INTERNATIONAL SOCIETY FOR INFECTIOUS DISEASES

GUIDE TO INFECTION CONTROL IN THE HEALTHCARE SETTING

The Operating Room

Author
Marie-Claude Roy, MD, MSc

Chapter Editor
Michael Stevens, MD, MPH, FACP, FIDSA, FSHEA

Topic Outline

Chapter last updated: February 2018

KEY ISSUES

Two to five percent of patients undergoing surgical procedures suffer from surgical site infections (SSIs). These infections cause significant patient morbidity and mortality and burden healthcare systems with immense costs. SSIs are the second most common cause of healthcare-associated infections but the most frequent in low-and middle-income countries (LMICs). In high-income countries (HICs), SSIs are the second most common type of adverse event among hospitalized patients, only surpassed by medication errors, and are the most frequent cause of readmissions. Because SSIs are primarily acquired during the surgical procedure while the wound is open, a number of infection control practices merit scrutiny in the operating room (OR). With the advent of minimally invasive surgery, the importance of infection control measures in the OR is much debated. The measures presented in this chapter address environmental and surgical issues as well as some patient-related factors which are implemented once the patient is in the OR.

KNOWN FACTS

- Many factors contribute to the risk of SSIs and their prevention is complex and requires implementing measures before, during, and after surgery. Most SSIs arise from the patient's endogenous flora, which contaminates the wound by direct contact during the procedure. Therefore, preparing patients for surgery aims at decreasing the microbiologic burden of the patient's bowels, skin, respiratory tract, genital tract, etc., depending on the procedure being performed. Examples of measures which decrease the microbiologic burden include: showering the patient with an antiseptic (such as chlorhexidine) or plain soap before surgery, giving proper antimicrobial prophylaxis

immediately before skin incision and, in some instances, applying mupirocin to the nares for *Staphylococcus aureus* nasal carriers. The extent of endogenous bacterial contamination at surgery depends on the type of procedure being performed: clean, clean-contaminated, contaminated, or dirty. The risk of SSI increases from <2% for the former to as high as 40% for the latter. The traditional wound classification is only a moderate predictor of the risk of SSI because other factors, host and surgical factors, also influence this risk.

- Exogenous contamination of wounds is also important in the pathophysiology of SSIs, particularly for clean surgical procedures. The major exogenous source is transmission by air; airborne particles contaminated with live bacteria can enter sterile surgical fields during operation, particularly when implants are being placed (e.g., total hip prostheses).
- Airborne bacteria in the OR originate primarily from the skin and hair of individuals in the room. Caps, gowns, and masks are designed to prevent such shedding. The number of persons present in the OR as well as their level of activity, the type of surgery, the quality of air provided, the rate of air exchange, the quality of staff clothing, the quality of cleaning process and the level of compliance with infection control practices, all influence airborne contamination. Although these may seem trivial issues for contaminated or dirty procedures, they are important to consider in clean and clean-contaminated surgery.

Controversial Issues

- Our understanding of the pathogenesis and prevention of SSI has evolved over recent years but much remains to be done. Many efforts have been made to reduce the airborne bacteria in the OR.
- ORs equipped with laminar airflow system provide almost sterile air, yet very few studies show a significant decrease in SSI rates for surgical procedures performed in this type of OR. Although revolutionary when

first published in 1982, the study on laminar airflow system done by Lidwell and colleagues, as well as more recent studies, all suffer from major drawbacks. Some of these experiments did not control for the antimicrobial regimen received as surgical prophylaxis, thus precluding any conclusion on the exact role of the laminar flow system. These are complex technologies that must function in strict adherence to maintenance protocols and are more expensive than the use of conventional ventilation systems.

