parenteral antibiotic by 77.8% of respondents. Most patients started the preparation as outpatients the day before surgery, and parenteral drugs were added to the regimen 1 to 2 hours before the procedure. The use of outpatient bowel preparation is increasing; however, patient selection is critical, and education is needed to reduce the rate of complications.

Antibiotic Prophylaxis for Appendectomy

The pathologic state of the appendix is the most important determinant of postoperative infection (28,29). Wound infection after appendectomy for perforative or gangrenous appendicitis is four to five times higher than for early disease. A prospective study of nonperforated appendicitis, using a logistic regression analysis of risk factors, showed that the risk for postoperative infection is related to lack of perioperative antibiotic prophylaxis and to the determination that the appendix was gangrenous (29). Because the pathologic state of the appendix often cannot be determined before or during operation, a parenteral antibiotic agent is recommended as prophylaxis in all patients.

Regimens with activity against both facultative gram-negative bacilli and anaerobes are more effective than those active only against aerobes (29). The use of antimicrobial agents in perforated appendicitis with evidence of local or general peritonitis or intraabdominal abscess, or both, should be considered therapeutic rather than prophylactic.

Preventive Antibiotics in Penetrating Abdominal Trauma

Hollow-lumen visceral damage with associated escape of endogenous microorganisms is the main risk factor for postoperative infections after exploratory laparotomy for penetrating abdominal trauma. A single dose of parenterally administered antibiotic, given just before abdominal exploration for penetrating abdominal trauma, is associated with low postoperative infection rate in patients with no observed gastrointestinal leakage (30). If gastrointestinal leakage is identified at the time of the operation, continuing the antibiotic agents for 1 to 3 days is usually recommended. It is important to use antibiotic agents with both facultative and anaerobic activity. Leaving the operative wound open, packed with saline-soaked gauze, decreases the incidence of postoperative wound infection in patients at high risk (31).

Preventive Antibiotic Use in Traumatic Chest Injuries

Recently published studies have shown the value of parenteral antibiotic prophylaxis in the prevention of pneumonia or empyema after the placement of a chest tube to correct the hemopneumothorax associated with chest trauma (32,33). In one study, 500 mg of cefazolin was given intravenously every 8 hours for 24 hours (32). In the other study, 1 g of cefonicid was administered every 24 hours until the chest tube was removed, usually before 5 days (33). In both studies patients receiving antibiotics had substantially lower infection rates than those receiving placebos.

Conclusions

Recent improvements in antibiotic prophylaxis, including the timing of initial administration, appropriate choice of antibiotic agents, and shortening the duration of administration, have established the value of this technique in many clinical surgical settings. Future study designs should strongly consider risk factors for individual patients when new antibiotic agents are tested or administration techniques are refined. A concentrated effort should be made in areas of clinical surgery where the value of antibiotic prophylaxis has not been proven. A single-dose systemic regimen of an appropriately chosen cephalosporin given during the immediate preoperative period is safe and the indicated practice.

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