

7 INFECTION CONTROL IN SURGICAL PRACTICE

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Surgical procedures, by their very nature, interfere with the normal protective skin barrier and expose the patient to microorganisms from both endogenous and exogenous sources. Infections resulting from this exposure may not be limited to the surgical site but may produce widespread systemic effects. Prevention of surgical site infections (SSIs) is therefore of primary concern to surgeons and must be addressed in the planning of any operation. Standards of control have been developed for every step of a surgical procedure to help reduce the impact of exposure to microorganisms.¹⁻³ Traditional control measures include sterilization of surgical equipment, disinfection of the skin, use of prophylactic antibiotics, and expeditious operation.

The Study on the Efficacy of Nosocomial Infection Control (SENIC), conducted in United States hospitals between 1976 and 1986, showed that surgical patients were at increased risk for all types of infection. The nosocomial, or hospital-acquired, infection rate at that time was estimated to be 5.7 cases out of every 100 hospital admissions.⁴ These infections included SSIs as well as bloodstream, urinary, and respiratory infections. Today, the increased use of minimally invasive surgical procedures and early discharge from the hospital necessitates postdischarge surveillance⁵ in addition to in-hospital surveillance for the tracking of nosocomial infections. With the reorganization of health care delivery programs, nosocomial infections will appear more frequently in the community and should therefore be considered a part of any patient care assessment plan.

Care assessment programs designed to help minimize the risk of nosocomial infections were first introduced in 1951 by the Joint Commission on Accreditation of Healthcare Organizations (JCAHO). Since then, as medical technology has changed, JCAHO has redesigned the survey process. In its plan for infection control programs, JCAHO strongly recommends that the survey, documentation, and reporting of infections be made mandatory for the purpose of hospital accreditation.⁶

Effective infection control and prevention requires an organized, hospital-wide program aimed at achieving specific objectives. The program's purpose should be to obtain relevant information on the occurrence of nosocomial infections both in patients and in employees. The data should be documented, analyzed, and communicated with a plan for corrective measures. Such surveillance activities, combined with education, form the basis of an infection control program.

Data relating to host factors are an integral part of infection data analysis. Documentation of host factors has made for a better appreciation of the associated risks and has allowed comparative evaluation of infection rates. Development of new surgical equipment and technological advances have influenced the impact of certain risk factors, such as lengthy operation and prolonged hospital stay. Clinical investigations have helped improve the understanding of host factors and have influenced other aspects of surgical practice.⁷⁻¹² Excessive use of and reliance on antibiotics have led to problems not previously encountered in practice—for

example, the emergence of drug-resistant microorganisms, such as methicillin-resistant *Staphylococcus aureus* (MRSA), glycopeptide-intermediate *S. aureus* (GISA), multidrug-resistant *Mycobacterium tuberculosis*, and multidrug-resistant *Enterococcus* strains.¹³⁻¹⁶ Such complications reemphasize the need to focus on infection control as an essential component of preventive medicine.

Besides the impact of morbidity and mortality on patients, there is the cost of treating nosocomial infections, which is a matter of concern for surgeons, hospital administrators, insurance companies, and government planners alike. Efforts to reduce the occurrence of nosocomial infections are now a part of hospital cost-control management programs.^{17,18} The challenge to clinicians is how to reduce cost while maintaining control over, and preventing spread of, infection.

The Surgical Wound and Infection Control

Nosocomial infections are defined as infections acquired in the hospital. There must be no evidence that the infection was present or incubating at the time of hospital admission. Usually, an infection that manifests 48 to 72 hours after admission is considered to be nosocomially acquired. An infection that is apparent on the day of admission is usually considered to be community acquired, unless it is epidemiologically linked to a previous admission or to an operative procedure at the time of admission.

IDENTIFICATION OF RISK FACTORS

The risk of development of an SSI depends on host factors, perioperative wound hygiene, and the duration of the surgical procedure. The risk of development of other nosocomial infections depends on these and other factors, including length of the hospital stay and appropriate management of the hospital environment [see Activities of an Infection Control Program, *below*]. Identification of host and operative risk factors can help determine the potential for infection and point toward measures that might be necessary for prevention and control.

Host Risk Factors

Host susceptibility to infection can be estimated according to the following variables: older age, severity of disease, physical-status classification (see below), prolonged preoperative hospitalization, morbid obesity, malnutrition, immunosuppressive therapy, smoking, preoperative colonization with *S. aureus*, and coexistent infection at a remote body site.¹⁹

A scale dividing patients into five classes according to their physical status was introduced by the American Society of Anesthesiologists (ASA) in 1974 and tested for precision in 1978.²⁰ The test results showed that the ASA scale is a workable system, although it lacks scientific definition [see *Table 1*].

Significant differences in infection rates have been shown in patients with different illnesses. In one prospective study, the severity of underlying disease (rated as fatal, ultimately fatal, or

Table 1 American Society of Anesthesiologists
Physical-Status Scale

Class 1	A normally healthy individual
Class 2	A patient with mild systemic disease
Class 3	A patient with severe systemic disease that is not incapacitating
Class 4	A patient with incapacitating systemic disease that is a constant threat to life
Class 5	A moribund patient who is not expected to survive 24 hr with or without operation
E	Added for emergency procedures

nonfatal) was shown to have predictive value for endemic nosocomial infections: the nosocomial infection rate in patients with fatal diseases was 23.6%, compared with 2.1% in patients with nonfatal diseases.²¹