- Other methods to decrease airborne bacteria in the OR during prosthesis implantation include the use of surgical gowning with exhaust hoods, ultraviolet light, and more recently a device used specifically at the incision site, creating a positive pressure, non turbulent clean air envelope that shields open surgical wounds from airborne bacteria (air barrier system). All these new methods still need more robust study designs to achieve clear conclusions on their benefit during joint replacement surgeries.
- The association between wearing nail polish by surgical team members and the risk of SSI has not been studied adequately. Therefore, expert societies differ in their recommendations.
- Some investigators have demonstrated a direct correlation between the duration of open exposure of instrument trays and the risk of bacterial contamination. Therefore, the timing of opening trays should occur as close to the start of the procedure as possible, with a theoretical advantage of covering trays with a sterile drape when not in use but further study regarding timing and techniques of covering trays are needed.
- Some surgeons adopt a clean closure protocol which includes changing instruments, gloves and gowns before skin closure although no study has demonstrated a benefit of this measure on SSI rates.
- No well-controlled studies evaluate whether restricting the use of surgical scrubs to the OR suite or allowing them outside the OR will make a difference on SSI rates. Some hospitals require covering gowns

when surgeons/nurses leave the OR still wearing surgical scrubs. It would make sense to change grossly soiled scrubs, scrubs worn while changing dressings on wards between surgical procedures, and probably changing scrubs after wearing them for 8 hours or more. No recommendation can be made on how and where to launder scrub suits.

- Other methods for prevention of SSI that also require additional investigation include:
    - Operating lights handled with a foot pedal or reached above eye level.
    - The utility of delayed primary closure of the contaminated surgical site.
    - Negative-pressure devices for surgical site management.
    - Topical antimicrobial or antiseptics at the time of incision closure.
    - Use of antibacterial sutures.
    - Applications of pressure irrigation at the time of incision closure.
    - Soaking prosthetic devices in antiseptic solution before implantation.

SUGGESTED PRACTICE

Environmental Issues

- The surgical suite is usually divided into two designated areas: semi-restricted and restricted, defined by the physical activities performed in each area. The **semi-restricted area** includes the peripheral support areas of the surgical suite, including storage areas for clean and sterile supplies, sterile processing rooms, scrub stations, and corridors leading to restricted areas. The semi-restricted area is limited to authorized personnel and to the patient. Surgical attire as well as headgear are recommended in this area. The **restricted area** is primarily intended to

support a high level of asepsis control. In the restricted area, which includes the ORs and clean core, surgical attire, head covering, and masks are required where open sterile supplies or scrubbed persons are present.

- Modern operating rooms which meet current air standards in the United States should be virtually free of particles larger than 0.5μm when no people are in the room. To achieve this, ORs should be equipped with positive-pressure systems to ensure that air travels from ORs to adjacent areas, thus minimizing inflow of air to the room. This positive pressure system is challenged every time a door is opened.
- Ventilation of ORs should filter air at a minimum of 20 air changes/hour of which at least four changes should be with fresh air. If resources allow, this air should be high-efficiency filtered (HEPA). The temperature of ORs should be kept between 68 F (20 C) and 75 F (24 C), with humidity of 20% to 60%.
- The inanimate theatre environment should make a negligible contribution to the incidence of SSIs. Cleaning and disinfection of the operating theatre should follow a precise schedule: for example, floors should be cleaned once a day, and at the end of each session. Horizontal surfaces and all surgical items (e.g., tables, buckets) should be cleaned between procedures. Specific blood or body fluid spillages should be dealt with immediately. Walls and ceilings are rarely heavily contaminated; therefore, cleaning them twice a year is reasonable.
- Culturing the OR environment is unnecessary because inanimate objects and surfaces are seldom the cause of SSIs.

Preparation of the Surgical Team and of the Surgical Field

- All members of the surgical team who will work on the operating field should scrub arms and hands with antiseptic solution, for at least 2 minutes before the first procedure of the day, and a shorter period may

be appropriate for subsequent procedures. The first scrub of the day should include a thorough cleaning underneath fingernails. A Cochrane review published in 2016 concluded that there was no firm evidence to suggest that one type of hand cleanser is superior to another in reducing SSIs. The investigators did find a weak superiority of chlorhexidine gluconate over povidone-iodine in reducing colony-forming units (CFUs). Also, low quality evidence showed that a three-minute scrub reduced more CFUs than a two-minute scrub. The use of an alcoholic chlorhexidine solution has a greater residual antimicrobial activity, which could give a theoretic advantage during a long surgical procedure. Hand rubbing with an alcoholic solution (without water) may be as effective as traditional hand scrubbing and also better tolerated by the surgical team.

