Prevention of Postoperative Wound Infections

33

Abstract

Surgery creates most hospital infections, injuries, accidents, invalidity and death in the global healthcare system. The number of surgically treated patients per year is high and increasing.

Surgical site infection (SSI) is dependent on type of operation and may occur in 5–20% after surgery, triggers 7–11 extra postoperative days in hospitals and results in 2–11 times higher risk of death than comparable, noninfected patients. Up to 60% of SSI can be prevented. Prevention of postoperative wound infection is done by good general hygiene, operative sterility and effective barriers against transmission of infections, before, during and after surgery. A basic support by hospital leaders, knowledge and skill of the surgical teams, enough resources, excellent treatment of the complete patient admission and monitoring patients after discharge may lead to significant reduction of SSIs, lower death rates and a less expensive health system.

33.1 Purpose

- To reduce the incidence and severity of postoperative wound infections (surgical site infections—SSI).
- To prevent spread of wound infections to other patients, staff, visitors and the environment [1–13].

33.2   Comprise

– All surgical patients, before, during and after surgery.
– Personnel, equipment and environment associated with operating treatment, before, during and after surgery [14].

33.3   Responsibility

Hospital management has the responsibility for providing:

• Hygienic and safe conditions for the patient at surgical wards, in the operation department and during the postoperative phase.
• Enough personnel, expertise and resources for professional and proper surgical treatment.
• A modern, sterile centre with knowledge and good storage conditions for sterile, surgical equipment
• A system for deviation and risk notification, for example, unnecessary removal of patients from planned operating programmes and lack of personnel, equipment, capacity or expertise that may expose patients to risk of hospital infection.

Department management has the responsibility for:

• Written and implemented surgical, hygienic and other procedures to prevent SSI
• A system for control, action and notification to the director in case of deviation concerning problems with sterile equipment, anaesthesia, capacity, risk of infection or any other risk to life and health of patients and personnel, such as overcrowded and understaffed wards, poor hygiene, etc.

Intensive-postoperative and anaesthesia departments have corresponding responsibilities, especially in pre- and postoperative phase. Deviations are reported to the head of the department where the patient is located.

The personnel follow procedures with respect to prevention of SSI and report deviations, problems, risk of poor hygiene and infection, to the department's management.

The surgeons inform and follow up their patients in pre- and postoperative phases. Deviations concerning hygiene, risk of infection and other risks are reported to the head of the department where the patient is located.

33.4   Practical Measures

Documentation and recommendations [1–13].

Grading of recommendations (1A, 1B, 1C, II) is often used according to CDC/HICPAC's supervisors where 1A is the strongest recommendation (see background information) [1, 8, 12, 13].

33.4.1 Information to the Patient: Before and After Surgery

- Inform about contact with healthcare abroad. Inform recent illness, stomach ache with vomiting, urinary tract infections, other infections or having received antibiotics.
- Good body wash, including the hair, and change to clean clothes—from the inside to the outside –before hospitalization.
- If diabetes, ask for a good control before, during and after surgery, to heal the wound quickly and not to be infected (1B).
- Quit smoking at least 1 month before elective surgery—especially orthopaedic surgery. Smoking increases the risk of infection and reduces bone healing (1B).
- Do not shave the area to be operated on before surgery (1A).
- No unnecessary hospital stays before surgery to avoid contact with more resistant hospital bacteria. Preferably admission the day before—or the same day as the operation. To remove the patient from a planned operating programme should be an exception!
- Notify the manager if poor hygiene and cleaning in the patient room.
- Perform good hand hygiene throughout your stay. If bedridden, ask for wipes for hand disinfection. Ask visitors to carry out hand hygiene on arrival and when they leave the hospital.
- Ask health professionals to carry out hand hygiene if this fails—before and after your examination.
- Good body wash before surgery, including hair. Use a disinfecting soap—Hibiscrub—containing chlorhexidine the night before and in the morning. This reduces the amount of bacteria on the skin (1B). Used especially in elective operations—when inserting prostheses and other foreign bodies.
- Learn good breathing exercises that are used after surgery.
- You should not be placed together with patients with infections—either before or after surgery, because of risk of infection. You should not be placed on the corridor or other places not intended for patients, since you there is more at risk for infections.
- Do not touch the wound or the bandages. Bacteria must not come to the wound while it is healing. Do not let the bandage get wet because bacteria can then grow more easily through.
- All who are going to take off the bandage and treat the wound should have clean hands and sterile gloves and use sterile equipment when removing stitches, doing wound care, etc.
- If itching, pain or leakage through the bandage, contact a doctor or nurse.
- Physiotherapist will help you with breathing so you get well soon after surgery.
- Be placed a little high up with your upper body in bed after surgery, it reduces problems with respiratory infections.

33.4.2 Central Checkpoints for Each Patient To Be Operated: Department and Operation Team

- Well-prepared patient; informed about the operation and infection prevention measures and has no ongoing infections (1A).
- Good surgical handwashing is carried out (1B).
- The operation team uses approved sterile operating clothing (1B).
- Good and proper skin disinfection and aseptic sterility are carried out (1B).
- Puncture of operating gloves avoided; good routines for change of gloves exist.
- The number of airborne bacteria that might contaminate the surgical wound during the operation is below the threshold level (<100 CFU/m^3 at normal surgery, <10 CFU/m^3 at ultraclean surgery—prostheses and other foreign bodies).
- The operating room has positive air pressure with a defined HEPA (high-efficiency particulate air)—filter that removes at least 99.97% of airborne particles that have a size of 0.3 μm—for air intake (1B).
- The surgical technique is good, the equipment is controlled and the operating team is experienced.
- Procedures for antibacterial prophylaxis are followed (1A) [13].
- Postoperative phase is protected for risk of infection—with skilled personnel.

33.4.2.1 Registration: Prevalence or Incidence

- In Norway, point prevalence of SSI is monitored 3–4 times a year as a part of all nosocomial infections in hospitals [14–18]. Incidence is followed continuously for certain types of SSI. Results are openly available [14–18].
- Registering and return of results to the clinics and surgical departments may increase the awareness of SSI and of the efficacy or lack of infection control measures (1B) [1, 4, 8].
- Registering usually reduces SSI; it is a tool in itself [1, 2, 4, 19–24].
- Registering may use a local "threshold" for infection control reaction, for instance, local upper threshold of more than [25, 26]:
  - 2–3% for postoperative deep wound infection after arthro-prosthesis surgery
  - 1% for bypass ACB (aorto-coronary bypass) surgery
  - 1.5% for elective neurosurgery [26]
  - 1.25% for prostheses in larger blood vessels
  - 1% for uncomplicated gallstones
  - 3% for uncomplicated appendicitis
  - 7% for colon surgery
  - 13% for active appendicitis [25].

33.4.2.2 Preoperatively Check for the Patient

1. Careful preoperative assessment, preparation and good outpatient clarification. Written information before admission. Well-planned surgery and well-prepared patient.

2. Ask if the patient has recently been ill; had fever, stomach ache with vomiting, urinary tract infections, other infections and received antibiotics; or had been exposed to norovirus prior to admission.
3. Eradicate infections. Ensure the eradication of infections, urinary tract infections, skin infections and other local infections prior to admission. Check the dental status, especially before larger elective interventions with implants and the like. Postpone surgery, if possible, until the infection is cleared (1A) [4, 8].
4. Resistant bacteria. Check if the patient has been in contact with the healthcare abroad for the past 12 months, has been exposed to MRSA (methicillin-resistant *Staphylococcus aureus*) or has previously been MRSA infected/carrier.
   (a) *If yes* for exposure or infection, this is tested in advance (preferably before admission) by taking samples for detection of MRSA, VRE (vancomycin-resistant enterococci), ESBL (extended-spectrum beta-lactamase-producing) gram-negative bacteria, CRE (carbapenem-resistant *Enterobacteriaceae*) and other current or epidemic, resistant bacteria.
   (b) *If not checked* negative in advance and have been exposed to or infected by resistant bacteria, postpone elective operations until this is clear.
   (c) NB! In acute disease state, necessary surgery should not be postponed but performed as an air contamination surgery.
5. Short preoperative stay, less than 1–2 days.
6. Intestinal surgery. Bacterial volume in the intestine should be reduced, but the effect of mechanical drainage alone is controversial. Estimated as important in the case of impaired immune defence. The most important is the systemic antibacterial prophylaxis as a single dose (usually) at the onset of anaesthesia.
7. Hair removal. It must be considered whether hair removal is necessary (1B). If done, it should be performed as close to the operation as possible, but not in the operating room. Remove loose hairs!
8. Glucose control perioperatively for all patients; use blood control target levels less than 200 mg/dl in patients with and without diabetes (1A) [13]. Monitor at regular measurements at least during the first postoperative day (1B).

33.4.2.3   Operational Department Requirements
1. Separated from general traffic and airflow through the hospital.
2. Do not mix with day surgery.
3. Increasing cleanliness and air quality in work zones—from the entrance to the operating rooms.
4. Movement between clean areas should be possible without needing to pass through "unclean" areas.
5. Remove unclean material from the operating room without passing through clean areas.
6. Airflow should pass from clean to more unclean areas. Positive air pressure on operating rooms and defined "clean rooms" (1B). Positive air pressure on the entire operation department relative to other departments and outdoor air (1B).

7. Heating and ventilation to ensure comfortable conditions for the patient and staff [4].
8. *Structural quality.* Dense, robust and easily washable walls, firm and complete ceilings and a solid floor that can withstand disinfectants. Do not use tiles that can be difficult to clean and replace. Do not use wood that attach bacteria more easily. No swing doors that produce piston power on air currents. No sliding doors that are impossible to wash and not doors with "brush material" or other edge material that collects dust and dirt.
9. *Good sluice conditions for patients*: Patients without infections or carrier state are sluiced into a clean bedroom waiting hall, "green area," for preoperative treatment.
10. *Good sluice conditions for personnel*: There is good place for changing clothes, spacious wardrobe, with a separate storage for clean clothes, bathroom and good daily cleaning.
11. *Storage* of clean or sterile equipment in separate rooms (14–20 m^2): sterile equipment, protheses, intravenous fluids, major medical equipment, sterile cover materials, operation tops, bandages, etc. Storage rooms are not offices, due to large amounts of bacteria-bearing skin cells and particles released from the skin and deposited around from persons present. A clean room has <100 CFU/m^3 air and a low particle load.
12. *Throughput lockers for equipment to operating rooms* should be avoided due to uncertain pressure conditions and risk of contamination of stored equipment and the operating room.
13. *Surgical specialties* should have their own custom-made equipment rooms for special materials. Reduces the need for intermediate storage in cabinets inside the operating room.
14. *Corridor* is not storage for any equipment that is used in operation rooms.
15. *Separate washing units* for operating tables, etc. and for shoe cleaning and drying.
16. *Separate anaesthetic unit* with plenty of space for cleaning and disinfection of equipment. A separate room for intravenous fluids.
17. *Sterilization central.* A separate, nearby located sterilization centre for cleaning, control, packing, sterilization of instruments and clean storage rooms and clean transport routes to the operating department.
18. *One operating room (surgery)* per 5–15 surgical beds. At least 42 m^2 area (6 × 7 m) for ample space for equipment, place around the operation table for the operating team and anaesthesia and for assistants, students, etc. that are not getting too close to the clean zone. Operation robots often need more space.
19. *Operations on infectious patients* are preferably carried out at the end of the day, if possible, and are well planned.
20. *Operation room, specific in use for most infectious agents* (resistant bacteria - MRSA, VRE, ESBL, CRE, and *Clostridium difficile*; mycobacteria, intestinal-pathogenic bacteria, etc, and virus like norovirus, influenza virus), can be established by switching off the positive-pressure ventilation, closing for air intake/air out and not using operating rooms with LAF (laminar airflow) filter.

The room should be large, stripped of unnecessary equipment and close to the entrance of the operating department. It is immediately disinfected after use with chemical liquids and dry hydrogen peroxide gas, according to defined arrangements, but notice that there is no documented effect of hydrogen peroxide gas on tuberculosis or other mycobacteria.

21. *Operation room, specific for high-risk, serious infectious agents* (multiresistant tuberculosis, other highly resistant bacteria and respiratory tract viruses such as SARS, MERS, Ebola and other haemorrhagic fever viruses, highly pathogenic avian influenza virus, etc.) that may cause airborne infection during the surgery. The entire operation unit (including rooms with openings directly into this high-risk area) must be on a negative pressure—25 Pa or lower with separate ventilation—not shared with other rooms or buildings. Air in and air out must be disinfected and filtered (HEPA filter) [4]. Air out, including filters, should be treated with chemical gases and or UVC. The unit should have designated disinfection room with instrument washer and autoclave, storage room, good sluice functions and direct, sheltered outside access. All waste and fluid from the unit should be disinfected as required (autoclaving, heat disinfection, chemical disinfection).