Operative Risk Factors

Several factors related to the operative procedure may be associated with the risk of development of an SSI [see 1:2 *Prevention of Postoperative Infection*]. These include method of hair removal (and likelihood of consequent skin injury), inappropriate use of antimicrobial prophylaxis, duration of the operation, and wound classification. The influence of hair removal methods on SSI has been examined by many investigators. Lower infection rates were reported with the use of depilatory agents and electric clippers than with razors.^{7,8} Antimicrobial prophylaxis is used for all operations that involve entry into a hollow viscus. Antimicrobial prophylaxis is also indicated for clean operations in which an intra-articular or intravascular prosthetic device will be inserted and for any operation in which an SSI would have a high morbidity.¹⁹ A comprehensive study determined that there is considerable variation in the timing of administration of prophylactic antibiotics, but that the administration within 2 hours before surgery reduces the risk of SSI.⁹

Operative wounds are susceptible to varying levels of bacterial contamination, by which they are classified as clean, clean-contaminated, contaminated, or dirty.²² In most institutions, the responsibility for classifying the incision site is assigned to the operating room circulating nurse; one assessment suggests that the accuracy of decisions made by this group is as high as 88%.²³

Composite Risk Indices

The Centers for Disease Control and Prevention (CDC) established the National Nosocomial Infections Surveillance (NNIS) system in 1970 to create a national database of nosocomial infections.²⁴ The NNIS system has been used to develop indices for predicting the risk of nosocomial infection in a given patient.

NNIS basic risk index NNIS developed a composite risk index composed of the following criteria: ASA score, wound class, and duration of surgery. Reporting on data collected from 44 United States hospitals between 1987 and 1990, NNIS demonstrated that this risk index is a significantly better predictor for development of SSI than the traditional wound classification system alone.^{25,26} The NNIS risk index is a useful method of risk adjustment for a wide variety of procedures.

The NNIS risk index is scored as 0, 1, 2, or 3. A patient's score is determined by counting the number of risk factors present from among the following: an ASA score of 3, 4, or 5; a surgical wound that is classified as contaminated or dirty/infected;

and an operation lasting over T hours (where T represents the 75th percentile of distribution of the duration of the operative procedure being performed, rounded to the nearest whole number of hours).

Modified NNIS basic risk index for procedures using laparoscopes For cholecystectomy and colon surgery procedures, the use of a laparoscope lowered the risk of SSI within each NNIS risk index category.²⁷ Hence, for these procedures, when the procedure is performed laparoscopically, the risk index should be modified by subtracting 1 from the basic NNIS risk index score. With this modification, the risk index has values of M (or -1), 0, 1, 2, or 3. For appendectomy and gastric surgery, use of a laparoscope affected SSI rates only when the NNIS basic risk index was 0, thereby yielding five risk categories: 0-Yes, 0-No, 1, 2, and 3, where Yes or No refers to whether the procedure was performed with a laparoscope.²⁷

Operation-specific risk factors It is likely that operation-specific logistic regression models will increasingly be used to calculate risk. For example, in spinal fusion surgery, Richards and colleagues identified diabetes mellitus, ASA score greater than 3, operation duration longer than 4 hours, and posterior surgical approach as significant independent predictors of SSI.²⁸ Other logistic regression models have been developed for craniotomy and cesarean section.^{29,30} These models should permit more precise risk adjustment.

PREVENTIVE MEASURES

In any surgical practice, policies and procedures should be in place pertaining to the making of a surgical incision and the prevention of infection. These policies and procedures should govern the following: (1) skin disinfection and hand-washing practices of the operating team, (2) preoperative preparation of the patient's skin (e.g., hair removal and use of antiseptics), (3) the use of prophylactic antibiotics, (4) techniques for preparation of the operative site, (5) management of the postoperative site if drains, dressings, or both are in place, (6) standards of behavior and practice for the operating team (e.g., the use of gown, mask, and gloves), (7) special training of the operating team, and (8) sterilization and disinfection of instruments.

Hand Hygiene

Although hand washing is considered the single most important measure for preventing nosocomial infections, poor compliance is frequent.³¹ Role modeling is important in positively influencing this behavior. One study showed that a hand-washing educational program contributed to a reduction in the rate of nosocomial infections.³² Good hand-washing habits can be encouraged by making facilities (with sink, soap, and towel) visible and easily accessible in patient care areas [see 1:2 *Prevention of Postoperative Infection*].

Cleansers used for hand hygiene include plain nonantimicrobial soap, antimicrobial soaps, and waterless alcohol-based hand antiseptics. Plain soaps have very little antimicrobial activity; they mainly remove dirt and transient flora.³³ Compared with plain soaps, antimicrobial soaps achieve a greater log reduction in eliminating transient flora and have the additional advantage of sustained activity against resident hand flora.³³ Alcohol-based hand antiseptics have an excellent spectrum of antimicrobial activity and rapid onset of action, dry rapidly, and do not require the use of water or towels.³⁴ Therefore, they are recommended for routine decontamination of hands during patient care except when hands are visibly soiled. Emollients are often added to alcohol-based

waterless hand antiseptics because of these antiseptics' tendency to cause drying of the skin.³⁴

Sterilization and Disinfection

Spaulding proposed in 1972 that the level of disinfection and sterilization for surgical and other instruments be determined by classifying the instruments into three categories—critical, semi-critical, and noncritical—according to the degree of infection risk involved in their use.³⁵

Critical items include objects or instruments that enter directly into the vascular system or sterile areas of the body. These items should be sterilized by steam under pressure, dry heat, ethylene oxide, or other approved methods. Flash sterilization is the process by which surgical instruments are sterilized for immediate use should an emergency situation arise (e.g., to sterilize an instrument that was accidentally dropped). This is usually achieved by leaving instruments unwrapped in a container and using a rapid steam cycle.³⁶ Instruments must still be manually cleaned, decontaminated, inspected, and properly arranged in the container before sterilization. Implantables should not be flash sterilized. Flash sterilization is not intended to replace conventional steam sterilization of surgical instruments or to reduce the need for adequate instrument inventory.³⁶

