Perioperative Strategies for Decreasing Infection: A Comprehensive Evidence-Based Approach

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Surgical site infections associated with orthopaedic surgical procedures are devastating complications. They increase morbidity, mortality, and cost and result in outcomes that are worse than those in uninfected cases. Decreasing the incidence of surgical site infections is not only of interest to patients and surgeons, it is also a major focus of several groups of interested parties. These range from payers, including the Centers for Medicare and Medicaid Services (CMS, Baltimore, Maryland), to institutions represented by the Surgical Care Improvement Project (SCIP), a multiple-institution partnership between major public and private health care organizations, including the Joint Commission on Accreditation of Healthcare Organizations (Oakbrook Terrace, Illinois). Decreasing the incidence of surgical site infections is, and will continue to be, a major focus in medicine.

To effectively prevent surgical site infections, the clinician must consider preoperative, intraoperative, and postoperative factors and interventions. Preoperative strategies for reduction of infection rates include identification of high-risk patients, screening and decolonization of patients with methicillin-sensitive Staphylococcus aureus and methicillin-resistant Staphylococcus aureus colonization, preoperative preparation of the patient with chlorhexidine gluconate, utilization of proper hair-removal techniques, and addressing preexisting dental and nutritional issues prior to surgery.

There are a variety of perioperative strategies that can and should be employed to decrease the risk of surgical site infections. Intraoperative interventions that have been shown to decrease surgical site infection rates include the proper selection, timing, and doses of prophylactic antibiotics and utilization of best practices for hand hygiene and surgical site preparation. Maintaining a sterile operating-room environment by decreasing operating-room traffic, monitoring for breaks in sterile technique, and decreasing the use of flash sterilization is vital. Finally, postoperative strategies for the reduction of surgical site infection rates include the proper use and duration in situ of urinary catheters and surgical drains; standardization of wound care; use of antibiotic-impregnated bandages; and, perhaps most importantly, maintenance of proper hand hygiene, isolation precautions, and room cleaning.

Preoperative Considerations

Although every precaution should be taken to prevent infection for all orthopaedic patients, the identification of high-risk patients enables clinicians to provide maximal prevention strategies for them. Furthermore, the identification of patients at high risk for infection allows appropriate preoperative counseling for shared decision-making and establishes appropriate patient expectations regarding surgical risks.

Numerous high-risk patient populations and risk factors that place patients at high risk for infection after total joint replacement or spine surgery have been described in the literature. Some of these factors can be modified,
perioperative strategies for decreasing infection

The risk of infection is increased when patients are counseled about their increased risk of infection with the proposed surgical procedure. In this way, patients will more completely understand the risks and benefits when deciding on surgery. Two common factors that cannot be modified and that increase the risk of infection with joint replacement are a history of infection in the joint and a history of steroid injection into the joint.

Factors that cannot be modified that increase the risk of infection in patients undergoing spine surgery include trauma-related surgery, use of instrumentation, and lumbar and posterior surgery.

Other factors that increase the risk of infection are potentially modifiable and, therefore, provide the opportunity for patient optimization prior to elective orthopaedic procedures. For example, patients with inflammatory arthritis, sickle-cell disease, diabetes, renal failure, and human immunodeficiency virus (HIV) have increased infection rates with joint replacement. Although these risk factors cannot be eliminated, the risks can be minimized.

For example, patients with inflammatory arthritis should have a preoperative consultation with their rheumatologist about reducing or discontinuing immunosuppressive medications perioperatively. Patients with sickle-cell disease should be screened for skin ulcerations or potential sources of osteomyelitis, which can cause seeding of the site of a prosthetic joint. Diabetic patients should have their hemoglobin A1C levels checked and normalized to <6.9%, which reflects long-term glucose control prior to surgery; consultation with an endocrinologist may be necessary. Patients with renal failure certainly should have their renal function optimized prior to surgery; and patients with HIV should be placed on regimens that achieve an undetectable viral load, if possible, prior to joint replacement.