22. *Surgical hand disinfection* room should not be storage for equipment and not a "coffee-break" room because of generation of aerosols during the washing process and risk for growth of bacteria. Choose a washstand that does not sprinkle outwards. As a wet room, it may have a lower air pressure in relation to the operating room, with air direction from the operation room to the hand disinfection room.

23. *Disinfection room for equipment and instruments* is not used as storage for equipment or used for packing of cleaned instruments. It is a process room—wet room—for disinfection and has a lower air pressure in relation to the operating room with air direction from the operation room to the disinfection room.

24. *Disinfected instruments* are packed in a separate, clean, packing room and autoclaved in a separate autoclave room with steam exhaust.

25. *Anaesthesia initiating room* is a clean room with storage in glass cabinets of equipment for preoperative treatment, but no office or warehouse at large.

26. *Break rooms, meeting rooms*; with plenty of space, easy to clean, and furniture that is cleaned and washed weekly—fabric furniture must not be used.

27. *Office space and expedition.* Enough areas for operating descriptions, journals, dictation, etc. Offices for the personnel should be outside the operating department to reduce the microbial and particle burden on the operating environment.

33.4.2.4   Air Quality: Requirements for Bacterial Number in Air, Airflows and Temperature

- *Incoming air* is directly from outside; it is HEPA-filtered and tempered before coming into the operating room. The air comes in from the ceiling or high up on the wall and goes out at the floor level—ca 15 cm above the floor area (1B) [4, 8]. There should be no heating-cooling systems in the operating room because of

accumulation of dust, skin cells, particles, bacteria and fungi. This may result in growth and spread of microbes to the air, as well as unsafe air currents.

- *Air filter on incoming air.* Two filter layers (HEPA) must be passed through before the air is entering the operating room (1B) [4]. EU filter with minimum 9 for intake of air at normal operating theatres and EU filter minimum 13 on LAF theatres. Filter quality is checked by DOP test (smoke/particle test), at least once a year.
- *Positive air pressure* in operating theatres should be 10–15 Pa, in relation to nearby rooms and corridor.
- *Daily control* of ventilation, temperature and humidity in the operating room.
- *Bacterial number in the air*; colony-forming units (CFU) per m^3 air:
  - Standard surgery room <100 CFU/m^3 air.
  - Ultraclean surgery room: <10 CFU/m^3 which applies to infection-sensitive surgery like implantation of foreign bodies, cardiovascular surgery and patients with impaired immune defence. An effective LAF system may often reduce bacteria in the air to 0–5 CFU/m^3, 30–50 cm above the incision site, throughout the operation.
    - Vertical LAF air with at least 500 air changes/h gives <2 CFU/m^3 when using conventional clothing with cotton textiles.
    - Horizontal LAF air may increase the CFU/m^3 >10 times.
    - By reducing the operation room to a "tent" and using very tight operation suits, <1 CFU/m^3 may be obtained by vertical air supply.
  - *Clean storage for sterile equipment* <100 CFU/m^3.
  - *Control and measurement of CFU in air (sterile covered measuring instrument!)*
    - 30–50 cm from incision
    - Close to the instrument table.
    - Central and peripheral in the operating room.
    - When the room is empty, when preparing, when opening wounds and when tidying up.
    - Analysis of samples: growth after 2–7 days, number of colonies, bacteria and fungi per m^3.
  - *Control of CFU in air—how often/when?*
    - 1–2 times each year
    - After newbuilding, rebuilding, filter changes (afterwards, all channels are vacuum cleaned, maximum ventilation for 24 h, then two 0 measurements of an empty room).
    - At high incidence of SSIs.
  - *Air changes.*
    - *Standard surgery*: 17–20 fresh air changes/h; minimum 15 air exchanges with HEPA-filtered air per hour, of which 3 with fresh outdoor air (1B)[4].
    - *Ultraclean:* ≫200 air changes/h (recycled): orthopaedics, cardiac surgery, implantation of foreign bodies, etc.
    - Lower number of air changes on other rooms like storage rooms and rooms for anaesthetic and surgical hand disinfection rooms and lowest at the entrance area, wardrobes, etc.

- *The airflow* in the operating room is of great importance. Everything "unclean" that comes between clean airflow in the direction of the operating area and the wound poses a risk of contamination of the wound. Any unclean thing that comes between airflow and uncovered instrument tables poses a risk of contamination of instruments. The use of tight operating suits and phantom hood that covers the neck, hair, ears and cheeks protects the wound and environment against release of skin cells and bacterial contamination.
- *Opening doors* lead to increased bacterial amount in the operating room from corridors, etc. The doors should be kept closed (1B).
- *Diathermia* releases large amounts of particles—diathermia smoke—partly with protein residues. This is a major burden on air quality. Protein residues on the diathermia needle may be difficult to remove. Check cleaning routines and reduce, if possible, use of diathermia.
- *Largest microbial load of the operating room* is registered when preparing the patient and when tidying up upon completion of surgery.
- *The number of persons present* is strongly associated with bacterial and particle numbers in air. Preferably, it should not be more than six to eight people present.

33.4.2.5   Contact Infection: Measures to Reduce Contact Transmission

Everyone who enters the operating department/operation room follows routines:

- Good hand hygiene at the entrance and exit of the surgical department.
- Follow routines for the use of uniform, shoes, cap and surgical mask.
- Change to green operation scrub suit and use the department's shoes.
- Put on the cap in the wardrobe, covering hair and ears.
- Private clothing—except for underwear—should not be used.
- Green-coloured uniform only in the surgical department; not used outside the department. In case of acute response elsewhere, change to new green laundry before returning the operating department. Exceptions are when following the surgical patient to postoperative treatment. Then white coat is taken over and shoes are changed.
- Jewellery, rings, piercing, wrist watches, etc. are not allowed, nor covered with bandages or clothes.
- Nail polish, fake nails, fake eyelashes, etc. are not allowed. Do not bring private equipment into the department and disinfect glasses and watch-phone.
- Beard is unsuitable in the operation department since it is not good enough covered by surgical mask.

33.4.2.6   Equipment: Preparing and Storage

- The operating room should be clean and empty—no storage space for sterile or other equipment. Storages with, for example, sutures in operation rooms may be loaded with large amounts of skin particles, microscopic blood and tissue particles, dust and bacteria and pose risk through air and contact transmission.

- Sterile equipment storage has restricted access, closed doors and daily cleaning of surfaces and weekly of cabinets and has <100 CFU/m³ air. Store rooms should be so large that personnel can move freely in the room.
- Equipment is stored in tight cabinets and boxes.
- Avoid throughput cabinets to the operating room due to the risk of imbalance in air pressure and ventilation. A locked cabinet can be used if it is airtight.
- The array of sterile instruments should be performed sterile in a clean and empty operating room—under the LAF ceiling, if it is a LAF operating room. This is because sterile instruments should be protected from dust, skin particles and microbes deposited.
- Sterile instruments with table are then covered—before the patient and the anaesthetic personnel come in and the preparation begins. More people and more activity increase particles and microbes in the air.
- All sterile equipment is best covered during the entire operation.
- Cotton textiles may emit particles that may become "locus minoris" for subsequent infection in wounds.
- Compressors should not emit particles ("locus minoris") and have a good suction effect.
- Place sterile instruments in clean airflows. Non-sterile items (arm, head, hair, etc.) may not come over sterile instruments or between sterile airflow and instruments.
- The instruments are thoroughly cleaned immediately after the operation in instrument machine washers, etc., to prevent drying of tissue, blood and protein on the instrument. This is a good general preventive against prions.
- Regular temperature and wash controls of decontaminators, instrument washing machines, autoclaves, etc.

33.4.2.7   Personnel
- Fewest possible present in the operating room during surgery (<6–8 persons) and reduced movements that may cause unfavourable air currents. The increasing number of people present has direct effect on the amount of particles and the number of bacteria (CFU/m³) in the air, especially in the case of uncovered skin.
- Personnel with infection or eczema of the hands with *Staphylococcus aureus* or group A streptococci should not be present in the operating department, as this may cause SSI (1B).
- Personnel with streptococcus or active tuberculosis should not stay in the operating department. It is recommended sick leave of employee having upper and lower respiratory tract infections, influenza, norovirus, other diarrheal infections, blood-borne virus infection (active or chronic hepatitis or HIV, etc.) and a number of other infections.

33.4.2.8   Attire: Uniform

Everyone Who Enters the Operating Room
- Always wear surgical masks and cap in operating theatres and follow procedures for hand hygiene and dressing (1B), even for short-term "visits" (IB).

- Bacterial tight operation uniform reduces airborne wound contamination.
- Trousers should be tight by the ankles so that skin particles and bacteria do not "flow out" and burden the environment in the operating room.
- *Cotton fabric/textiles* should be avoided; they may be permeable and release relatively large amounts of particles, including bacteria-bearing skin particles.
- Avoid getting wet on cotton clothes if this is still being used; moisture increases the growth of bacteria from the skin.

Surgical Team
- Check proper attire, cover of hair and ears and absence of jewellery before entering the department.
- Follow the hospital's procedures for surgical handwash and hand hygiene (1B).
- *Sterile operating gowns*; tight, pressure-tolerant, durable and wet-resistant are recommended (1B). The gown should be close around the neck, have long sleeves with long cuffs and provide enough room for free movements.
- *In humid or wet operations*, use surgical gowns with liquid-tight sleeve and front (1B).
- *Caps* covering all hair and ears. Ears may release considerable amounts of bacteria.
- *Phantom hood* protects against bacteria and particles from the neck, head, ears and cheeks running down into the operating wound. In LAF operating room with vertical ventilation, phantom hood should be used, on the outside of a cap and surgical mask. This applies to the operation team.
- *Operation helmet* designed to prevent "fallout" from the head/hair can be used instead or other organized measures that provide the same protection.
- Wear *tight surgical masks* which cover the nose and mouth and is stuck and at rest (1B). If too much movement of a loose-sitting face mask, the release of microbes and particles increases—from the face to the air. It is not avoidable that some skin particles and microbes may "run out" from the underside of the mask.
- *Beard* cannot be fully covered by surgical mask and may cause release of microbes into the air. Remove beard if you are going to work in an operating department.
- *Protecting against blood and tissues.* Surgical mask protects against large amounts of invisible blood and tissue drops that come from surgery, especially diathermy, suction, etc. Most of the blood drops and spills around the operation team are invisible. Respirator (P3 mask) protects best against diathermy smoke. Visor or goggles may protect the eye mucosa against risk of blood-borne microbes, since hepatitis virus and HIV can invade the eye mucosa.
- *Disciplined clothing* must be followed by all personnel working in the operating area. Be particularly careful with "fallout" of skin cells and particles from the head and neck when working under LAF roofs; also applies to anaesthesia.
- Sterile dressing kits are opened by an assistant immediately before taking on in the operating room.
- Check that sterile gown is large enough, is suitable for current surgery (e.g. a lot of blood-fluid spills), has good cuffs and is comfortable around the neck.

- Learn careful dressing of sterile operating equipment.
    - It is easy to contaminate sleeves and cuffs when putting on sterile gloves. Learn the safest method to put on gloves—with the help of an assistant.
    - Use sterile strong gloves with long cuff covering the entire cuff on the gown. After surgery, punctures are often detected in the gloves. Therefore, it is particularly important with good hand disinfection before surgery. If puncture is detected during the operation, turn away from the operating table, remove the gloves, disinfect hands and put on new sterile gloves.
    - Preferably use *double gloves*, possibly with colour indicator for holes, especially at the risk of puncture. Double gloves should be used in orthopaedics and other infection-sensitive surgeries, for procedures where the glove easily gets rifles and always for possible blood-borne infection (hepatitis, HIV, etc.).
    - Change gloves and disinfect hands—from an unclean operating area to a cleaner.
    - Change gloves and disinfect hands—if there is a very large amount of biologic material on the gloves or if suspected contamination.

33.4.2.9   Surgical Technique
- A well-trained surgical "team" has normally fewer SSIs than others that are new in the department, and this team is also working more efficiently and faster.
- Operating volume has a certain effect on the infection rate, but large volume does not mean lower infection rate.
- Before starting the operation, make peace in the room for a few minutes so that swirled dust/bacteria "settle," keep the doors closed and provide fewest possible major movements and fewest people present. This applies during the surgery until the wound is sewn and covered with bandages.
- Use least possible amount of foreign materials, thin suture thread, preferably synthetic (minimum reaction), and check that it is stored sterile.
- Monophilic sutures may imply less infection risk than twisted wire of the same material.
- If possible, choose synthetic, resorbable suture material, and use the least possible variants in the standard scheme.
- Avoid tissue damage with poor blood supply (less with sharp cuts than with diathermy) (1B).
- Avoid drying, strong pressure against tissue and local constringent medicaments.
- Avoid haematoma and seroma (blood fluid) that give growth conditions for bacteria.
- Instruments and equipment must be sterile—throughout the operation—and must therefore be covered (1A).
- Avoid sedimentation of bacteria and particles on an open instrument tables that can further be transferred to surgical wound.
- Avoid direct touch with gloves on foreign materials (screws, prostheses, sutures) that are to be inserted into tissues for a long period; use sterile forceps, etc.