Semicritical items are those that come into contact with mucous membranes or skin that is not intact (e.g., bronchoscopes and gastroscopes). Scopes have the potential to cause infection if they are improperly cleaned and disinfected. Transmission of infection has been documented after endoscopic investigations, including infection with *Salmonella typhi*³⁷ and *Helicobacter pylori*.³⁸ Such incidents emphasize the need for sterilization of the endoscopic biopsy forceps. Semicritical items generally require high-level disinfection that kills all microorganisms except bacterial spores.³⁹

Glutaraldehyde 2% is a high-level disinfectant that has been used extensively in flexible endoscopy. Before disinfection, scopes should receive a thorough manual cleaning to eliminate gross debris. To achieve high-level disinfection, the internal and external surfaces and channels should come into contact with the disinfecting agent for a minimum of 20 minutes.³⁹ Glutaraldehyde has certain disadvantages. In particular, it requires activation before use; moreover, it is irritating to the skin, eyes, and nasal mucosa, and thus, its use requires special ventilation or a ducted fume hood.³⁹

An alternative to glutaraldehyde is orthophthaldehyde (OPA), a newer agent approved by the Food and Drug Administration (FDA) for high-level disinfection. OPA is odorless and nonirritating and does not require activation before use.⁴⁰

Noncritical items are those that come in contact with intact skin (e.g., blood pressure cuffs). They require only washing or scrubbing with a detergent and warm water or disinfection with an intermediate-level or low-level germicide for 10 minutes.

The reuse of single-use medical devices has become a topic of interest because of the implied cost saving. The central concerns are the effectiveness of sterilization or disinfection according to category of use, as well as maintenance of the essential mechanical features and the functional integrity of the item to be reused. The FDA has issued regulations governing third-party and hospital reproducers engaged in reprocessing single-use devices for reuse.⁴¹ These regulations are available on the FDA's web site (www.fda.gov/cdrh/comp/guidance/1168.pdf).

Hair Removal

An infection control program should have a hair-removal policy for preoperative skin preparation [*see 1:2 Prevention of Post-operative Infection*].

Operating Room Environment

Environmental controls in the OR have been used to reduce the risk of SSI [*see 1:1 Preparation of the Operating Room*]. The OR should be maintained under positive pressure of at least 2.5 Pa in relation to corridors and adjacent areas. In addition, there should be at least 15 air changes per hour, of which three should involve fresh air.⁴²

HEALTH STATUS OF THE HEALTH CARE TEAM

The health care team has a primary role in the prevention of infection. Continued education and indoctrination of policies are essential: the team must be kept well informed and up to date on concepts of infection control. Inadvertently, team members may also be the source of, or the vector in, transmission of infection. Nosocomial infection outbreaks with MRSA have been traced to MRSA carriers among health care workers.⁴³ Screening of personnel to identify carriers is undertaken only when an outbreak of nosocomial infection occurs that cannot be contained despite implementation of effective control measures and when a health care worker is epidemiologically linked to cases.

Protecting the health care team from infection is a constant concern. Preventive measures, such as immunizations and pre-employment medical examinations, should be undertaken at an employee health care center staffed by knowledgeable personnel.⁴⁴ Preventable infectious diseases, such as chickenpox and rubella, should be tightly controlled in hospitals that serve immunocompromised and obstetric patients. It is highly recommended that a record be maintained of an employee's immunizations. Knowledge of the employee's health status on entry to the hospital helps ensure appropriate placement and good preventive care.

When exposure to contagious infections is unavoidable, susceptible personnel should be located, screened, and given prophylactic treatment if necessary. Infection control personnel should define the problem, establish a definition of contact, and take measures to help reduce panic.

Isolation Precautions

CDC guidelines have been developed to prevent the transmission of infections.⁴⁵ These isolation guidelines promote two levels of isolation precautions: standard precautions and transmission-based precautions.

Standard precautions The standard precautions guidelines—which incorporate the main features of the older universal precautions and body substance isolation guidelines—were developed to reduce the risk of transmission of microorganisms for all patients regardless of their diagnosis.⁴⁵⁻⁴⁷ Standard precautions apply to blood, all body fluids, secretions and excretions, and mucous membranes.

Transmission-based precautions Transmission-based precautions were developed for certain epidemiologically important pathogens or clinical presentations. These precautions comprise three categories, based on the mode of transmission: airborne precautions, droplet precautions, and contact precautions.⁴⁵ Precautions may be combined for certain microorganisms or clinical presentations (e.g., both contact and airborne precautions are indicated for a patient with varicella).

Airborne precautions are designed to reduce transmission of microorganisms spread via droplets that have nuclei 5 μm in size or smaller, remain suspended in air for prolonged periods of time,

and have the capability of being dispersed widely.⁴⁵ Airborne precautions include wearing an N95 respirator, placing the patient in a single room that is under negative pressure of 2.5 Pa in relation to adjacent areas, keeping the door closed, providing a minimum of 6 to 12 air changes per hour, and exhausting room air outside the building and away from intake ducts or through a high-efficiency particulate air (HEPA) filter if recirculated.^{45,48} Airborne precautions are indicated for patients with suspected or confirmed infectious pulmonary or laryngeal tuberculosis; measles; varicella; disseminated zoster; and Lassa, Ebola, Marburg, and other hemorrhagic fevers with pneumonia. Varicella, disseminated herpes zoster, and hemorrhagic fevers with pneumonia also call for contact precautions (see below).

Droplet precautions are designed to reduce the risk of transmission of microorganisms spread via large-particle droplets that are greater than 5 µm in size, do not remain suspended in the air for prolonged periods, and usually travel 1 m or less.⁴⁵ No special ventilation requirements are required to prevent droplet transmission. A single room is preferable, and the door may remain open. Examples of patients for whom droplet precautions are indicated are those with influenza, rubella, mumps, and meningitis caused by *Haemophilus influenzae* and *Neisseria meningitidis*.