Malnutrition is associated with an increased risk of infection; therefore, preoperative optimization, with the assistance of a nutritionist if necessary, is beneficial. Smoking and obesity increase the risk of infection with spine surgery. Although these factors are often difficult to modify, patients should be counseled that a benefit of smoking cessation and weight reduction is a decreased risk of infection with spine surgery. Patients considering or planning surgical weight-loss treatments, such as gastric bypass surgery, probably should be advised to pursue these procedures first to reduce the risk of infection at the sites of hardware or prostheses as a benefit from weight loss. Working with patients and the appropriate consultants to optimize these factors prior to surgery may improve patient outcomes by lowering the risk of infection with high-risk joint-replacement and spine procedures.

Another important preoperative consideration is preoperative bathing. Preoperative bathing has been used to reduce the bacterial load of the skin prior to surgery because skin preparation immediately before surgery does not completely sterilize the skin. In addition, direct contamination can occur at the time of surgery. A recent Cochrane review was performed to assess the information in the literature regarding preoperative bathing with antiseptics for the prevention of surgical site infection. Chlorhexidine gluconate is the most commonly used antiseptic for preoperative bathing. The Cochrane review revealed evidence that the bacterial load of resident skin flora is reduced by use of chlorhexidine gluconate preparations for preoperative bathing. Repeated, consecutive treatments reduce this load progressively over time. However, concerns about the development of resistant organisms and hypersensitivity remain. Therefore, the authors of the review concluded that there is no clear evidence that preoperative bathing with chlorhexidine gluconate is superior to preoperative bathing with other products, such as bar soap, for reducing the incidence of surgical site infection.

Hair removal has been used traditionally to keep hair from contaminating the wound. More recently, hair removal has allowed surgeons to apply occlusive dressings to the skin perioperatively to keep skin flora from directly contaminating the wound. Three methods used for hair removal include traditional razors, clippers, and hair-removal creams or depilatories. Hairless surgical sites can make the surgery and application of dressings and protective draping easier, but the use of razors to shave the surgical site increases the risk of introducing primary infections through microscopic injuries to the skin. The Centers for Disease Control and Prevention (CDC) recommend that hair removal be minimized and that, when it is necessary, electric clippers or depilatories be used rather than razors. A Cochrane review of the literature on hair removal prior to surgery supported the CDC recommendations and added that hair removal can be done on the day of the surgery.

Dental care is another preoperative issue to be discussed with high-risk orthopaedic patients. All patients, but particularly those at high risk for infection, should be encouraged to maintain good dental health before and after surgery. Bacteremia from a dental infection can cause acute hematogenous infection at the site of a total joint replacement. Evidence shows that the most critical period is the first two years after surgery. The American Academy of Orthopaedic Surgeons (AAOS) in conjunction with the American Dental Association (ADA) developed guidelines for antibiotic prophylaxis for patients with a total joint replacement who require dental procedures. Patients are identified as being at high or low risk depending on their medical comorbidities. Dental procedures are categorized as high or low risk depending on the risk of bacteremia. All patients should receive antibiotic prophylaxis for high-risk dental procedures for two years after the joint replacement, and high-risk patients should receive prophylaxis for high-risk dental procedures for life. Antibiotic regimens are included in the recommendations (Table I).
Antibiotics

Perioperative prophylactic antibiotics are effective in reducing the rate of surgical site infections in high-risk orthopaedic cases. In a 2002 meta-analysis of spine fusion surgery, Barker reported that use of antibiotic therapy for such procedures is beneficial even when the infection rates without antibiotics are low. Similar studies have demonstrated the efficacy of preoperative antibiotics in general orthopaedic surgery and before total joint replacement.