- NB. The tip of operating suction system is easily contaminated! Change if suspected to be contaminated. For interventions on different places during an operation, use different suction systems. Also separate use of other equipment between several operating sites during the same operation.
- Use closed drainage when pus is collected (1B).
- Avoid prophylactic drainage, or use closed drainage that is treated sterile.
- Check compressed air and compressed air equipment, preferably battery-powered equipment since compressed air from the wall can contain some bacteria (coagulase-negative staphylococci and others).

33.4.2.10 Antibacterial Prophylaxis
- Correct antibacterial agent adapted to specific surgery type (1A).
- Avoid resistant-driving agents like cephalosporins (third generation), quinolones, clindamycin, etc., and avoid using "commonly" used and important agents.
- Avoid using vancomycin as a prophylaxis (1B).
- The prophylaxis should only cover the current operating time and start at the beginning of anaesthesia (1A).
- The prophylaxis should reach high enough tissue doses before incision (1A). Short half-life preparations (e.g. cefalotin) must be followed up with a new dose if prolonged operating time.
- Note: antibiotic prophylaxis when elective colorectal surgery (1A).
- Note: antibiotic prophylaxis at high-risk caesarean section (1A).
- Note: antibiotic prophylaxis to defined patient groups (foreign bodies, endocarditis, multiple, contaminated trauma, drowning, CNS leakage, frostbite, aspiration, etc.).

33.5 Background Information

Surgery creates most hospital infections, injuries, invalidity and death in the healthcare system [1–13].

The basis for preventive actions lies in major US materials from 1964 with wound classification (clean-dirty), later on Cruse and Foord's 10-year observation of 63,000 operations (1980), Olson's 5-year studies of 20,200 surgical wounds (1984) and CDC's studies of 84,700 operations (1990) [1, 27–29].

Charnley's [30] and Lidwell's [31] air contamination studies laid the foundation for infection control in modern surgery. Antibacterial prophylaxis was effective but weakened the importance of other infection control measures [32]. Long-term problems with antibiotic resistance were not considered at that time [32, 33].

The first Norwegian studies came in the 1960s from Haukeland Hospital, Aker Hospital, Rikshospitalet and Lillehammer County Hospital [34–38]. CDC's guidelines for prevention of SSI was translated by the Hygiene Group for Eastern Norway in 1985 [38–40].

33.5.1 Knowledge, Evidence and Recommendations

Skilled knowledge in infection control may be low, often not well studied or well documented. High surgical activity in hospitals often results in a high rate of complications like SSIs which leads to serious consequences for patients, healthcare and society. Still, infection control is lacking or rated too low in healthcare. The prevention of SSI is dependent on enough resources, interest, studies, surveys, organization and responsibility. One in three patients in Norwegian hospitals is operated, and 10–20% is complicated by hospital infections that often are preventable! [15–17, 41].

Knowledge is based on studies, experience, attitude and evaluation [4–12, 39, 40]. Requirements for strict evidence may allow most studies to fall through. And "evidence" may often be based on personal understanding and attitude and governed by limited economic resources (Table 33.1).

An easier method of rating may be "grading of the quality of evidence"; GRADE (grades of recommendation, assessment, development, and evaluation) *freely summed up from reference* [11]:

- Level I—high level—many studies that show essentially the same.
- Level II—moderate level—fewer studies, limited but showing about the same, not controversial.
- Level III—low level—low-quality studies, varied, differentiating results or no rigorous studies, only expert consensus [11].

"Evidence-based medicine" is often used incorrectly, for example, in case of missing studies. During the SARS epidemic in 2003, the WHO reported that

Table 33.1 Levels of evidence for Intervention Studies, According to Research, Theory, Etc. [6]

Level and source of evidence	
1++	High-quality meta-analyses, systematic reviews of randomized, controlled trials (RCTs) or RCTs with a very low risk of bias (failure)
1+	Well-conducted meta-analyses (review of others' studies), systematic reviews of RCTs or RCTs with a low risk of bias
1−	Meta-analyses, systematic reviews of RCTs or RCTs with a high risk of bias
2++	High-quality systematic review of case-control or cohort studies; high-quality case-control or cohort studies with a very low risk of confounding, bias or chance, and a high probability that the relationship is causal
2+	Well-conducted case-control or cohort studies with a low risk of confounding, bias or chance, and a moderate probability that the relationship is causal
2−	Case-control or cohort studies with a high risk of confounding, bias or chance, and a significant risk that the relationship is not causal
3	Non-analytical studies (e.g. case reports, case series)
4	Expert opinion, formal consensus
	Nation Coll Center Wom Child Health 2008. Surgical site infection [6]

Table 33.2 Recommendation categories for infection protection: divided into categories from the CDC/HICPAC system

According to research, theory, feasibility and if possible economic solution	
Category IA	A strong recommendation supported by high- to moderate-quality evidence suggesting net clinical benefits or harms
Category IB	A strong recommendation supported by low-quality evidence suggesting net clinical benefits or harms or an accepted practice (e.g. aseptic technique), supported by low- to very low-quality evidence
Category IC	A strong recommendation required by state or federal regulation
Category II	A weak recommendation supported by any quality evidence suggesting a trade-off between clinical benefits and harms
No recommendation/ unsolved issue	An issue for which there is low- to very low-quality evidence with uncertain trade-offs between the benefits and harms or no published evidence on outcomes deemed critical to weighing the risk and benefits of a given intervention

Refs. 2–4, 12, 13, 39, 40, 44

"there was no evidence of" SARS transmission in airplanes, which led to greater spread of infection among air passengers where SARS patients had been passengers [42]. During the Ebola epidemic in 2014–2015, WHO said that there was "no evidence of airborne transmission," which resulted in only contact isolation (contact and droplets, rate 1 m from the patient) and lack of infection protection equipment for healthcare professionals and assistants. Several hundreds were infected and died before personal protective equipment for airborne transmission came into place [43].

Many key infection control studies are *ethically* not feasible for evidence-based medicine. It is never documented that using sterile gloves leads to fewer SSIs than the use of non-sterile gloves or no gloves at all. It has never been studied whether disinfection of the operating area has any effect. Therefore, "recommendations" are often used: 1A, 1B, 1C, II and unclear (see Table 33.2), which is easier to acquire [2, 4, 12, 13, 39, 40, 44].

Practical learning and experience determine the outcome. Degree of implementation of preventive measures and written procedures depends on management, knowledge and responsibility.

33.5.2 Definitions, Diagnosis and Registration

Surgical site infection may occur up to 30 days after surgery and up to 1 year of implanted prosthesis and other foreign matters [2–4, 7, 8–13]. Definitions and methods of registration change constantly [2–13, 18]. Daily observation and registration is the gold standard [11].

33.5.2.1   Wound Classification

In 1964, the National Academy of Sciences-Research Council classified surgical wounds [27]:

1. Clean wound—sterile tissue.
2. Clean-contaminated wounds—through mucous membranes—controlled measures may be taken.
3. Contaminated wounds—open trauma or contamination from the intestinal tract or major break of sterility.
4. Heavily contaminated or infected surgical wound—pus, perforated intestines, etc. [27].

The Research Council's wound classification system resulted in prevalence of SSI in 3.3%, 7.4%, 16.4% and 28.6% in classes 1–4, respectively [27]. The highest rate of SSI was found among patients with heavily contaminated surgical wound, class 4 [27]. In Cruse and Foord's surveys were classes 1–4 consistent with the development of SSI in 1.5%, 7.7%, 15.2% and 40%, respectively, and in the CDC's large material, 2.1%, 3.3%, 6.4% and 7.1%, respectively [1, 29]. The definitions are further developed by CDC [7, 18].

Special Diagnosis: SSI (CDC) [3]

Superficial Wound Infection
Occurring within 30 days after operation + involving the skin, subcutaneous tissue or musculature over fasciae + one of the following:

- Pus from the wound or the drain.
- Microorganism isolated from sore fluid prior to primary suture.
- The wound is opened/drained.
- Medical doctor's diagnosis.

Deep Wound Infection
Inflammation/pus in deeper tissues (the fascia, intra-abdominal, intramuscular, osteitis, arthritis, mediastinitis, mm.)—occurring within 30 days postoperatively or up to 1 year after implant (foreign) prosthesis, metal wire (sternum, etc.) + one of the following:

- Infection is related to operative treatment.
- Involves tissue at or under fascia.
- + one of the following:
  - Pus from the wound or the drain.
  - Wound opens spontaneously with pus production and/or is opened by a surgeon when the patient has a fever (>38 °C) and/or localized pain or tenderness.
  - Abscess occurs.
  - Medical doctor's diagnosis.

More recent definitions divide postoperative deep wound infections into deep infections and deep infections in organs/cavities (organ/space) [7, 18].

33.5.2.2   Quality of Registration Is Discussed

Definitions of SSI are often perceived as varied, partly unclear and different [45, 46]. In a study from 156 hospitals in the United Kingdom, definitions for SSI were not used (15%), superficial wound infections not reported (10%), postoperative period not followed up (8%) or not according to routines, and a large number of hospitals delivered non-compliant data [47]. Similar problems are detected in Norway. The patient is often not informed—even when serious SSI [48]. Partly this may be due to lack of consensus and/or the wish for good results [48].

Since 1970, many national registration systems for hospital infections have been developed. However, they are not completely comparable. There are separate systems for the United States (NHSN), Spain (INCLIMECC), France (RAISIN), Hungary (NNSR), Germany (KISS), Finland (SIRO), the Netherlands (PREZIES), Scotland (SSHAIP) and the United Kingdom (NINSS) and for Europe (HELICS) [49, 50]. In all systems, registration generally leads to lower infection rates [49].

Registering the Operations Team's Competence

There is a lack of methods for monitoring surgical skills and competence of the operation team; some surgeons may have a too high share of SSI compared to others [1]. In one study, four factors were significantly associated with SSI: patient age, preoperative hospital stay, preoperative shaving and the surgeon [51]. Recently graduated surgeons may have a some higher rate of SSI than experienced surgeons without having more risk patients, but because of longer operating time. With more experience, operating time and SSI rate may decrease [52].

Sherlaw et al. [53] observed SSI in 11.9% of 2146 cardiac surgery patients in London. Accumulation of SSI was seen in some surgeons, so called bad run, which was corrected when detected [53]. In the United States, the prevalence of SSI may be connected to the individual surgeon as the basis for evaluation and further employment contracts.

The operation team must have good competence in infection control and should follow established routines [54].

Syndrome Monitoring and Registration

Algorithms, with data from the patient administration system, can be used with relatively high sensitivity and specificity regarding SSI, which in one study was 6.6% of all operated patients [55].

33.5.2.3   Surgical Quality: Volume and Number of Beds

Medicare patient complaints are used in the United States for the ranking of hospitals with high or low rate of infection after hip arthroplasty [56]. Among 524, 900

patients hip-operated at 3300 US hospitals in the period 2005–2007, 7.8% had SSI [56]. The best hospital ("best-performing") had an infection rate of 4.3% against 14.9% among the worst (worst-performing). Patients in the "worst hospitals" had a 2.9-fold chance of getting SSI. Most infections, 90–97%, were detected after discharge from the hospitals (stay in hospital ca 5 days), after 16.5 days for superficial SSI and 30 days for deep and organ/cavity SSI (21–59 days) [56]. One in five deep infections were detected more than 3 months after surgery. In all, 90% of the "best" hospitals and 74% of the "worst" hospitals performed less than 20 hip prostheses surgery each year on Medicare patients. The annual operating volume per hospital was often very low [56].

A prospective study of surgical volume and SSI was conducted at 18 hospitals between 2004 and 2005 [57]. Hospitals were divided into small volumes (<1500 procedures), medium volumes (1500–4000 operations) and large volumes (≥4000 operations). The smallest and largest hospitals had almost two times the risk of SSI, compared to medium-sized hospitals [57].