- All jewelry should be removed, and artificial nails must not be worn as these are associated with enhanced hand colonization with bacteria and fungi.
- After performing the surgical scrub, members of the surgical team should keep hands up and away from the body so that the water runs from the tips of the fingers toward the elbows.
- Sterile gloves should be of good quality. Wearing two pairs of gloves is advisable in orthopedic surgery where as many as 50% of gloves are punctured, particularly during cemented total joint arthroplasties, but studies of low quality cannot make this measure a clear recommendation. Wearing double gloves may also help protect the surgical team from viral transmission. Gloves should be changed immediately after any accidental puncture. Some experts also recommend routine changing of the outer gloves after draping, as this procedure is likely to contaminate gloves.
- The operative site should be scrubbed with a detergent and an antiseptic soap should be applied. Alcohol solutions are preferred to aqueous solutions for skin preparation but it is important to allow the alcohol to dry after application and before the use of electrocautery. The best reduction in bacteria at the surgical site has been achieved with

chlorhexidine-alcohol when compared with povidone-iodine in a surgical population undergoing clean-contaminated surgery. In this report, a greater than 40% decrease in total SSI rates was achieved in the chlorhexidine-alcohol group. No study has clearly demonstrated that the ritual of skin preparation from the proposed operative site outward is superior.

- Sterile drapes must be placed on the patient and on any equipment included in the sterile field. Once a sterile drape is in position, it must not be moved. Plastic adhesive drapes (with or without antimicrobial properties) have gained popularity in recent years, with the intent to prevent contamination of the surgical incision by the skin and subcutaneous tissues. In a review by Webster and al, no evidence exists in support of their efficacy in reducing SSIs. Either sterile, disposable, non-woven or sterile, reusable, woven drapes can be used during surgical procedures.
- Meticulous operative techniques reduce the risk of SSIs: surgeons should obliterate dead spaces, where possible, they should handle tissues gently, limit use of electrocautery and remove all devitalized tissue before closure. Good surgical technique may be reflected in shorter durations of procedures which are clearly associated with a lower risk of SSI.
- Scheduling dirty cases at the end of the day is a practice which should be abandoned.
- Antibiotic-coated sutures may be used for the purpose of decreasing SSI rates but is only a weak recommendation according to United States Centers for Disease Control and Prevention (CDC) experts.

Surgical attire

- Members of the surgical team entering the OR when an operation is about to begin or already underway should wear a mask and headgear

which fully covers hair, sideburns, and neckline. Experimental studies using tracer particles have shown that bacteria can be shed from hair, exposed skin, and mucous membranes of both OR personnel and the patient's skin. This is why we use barriers (masks, gowns, hood, and drapes) in the OR. But besides sterile gloves and impervious surgical gowns, no clinical studies have proved that the use of these barriers has led to a decrease in SSI rates. They are nonetheless recommended not only for the purpose of reducing the shedding of microorganisms in the OR but also as part of standard precautions. Barriers are most important when the procedure implies the insertion of an implant/prosthesis.

- The type of surgical headgear (bouffant, calotte style, in tissue) has been called into question. The 2016 edition of the US Association of perioperative registered nurses procedure manual suggested that all OR personnel wear disposable bouffant type hats. However, no definitive scientific evidence links bacteria in the hair to SSIs. A recent study suggests that cloth skull caps worn during mock surgical procedures were superior to disposable bouffant hats in preventing airborne contamination in the OR.
- Shoe covers can be replaced by ordinary shoes dedicated exclusively to the operating theater or clean shoes, because no significant difference was found in floor contamination whether personnel wear shoe covers or ordinary shoes. These latter shoes must be easy to wash. The practice of wearing plastic/paper shoe covers for the purpose of decreasing SSIs should be abandoned.
- The Association of periOperative Registered Nurses (AORN) recommendation of scrub suits covering most bare skin to decrease shedding of microorganisms from uncovered skin is much debated and finds opposing practices in Europe (the "bare-below the elbows" policy).
- Strike-through in operating gowns is also a potential source for contamination, particularly at the sleeve or abdominal area. For procedures at high risk of blood contamination, a waterproof apron or more resistant gowns should be worn.