Contact precautions are designed to reduce the risk of transmission of microorganisms by direct or indirect contact. Direct contact involves skin-to-skin contact resulting in physical transfer of microorganisms.⁴⁵ Indirect contact involves contact with a contaminated inanimate object that acts as an intermediary. Contact precautions are indicated for patients colonized or infected with multidrug-resistant bacteria that the infection control program judges to be of special clinical and epidemiologic significance on the basis of recommendations in the literature.⁴⁵

Exposure to Bloodborne Pathogens

The risk of transmission of HIV and hepatitis B virus (HBV) from patient to surgeon or from surgeon to patient has resulted in a series of recommendations governing contact with blood and body fluids.⁴⁸ The risk of acquiring a bloodborne infection—such as with HBV, hepatitis C virus (HCV), or HIV—depends on three factors: type of exposure to the bloodborne pathogen, prevalence of infection in the population, and the rate of infection after exposure to the bloodborne pathogen.⁴⁹ Postexposure management has been discussed in CDC guidelines (www.cdc.gov/mmwr/pdf/rr/rr5011.pdf).⁵⁰

Protection of the face and hands during operation has become important. A study of 8,502 operations found that the rate of direct blood exposure was 12.4%, whereas the rate of parenteral exposure via puncture wounds and cuts was 2.2%. Parenteral blood contacts were twice as likely to occur among surgeons as among other OR personnel.⁵¹ These findings support the need for OR practice policies and the choice of appropriate protective garments for the OR staff. OR practice policy should give particular attention to methods of using sharp instruments and to ways of reducing the frequency of percutaneous injuries: sharp instruments should be passed in a metal dish, cautery should be used, and great care should be taken in wound closures. It is important that masks protect the operating team from aerosolized fluids. Researchers have shown that for ideal protection, a mask should be fluid-capture efficient and air resistant.⁵²

For invasive surgical procedures, double gloving has become routine. However, there are recognized differences among the gloves available. Latex allergy is an important issue; nonlatex alternatives are available for those who are allergic.⁵³

Table 2 CDC Recommendations for Prevention of HIV and HBV Transmission during Invasive Procedures⁴⁸

- Health care workers with exudative lesions or weeping dermatitis should cover any unprotected skin, or they should not provide patient care until the damaged skin has healed.
- Hands should be washed after every patient contact.
- Health care workers should wear gloves when contact with blood or body substances is anticipated; double gloves should be used during operative procedures; hands should be washed after gloves are removed.
- Gowns, plastic aprons, or both should be worn when soiling of clothing is anticipated.
- Mask and protective eyewear or face shield should be worn if aerosolization or splattering of blood or body substances is expected.
- Resuscitation devices should be used to minimize the need for mouth-to-mouth resuscitation.
- Disposable containers should be used to dispose of needles and sharp instruments.
- Avoid accidents and self-wounding with sharp instruments by following these measures:
 - Do not recap needles.
 - Use needleless systems when possible.
 - Use cautery and stapling devices when possible.
 - Pass sharp instruments in metal tray during operative procedures.
- In the case of an accidental spill of blood or body substance on skin or mucous membranes, do the following:
 - Rinse the site immediately and thoroughly under water.
 - Wash the site with soap and water.
 - Document the incident (i.e., report to Occupational Safety and Health Administration or to the Infection Control Service).
- Blood specimens from all patients should be considered hazardous at all times.
- Prompt attention should be given to spills of blood or body substances, which should be cleaned with an appropriate disinfectant.

Hepatitis B virus For active surgeons and other members of the health care team, HBV infection continues to pose a major risk. Hepatitis B vaccination has proved safe and protective and is highly recommended for all high-risk employees; it should be made available through the employee health care center.

Despite the efficacy of the vaccine, many surgeons and other personnel remain unimmunized and are at high risk for HBV infection.⁴⁸ HBV is far more easily transmitted than HIV and continues to have a greater impact on the morbidity and mortality of health care personnel. An estimated 8,700 new cases of hepatitis B are acquired occupationally by health care workers each year; 200 to 250 of these cases result in death.⁵⁴ The risk of seroconversion is at least 30% after a percutaneous exposure to blood from a hepatitis B e antigen-seropositive source.⁵⁰ Given that a patient's serostatus may be unknown, it is important that health care workers follow standard precautions for all patients.

With HBV infection, as with HIV (see below), the approach to prevention and control is a two-way street—that is, protection should be afforded to patients as well as health care personnel. In addition to standard precautions, the CDC has developed recommendations for health care workers that are designed to prevent transmission of HBV and HIV from health care worker to patient or from patient to health care worker during exposure-prone invasive procedures [see Table 2]. Cognizant of the CDC recommendations, the American College of Surgeons has issued additional recommendations regarding the surgeon's role in the prevention of hepatitis transmission [see Table 3].⁵⁴

Hepatitis C virus The average incidence of seroconversion after percutaneous exposure from an HCV-positive source is 1.8% (range, 0% to 7%).⁵⁵⁻⁵⁷ Mucous membrane exposure to blood rarely results in transmission, and no transmission has been documented from exposure of intact or nonintact skin to blood.^{50,58} There is no recommended postexposure prophylaxis regimen for HCV. The use of immunoglobulin has not been demonstrated to be protective.⁵⁰ There are no antiviral medications recommended for postexposure prophylaxis.⁵⁰

Human immunodeficiency virus Exposure to blood and body substances of patients who have AIDS or who are seropositive for HIV constitutes a health hazard to hospital employees. The magnitude of the risk depends on the degree and method of exposure [see 8:21 *Acquired Immunodeficiency Syndrome*].