A health network study (NHSN) from the United States, detected SSI in 1.9% of 849,659 surgery patients at 847 hospitals in 43 states from 2006 to 2009 [58]. A total of 39 types of surgery were studied and only deep/body cavity infections were recorded. Only hospitalized and readmitted patients were examined [58]. Several types of surgery had an increased risk of SSI associated with larger hospitals than hospitals with fewer beds. In hip arthroplasty, there was a significantly greater risk of SSI in hospitals with >200 beds versus ≤200 beds ($p < 0.0001$, multivariate analysis). Similar findings were shown for knee replacement surgery, open surgery on long tubular fractures, colon surgery, rectum surgery, appendectomy, hernia surgery, small intestine surgery, exploratory abdominal laparotomy, thoracic surgery, amputation, cholecystectomy, laminectomy and craniotomy. Between 201 and 500 beds (versus <200/>500) were associated with fewer SSIs for ventricular shunt, chest surgery and coronary artery bypass graft. Fewer SSIs after surgery on the biliary tract, liver and pancreas were associated with <200 beds or >500 beds (versus 200–500), and fewer SSIs were reported after hysterectomy and renal transplantation in hospitals with more than 500 beds (versus <500) [58].

In some cases, large hospitals may be an advantage, while most surgical procedures provide significant best results with regard to SSI in smaller hospitals, ≤200 or 200–500 beds; see Table 33.3 [58].

33.5.3 Occurrence and Mortality

- In Europe, 1.5–20% of operations may result in SSI, depending on type of surgery and wound classification [20–22, 49, 50]. Patients with SSI are being up to 60% more frequent intensive patients, five times more frequently readmitted to hospital, and have 2–3 times greater risk of dying than corresponding patients without SSI.

Table 33.3 Deep or organ/cavity SSIs detected during admission/readmission at the same hospital; National Healthcare Safety Network, 2006–2008

Type of operation	Operations	Number of beds	OR	p-value	Statistics analysis	Lowest SSI at larger hospitals
		«bed size»			Ref mu	Or smaller hospitals?
Appendectomies	5889	>500 vs <500	2.6	0.0013	Multivariate	Less than 500
Craniotomy	9918	>500 vs <500	1.8	0.0013	Multivariate	Less than 500
Laminectomy	40,513	>500 vs <500	1.8	0.0003	Multivariate	Less than 500
					Multivariate	
Rectum Surgery	1215	>500 vs <500	3.5	0006	Multivariate	Less than 500
Small intestine surgery	4200	>500 vs ≤200	1.8	0.0001	Multivariate	Less than 200
Cholecystectomy	14,726	>200 vs ≤200	2.6	0.0022	Multivariate	Less than 200
Colon Surgery	62,782	>200 vs ≤200	1.2	0.0004	Multivariate	Less than 200
Caesarean Section	30,645	>200 vs ≤200	2.3	<0.0001	Multivariate	Less than 200
Open op. fracture long bones	10,646	>200 vs ≤200	1.7	0.0064	Multivariate	Less than 200
Hernia operation	7487	>200 vs ≤200	2.3	0.0035	Multivariate	Less than 200
Hip arthroplasty	131,823	>200 vs ≤200	1.4	<0.0001	Multivariate	Less than 200
		>500 vs ≤500	1.2	0.0004	Univariate	Less than 500
Knee arthroplasty	172,055	>200 vs ≤200	1.2	0.01	Multivariate	Less than 200
		>200 vs ≤200	1.12	0,039	Univariate	Less than 200
Hysterectomy	54,877	≤500 vs >500	1.4	0.0137	Multivariate	Greater than 500
Kidney transplant	1625	≤500 vs >500	3.7	<0.0001	Univariate	Greater than 500
Breast surgery	3167	≤200/>500 vs 201–500	4.5	0.0422	Multivariate	200–500 beds
Ventricular shunt	5379	≤200/>500 vs 201–500	5.9	<0.0001	Multivariate	200–500 beds

Source: Mu et al. [58]

- In the United States, it is calculated that 2–5% of surgical patients may develop SSI. This generates 7–11 extra days in hospital and leads to 2–11 times as high mortality where 77% of deaths are directly related to the infection [4, 11].
- After general surgery, the risk of death may be 7.5% with one postoperative infection, and if there are more hospital infections in the patient at the same time, the risk of death may increase to 17.1% [59]. Organ-associated postoperative infection shows very high "in-hospital" mortality [59].
- Elderly patients (70 years or more) with SSI caused by *S. aureus* have approximately three times greater risk of death than the same age group without infection [60]. If more virulent bacteria, like MRSA, the death rate may increase up to 74% [8, 61].
- A survey of 114,677 patients in the period 2009–2011 showed that among surgical patients with hospital infection, 14.4% died, against 3.7% of non-operated with the same type of hospital infection [62]. If all complications were merged, mortality was 73% among surgical patients, versus 37% of non-operated with the same proportion of complications [62].

33.5.3.1 Smaller Hospital: Fewer Infections and Lower Mortality?

In Pennsylvania State, 4.1% of patients with SSI died in 2007 [24]. Mortality rate was twice as large at hospitals with the greatest surgical activity, compared with small hospitals with only half of the surgical activity; see Table 33.4.

33.5.4 All Types of Operations

- In a national study based on hospital data (NIS) from 723,500 operations in the United States in 2009, only 1% had SSI; extra stay in hospital was 9.7 days and extra expenses approximately 20,850 USD per patient [63]. Lowest infection rates were in obstetrics/gynaecology, 0.06%, and highest for small intestine resection (6.24%) [63].
- Health network study from the United States in 2011 detected SSI in 1.9% of 849, 659 operated patients [58]. A total of 39 surgery types were investigated; only deep/organ-cavity infections were recorded, and only admitted and readmitted patients were examined [58]. Increased risk for SSI was related to higher risk

Table 33.3 Infections and death in large and small hospitals—Pennsylvania 2005 PHC4 [24]

Type of hospital (patients)	Surgical activity	HAI	Died with HAI	Died without HAI
Group 1 hospital (636998)	36%	1.40%	14.2%	2.2%
Group 2 hospital (352047)	31%	1.18%	14.4%	2.4%
Group 3 hospital (426984)	22%	0.93%	11.5%	2.4%
Group 4 hospitals (104189)	16%	0.57%	10.5%	2.6%

Source: Pennsylvania Healthcare C42005. *HAI* hospital-associated infection [24]

score (ASA score), contaminated-strongly contaminated surgeries, long operating time and at larger hospitals compared to smaller hospitals [58].

- In France it was 38% reduction of SSI after surgery in 964,128 patients, from 2.0% in 1999 to 1.26% in 2006 ($p < 0.001$) [21]. Risk factors were age ($\geq$65 years), ASA score 3–5, wound classes 3 and 4, operation duration over the 75 percentile, emergency operation, many procedures on the same patient and admitted for 48 h or more preoperatively. Gastrointestinal and gynaecological surgery had the highest infection rate, 2.81% and 1.72%, respectively [21].
- A multicentre study from four continents found that 2.9% of 261,000 surgical patients had SSI [64].
- In Australia, 183,625 operations were monitored in the period 2002–2013. In all, 2.8% had SSI [19]. Infection rate fell by an annual reduction of 11% for superficial infections, 9% for deep and 5% for organ/cavity infections [19]. But in the same period, the SSI with antibiotic-resistant bacteria increased [19].

33.5.4.1 Norway
- Investigations from the 1960s showed incidence of SSI in 13.1% of the cases at Haukeland Hospital, Bergen (1968–1969); 2.3% at Aker Hospital, Oslo (1975–1976); 8% at Rikshospitalet, Oslo (1975–1976); and 2.2% at Lillehammer County Hospital, Oppland (1976–1977) [34–38]. Variations may have been related to registration methods. In 1981, the prevalence of SSI registered nationwide was 4% [65]. Over the past 20 years, SSI has varied between 5% and 12%, and up to 15–20% of patients have been followed up after discharge [15–17, 41]. The number of patients with SSI is relatively large in Norway, since one out of three admitted to hospitals is operated [17].
- At Ullevål University Hospital, 57,300 patients were followed with prevalence studies during the period 1995–2007 [17]. In all, 13.4% of 12,430 operated patients had postoperative HAI compared to 5% among non-operated, which documented surgery as a risk area in medicine [17]. SSI was detected in 6.2%, with an annual variation from 3.9% to 7.2% and with the lowest rate in 2002. There was a significant reduction of SSI from 1995 to 2002. Establishment of healthcare enterprises in 2002, according to "new public management" with a focus on efficiency and profit, resulted in increased prevalence of SSI and other hospital infections [17]. The general workload with patients increased, while cleaning and maintenance of the hospital fell into decay. This may have led to increase in hospital infections, including SSI [17].
- Most SSIs are deep infections in Norway. In 2011, SSI was proven nationwide in 7.8% (6.8–8.8) of surgical patients at hospitals, and 80% of these were deep or cavity infections. At the same time, 12.7% (9.5–16.0) of recently operated patients in Norwegian nursing homes had SSI, and half of these had serious, deep infections (National Public Health). Mortality of SSI is not recorded in Norway.

33.5.5   Special Types of Operations

33.5.5.1   Prosthesis Operations

- Prosthetic surgery in the hip and knee is increasing and is a source of severe SSIs [49]. Registration in Europe and the United States shows a similar rate of infection, 1–3%; total hip joint arthroplasty, 1.3–2.91%; and total knee joint arthroplasty, 0.67–3.7% [49].
- In 2004, 49,500 hip operations were examined in 14 European countries; 2.2% had SSI, total prosthesis 1.6% and partial 4% [50].
- Simultaneous arthroplasty for the knee joint and hips showed no difference with regard to SSI between unilateral and bilateral operations. An exception was for antibiotic prophylaxis that could be prolonged by bilateral surgery [66].
- In the United States, SSIs after hip surgery are monitored by insurance companies such as Medicare at 3300 hospitals [56]. During the period 2005–2007, 7.8% of 524,892 operated patients had SSI [56]. By a ranking of hospitals, the best had a prevalence of approximately 1.5% SSIs and the worst 2.5–3%. The worst of all hospitals, with SSIs of 5–8.8%, were represented by only 0.2% of all hospitals [56].
- In France, there was 36% reduction of SSI after hip prosthesis, from 1.1% in 1999 to 0.7% in 2006 ($p = 0.002$ for linear trend) [21].
- In Sweden, deep infections following total hip prosthesis were followed up for 2 years. In all, 0.9% had deep SSIs, and 405 of 443 were reoperated one or more times. The most common microbes isolated were *S. aureus* and white staphylococci [67].
- Norway established a hip register in 1987 with extension to register for other prosthesis surgeries in 1994 [68, 69]. Ca. 2% of 854 total prostheses of the knee were reoperated because of infection in 1994 [68]. During the period 1987–2011, there were ca. 11,000 surgeries with hip prosthesis every year, having an SSI rate of 3%; and 1% were reoperated [70]. The SSI rate was for total prosthesis 2.6% and for hemiprosthesis 7.7%. Risk factors were hemiprosthesis, man, high age, other concomitant diseases, too short or long operating time, immediate help operations, uncemented prosthesis and NNIS risk index of >0. The reasons why—despite many preventive measures—there is now more than a threefold risk of reoperation due to prosthetic infection, compared to earlier, are discussed [70].
- Uckay et al. [10] refer to the risk of SSI according to different SSIs—registers for primary hip—and knee operations, such as 0.8% (Norwegian register, 73,000 arthroplastics), 0.9% (Finnish register, 4628 arthroplastics) and 0.9% (Geneva register, 6101 arthroplastics), and recommend active follow-up of the patient after discharge (1A), multimodal intervention (1A) and adequate antibiotic prophylaxis (1A).
- Deep/organ-cavity infections were detected in 0.7% of 131,879 hip-operated patients in a US healthcare study in 2011. Only inpatient and recruited patients were investigated [58]. Multivariate analysis showed increased risk of SSI in older patients, higher ASA scores, longer operating time, type of surgery (total, partial, reoperated) and larger hospitals, >200 beds versus ≤200 beds [58].

33.5.5.2 Hernia Operations

- In France it was 70% reduction of SSI, from 1.0% in 1999 to 0.3% in 2006 ($p < 0.0001$) [21].
- Among 120,000 hernia operations, the following anatomical site was associated with risk of SSI, 0.45% for inguinal/femoral, 1.16% for umbilical and 4.11% for ventral hernia surgery [71]. SSI was higher at open surgery than endoscopic surgery by bowel obstruction/necrosis [71].

33.5.5.3 Caesarean Sections

- Among 1605 patients with lower-segment caesarean sections in the United States, 5% had SSI [72].
- In France there were 56% reduction of SSI after caesarean section, from 3.6% in 1999 to 1.6% in 2006 ($p < 0.0001$) [21].
- Deep/organ-cavity infections were detected at 1.9% of 30,645 caesarean surgery patients in the United States, 2011 [58]. Multivariate analysis showed increased risk of SSI in obesity, older pregnant women, higher-risk scores, contaminated/highly contaminated surgery and major hospitals, >200 beds versus ≤200 beds [58].
- In England (2008), after 5563 caesarean sections, 13.6% reported wound problems, hence 84% after discharge, while 8.9% (2.9–17.9%) had defined SSIs [73]. In all, five risk factors for SSI were detected: obesity, age, blood loss, wound closure method and haste operation [73].
- In four hospitals in the United Kingdom, 9.8% out of 4107 caesarean patients developed SSI; median time of detection was 10 days [74]. Sixty-six percent of the cases were detected by healthcare professionals and 34% of the patient herself [74]. Follow-up time was 30 days but might vary.
- In Norway, SSI rate was 5.2% in 6855 caesarean sections during the period 2009–2011 with a large variation between the different hospitals [75]. The smaller hospitals had no more SSI than the large university hospitals. Ullevål University Hospital with the largest number of patients had a very low postoperative wound infection rate, 2.9% [75]. In 2014 the national incidence was 4.9%, thereof deep 1.2%, with significant variation between hospitals.