- Any member of the surgical team who suffers from a skin lesion such as a boil should refrain from working in the OR as such an individual may be dispersing tremendous amounts of bacteria, namely *S. aureus*, in the air of the OR. Dermatitis of the hands sometimes caused by glove allergy should also be taken seriously for the same reason.

Patient Issues in the Operating Room

- Antibiotic prophylaxis is a very important preoperative practice and excellent guidelines have been published (https://www.idsociety.org/uploadedFiles/IDSA/Guidelines-Patient_Care/PDF_Library/2013 Surgical Prophylaxis ASHP, IDSA, SHEA, SIS(1).pdf). The choice of antibiotic according to the procedure, the dose according to the patient's weight, the timing of administration before incision, and the timing of intra-operative re-dosing, where appropriate, are all important issues to consider. Proper antimicrobial prophylaxis involves administering the first dose within 60 minutes before incision to obtain adequate tissue levels of antibiotic. Thus, the antibiotic should be administered in the OR by a designated person who should also make sure that it is repeated if the intervention is prolonged (for example, cefazolin should be repeated every 4 hours if the procedure lasts longer than 4 hours). Using a checklist for preoperative briefing ensures that the antibiotic is correctly administered in the OR.
- Any perioperative event that causes vasoconstriction, for example hypothermia or subtle hypovolemia, alters the oxygenation of normal soft tissues, which in turn may result in higher infection rates. The effect of hypothermia on the development of SSI has been studied particularly well in patients undergoing colorectal surgery, but also in breast, varicose vein, and hernia surgeries, and is now recommended for all types of surgical procedures.

- Avoiding hypothermia reduces SSI rates and this practice was included in the Surgical Care Improvement Project (SCIP) in the US (warming patients to 96.8 F (36 C) in the OR and within 15 minutes of their arrival in the post-anesthesia care unit). Recent US Centers for Disease Control and Prevention (CDC) and WHO guidelines recommend maintaining normothermia for all types of procedures but the best approach to do this is not yet determined. Likewise, increased fraction of inspired oxygen should be administered during surgery and after extubation in the immediate post-operative period for patients with normal pulmonary function undergoing general anesthesia with endotracheal intubation.
- Hyperglycemia is a risk factor for SSI independent from diabetes. It has been associated with an increase in SSIs after colorectal, spinal, pancreatic, vascular, and cardiac surgery, and mastectomy. Stringent glucose control should be followed intra-operatively as well as post-operatively. Experts recommend less than 200 mg/dL for a maximum glucose target for all operations and for diabetic patients as well as non-diabetics.
- Another process measure which was included in SCIP is hair removal. As hair removal with a razor is clearly associated with increased risk of SSI, hair removal before surgery should be done with a clipper, immediately before the intervention if necessary, or no hair removal.
- The use of double ring wound protectors when a visceral cavity is entered and the wound is exposed to a contaminated epithelial surface such as the mouth, intestine, or vagina, is another approach for shielding exposed tissues from microbes during the procedure. Such devices have shown some success in randomized clinical trials.
- Data on irrigation of the compartmentalized wound to wash away any contaminates before skin closure are also encouraging. Topical antimicrobial agents should not be applied to the surgical incision but consideration of intraoperative irrigation of deep or subcutaneous tissues with aqueous iodophor solution is promising.