The presence of HIV infection in a patient is not always known. Because the prevalence of HIV in the North American patient population is less than 1% (range, 0.09% to 0.89%), and because a caregiver's risk of seroconversion after needlestick injury is likewise less than 1%, the CDC recommends taking standard precautions [see 8:20 *Viral Infection*] and following in all patients the same guidelines for invasive procedures that one would use in cases of known HBV-infected patients [see Table 2].⁴⁸ Infection control personnel have introduced realistic control measures and educational programs to help alleviate fears that health care workers might have about coming in contact with patients infected with HIV.

Exposure to Tuberculosis

In studies of health care workers, positive results on tuberculin skin testing have ranged from 0.11% to 10%.^{59,60} Health care workers who are immunocompromised are at high risk for development of disease postexposure.⁵⁹

The CDC recommendation for tuberculosis prevention places emphasis on a hierarchy of control measures, including administrative engineering controls and personal respiratory protection

(www.cdc.gov/mmwr/pdf/rr/rr4313.pdf). The following measures should be considered:

1. The use of risk assessments and development of a written tuberculosis control protocol.
2. Early identification and treatment of persons who have tuberculosis.
3. Tuberculosis screening programs for health care workers.
4. Training and education.
5. Evaluation of tuberculosis infection control programs.⁶¹

Activities of an Infection Control Program

SURVEILLANCE

The cornerstone of an infection control program is surveillance. This process depends on the verification, classification, analysis, reporting, and investigation of infection occurrences, with the intent of generating or correcting policies and procedures. Five surveillance methods can be applied^{62,63}:

1. Total, or hospital-wide, surveillance—collection of comprehensive data on all infections in the facility, with the aim of correcting problems as they arise. This is labor intensive.
2. Surveillance by objective, or targeted surveillance, in which a specific goal is set for reducing certain types of infection. This concept is priority-directed and can be further subdivided into two distinct activities:
 - a. The setting of outcome objectives, in which the objectives for the month or year are established and all efforts applied to achieve a desired rate of infection. As with the hospital-wide approach, a short-term plan would be made to monitor, record, and measure results and provide feedback on the data.
 - b. The setting of process objectives, which incorporates the patient care practices of doctors and nurses as they relate to outcome (e.g., wound infections and their control).
3. Periodic surveillance—intensive surveillance of infections and patient-care practices by unit or by service at different times of the year.
4. Prevalence survey—the counting and analysis of all active infections during a specified time period. This permits identification of nosocomial infection trends and problem areas.
5. Outbreak surveillance—the identification and control of outbreaks of infection. Identification can be made on the basis of outbreak thresholds if baseline bacterial isolate rates are available and outbreak thresholds can be developed. Problems are evaluated only when the number of isolates of a particular bacterial species exceeds outbreak thresholds.

Surveillance techniques include the practice of direct patient observation⁷ and indirect observation by review of microbiology reports, nursing Kardex, or the medical record to obtain data on nosocomial infections. The sensitivity of case finding by microbiology reports was found to be 33% to 65%; by Kardex, 85%; and by total chart review, 90%.⁶² These methods may be used either separately or in combination to obtain data on clinical outcomes.

One use of surveillance data is to generate information for individual surgeons, service chiefs, and nursing personnel as a reminder of their progress in keeping infections and diseases under control. This technique was used by Cruse in 1980 to show a progressive decrease in infection rates of clean surgical wounds to less than 1% over 10 years.⁸ In other settings, endemic rates of bloodstream, respiratory, and urinary tract infections were cor-

Table 3 ACS Recommendations for Preventing Transmission of Hepatitis⁵⁴

Surgeons should continue to utilize the highest standards of infection control, involving the most effective known sterile barriers, universal precautions, and scientifically accepted measures to prevent blood exposure during every operation. This practice should extend to all sites where surgical care is rendered and should include safe handling practices for needles and sharp instruments.

Surgeons have the same ethical obligations to render care to patients with hepatitis as they have to render care to other patients.

Surgeons with natural or acquired antibodies to HBV are protected from acquiring HBV from patients and cannot transmit the disease to patients. All surgeons and other members of the health care team should know their HBV immune status and become immunized as early as possible in their medical career.

Surgeons without evidence of immunity to HBV who perform procedures should know their HBsAg status and, if this is positive, should also know their HBeAg status. In both instances, expert medical advice should be obtained and all appropriate measures taken to prevent disease transmission to patients. Medical advice should be rendered by an expert panel composed and convened to fully protect practitioner confidentiality. The HBeAg-positive surgeon and the panel should discuss and agree on a strategy for protecting patients at risk for disease transmission.

On the basis of current information, surgeons infected with HCV have no reason to alter their practice but should seek expert medical advice and appropriate treatment to prevent chronic liver disease.

rected and reduced by routine monitoring and reporting to medical and nursing staff.²¹

The increasing practice of same-day or short-stay surgical procedures has led to the need for postdischarge surveillance. This may be done by direct observation in a follow-up clinic, by surveying patients through the mail or over the telephone, by reviewing medical records, or by mailing questionnaires directly to surgeons. The original CDC recommendation of 30 days for follow-up was used by one hospital to randomly screen post-joint arthroplasty patients by telephone. This screening identified an infection rate of 7.5%, compared with 2% for hospitalized orthopedic patients.⁶⁴ Results from another medical center suggested that 90% of cases would be captured in a 21-day postoperative follow-up program.⁵ Infections that occur after discharge are more likely with clean operations, operations of short duration, and operations in obese patients and in nonalcoholic patients. The use of prosthetic materials for implants requires extending the follow-up period to 1 year.