33.5.5.4 Hysterectomy

- In Finland, a study among 516 patients with abdominal hysterectomy (benign conditions) showed a SSI rate of 4.7% [76].

33.5.5.5 Kidney Transplants

- Among 441 kidney transplant patients in the period 2010–2011, 15% had SSI, of which over half were deep or cavity infections [77]. The most vulnerable were obese patients (BMI > 30) or former drug addicts.

33.5.5.6 Coronary Artery Bypass Graft (CABG) and Other Cardiac Surgeries

- SSI after cardiac surgery varies, 6.2% or more. Among 1000 CABG patients, 5.6% had SSI [78]. Over 60% were detected after discharge. Diabetic patients

had a longer incubation time for SSI—more than 17 days postoperatively, than others. In order to make SSI a more reliable indicator, it is recommended that the patient should be followed up for more than 6 weeks [78].

- CDC reported 7.8% SSIs in 2576 patients, largely bypass operated, in 2000 [79]. Patients with SSIs had significantly longer operation time and time on cardiopulmonary bypass, than patients without infection [79].
- A total of 4.5% SSIs among 2620 bypass-operated patients in 2012 resulted in reoperation in 7.7% of the cases [80]. There was SSI in the sternal wound in 3.6% and in the donor wound in 1.2% of the cases. SSI prolonged hospital stay from 14.5 to 42.2 days, $p < 0.001$, and quadrupled time in intensive units, from 4 days to 15 days, $p < 0.001$.
- A high infection rate, 11.9%, detected among 2146 heart-operated patients in London, was associated with age over 70 years, number of surgical procedures, CABG and flap operated combined, kidney disease and 3 or more days between admission and surgery [53].
- The number of major heart surgery (MHS) operations among 13 countries in Europe was in 2006 estimated to be 25,570; 26.8% had postoperative infections, and 2.2% had SSIs [81].
- Sternal infections were studied among 18,460 patients in the period 2005–2012 in Turkey [82]. In all, 2.6% got SSI caused by white staphylococcus (36%) or *S. aureus* (31%) [82].
- Surgical site infections caused by environmental flora and by contamination of sterile procedures (ice water cardioplegic) are well known, especially of multiresistant *Enterobacter cloacae* [83–86].
- From 1987 to 1988, nine patients had postoperative infections with multidrug-resistant *E. cloacae* after cardiovascular surgery [83, 84]. All survived the infection that was transmitted via contaminated sterile fluids (cardioplegic fluids—for cooling the heart) [83, 84].
- *Postoperative mediastinitis* caused by MRSA is more serious than MSSA (methicillin-sensitive *S. aureus*), in that patients with MRSA have significantly shorter survival time than patients with MSSA [87]. After 1 month, 1 year and 3 years, the survival rate was 60%, 52.5% and 26.3% for MRSA patients, respectively, compared to 84.6%, 79% and 79% for MSSA patients, respectively. There was a significantly greater treatment failure in MRSA patients than MSSA patients with medianistitis [87].
- Sternal wound infections occur three times more frequently in men than women, and smoking, use of internal mammary artery for grafting and age over 70 years are associated with sternal wound infection [88].
- Among 12,315 patients with median sternotomy in the period 1987–1998, 3.3% became reoperated due to postoperative bleeding [89]. Of these, 14% died postoperatively by noninfectious complications. Early reoperation reduced wound infections, sepsis and respiratory treatment. Late reoperation resulted in more than 20 days of extra hospital stay [89].

- Bitkover et al. [90] examined sternal wound infections caused by coagulase-negative staphylococci (kns) and found that in an ultraclean environment, the bacteria come into the wound during surgery from the patient's skin and from the operation team.
- Tegnell et al. [91] compared sternal wound infection caused by kns with uninfected matched controls and found that the risk of infection was associated with the number of preoperative days in the hospital, total surgery length and early reoperation for other reasons. A long exposure to the hospital environment is a risk factor and the treatment may be difficult because of more resistant bacteria [91].
- De Feo et al. [92] studied the prognosis of deep postoperative sternal infection among 13,420 operated and found that 0.8% had deep infection; hence 16.9% died in hospitals. Early and aggressive treatment reduced morbidity and mortality [92].
- Among 133,488 patients with CABG, SSI was detected in 2.2% of the sternal wounds and in 1.2% of deep/organ-cavity wounds [58]. Only hospitalized and rehospitalized patients were recorded [58]. Small hospitals ≤200 or large hospitals >500 beds were significantly associated with the occurrence of deep, serious SSIs, $p = 0.0001$, than mid-sized hospitals [58].
- At Ullevål University Hospital, Norway, in all 1237 CABG-ACB patients were monitored in the period 2005–2009 [93]. SSI was detected in the sternal wound, drainage site and/or donor site in 17.8% of the patients. In all, 14.3% of SSIs were detected within 30 days and 3.5% between 30 and 60 days. Infection in sternal wound occurred in 5.7% (superficial 4.7% and deep 1.1%), leg wound (donor site) in 7.3% and drainage site in 1.3%. *S. aureus* was the most frequently detected bacterium (23.2%) and MRSA in one patient (0.6%) [93].
- Risk factors are obesity, diabetes, age over 70 years, nasal carrier state of *S. aureus* in the patient (occasionally also in the operation team), preoperative long retention (48 h or more), high-risk score (ASA score, etc.) and long operating time (over 75 percentile).

33.5.5.7 Colorectal Surgery: Elective
- In a study of 99 patients at Lillehammer County Hospital, SSI was detected in 8%, seven in the abdominal wound and one in the perineum after rectum amputation [94].
- SSI was detected in 20.7% of 13,661 patients with elective colorectal surgery in Spain in 2007–2011, one in five after discharge, and these were most often operated by laparoscopy [95].
- Antibiotic-resistant gram-negative rod bacteria increase strongly and pose a particular risk at intestinal surgery, also concerning the selection of antibiotic prophylaxis [96].

33.5.5.8 Cholecystectomy

- In France there were 55% reduction of SSI after cholecystectomy, from 0.9% in 1999 to 0.4% in 2006 ($p = 0.01$ for linear trend) [21].
- In the United States, among national materials of 14,726 patients, 0.4% had deep/organ-cavity infection after surgery [58]. Age over 52 years, ASA score >2 and the duration of the operation were significantly related to SSI ($p = 0.013$, $p = 0.38$ and $p < 0.0001$). Hospitals with beds over 200 were significantly associated with increased incidence of deep, serious hospital infection, $p = 0.002$ [58].

33.5.5.9 Neurosurgery: External Ventricular Drainage

- Risk of ventriculitis after neurosurgery is significantly associated with the drain placed under unsterile conditions and with the number of samples taken from the drain [97]. In a retrospective study of 410 patients during 2005–2010, 10.2% of the patients had postoperative ventriculitis [97]. It is assumed that 5–20% of these patients may develop postoperative ventriculitis, mostly by *S. aureus* and *S. epidermidis.*
- In the United States, 5% of 5373 patients operated with a ventricular shunt developed a deep/organ-cavity infection [58]. Small hospitals with fewer beds ≤200 or large hospitals with >500 beds were significantly associated with an increased incidence of deep, serious hospital infection, $p = 0.0001$, than medium-sized hospital with 201–500 patient beds [58].

33.5.5.10 Robot-Assisted Surgery

- Increased incidence of SSI has been demonstrated for certain types of robot-assisted surgery compared with national data for open surgery in the United States [98]. This can be related to "learning curve" by use of the robot [98]. After 273 robot-assisted procedures, 5.9% developed SSIs [98]. Operating time was mean 333.6 min (>5.5 h), and those with the longest operating time had significantly more infections than those with shorter time ($p < 0.001$) [98]. Robot-assisted and open surgery showed a difference in incidence of SSI, especially in prostate, gynaecological, colon and hernia surgery [98].

33.5.6 Norway

In 2014, the incidence of registered SSI was 4.5%, for bypass operations, 4.1%; for caesarean section, 4.9%; for hip prosthesis total, 1.8%; for hip prosthesis hemi, 3.1%; for open cholecystectomy, 14.2%; for laparoscopic cholecystectomy, 4.1%; and for colon surgery, 11.8% (Table 33.5) [99].

Table 33.4 Postoperative wound infection—surgical site infections: international and Norwegian results

Reference	Operation type	Year publ.	Total operated	Total %	Hip prothesis total	Hip prothesis partiell	CAGB sterum and donor	Cesarean section	Colon surgery	Cholesystectomi	Comments
Rosenthal et al.; INICC	More types	2013	261,000	2,9			4,5	0,7	9,4		4 Continents
CDC-NHSN data, Edwards	More types	2009					2,9	1,8	5,6		USA
Lissovy	More types	2009	723,490	1				0	4,1	1,1	USA 2005
Mu, USA[a]	Many types	2011	849,659	1,9	1,4		2,2	1,9	5,8	0,6	USA National[a]
Wilson 2007	More types	2007	111,360		1,6	4	3,7	2,7	8,9	1,3	Europe 2004; HELICS
Worth 2015	More types	2015	183,625	2,8			4,9	2	8,7		Australia
Sherlaw-Johnson	CAGB	2007	2146				11,9				England
King	CAGB	2014	303				6,6				London
Wilson	Cesarean	2013	4107					9,8			UK
Calderwood	Hip prothesis	2013	524,892		7,8						Medicare, USA
Lindgren	Hip prothesis	2014	45,531		0,9						Sweden
Norway											
Ullevål (Andersen)	All	2009	12,430	6,2							Prevalence Ullevål

(continued)

Table 33.4 (continued)

Reference	Operation type	Year publ.	Total operated	Total %	Hip prothesis total	Hip prothesis partiell	CAGB sterum and donor	Cesarean section	Colon surgery	Cholesystectomi	Comments
National prevalence (FHI)	All	2014	?	7							National Public Health
Flatmark	Colon surgery	2000	100						8		Lillehammer FSH
Dale H (1987–2011)	Hip prothesis	2011	11,000		2,6	7,7					Norwegian register
Norway FHI—6 op. types	6 types	2011	6469		3,1	5,1	6,7	6,9	15,9	7,1	Incidence 2011
Norway FHI—6 op. types	6 types	2013	29,016		2,2	3,9	3,6	4,2	13,5	4,5	Incidence 2013

CABG, coronary artery bypass graft; ACB, artery coronary bypass. Ref. 100
[a] Primary wound, only detected in hospital + readmitted same hospital

33.5.7 Monitoring and Readmissions for SSIs

Over 60% of postoperative surgical site infections may be detected after discharge from hospital, mostly due to the short length of stay [11]. The SSI was detected after discharge in one of four patients in a study of 1103 patients, of which 9.4% had SSI [100]. The same was found in 13,661 uncomplicated elective, colorectal operations, of which 20.7% had SSI; one of four patients with SSIs were detected after discharge [95]. More than half of them were readmitted. The SSI was related to younger age, women and endoscopic surgery [95].

SSIs are often deep and severe infections that most often may lead to rehospitalization and additional surgery [14–17, 47, 48]. In Norway, about 0.5% of all patients in hospitals are readmitted, mainly because of surgical site infections [14–17].

Most SSIs occur within 30 days, but for prosthesis and other foreign materials, a significant proportion may occur later on (Fig. 33.1) [101]. The time from surgery to deep/organ SSI after total knee replacement (TKR) surgery can often be up to 1 year, and the same may apply to mastectomy with prosthetic implant, while infections after total hip prosthesis (THR) and coronary artery bypass grafting (CABG) seem to occur some earlier, within 60–90 days (see Figure 33.1) [101].

A short follow-up after surgery may often fail [47, 48, 101–106].