The choice of antibiotic for patients with a low risk of methicillin-resistant Staphylococcus aureus colonization is either cefazolin (1 to 2 g administered intravenously) or cefuroxime (1.5 g administered intravenously). These doses must be adjusted for children. For patients with a beta-lactam allergy, clindamycin (600 mg administered intravenously) or vancomycin (1.0 g administered intravenously) should be used in lieu of cephalosporins. Patients who are colonized with methicillin-resistant Staphylococcus aureus are at high risk for colonization (e.g., nursing home residents), or have had a previous methicillin-resistant Staphylococcus aureus infection have an increased risk for the development of an infection with methicillin-resistant Staphylococcus aureus. Prophylaxis with vancomycin (1.0 g administered intravenously) should be considered for these patients.

The proper timing and duration of antibiotic prophylaxis are imperative for safety and effectiveness. In general, antibiotic therapy should be started within one hour prior to the surgical incision, and the drugs should be completely infused prior to tourniquet inflation. The exception to this recommendation is vancomycin, the administration of which may be started up to two hours prior to the surgical incision. This allows a slower infusion and decreases the likelihood of red man syndrome. Red man syndrome occurs when hypersensitivity to vancomycin causes degranulation of mast cells and a release of histamine. The histamine leads to hypotension and facial flushing. Red man syndrome is prevented by the slow administration of vancomycin over a period of one to two hours.

Antibiotic treatment should be stopped within twenty-four hours after wound closure. Administration of prophylactic antibiotics for longer than twenty-four hours has not been demonstrated to be effective and may actually lead to superinfection with drug-resistant organisms. Repeat dosing with antibiotics is recommended during surgical procedures that last for longer than four hours or when there is >1500 mL of blood loss.

We recommend that, in order to ensure the proper selection and timing of antibiotic prophylaxis, the choice of antibiotics and duration of administration be incorporated into the surgical “time-out.” Rosenberg et al. reported that compliance with the proper timing and selection of antibiotics increased from 65% to 99% when the protocol was incorporated into the time-out.

Surgical Site Preparation

Chlorhexidine gluconate-based solutions have supplanted alcohol and iodine-based solutions for surgical site preparation. Ostrander et al. examined the residual amounts of bacteria on feet prepared with a chlorhexidine gluconate, iodine/isopropanol, or chloroxylenol scrub. They found that chlorhexidine gluconate was superior to the other two preparation solutions in reducing or eliminating bacteria from the feet prior to surgery. Chlorhexidine gluconate skin preparation was superior to either 70% alcohol or iodine in decreasing infection associated with the placement of central venous catheters and the drawing of blood for culture.

Thus, the current evidence-based recommendations and best-practice guidelines call for the use of chlorhexidine gluconate-based solutions for surgical site preparation and placement of central venous catheters.
Decreasing the Risk of Surgical Site Infection Related to the Operating-Room Environment

Although the arcane details of techniques used to sterilize surgical instruments are beyond the expected knowledge of most orthopaedic surgeons, many of a surgeon’s actions can adversely affect sterilization and increase the risk of surgical site infections. Flash sterilization is a procedure used by operating-room staff to sterilize instruments or implants with steam, on an as-needed basis. Flash sterilization is not equivalent to sterilization in central processing. In central sterile processing, instruments are properly cleaned and all lumens are inspected; the instruments are then sterilized and allowed to dry completely, after which they are delivered in closed containers that ensure maintenance of sterility. Most importantly, the process is performed by trained, focused professionals. The entire process takes three to four hours. Flash sterilization should be used only for dropped instruments or in an emergency situation. Preventable reasons for flash sterilization include an insufficient quantity of instruments, loaner instruments and/or instruments not delivered in time for proper processing, and inaccurate or incomplete surgical booking requiring the emergency, unplanned use of instruments and/or implants.

To reduce the incidence of flash sterilization, we recommend an increase in physician awareness about the inadequacy of the technique; improvement in the accuracy of surgical booking; mandating cooperation from vendors to ensure timely delivery of equipment, including financial penalties for late delivery; purchase of more frequently flash-sterilized items; surgical scheduling to accommodate and mitigate equipment shortages; and, finally, generation of incident reports when a flash-sterilized implant is used in a patient. Adopting these policies and procedures leads to a decrease in the incidence of flash sterilization.