Definition of Surgical Site Infections

The CDC defines an incisional SSI as an infection that occurs at the incision site within 30 days after surgery or within 1 year if a prosthetic implant is in place. Infection is characterized by redness, swelling, or heat with tenderness, pain, or dehiscence at the incision site and by purulent drainage. Other indicators of infection include fever, deliberate opening of the wound, culture-positive drainage, and a physician's diagnosis of infection with prescription of antibiotics. To encourage a uniform approach among data collectors, the CDC has suggested three categories of SSIs, with definitions for each category [see Table 4].⁶⁵ The category of organ or space SSI was included to cover any part of the anatomy (i.e., organs or spaces) other than the incision that might have been opened or manipulated during the operative procedure. This category would include, for example, arterial and venous infections, endometritis, disk space infections, and mediastinitis.⁶⁵

There should be collaboration between the physician or nurse and the infection control practitioner to establish the presence of an SSI. The practitioner should complete the surveillance with a chart review and document the incident in a computer database program for later analysis. The data must be systematically recorded; many commercial computer programs are available for this purpose. One group reported that their experience with the Health Evaluation through Logical Processing system was useful for identifying patients at high risk for nosocomial infections.⁶⁶

Verification of Infection

A complete assessment should include clinical evaluation of commonly recognized sites (e.g., wound, respiratory system, urinary tract, and intravenous access sites) for evidence of infection, especially when no obvious infection is seen at the surgical site. Microbiologic evaluation should identify the microorganism. Such evaluation, however, depends on an adequate specimen for a Gram stain and culture. For epidemiologic reasons, DNA fingerprinting may be required, especially for outbreak investigation.

A system of internal auditing should alert the infection control service to multiresistant microorganisms—for example, to the presence of MRSA or vancomycin-resistant *Enterococcus* (VRE) in a patient. Differentiation between infection and colonization is important for the decision of how to treat. Regardless of whether infection or colonization is identified, verification of MRSA or VRE should generate a discussion on control measures.

Table 4 Surgical Site Infections (SSIs)⁶⁵

Superficial SSIs
Skin
Deep incisional SSIs
Fascia
Muscle layers
Organ or space SSIs
Body organs
Body spaces

Data Interpretation

The predictive value of data is deemed more useful when it is applied to specific situations. According to CDC experts, the scoring for infections depends on specified, related denominators to interpret the data, especially when there is to be interhospital comparison.⁶⁷

Data Analysis

The original practice of presenting overall hospital-wide crude rates provided little means for adjustment of variables (e.g., risk related to the patient or to the operation). The following three formulas, however, are said to offer more precision than traditional methods⁶⁷:

$$(\text{Number of nosocomial infections/Service operations}) \times 100$$

$$[\text{Number of site-specific nosocomial infections/Specific operations (e.g., number of inguinal hernias)}] \times 100$$

$$[\text{Number of nosocomial infections/Hospital admissions (patient-days)}] \times 1,000$$

Data on infections of the urinary tract, respiratory system, and circulatory system resulting from exposure to devices such as Foley catheters, ventilators, and intravascular lines can be illustrated as device-associated risks according to site, as follows:

$$(\text{Number of device-associated infections of a site/Number of device days}) \times 1,000$$

Reporting

Infection notification to surgeons has been shown by Cruse and Foord to have a positive influence on clean-wound infection rates.^{7,8} In a medical setting, Britt and colleagues also reported a reduction in endemic nosocomial infection rates for urinary tract infections, from 3.7% to 1.3%, and for respiratory tract infections, from 4.0% to 1.6%, simply by keeping medical personnel aware of the rates.²¹

Outbreak Investigation

There are 10 essential components to an outbreak investigation:

1. Verify the diagnosis and confirm that an outbreak exists. This is an important step, because other factors may account for an apparent increase in infections. These factors may include a reporting artifact resulting from a change in surveillance methodology, a laboratory error or change in laboratory methodology, or an increase in the denominator of the formula used for data analysis (if this increase is proportionate to the rise in the numerator, the infection rate has not changed).
2. Formulate a case definition to guide the search for potential patients with disease.
3. Draw an epidemic curve that plots cases of the disease against time of onset of illness. This curve compares the number of cases during the epidemic period with the baseline. In addi-

tion, the epidemic curve helps to determine the probable incubation period and how the disease is being transmitted (i.e., a common source versus person to person).

4. Review the charts of case patients to determine demographics and exposures to staff, medications, therapeutic modalities, and other variables of importance.
5. Perform a line listing of case patients to determine whether there is any common exposure.
6. Calculate the infection rate. The numerator is the number of infected patients and the denominator is the number of patients at risk.
7. Formulate a tentative hypothesis to explain the reservoir and the mode of transmission. A review of the literature on similar outbreaks may be necessary.
8. Test the hypothesis, using a case-control study, cohort study, prospective intervention study, or microbiologic study. A case-control study is usually used, because it is less labor intensive. For a case-control study, control subjects should be selected from an uninfected surgical population of patients who were hospitalized at the same time as those identified during the epidemic period and matched for age, gender, service operation, operation date, and health status (ASA score). Two or three control patients are usually selected for every case patient. The cases and controls are then compared with respect to possible exposures that may increase the risk of disease. Patient, personnel, and environmental microbiologic isolates (if any) should be kept for fingerprinting (e.g., pulsed-field gel electrophoresis, random amplified polymorphic DNA polymerase chain reaction).
9. Institute infection control measures. This may be done at any time during the investigation. The control measures should be reviewed after institution to determine their efficacy and the possible need for changing them.
10. Report the incident to the infection control committee and, at the completion of the investigation, submit a report. The administrators, physicians, and nurses involved should be informed and updated as events change.⁶⁸