- A study of 50,128 procedures (most with implants) over 10 years showed that most SSIs were detected within a month (75–92%) after operation, 93% after 3 months, 97% after 6 months and 100% after 12 months [103]. Surgical procedures examined were heart, orthopaedic, neuro, spinal, thorax and vascular operations, a total of 888 infections, 1.7% [103].
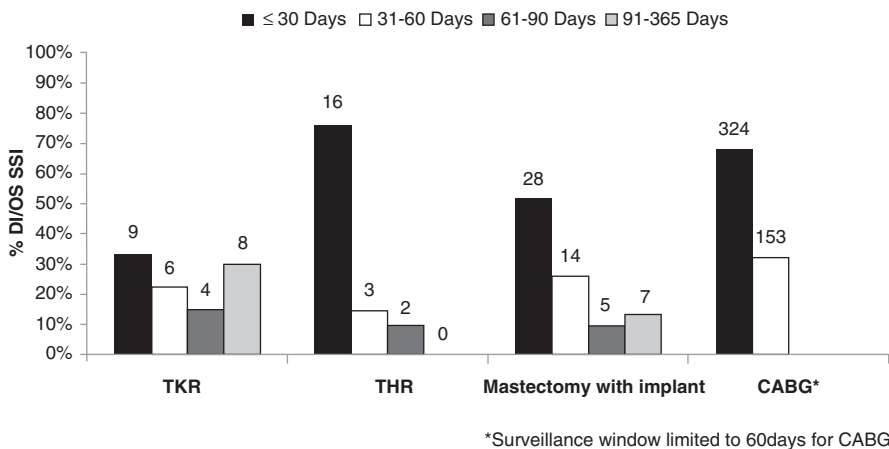

Fig. 33.1 Time from surgery to deep/organ SSI after total knee replacement surgery (TKR), mastectomy with prosthetic implant, total hip prosthesis (THR) and coronary artery bypass grafting (CABG). *Source: Julie D Lankiewicz, ICHE 2012* [101]

- In a study of Norwegian SSI after coronary bypass surgery of 1237 patients at Ullevål University Hospital in Norway, SSIs occurred in 12% of the patients, 3.5% after 30 days [93].
- Among Swedish ACB-operated patients, SSIs were found in totally 30.5% [104]. Most sternal infections came within 30 days postoperatively, while 27% of leg infections (harvesting site) came 30–60 days postoperatively [104]. Similar findings have been made by Sharma et al. [105].
- In a large study from the United States of 723,490 surgical procedures from seven specialties (neuro, cardio, colorectal, skin/chest, gastrointestinal, ortho, obstr-gyn), only 1% had defined SSI, but ca. 2.5% of the patients (ca. 18,300) were readmitted one or more times because of SSI! [63].

Registration of SSI is still a major challenge [47, 48, 78, 106].

33.5.7.1   Long-Lasting SSIs

Monitoring shows long-term sick leave, out of work, early retirement, large consumption of home care, many subsequent readmissions and prolonged hospital stay, transfer to nursing homes, etc. because of SSIs [48]. So the final cost for the patient and for society at large is probably great.

The Norwegian System of Patient Injury Compensation (NPE) (Norsk Pasientskade Erstatning) treated in the period 2001–2012 137 cases concerning equipment left behind in the patient during surgery. Out of these, 83 were approved and 54 rejected. Forgotten compresses and tampons dominated, but it was also abandoned metal equipment [107].

33.5.7.2   Short Postoperative Hospital Stay Is Associated with Increased Mortality

Studies from Sweden show that short postoperative hospital stay, <10 days after hip fracture, results in significantly increased mortality [108]. A total of 116,100 hip surgery patients were in the period 2006–2012 examined for death within 30 days [108]. Increased mortality rate may be the result of savings, shorter hospital stays, fewer beds and sicker patients, treated by a less competent and deficient health level outside hospitals. A good system for registering mortality rate according to hospital infections and other injuries should be established in all countries, including Norway.

33.5.7.3   Healthcare Personnel May Be Infected and Be a Source of Infection

The staff can become infected from patients, resulting in long-term sick leave, residual damage and disability benefits. Among 389 healthcare professionals with work-related infection in Germany, only 17 complaints were accepted, the rest rejected [109]. Outbreaks of infections among surgery patients may be related to infection or carrier state in the surgical personnel or the personnel handling the patients in the pre- or postoperative phases [110–112].

33.5.8 Expenses Related to SSIs

Hospital infections may cost extra, depending on the severity and on each country's basic costs and contribution for patients in hospital [11, 60, 83, 113–119]. SSI means often 6–14 days extra stay in hospital, reduced capacity and resources and delayed treatment of other patients.

- Additional costs for SSIs were in 2008, from 3000 to 29,000 USD per patient with SSI in the United States [11].
- After SSIs in hip replacement (Sweden) or heart surgery (France) were the direct costs for many years ago approximately 35,700 USD per patient.
- In Norway, the extra expense of three heart surgery patients with SSIs during an outbreak was about 142,860 USD [83].
- Elderly patients with SSIs caused by *S. aureus* compared to those in the same age group without infection have longer hospital stays (13 days compared to 9 days) and are almost doubling the direct expenses for the hospital (85,600 USD against 45,700 USD, $p < 0001$) [60]. They have about three times greater risk of death than the same age group without infection [60].
- SSI in 12.4% of patients after breast surgery implant costed "crude medial" 16,900 USD for the patient with SSI compared to 6100 USD without infection [113].
- SSI after orthopaedic surgery prolongs length of stay in hospital of about 2 weeks, doubles rehospitalization rate and increases healthcare costs to >300%, compared with noninfected patients [116]. In addition, SSI patients have often a marked limited physical activity and a significant reduction of health-related quality of life.
- In the Netherlands (2009), the cost of a patient with SSI tended to double the cost of a patient without SSI [119].
- After discharge, there are often large extra costs of the SSIs [116–118]. A study (2003) found that cost for the first 8 weeks during the postoperative period was about 5100 USD with SSI, compared to 1800 USD without SSI ($p < 0001$) [117].

33.5.9 Microbes and Transmission Routes

Peroperative and particularly *intraoperative* bacterial contamination of the wound is of greatest importance. Up to 98% of bacteria in orthopaedic wounds are arising from operational environment. They come from the environment, equipment and persons *exogenously* or from the patients themselves (skin, intestine, the mucosa), *endogenously*. Endogenous flora may change 1–2 days after admission to "hospital flora," often with more resistant bacteria. Therefore, patients should be operated within 1 day after admission.

33.5.9.1 Microbes and Particle Load in the Wound

During surgery, at least five to seven people are present in the operating room. They are continuously liberating skin cells and particles with and without bacteria to air and surfaces. Each person liberates 30,000–60,000 skin cells per minute as dust, 600,000 to one million or more, per hour. Dead skin cells are laying as traces in the room and ca 10% of loose skin particles are carrying bacteria. Therefore, good personal hygiene, use of clean operation textiles and cleaning between each operation are important.

The skin is protected as long as it is intact. Normal skin flora represents coagulase-negative staphylococci, dominated by *Staphylococcus epidermidis*, 10^{3-4} per cm^2. Diphtheroides, anaerobic bacteria (*Propionibacterium acnes*), gram-negative rods, *Candida* (yeast) and mites (*Demodex*) are common findings and also *Staphylococcus aureus*. New microbes are continuously deposited on the skin, usually transient and loose. Greatest amount is found on the forehead (half million per cm^2), around the ears, the head (6.1 million per cm^2), axillae and nose opening (10.1 million per cm^2), the upper back (10,000–100,000 per cm^2) and palmar side of the hands, arms, chest (1000–10,000 per cm^2), etc., with variation between gender [120]. Hair and beard may contain large amounts of microbes.

The heavy skin flora and liberation of skin particles from bare skin must be considered when working with sterile procedures, with infection-susceptible patients, surgical activity, wound care and care of drains and intravascular equipment [120].

33.5.9.2 Bacteria Types Causing SSIs

SSI is most frequently caused by *S. aureus.* Coagulase-negative staphylococci as *S. epidermidis* is the most common cause of infections in implant surgery. Others are *Escherichia coli*, *Klebsiella* sp.*, *Enterobacter cloacae*, *Pseudomonas* species, etc. and enterococci and anaerobic bacteria. *Candida* can be significant with prolonged antibacterial therapy. *S. aureus* is an increasing problem and especially resistant *S. aureus* as MRSA.

Group B streptococci, unusual gram-negative bacteria and anaerobic bacteria increase [121]. More resistant and super-resistant gram-negative rods (ESBL, carbapenem resistant, etc.) and VRE can be linked to "medical tourism," patients who undergo surgery or dental treatment abroad. These patients should be tested and isolated as for MRSA until known result.

MRSA is the worst of all bacteria and in the United States the dominant cause of fatal nosocomial infections. A total of 3.5–6.5/100,000 population in the United States dies each year from MRSA [122, 123]. SSIs caused by MRSA led—in one study from the United States—to 16 extra days in hospital, 13.5% increase in discharge to long-term institutions, about 70% more frequent readmissions and 14% higher mortality rate than in surgical patients without SSIs [124]. The additional cost was about 40,000 USD per MRSA patient [124]. In Europe, the risk of unknown MRSA in patients hospitalized in surgical wards is estimated to about 4% [125].

33.5.9.3 Transmission Routes

About 25% of *S. aureus* in surgical wounds comes from operating personnel, 25% from the patient and the rest from environment, pre-, per- or postoperatively. *S. epidermidis* is related to airborne transmission. Surgery with ultraclean air reduces airborne infection if staff is properly dressed [30–32, 126, 127]. SSI may also occur via infected urinary catheters, intravascular accesses or intubation and mechanical ventilation before surgery.

S. aureus is normally present in the nose of 10–20% of healthy individuals and 5–15% in the perineum and can periodically be on hands/wrists and other skin areas, especially if eczema and other skin infections [128].

Endogenous wound infection. Presence of *S. aureus* in the nose of the patient may be an independent risk factor for endogenous SSI. Surgery on patients with infections may always be a risk of SSI [1]. Gram-negative rods present in the airway preoperatively may dispose for postoperative infections, including wound infections [129].

Exogenous wound infection. Large numbers of bacteria present on the staff's skin, especially on the head and neck areas, around the ears and upper back, is a challenge concerning SSI, because of the bent work situation over instruments and wounds [120].

33.5.9.4 Conventional and Ultraclean Conditions: Airborne Microbes and Particles

The amount of air contamination is dependent on free particles and microbes generated by activities, air currents, personnel, equipment, environment and dust from furniture, equipment, floors, etc.

Air quality is important—especially in the area around the wound—and is the main cause of wound contamination [130–132]. In conventional ventilation, after total joint prosthesis, SSI was 3.4%, by ultraclean air 1.7%, with addition of exhaust suits 0.75% and with addition of antibacterial prophylaxis 0.2% [131]. Friberg et al. [132] conducted many studies concerning ultraclean conditions and the effect of dressing concerning wound contamination.

Ultraclean operating rooms with vertical laminar airflow (LAF) have <10 CFU/m³ air during the entire operating period, even by up to 12 people present, while conventional operating rooms may reach over the maximum limit >100 CFU/m³, even when there are few persons present [126]. Particles in air reach high values, in particular by diathermy [126]. LAF and conventional operating rooms have a low bacterial count on the floor before operational activity which remains low on effective LAF operation rooms throughout the day [126]. In contrary, the conventional operation rooms have a rise of the floor contamination to 100–120 bacteria per 20 cm² before day's last end cleaning. This may occur despite good routines of washing the floors between all operations [126]. The LAF system has effects both on the bacterial load in the air and on the amount deposited on surfaces in the room [126]. Hambreus et al. [133] described already in 1978 floor contamination as a source of airborne bacteria.

There is still a discussion concerning the effect of ultraclean laminar flow [134]. Surgeons observe that LAF conditions may lead to "false security" with reduced operating room discipline, lack of use of masks, increased traffic under the surgical phase, etc. [134]. LAF system is still recommended by the CDC by ultraclean surgery with insertion of foreign objects, provided good discipline.

Healthy individuals may release varied amounts of bacteria and skin particles into the air and the environment, as shown in a Swedish study [135]. Many infectious outbreaks may start from "heavy dispersers" and people with eczema. Upper respiratory tract infections may increase the release of *S. aureus* and other microbes from the nose to the air. Males emit more bacteria than women and shower increases the release of bacteria for 1–2 h afterwards. High temperature and humidity increase bacterial growth, and bacterial and particle count increases with the number of people and activities in the operating room. Ears, forehead and eyebrows in surgical personnel who are bent over surgical and instrument tables pose the risk of shedding particles and bacteria in the wound, and therefore good covering of hair and ears is recommended [136].

Small particles and microbial contaminants floating in the air increase with surgical time, mostly because of use of diathermy [126, 137]. If the door of the operating room is opened several times, the small dust particles from the air are reduced, while the bacteria count rises from unfiltered corridor air [137].

Patients with infected wounds constitute an additional load, in particular by pus, leakages, punctures and care of dressings. A fast removal of the dressing may release more bacteria from the wound up in the air [138].