Powderless Gloves

Traditionally, surgical gloves contained powder to aid in the manufacturing process and to make donning easier. The powder was either talc or lycopodium spores. Because of concerns about granuloma formation and adhesions associated with the use of these substances, cornstarch is now the powder of choice. However, cornstarch is not benign. It causes foreign-body granuloma formation and delayed wound-healing and can decrease the amount of bacteria required to cause a clinically apparent infection. Cornstarch also leads to increased latex sensitivity in health-care workers. Type-I and type-IV hypersensitivity reactions to latex protein in hospital staff lead to increases in sick time and decreased job satisfaction. Powderless gloves decrease staff absenteeism and eliminate the potential for foreign-body granuloma formation. These gloves cost 25% more than powdered gloves, but the added expense is mitigated by increased productivity of the operating-room staff.

Antiseptic-Coated Sutures

The use of antiseptic-coated sutures has generated increased interest. These sutures are typically coated with the antiseptic triclosan. Edmiston et al. demonstrated the effectiveness of coated sutures in inhibiting bacterial growth and contamination in an in vitro model. In a randomized controlled trial, Rozzelle et al. reported a significant reduction in surgical site infection rates following cerebral spinal-fluid-shunt surgery with the use of antiseptic-coated sutures as compared with the rate following the same procedure without the use of such sutures. These sutures cost 7% to 10% more than their uncoated counterparts. To our knowledge, no cost-effectiveness analysis has been published; however, the use of these sutures in high-risk patients may be justified.

Operating-Room Traffic

Maintaining a disciplined operating-room culture can reduce the risk of surgical site infections. Unnecessary operating-room traffic increases the rate of infections. In a study of spine surgery, Olsen et al. reported that two or more residents participating in the operative procedure was an independent risk factor for surgical site infections, with an odds ratio of 2.2. Babkin et al. found that the rate of surgical site infections associated with left knee replacements was 6.7 times higher than that associated with right knee replacements performed during the same time period and in the same operating rooms. When the door on the left side of the operating room was locked, preventing ingress or egress, the surgical site infection rate associated with the left knee replacements rapidly decreased to that associated with the right knee replacements, a finding that supports the importance of limiting operating-room traffic.

Drains and Blood Transfusions

Whether to use drains at the end of orthopaedic surgical procedures is a decision that surgeons make on the basis of their training, opinions, and personal experience, in addition to research findings. A recent Cochrane review on this topic that included findings from thirty-six studies (5464 patients) revealed that the use of closed drains reduced bruising and the need for reinforcement of dressings. However, the use of closed drains was also associated with an increased need for transfusion, a risk factor that is discussed below. There was no difference in surgical site infection rates between drained and undrained wounds. The authors concluded that closed suction drains were of doubtful benefit.

In addition to the doubtful benefit of surgical drains in orthopaedic procedures, they are associated with a more frequent need for blood transfusion. Blood transfusion carries the general risk of infection with blood-borne pathogens, such as HIV or hepatitis, and with other bacteria or parasites. This risk is very small, although still present, in the United States and other developed countries that have rigorous testing procedures for donated blood. The more immediate risk associated with transfusion is surgical site infection and an increased length of hospital stay.
Transfusion of blood induces immunomodulation that can lead to an increased risk of infection at the surgical site. Talbot et al. reported a 3.2-fold increase in the post-sternotomy infection rate among patients who had had a transfusion compared with the rate among those who had not. In a study of cardiac surgery, Bower et al. reported that the rate of infection in patients who had had a transfusion was almost twice as high as that in patients who had not. Weber et al. found that patients who had had a transfusion after hip arthroplasty had an increased length of hospital stay, even when the authors controlled for surgical site infection. Strategies to decrease the need for transfusion include preoperative assessment of hemoglobin levels and the hematocrit and prescription of drugs to improve these parameters, if indicated, as well as the use of an algorithm that depends on symptomatic anemia, rather than hemoglobin and hematocrit results alone, to determine transfusion need.