ANTIMICROBIAL-RESISTANT MICROORGANISMS

Hospitals and communities worldwide are facing the challenge posed by the spread of antimicrobial-resistant microorganisms. Strains of MRSA are increasing in hospitals and are an important cause of nosocomial infections; in the United States in the year 2002, the proportion of *S. aureus* isolates resistant to methicillin or oxacillin was more than 55%.⁶⁹ MRSA strains do not merely replace methicillin-susceptible strains as a cause of hospital-acquired infections but actually increase the burden of nosocomial infections.⁷⁰ Moreover, there are reports that MRSA may be becoming a community-acquired pathogen.^{71,72} A proactive approach for controlling MRSA at all levels of health care can result in decreased MRSA infection rates.^{73,74}

Strains of GISA, an emerging pathogen, exhibit reduced susceptibility to vancomycin and teicoplanin. The first GISA strain was isolated in 1996 in Japan.⁷⁵ DNA fingerprinting suggests that these GISA strains evolved from preexisting MRSA strains that infected patients in the months before the GISA infection. Contact precautions are indicated for patients infected or colonized with GISA; infection control guidelines to prevent the spread of GISA are available.⁷⁶

VRE accounts for 31% of all enterococci in the NNIS system.⁷⁰ Transmission usually occurs through contact with the contaminated hands of a health care worker. The environment is an important reservoir for VRE, but it is not clear whether the environment plays a significant role in transmission.⁷⁷ Risk factors for VRE

acquisition include length of hospital stay, liver transplantation, presence of feeding tubes, dialysis, and exposure to cephalosporins.⁷⁸ Contact precautions are indicated for patients infected or colonized with VRE.⁷⁹

Strategies to prevent and control the emergence and spread of antimicrobial-resistant microorganisms have been developed. These include optimal use of antimicrobial prophylaxis for surgical procedures; optimizing choice and duration of empirical therapy; improving antimicrobial prescribing patterns by physicians; monitoring and providing feedback regarding antibiotic resistance; formulating and using practice guidelines for antibiotic usage; developing a system to detect and report trends in antimicrobial resistance; ensuring that caregivers respond rapidly to the detection of antimicrobial resistance in individual patients; incorporating the importance of controlling antimicrobial resistance into the institutional mission and climate; increasing compliance with basic infection control policies and procedures; and developing a plan for identifying, transferring, discharging, and readmitting patients colonized or infected with specific antimicrobial-resistant microorganisms.⁸⁰

Severe Acute Respiratory Syndrome

The severe acute respiratory syndrome (SARS) first emerged in Guangdong Province, China, in November 2002. SARS is caused by a novel coronavirus (SARS-CoV) that may have originated from an animal reservoir.⁸¹ It is characterized by fever, chills, cough, dyspnea, and diarrhea and radiologic findings suggestive of atypical pneumonia.⁸² As of August 7, 2003, a total of 8,422 probable cases, with 916 deaths (11%), had been reported from 29 countries.⁸³

The incubation period is estimated to be 10 days, and patients appear to be most infectious during the second week of illness.⁸³ Available evidence suggests that SARS-CoV is spread through contact, in droplets, and possibly by airborne transmission.⁸³ Accordingly, health care workers must adhere to contact, droplet, and airborne precautions when caring for SARS patients. Included in such precautions are the use of gloves, gowns, eye protection, and the N95 respirator.⁸³ A comprehensive review of SARS is available at the WHO web site (www.who.int/csr/sars/en/WHOCconsensus.pdf).

ENVIRONMENTAL CONTROL

Control of the microbial reservoir of the patient's immediate environment in the hospital is the goal of an infection control program. Environmental control begins with design of the hospital's physical plant. The design must meet the functional standards for patient care and must be integrated into the architecture to provide traffic accessibility and control. Since the 1960s, the practice of centralizing seriously ill patients in intensive care, dialysis, and transplant units has accentuated the need for more careful analysis and planning of space. The primary standards for these special care units and ORs require planning of floor space, physical surfaces, lighting, ventilation, water, and sanitation to accommodate easy cleaning and disinfecting of surfaces, sterilization of instruments, proper food handling, and garbage disposal. These activities should then be governed by workable policies that are understandable to the staff. Preventive maintenance should be a basic and integral activity of the physical plant department.

Surveillance of the environment by routine culturing of operating room floors and walls was discontinued in the late 1970s. Autoclaves and sterilization systems should, however, be continuously monitored with routine testing for efficiency and performance. The results should be documented and records maintained.

Investigations of the physical plant should be reserved for specific outbreaks, depending on the organism and its potential for

causing infection. This was demonstrated by the incident of a cluster outbreak of sternal wound *Legionella* infections in post-cardiovascular surgery patients after they were exposed to tap water during bathing.⁸⁴ Because outbreaks of nosocomial respiratory infections caused by *L. pneumophila* continue to be a problem,⁸⁵ the CDC includes precautionary measures for this disease in its pneumonia prevention guidelines.⁸⁶ In addition, several water-treatment measures are available to help eradicate or clear the water of these bacteria.⁸⁷

Hospital-acquired aspergillosis is caused by another ubiquitous type of microorganism that is often a contaminant of ambient air during construction. The patients most at risk are usually immunosuppressed (i.e., neutropenic). It is recommended that preventive measures be organized for these patients when construction is being planned.⁸⁸ The provision of clean (i.e., HEPA-filtered) air in positive pressure-ventilated rooms, with up to 12 air exchanges an hour, is the basic requirement for these patients.⁴²

A comprehensive review of environmental infection control in health care facilities is available at the CDC Web site (www.cdc.gov/mmwr/pdf/rr/rr5210.pdf). This review contains recommendations for preventing nosocomial infections associated with construction, demolition, and renovation.

EDUCATION

A strategy for routine training of the health care team is necessary at every professional level. The process may vary from institution to institution, but some form of communication should be established for the transmittal of information about the following:

1. Endemic infection rates.
2. Endemic bacterial trends.
3. Updates on infection prevention measures (especially during and after an outbreak).
4. Updates on preventive policies pertaining to intravenous line management, hand washing, isolation precautions, and other areas of concern.