33.5.9.5   Contaminated Ventilation System and Control

Ducts, filters and other equipment that are not controlled, cleaned and replaced can result in serious infections. In a 4-year period, 47 patients were infected by *Penicillium* species, due to the growth of *Penicillium* and *Aspergillus* in ventilation ducts and fibre glass filter in a surgical department [139]. Filters were replaced and ventilation ducts were disinfected with chlorine solution in gaseous form. This had an effect, but 7 months later the problem reiterated [139]. It is important to control the ventilation and the operating room for both bacteria and fungi. Ventilation systems and operating rooms may also sometimes be invaded by flies and other insects [140].

The Norwegian Board of Health Supervision has defined microbiological control of operating rooms (IK-2/97): "Ventilation for operating rooms should ensure: 1. The supplied air is sufficiently free of microbes, 2. The microbe particles generated in the operating room is removed, 3. That the air in the operation area to a minimum degree streams from people against the wound, 4. That there is not a negative pressure in the operating room so that the microbes may be supplied from the neighbouring rooms."

Ventilation can be regulated down during rest but must be set up again at least 30 min before the next operation [141].

33.5.9.6   Routine Errors, Accidents and Failures

Surgical staff who do not follow procedures for personal hygiene, dressing, hand hygiene or use of jewellery pose a risk for development of SSI.

- *Nocardia farcinica* caused sternal infection in five patients undergoing heart surgery [112]. Case-control studies showed that the patients had been exposed to an anaesthesiologist A having identical ribotype profile of *Nocardia* on the hands, in own home, including the house cat. The outbreak stopped after intensive cleaning, hand hygiene, use of personal infection control equipment and cleaning the anaesthesiologist A's home [112].
- Mediastinitis caused by MRSA among five cardiac surgery patients was tracked to a surgeon who had identical genotype in the nose [110]. After elimination of the carrier state, the outbreak stopped [110].
- Major outbreaks of group A streptococci have been traced to the surgical staff with chronic carrier state [111].
- Prostate abscess with bilateral orchiectomy and flushing the incisional wound proved to be active tuberculosis, *Mycobacterium tuberculosis* [142]. In all, 128 HCW were exposed to infection, including 12 (13%) who became tuberculin positive, including 1 of 12 in the surgical team [142].
- *Rhodococcus (Gordona) bronchialis* in sternal wound in seven patients after open heart surgery was associated with surgical nurse A. The bacterium was detected on the hands, head and other skin areas of nurse A, in the environment and in the air around A, in A's home and in A's dogs [143]. Attempts to remove the bacteria from nurse A were unsuccessful [143].
- Nasal carrier state—with large amounts of *S. aureus*—increases risk of SSIs. When the surgeon is a nose carrier of *S. aureus*, the risk is highest [144].
- During 1 month, seven heart surgery patients in California had SSI with *Serratia marcescens*, and one died [145]. The infection was traced to an operation-nurse A, who used artificial nails and in a cream tube in A's home. The outbreak stopped after removing the cause.
- During 1 year, 15 neurosurgical patients in the Netherlands got SSIs with *Serratia marcescens* [146]. Environmental samples were negative. Nurse A, 1 of 100 in contact with the actual patients, had identical bacteria on the hands [146]. Nurse A that had been most in contact with the infected patients had psoriasis on hands. Nurse A was on sick leave for 3 months with persistent positive samples, while the outbreak stopped in the department. One year later there was a new outbreak of three patients related to nurse A which again was infected and who had not got rid of the bacteria because of the psoriasis [146].
- In a cardiac surgical unit in England, four patients got deep surgical infections and pneumonia with MRSA during 1 year (epidemic strain MRSA-15) [147]. Employees were then tested with the discovery of a nurse who was nasal carrier and without symptoms. After clearance, the outbreak stopped. It was recommended screening of personnel for MRSA [147].

- A highly resistant—*Pseudomonas aeruginosa*—strain was transferred to four patients via contaminated gastroscope during a few months in 2013 [148]. The reason was deviations in cleaning, disinfecting and drying the scope. After removal of the gastroscope and establishment of safe practices, the outbreak stopped [148].
- *Serratia marcescens* caused increased number of patients with postoperative empyema at a thoracic-surgical intensive care unit in March 2013 in Turkey [149]. The common source of infection was a portable suction machine. After full disinfection, sterilization and control of the equipment, the outbreak stopped.
- Ear cleaning instruments may be too poor disinfected, as shown by subsequent transmission of *Pseudomonas aeruginosa* to 17 patients with severe external otitis [150].
- Contaminated tap water in surgical wound has caused outbreaks of *Legionella* SSIs [151].
- Water may often contain mycobacteria which are not detectable by conventional bacteriological tests and are resistant to chemical disinfectants and to some extent also to heat.
- *Mycobacterium fortuitum* endocarditis was detected in three heart-operated children in Serbia in 2013 [152]. Bovine pericardial patches were used for correction of ventricular septal defect. Parts of the same pieces of tissue had been used for several operations, and this was not compatible with a good routine. Estimated infection cause was contamination by thawing and freezing. All three children survived after antimicrobial therapy [152].
- Contaminated equipment brought into the operating theatre is linked to repeated outbreaks of infections.

33.5.10 Risk Factors for Development of Surgical Site Infections

There are many well-documented risk factors for SSIs; however, they may often be mixed, combined, transient, not recorded and difficult to trace [1, 4, 8, 11, 20, 21, 24, 29, 56–58, 144, 153–164].

Risk is primarily associated to wound pathogenic types of bacteria introduced during surgery or afterwards. Development is dependent on four factors: (1) the amount of bacteria in the wound at the end of operation, (2) the bacterial virulence (invasion properties), (3) the patient's immune defence and general condition and (4) the condition of the surgical site at the end of surgery (tissue necrosis, loss of vascularization, foreign bodies, poor surgical technique, etc.) [4, 8, 159].

The risk of SSI increases at 10^5 bacteria per gram of tissue but low bacterial levels; 10–20 bacteria can start infection if present close to sutures and other foreign matters [4, 8].

SSIs registered in Canada, 2002–2008, were detected in 13.5% of 622,683 patients followed up postoperatively for 30 days [160]. Over half (7.8%) of SSIs

occurred after discharge. The reason for detection of SSIs after discharge was related to shorter surgical time, shorter hospitalization, "rural residence," alcoholism, diabetes, obesity, increased risk of readmission, reoperation and urgent hospitalization [160]. DeBoer et al. found that for orthopaedic patients the increased risk of SSIs was related to increasing age from 45 years, preoperative stay in hospital in more than 4 days, more than one surgery, more hospital infections at the same time in the patient, the use of antibiotic prophylaxis, emergency surgery, contaminated wounds and surgery duration of 2 h or more [155].

33.5.10.1   Patient-Related Risk [4, 8, 153]

Documented
- General condition and underlying disease.
- High or low age (elderly, infants) [20, 160].
- Overweight - obs increased dosage of prophylactic antibiotics [20, 160].
- ASA score >2 [20, 160].
- Infections in the patient—before surgery—especially hospital infections (skin, airways, teeth, urinary tract) [1].
- Carrier state of *S. aureus* in the nose [110, 144].
- Preoperative stay in hospital >1–2 days [20].
- Preoperative shaving.
- Short postoperative hospital stay [108, 160].

Likely
- Diabetes and hyperglycaemia—recommended well regulated [160–162].
- Malnutrition and low albumin.
- Steroids (high dose).
- Age >70 years is frequently associated with deep infections by ACB operations [105].
- Smoking; recommended to stop 30 days prior to surgery.

Possible
- Alcohol consumption [160].

33.5.10.2   Procedure-Related Risk

Documented
- Urgent surgery [20, 160].
- Contaminated wounds; wound class >2. Classification of wounds, 1–4 (clean, clean-contaminated, contaminated, heavily polluted), transplantation and implantation [20].
- Preoperative shaving of hair.
- Failure in preoperative preparation.

- Surgical type.
- Surgical technique and complications—bad run [53].
- Treatment and control of sterile equipment and prosthesis.
- Microbial contamination of the wound at the end of the operation. About 70% of wounds may be contaminated during surgery.
- Antibacterial prophylaxis.
- Surgical time >2 h.
- Too short or too long surgical time, over 75 and under 25 percentile [20, 70, 160].

Likely
- Multiple procedures.
- Trauma to tissues, necrosis, bleeding.
- Foreign materials.
- Blood transfusion.
- Intensive treatment—ASA score.
- Disinfection of skin and covering surgical site.
- Ventilation system and CFU/m^3 air.
- Drainage.

Possible
- Lack of preoperative shower with disinfectant (Hibiscrub).
- Urgent surgery.
- Hypothermia.
- Low oxygen saturation of tissues.

33.5.11   Preoperative Phase

33.5.11.1   Patient Assessment and Protection Against Infection
All patients should undergo a careful preoperative assessment and preparation with clearance of infections of the skin, urinary tract, tooth, etc. Dental status should be checked before elective surgery with foreign materials like prosthesis. The risk of surgical wound infection is high in patients that have ongoing infections (18.4% with other infections and 6.7% without) [1]. In 55% of the cases in one study, the same microbes were found in the wound as in primary infection [1].

Glucose level should be controlled in all patients and patients with diabetes should be specially followed up. The shortest possible preoperative length of stay, <2 days, is well documented to avoid transmission of hospital microorganisms [1, 8]. Cancellation of operations and readmissions is not compatible with infection control.

Shielding against infection is important. In England, MRSA testing was done at home, before arthroplasty [165]. MRSA-positive cases were cleared for carrier state before surgery. MRSA-negative patients were physically separated in a unit with

restricted admission for healthcare personnel and relatives. This measure provided significant reduction of SSIs, $p < 0.001$, and increased the surgical capacity by 17% [165].

33.5.11.2 Shaving, Clipping and Shampoo

Shaving may cause SSI by making many small wounds in the skin which are gateways for microbes [1, 166–168]. Among 406 patients, 5.6% had postoperative wound infection after shaving, 0.6% after cutting and 0.6% after the hair was not removed [168]. That all mothers in Toronto, Canada, were asked not to remove hair on the stomach and below, last month before birth, resulted in a halving of the SSIs [168]. Ten heart-operated male patients had during 3 months SSIs, osteomyelitis and sepsis with *Serratia marcescens* [169]. Common to all ten patients was shaving by a barber that had the same bacteria on hands and equipment. Similar outbreaks are described in a neurosurgical department [170]. Fourteen neurosurgical patients developed SSIs with *Serratia marcescens* within a 6-month period at a hospital in China [171]. This infection was traced back to two barbers and their shaving equipment; they had performed wet shaving of the patients preoperatively [171].

It has been detected a rich flora of resistant gram-negative bacilli in different types of shampoo and cream tubes and boxes [145, 172]. Outbreak with *Serratia marcescens* among 14 newborns in Saudi Arabia was traced back to a contaminated baby shampoo [173]. Sepsis and other serious infections were recorded and one child died.

33.5.11.3 Body Wash with Chlorhexidine, Etc.

Cruse and Foord found that by clean surgery, 2.3% had SSIs without shower before the operation, 2.1% after shower with soap and only 1.3% after shower with hexachlorophene soap [1]. In one study, Hibiscrub body wash led to a reduction of bacteria from 900 to 50 colonies per plate [174]. Whole body wash, including hair, is recommended the night before surgery, possibly also in the morning (sweat, using the toilet, etc.). The final wash must be completed at least 2 h prior to surgery due to the release of skin particles. Still, there is insufficient evidence for this action (Cochrane) [175].

The use of disinfectant wipes from dispensers and open packages may cause infection since many of the most resistant bacteria can survive and multiply in the presence of various disinfectants [176].

33.5.11.4 Internal Check of Personnel

Procedures for internal check of surgical staff should be present in the department, like the following: not active infections; access control works; staff change clothes; uses hand hygiene and does not use jewellery; uses green operation clothes; shoes that are machine washable; hair and ears covered with hoods; surgical face mask taken on before entering the operating room and removed

afterwards; especially clothing protection by vertical laminar flow airstream; surgical handwashing/disinfection performed as a routine; sterile dressing opened immediately before dressing; and sterile gloves should be double, with indicator, and strong with long cuff.

33.5.11.5   Cleaning, Disinfection and Environmental Treatment of Floors and Surfaces

Operations may generate large amounts of visible and even more invisible biological material in the environment of the operating room [126, 127]. Cleaning is performed between each operation after defined methods, often with varying quality [126, 127]. Dry mopping should not be used due to poor effect on biological, dried materials, biofilms and dust that may swirled up [177–179]. Terminal cleaning each day and disinfection of inventory in the morning before operational activity are recommended [179]. Closets and drawers for instruments, bandages and other equipment are cleaned each week, and all storage rooms are cleaned daily. A major cleaning of walls and ceiling and inventory of all rooms in the operation department twice a year is recommended [179].