Postoperative Wound Management
The CDC recommends maintaining surgical dressings for twenty-four to forty-eight hours postoperatively. Some surgeons use a three-day rule, keeping the original surgical dressing in place for seventy-two hours. There is little evidence that keeping dressings on for an extra day or two decreases the infection risk; however, if the dressing is not clean and dry, it may become a source of microbes close to the incision. Perhaps as important as the duration that the dressing is in place is ensuring the proper process for postoperative wound management. The surgeon should review policies and procedures to determine who changes dressings (e.g., nurses, or physicians only), under what circumstances they are changed, and if they are ever reinforced rather than changed. The basic concept of infection prevention is to keep the wound clean and dry. Soiled or blood-soaked dressings should be removed immediately rather than reinforced. If dressings do not stay intact, use of a different product may be warranted.

A multidisciplinary group should evaluate current practices and discuss ways to optimize postoperative wound care. Some basic issues are ensuring that an aseptic technique is used for dressing changes and having accurate descriptions of the amount and character of the wound drainage and of the wound itself in an accessible place. We have found that restrictions on the use of products due to cost may hinder good wound care. For example, restricting the use of semipermeable occlusive dressings to the operating room leaves staff on the nursing units without an appropriate product with which to keep surgical dressings intact. When viewed with respect to the cost of surgical site infections, the cost of the occlusive dressing is very reasonable. Staff education is needed if long-standing policies and procedures are to be changed.

Antimicrobial dressings are available, and research indicates that they may be helpful in reducing infection risk. Silver-based dressings have been available for a long time, and they are effective in decreasing the risk of mediastinitis following cardiac surgery and following lumbar laminectomy and fusion. They are not routinely used for surgical care, most likely because they are expensive and not always covered by insurance. Other compounds, such as polyhexamethylene biguanide (PHMB), have shown promise in small studies. PHMB dressings look and feel similar to traditional gauze dressings and are much less expensive than silver-containing dressings. The cost of a PHMB-containing 4 × 4-inch sponge is roughly twice the cost of regular 4 × 4-inch gauze (the least expensive antimicrobial dressing). Gentian violet and methylene blue are combined for bacteriostatic effect in some dressings, but there is little evidence to support their use for clean surgical incisions.

Other Issues Concerning Infection Prevention
Hand Hygiene
Proper hand hygiene is the most important way to prevent infections in health-care settings, yet compliance with hand-hygiene procedures is sub-optimal. The authors of the 2002 CDC Guideline for Hand Hygiene in Healthcare Settings reported an average compliance rate of 40%. Since that time, the Joint Commission on Accreditation of Healthcare Organizations has made decreasing rates of health-care-associated infections one of its national patient-safety goals, and hospitals that are accredited by the Joint Commission are required to have a hand-hygiene monitoring and improvement program. Studies have linked improved compliance with hand-hygiene protocols with decreased rates of marker organisms, such as methicillin-resistant Staphylococcus aureus. Many studies have demonstrated that multi-pronged interventions that include strong administrative support are more successful over time than are traditional single interventions, such as education or feedback of hand-hygiene-compliance data. Another strategy that has helped increase hand-hygiene compliance is the use of alcohol-based hand sanitizers. These are recommended preferentially by the CDC for routine hand hygiene. The rationale is that alcohol-based sanitizers can be more conveniently located than sinks and take less time to use than traditional hand washing. In addition, a counterintuitive finding is that alcohol hand sanitizers are less irritating to skin than hand washing with soap and water.

Isolation Precautions
Contact isolation precautions are recommended by the CDC for patients with drug-resistant organisms, and this is now part of the national patient safety goals of the Joint Commission. Patients with drug-resistant organisms are placed in private rooms, if possible, or with other patients who harbor the same organism. Gowns and gloves are required for care of these patients and should be donned on entry into the room. The decision about when to don gowns and gloves is no longer at the discretion of clinicians, since that leads to substantial variability in adherence. The Joint Commission requires hospitals to monitor adherence to contact precautions and to have a program to
improve compliance. Some issues regarding contact precautions are unclear. These include decisions about how to handle patients who have been decolonized for methicillin-resistant *Staphylococcus aureus*, a standardized definition of resistant gram-negative organisms, and how long to continue contact precautions for various organisms. More research is needed in these areas. Contact precautions are not without consequences. Recent study results indicate that patients subjected to contact isolation precautions are seen less frequently by attending physicians, are more likely to have skin breakdown or falls, and are more likely to complain about their care. Hospitals should include strategies to ameliorate these consequences when isolation precautions are indicated.