Although members of the infection control team are the responsible resource persons in the hospital system, each member of the health care team also has a responsibility to help prevent infection in hospitalized patients. Under the JCAHO guidelines,⁶ education of patients and their families should become a part of teaching plans, as well.

RESEARCH

Infection control policies are constantly being evaluated and remodeled because most traditional preventive measures are not scientifically proved but are based on clinical experience. Although infection data are useful, research in infection control requires microbiologic support to conduct realistic studies. Very few infection control programs have the personnel and resources for these activities.

PUBLIC HEALTH AND COMMUNITY HEALTH SERVICE

According to existing public health acts, certain infectious diseases must be reported by law. Differences exist between the reporting systems of one country and those of another, but on the whole, diseases such as tuberculosis and meningococcal meningitis are reported for community follow-up.

Open communication with community hospitals and other health care facilities provides for better management of patients with infections, allowing for notification and planning for additional hospitalization or convalescence as the patient moves to and from the community and hospital.

Benefits of an Infection Control Program

The establishment of an infection control program can greatly benefit a hospital. An infection control program supports patient care activities and is a means for continuous quality improvement in the care that is given, in addition to being an accreditation requirement. In Canada and the United States, the need for infection control programs is supported by all governing agents, including the Canadian Council on Hospital Accreditation, JCAHO, the American Hospital Association (AHA), the Canadian Hospital Association, the Association for Practitioners in Infection Control (APIC), the Society of Hospital Epidemiologists of America (SHEA) Joint Commission Task Force, and the Community and Hospital Infection Control Association—Canada (CHICA-Canada).

An infection control program requires a multidisciplinary committee that includes an infection control practitioner, who may be a nurse or a technician. In the original concept, Infection Control Officer was the title given to the person in charge of the program. As the practice has expanded into research and more sophisticated data analysis, physicians and nurses have had to update their epidemiologic skills, and some hospitals have acquired the services of an epidemiologist. The historical development of infection control programs in hospitals dates to the late 1970s. The SENIC project endorsed the use of nurses⁸⁹ because of their patient care expertise; the literature contains many examples of collaboration between infection control officers and nurse practitioners.

Controlling and preventing the spread of infections in health care facilities has taken many forms:

1. Prevention of cross-infection between patients.
2. Monitoring environmental systems (e.g., plumbing and ventilation).
3. Procedures for sterilization of equipment and instruments.
4. Policies and procedures for the implementation of sterile technique for surgical and other invasive procedures.
5. Procedures for nursing care activities for the postoperative patient.
6. Policies and procedures for dietary, housekeeping, and other ancillary services.
7. Policies for the control of antibiotics.
8. Policies and procedures for occupational health prevention.
9. Educational strategies for the implementation of isolation precautions.

At present, infection control practices have developed into a sophisticated network that does not allow for hospital-wide surveillance as it was once practiced. However, the use of surveillance by objective and the use of indicators to monitor select groups of patients or select situations provide information that will benefit the entire hospital. For example, monitoring bloodborne infections in an intensive care setting will provide data to support an intravenous care plan for general use. Accomplishing a high-quality infection control program requires organization and the dedicated service of all health care employees.

Organization of an Infection Control Program

INFECTION CONTROL COMMITTEE

The chair of the infection control committee should have an ongoing interest in the prevention and control of infection. Members should represent microbiology, nursing, the OR, central supply, medicine, surgery, pharmacy, and housekeeping. This multidisciplinary group becomes the advocate for the entire hospital. The members

work with the infection control service to make decisions in the following areas: (1) assessing the effectiveness and pertinence of infection control policies and protocols in their areas and (2) raising infection control-related concerns.

INFECTION CONTROL SERVICE

Collecting surveillance data on nosocomial infections and taking actions to decrease nosocomial infections are the benchmarks of the infection control service. In the traditional sense, the service provides information on all types of endemic infections (e.g., wound, urinary tract, and bloodstream) to the benefit of the health care system. The cost-effectiveness of data collection was demonstrated by the SENIC study.⁹⁰ Since then, other studies have shown that there are benefits in reducing nosocomial infection.^{17,18,50} Cruse and Foord presented data to show that clean-wound infection rates could be brought below 0.8%.⁸ Such reductions bring multiple benefits because nosocomial infections have a substantial impact on morbidity, mortality, length of stay, and cost⁹⁰; for example, the extra costs of treating bloodstream infections in an intensive care setting were recently estimated to be \$40,000 per survivor.⁹¹

INFECTION CONTROL PRACTITIONERS

The reshaping of hospitals because of cost constraints will have an effect on the work of infection control practitioners. Already, some institutions have regrouped responsibilities and changed the role of these professionals. Given the accreditation mandate, the need to continue an active program may be reviewed. Many training pro-

grams are available to assist with professional and organizational development (see below), and the APIC certification program supports continuous professional improvement. A viable and useful program for surveillance and collection of data requires a computer database program networked to microbiology, the OR, and nursing units. Methods for collecting, editing, storing, and sharing data should be based on the CDC's NNIS system,²⁶ which promotes the use of high-quality indicators for future monitoring and comparison among health care institutions.

Training programs for infection control practitioners are available through the following organizations:

Society of Hospital Epidemiologists of America (SHEA)
19 Mantua Road, Mt. Royal, NJ 08061
Telephone: 856-423-7222; Fax: 856-423-3420
E-mail: sheamtg@talley.com
Web site: www.shea-online.org

Association for Professionals in Infection Control (APIC)
1275 K Street NW, Suite 1000
Washington, DC 20005-4006
Telephone: 202-789-1890; Fax: 202-789-1899
E-mail: APICinfo@apic.org
Web site: www.apic.org

Community and Hospital Infection Control Association—Canada (CHICA—Canada)
Web site: www.chica.org

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