SUGGESTED PRACTICE IN UNDER-RESOURCED SETTINGS:

- For hospitals with limited resources, less expensive strategies to keep air in the OR as clean as possible might include:
  1. Keep personnel to minimum in the OR during a procedure.
  2. Limit idle conversations as this creates dispersion of bacteria.
  3. Keep doors closed, and
  4. Keep entries into the OR to a minimum during a procedure, as the opening/closing of doors can generate significant air currents and increase the probability of bacteria being deposited in the surgical site.
- Because chlorhexidine is more expensive, some evidence may support the use of alcohol based antiseptics with iodine for surgical skin preparation.
- Evidence of alcohol-based handrub as surgical hand preparation does exist in cost-effectiveness studies. Local production should be encouraged as access to clean water may be a challenge in poor rural areas (see Guide to Local Production: WHO-recommended Handrub Formulations. 2010; http://www.who.int/gpsc/5may/Guide_to_Local_Production.pdf)
- Simple blankets instead of electrical or active forced-air warming systems might function as efficiently to warm patients during surgical procedure.

SUMMARY

- Preparation of the surgical team and maintaining a clean operating environment are important because a number of intraoperative risk factors contribute to the development of SSIs. Very little has changed over the years concerning the surgical rituals of scrubbing, gowning, and gloving perhaps because of a lack of scientific data or for ethical reasons. Many of these rituals still hold today not only for the prevention of SSIs but also for the protection of the surgical team. In clean surgical procedures, particularly when an implant is inserted, these rituals merit attention because airborne contamination by members of the surgical team from their skin may contribute to SSIs. Wearing proper surgical attire, keeping OR doors closed, and traffic to a minimum are simple measures that decrease airborne contamination. Applying basic principles of antisepsis in the OR should be a priority for every member of the surgical team. Every OR department should develop its own infection control policy.
- Prevention of SSIs by well approved measures (e.g., glucose control, normothermia, increased oxygen) may decrease morbidity and mortality associated with SSIs and healthcare costs.

REFERENCES

1. Roy M-C. Modern Approaches to Preventing Surgical Site Infections. In: Prevention and Control of Nosocomial Infections (4th Edition), RP Wenzel (Ed). Baltimore: Lippincott Williams & Wilkins, 2003; 369–84.

2. Lafrenière R, Bohnen JM, Pasieka J, Spry CC. Infection Control in the Operating Room: Current Practices or Sacred Cows? J Am Coll Surg 2001; 193(4):407–16.

3. Facility Guidelines Institute. Guidelines for Design and Construction of Hospitals and Outpatient Facilities. Chicago, IL: American Society of Healthcare Engineering of the American Hospital Association. 2014.

4. Boyce JM, Pittet D. Guidelines for Hand Hygiene in Healthcare Settings: Recommendations of the Healthcare Infection Control Practices Advisory Committee and the HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force. MMWR Recomm Rep. 2002; 51(RR-16):1-45, quiz CE1-4; available at https://www.cdc.gov/mmwr/PDF/rr/rr5116.pdf.

5. Wong ES. Surgical Site Infections. In: Infection Control and Hospital Epidemiology, CG Mayhall CG (Ed). Baltimore: Lippincott Williams & Wilkins, 2004.

6. Gastmeier P, Breier AC, Brandt C. Influence of Laminar Airflow on Prosthetic Joint Infections: a Systematic Review. J Hosp Infect 2012; 81(2):73–8. doi: 10.1016/j.jhin.2012.04.008.

7. Bischoff P, Kubilay NZ, Allegranzi B, et al. Effect of Laminar Airflow Ventilation on Surgical Site Infections: a Systematic Review and Meta-Analysis. Lancet Infect Dis. 2017; 17(5):553–61. doi: 10.1016/S1473-3099(17)30059-2.

8. Bratzler DW, Dellinger EP, Olsen KM, et al. Clinical Practice Guidelines for Antimicrobial Prophylaxis in Surgery. Am J Health Syst Pharm 2013; 70(3):195–283. doi: 10.2146/ajhp120568.

9. Alexander JW, Solomkin JS, Edwards MJ. Updated Recommendations for Control of Surgical Site Infections. Ann Surg 2011; 253(6):1082–93. doi: 10.1097/SLA.0b013e31821175f8.