**Health-Care-Associated Infections**

The CMS is changing government payments for infections that arise as a result of hospital care. Successful interventions, such as the Institute for Healthcare Improvement’s “100,000 Lives” campaign (currently, the “5 Million Lives” campaign; http://www.ihi.org/IHI/Programs/Campaign) and the Keystone (Michigan Health and Hospital Association Keystone Center) initiative (http://www.mibcn.com/newsroom/2008/pr_03-12-2008_47388.shtml) have shown that infections are not simply an unavoidable complication of health care and that, with attention to infection-prevention practices, many infections may be prevented. As a payer, the CMS has decided to reward institutions that use best practices and not pay extra for certain preventable complications that are referred to as “never events.” As of October 2008, the CMS is not paying extra for infectious complications including catheter-associated urinary tract infections; central venous catheter-associated bloodstream infections; surgical site infections following spine, neck, shoulder, or elbow procedures; or mediastinitis following cardiac surgery (http://www.cms.hhs.gov/HospitalAcqCond/06_Hospital-Acquired_Conditions.asp#TopOfPage).

Of these health-care-associated events, urinary tract infections are the most numerous, so efforts at decreasing their occurrence are now a focus of hospitals around the country. Recent studies have shed light on the fact that many clinicians do not know which of their patients have urinary catheters and that there is a great opportunity to decrease the use of urinary catheterization. There are new guidelines and recommendations for appropriate use of urinary catheters (http://www.journals.uchicago.edu/doi/full/10.1086/591066). A daily assessment of the necessity for the device is among these recommendations and is probably the most straightforward approach to decreasing the use of urinary catheters and the associated infection risk.

**Public Reporting of Health-Care-Associated Infections**

As a result of consumer and payer demands for more transparency about health-care quality, many states now require some level of public reporting of health-care-associated infections. The elements of required reporting and the methodology for reporting vary from state to state, but many are using the CDC National Healthcare Safety Network (NHSN) as the required system. The NHSN is a web-based version of the CDC’s hospital infection reporting system that has been in place since the 1970s. The standardized definitions of infection have been used for many years and have become the gold standard for surveillance definitions. In addition to its long track record, advantages of the NHSN system include the fact that it is a secure database and that it allows groups (such as states) to sign up together, allows a conferral of rights to see institutional data, provides some data analysis and data display capabilities, produces the national benchmarks for infection rates, and is free to use. NHSN modules can be accessed online (http://www.cdc.gov/nhsn/psc_da.html).

Infection prevention has become a focus of attention for patients, payers, and regulators. Physicians and hospitals must now incorporate infection-prevention practices into their care or risk losing payment and patients and having negative publicity when their rates become public. Fortunately, this gives surgeons the opportunity to collaborate with partners throughout the health-care system to deliver the best care possible, paying attention to all processes of care for their patients.

**Overview**

Reduction of rates of surgical site infections promises to be an area of intense interest and activity in the foreseeable future. Health-care payers and regulatory organizations such as CMS and the Joint Commission are demanding accountability and reductions in rates of surgical site infection. In the areas in which evidence-based literature has demonstrated a clear best practice, such as prophylactic use of antibiotics and surgical scrub techniques, physicians and hospitals will be held accountable for compliance with these standards. This accountability will be quantified, and the data will be made available to the public. It is also clear that payers will penalize those responsible for failure to comply with these standards of care. Thus, it is necessary for all to become familiar with the known best practices and standards of care for the reduction of the rates of surgical site infections.

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