10. Webster J, Alghamdi A. Use of Plastic Adhesive Drapes during Surgery for Preventing Surgical Site Infection. Cochrane Database of Systematic Reviews 2015, Issue 4. Art. No.: CD006353. doi: 10.1002/14651858.CD006353.pub4.

11. Darouiche RO, Wall MJ, Itani KMF et al. Chlorhexidine-Alcohol versus Povidone-Iodine for Surgical-Site Antisepsis. New Engl J Med 2010; 362(1):18–26. doi: 10.1056/NEJMoa0810988.

12. Markel TA, Gormley T, Greeley d, et al. Hats Off: a Study of Different Operating Room Headgear Assessed by Environmental Quality Indicators. J Am Coll Surg 2017; 225(5):573–81. doi: 10.1016/j.jamcollsurg.2017.08.014.

13. Berrios-Torres SI, Umscheid CA, Bratzler DW, et al. Centers for Disease Control and Prevention Guideline for the Prevention of Surgical Site Infection, 2017. JAMA Surgery 2017; 152(8):784–91. doi: 10.1001/jamasurg.2017.0904; available at https://jamanetwork.com/journals/jamasurgery/fullarticle/2623725.

14. Allegranzi B, Bischoff P, de Jonge S, et al. Surgical Site Infections 1. New WHO Recommendations on Preoperative Measures for Surgical Site Infection Prevention: an Evidence-Based Global Perspective. Lancet Infect Dis 2016; 16(12):e276–87. doi: 10.1016/S1473-3099(16)30398-X; available at http://www.thelancet.com/journals/laninf/article/PIIS1473-3099(16)30398-X/fulltext.

15. Allegranzi B, Zayed B, Bischoff P, et al. Surgical Site Infections 2. New WHO Recommendations on Intraoperative and Postoperative Measures for Surgical Site Infection Prevention: an Evidence-Based

Global Perspective. Lancet Infect Dis 2016; 16(12):e288–303. doi: 10.1016/S1473-3099(16)30402-9. http://www.thelancet.com/journals/laninf/article/PIIS1473-3099(16)30402-9/fulltext.

16. Parvizi J, Gehrke T. Proceedings of the International Consensus Meeting on Periprosthetic Joint Infection 2014.

17. Darouiche RO, Green DM, Harrington MA, et al. Association of Airborne Microorganisms in the Operating Room with Implant Infections: a Randomized Controlled Trial. Infect Control Hosp Epidemiol 2017; 38(1):3–10. doi: 10.1017/ice.2016.240.

18. Woodhead K, Taylor EW, Bannister G, et al. Behaviours and Rituals in the Operating Theatre. A Report from the Hospital Infection Society Working Party on Infection Control in Operating Theatres. J Hosp Infect 2002; 51(4):241–55.

19. Gaines S, Luo JN, Gilbert J, et al. Optimum Operating Room Environment for the Prevention of Surgical Site Infections. Surg Infect (Larchmt). 2017; 18(4):503–7. doi: 10.1089/sur.2017.020.

20. Tanner J, Dumville JC, Norman G, Fortnam M. Surgical Hand Antisepsis to Reduce Surgical Site Infection. Cochrane Database of Systematic Reviews 2016, Issue 1. Art. No.: CD004288. doi: 10.1002/14651858.CD004288.pub3.

21. Maiwald M, Widmer AF. WHO's Recommendation for Surgical Skin Antisepsis Is Premature. Lancet Infect Dis. 2017; 17(10):1023–4. doi: 10.1016/S1473-3099(17)30448-6.

22. de Jonge SW, Boldingh QJJ, Solomkin JS, et al. Systematic Review and Meta-Analysis of Randomized Controlled Trials Evaluating Prophylactic Intra-Operative Wound Irrigation for the Prevention of Surgical Site Infections. Surg Infect (Larchmt). 2017; 18(4):508–19. doi: 10.1089/sur.2016.272.