After operations with "pus" and infections, disinfection is carried out with 5% chloramine or PeraSafe and/or hydrogen peroxide gas, before the ordinary cleaning [179, 180]. The disinfection includes all technical equipment in the room, including inner parts of medical technical equipment, which are otherwise difficult to reach [180, 181]. Start the machine and let it draw hydrogen peroxide gas through the inner parts during the room disinfection [181]. Note that gas disinfection does not kill *Mycobacterium tuberculosis* [182, 183]. UV light has not been proven beneficial in this situation [184]. Newer disinfectants and methods must be checked thoroughly for effect (spore test, etc.), and the disinfectant does not harm equipment and people or develop resistance. Ineffective disinfection can lead to the spread of more resistant, environmental microbes [185].

Quality of the cleanness is monitored and controlled by the detection of biological material (ATP—adenosine triphosphate test), bacterial counts and other methods. ATP methods provide quick answers used properly [178, 186]. Regular cleaning with soap and water reduces the amount of bacteria significantly and the organic material is also removed [126, 127, 178, 179, 187]. Environmental contamination of blood and tissue particles in an operating room is considerable, both through the air and as debris [188].

33.5.11.6   Uncleaned Equipment

The surgical department should not be a "sterile central" for other departments. All equipment, including drugs, medical equipment, paper and records, beds and stretchers, fluids, cloth, shoes, mobile phones, pens, stethoscopes, etc., which enters the surgical department, should be clean.

Mobile phones, *tourniquet*, *stethoscope*, *PC board*, *blood pressure gauge*, etc. carry large amounts of bacteria [189–191]. Among 90 surgeons, anaesthesia

personnel and medical students, 53% were carrying their mobile phones, etc. into the operating room. About 15% had two or more phones, and most of them (85–96%) were never cleaned by the owner. Nearly all were contaminated (90%), and more than 11% were colonized with *S. aureus*, *Pseudomonas aeruginosa*, *Acinetobacter* and *Stenotrophomonas maltophilia*, microbes that may cause severe wound infections [191].

Paper and journals. Bacteria and virus survive on dry paper and journals for days to months and should therefore be handled with care and not brought into rooms where there may be infections [192].

Outer packaging of goods to the surgical department should be unpacked in a separate room outside the department because of possible contamination with resistant bacteria, viruses and fungi and even with parasites.

Equipment to assist placement of the patient on the operation table is often reusable, used to adapt the patient to the operation table or to protect against pressure sores. It is packaged in plastic or leather, may be difficult to clean between patients and may transmit significant amounts of bacteria into the surgical wound if not disinfected and stored clean. In a study of primary hip operations, 11 of 13 patients used this equipment which was contaminated with *Proteus*, *Acinetobacter*, *Enterococcus*, CNS and coliform rods [193].

Non-sterile cotton, *plaster*, *tape or bandages* should not be deposited around the wound of recently operated patients. Cotton, cotton wool and tape used in the area, nearby wounds, must be sterile. Storages for plaster should be clean and protected from dirt and dust. Bacteria grow well in plaster, especially when tissue fluid is present.

Markers for indicating the surgical field may contain bacteria which pose risks for SSIs [194]. Markers should be sterile and disposable [194].

Oesophageal pressure gauge should be disposable because of risk of disease transmission [195]. Disinfection is expensive because it is fragile instruments. Single use is recommended in England.

Transoesophageal echocardiography (TOE) has caused outbreak of *Enterobacter cloacae* infection in a cardiovascular department in Japan [196]. The outbreak stopped after proper disinfection and modified routine [196].

*Wound drain suction—reusable—*may follow the patient from the operating room to the postoperative and later to and from the hospital. Lack of disinfection of internal components makes it necessary to treat this instrument as infectious. Medical devices that are cooled down with room air may concentrate internally bacteria, fungi, dust, organic materials and other dirt that next may be blown out into the room [181].

Actively heating systems for normothermia is not defined as a risk of infection [197].

Wet areas such as surgical hand disinfection rooms may generate large amounts of aerosols. Sterile equipment or clean equipment should not be stored in wet areas,

because of contamination of the external cover and a fast growth through the covering material.

Intravenous, *sterile liquids* should be stored in a clean and dry room [83, 84].

33.5.11.7 Anaesthesia and Equipment

Anaesthesia machines are often contaminated [198]. Focus on hand hygiene for anaesthesia personnel resulted in 27-fold increase in hand hygiene during work with the patient, reduction of bacteria on the anaesthesia machine and stopcock ($p < 0002$) and reduction of postoperative infections, including SSIs, from 17.2% to 3.8%, $p = 0.02$ [198].

PC keyboard, including the PC of the anaesthesia personnel, is always contaminated with microbes from different users. Plenty of gram-negative bacteria, CNS, *Bacillus* and MRSA can be detected, depending on the local microbiology [199]. Only 17% of anaesthesia personnel in a study carried out hand hygiene before anaesthesia started, while the proportion was significantly higher, 64–69%, after anaesthesia or before lunch! [199] Proper cleaning and disinfection of the keyboard with alcohol resulted in drastic reduction of bacteria. Daily cleaning and disinfection of computer keyboard and hand hygiene compliance with change of gloves after each procedure is recommended to reduce the infection [199].

Intraoperative infection via the patient's intravenous "stopcock" (three-way) is associated with increased patient mortality [200]. Intraoperative infection of the stopcock occurred in a study in 11.5% of cases, and almost half (47%) of the contamination came from the staff. Spread of bacteria to the environment around the anaesthesia place occurred in most cases (89%), and 12% of these were from the staff [200]. Number of operating theatres the anaesthesiologist had responsibility for at the same period, age of the patient and patient transfer to an intensive unit were linked to an increased risk of transmission of infections [200]. Contaminated hands of anaesthesia personnel were probably a significant infection factor during surgery [200].

Bacterial deposits on the surface of syringes, IV sets of three-way taps and anaesthesia (ventilator) machines were studied among 101 elective and urgent surgical patients [201]. Culture of samples from the syringe surface and from the syringe content showed growth of bacteria in, respectively, 46% and 15% of cases [201]. The same bacterial strain was grown from both the ventilator and the syringe in 13% of the cases and was also detected on the IV set in two patients. There was a significant correlation between the urgent surgery and contaminated syringes. Risk was also related to the absence of the use of gloves and missing cap on the three-way tap after use. Particularly during ultraclean operations and a patient in a bad condition, intravenous injection of bacteria via the anaesthetic syringe may cause development of postoperative infections, including SSIs [201].

Laryngoscope blade and handle, etc. are sources of infection in the surgical department and for the patients, unless the devices are adequately disinfected and sterilized [202].

33.5.11.8 Technique and Complications

The risk of infection via equipment is related to the reuse of disposable articles, mishap, lack of coverage of sterile equipment, poor quality of gloves, sterile gowns that provide inadequate covering, compresses which leave fluff in incisional wounds and become "locus minoris" for infection, etc.

Lack of exercise and knowledge, particularly by the surgeon, poor surgical technique, contamination from the bowel (abdominal surgery), too much use of diathermy (the United Kingdom—recommends to avoid diathermy during skin incision because of prion disease), bleeding, haematoma and injuries to tissues, contamination of instruments, a too long operation time, and unnecessary use of drains often increases the risk of SSIs [1, 51–54, 203].

The number and type of bacteria in the surgical wound at the end of surgery, tissue necrosis, poorly oxygenated tissues and the use of drainage increase the risk of SSIs [20, 153–158].

Robot-assisted surgery has been associated with longer operative time and significantly more infections than open surgery but may be the result of a learning curve [98].

Drilling in bone and surgical wound debridement may cause splashing and scattering of tissues and microbes to the environment. This must be avoided, especially when the tissue is infected [204].

Adhesive plastic covers do not reduce recolonization of bacteria in the disinfected surgical area, compared with bare skin [205]. Recolonization on the skin occurs after 2–3 h [205].

Types of sutures and the number of variants used per operation type are discussed. For abdominal surgery it is claimed reduced risk of SSIs by using triclosan-coated sutures [206]. However, triclosan is not recommended for use as a disinfectant because of development of resistance and should not be used for sutures. The most important is use of fewer suture types, that experiences increase and that the sutures are both stored and treated sterile.

Lost equipment in the surgical wound occurs, despite of a mostly consistent control [107].

33.5.11.9 Diathermy and Suction

At the tip of diathermy needle, often large amounts of tissue debris may be found. This is specially a risk concerning prions [207]. In a study, the suction tip used in ultraclean surgery had one or more microbes in 41% of patients, comprising *S. aureus*, CNS, *E. coli*, *Proteus*, group B streptococci, micrococci and diphtheroides [208]. Similar findings have also been done by others. The compressed air from the wall may be contaminated with small amounts of CNS constituting risk when using

pneumatic tools in wounds. Suction regulators may be source of infection in surgical departments and other departments [209]. In one study, 37% of 470 regulators were colonized with bacteria like *S. aureus*, *Pseudomonas aeruginosa*, CNS, enterococci, *Bacillus* and *Micrococcus* species [209]. Miscellaneous medical devices with suction or compressed air or in-out air from the room itself are risks for patients and staff if not disinfected/sterilized/filtered and controlled properly [210].

33.5.11.10 Bandage Types

Meta-analysis shows that there is no significant difference in bandages if they are stored, processed and placed on the wound with a sterile method [211]. The storage of bandages is often not clean enough. Microbes can be disposed on the outer packages, released to the air by opening and thus transferred to the surgical wound by air or gloves. The storing of sterile bandages in surgical wards demands qualities like a sterile storage room and excellent cleaning.

33.5.11.11 Disinfection and Sterilization

Inadequate sterilization and disinfection is a great risk if introduced into sterile tissue or mucosa [212]. CDC does not recommend use of flash sterilization (CDC 1B) which is often a sign of lack of instruments at the department.

Biofilm is difficult to prevent unless the instruments are cleaned thoroughly. Instruments should not dry with biological materials on, especially with regard to an effective removal of prions [213]. Reprocessing of medical devices is currently being updated in the United States (FDA—Food and Drug Administration) [213]. It involves the following: (1) after use of the equipment, immediately remove and/or prevent desiccation of the material; (2) thorough cleaning of the equipment; and (3) disinfection (low, intermediate, high level) or sterilization [213].

Manual disinfection may be significantly poorer than semi-automatic or automatic disinfection; especially *E. coli*, other gram-negative rods, streptococci and enterococci are frequently isolated from the instruments after manual disinfection [214].

During a period of 3 months, 17 patients got lower respiratory tract infections with *Pseudomonas aeruginosa*, infected via a flexible bronchoscope that was not good enough cleaned [215].

Unsterile *anti-mist solutions* to treat scopes have caused outbreaks with *Burkholderia cepacia* [216]. *Mycobacterium chelonae* was detected in bronchoalveolar lavage (BAL) from nine patients without symptoms, but the bacterium was detected in the scope, a contaminated bronchoscopic washing machine and in water [217]. Controls and good routines are important, especially where water sources have variable quality.

Contaminated arthroscopes transferred *Pseudomonas aeruginosa* (PA) to seven patients, which resulted in deep/cavity infections [218]. The bacterial strain was detected in the sink, the suction bottle, the wall suction system and in the scope. Tissue debris was left in the inlet and outlet channels of the scope and the "shaver

handpiece suction channel." *Pseudomonas aeruginosa* survived flash sterilization and autoclaving—probably in tissue debris [218].

A gastroscope was a common source of infection in four cases (France, 2011) that was infected with a multidrug-resistant (MDR) *Pseudomonas aeruginosa* producing extended-spectrum beta-lactamase (ESBL) [219]. Observation revealed severe failures as inadequate cleaning, too short disinfection time, insufficient brushing and purging of channels and inadequate drying. The gastroscope was removed, the routines changed, and the outbreak stopped [219].

Infections with resistant bacteria resulting in death of the patients are reported connected to inadequate cleaning of endoscopes [213, 220].

Hepatitis C infection has been transmitted via colonoscopy from one to two other patients in France [221]. All three were examined by colonoscopy at 1-h intervals, the HCV-carrying patient first. The two infected got symptoms 3 months later. The index patient was known in advance and had 3.5 million HCV—virus particles per ml of blood. Colonoscopes had been cleaned, washed and treated for 5 min in 2% glutaraldehyde. But the biopsy channel had never been brushed, and biopsy forceps and diathermy tube were only treated with glutaraldehyde, never sterilized [221].

Reuse of disposable sterile equipment, labelled "single use" may still be used—to save expenses. Among 100 hospitals in the Nordic countries, there were 542 cases of re-sterilization of medical disposable sterile equipment including implants [222]. More than half of the hospitals used re-sterilization of single-use sterile equipment. Sterilization of disposable equipment can change the instrument's strength, integrity, shape and other important properties as the transfer of organic material and infection between patients.

In Norway, this has been a widespread practice [222]. Re-sterilization has been done on unused single-use equipment of about 50 different products, essentially orthopaedic implants. Pacemakers were re-sterilized after use on patients, likewise catheter, knives, scissors, tweezers, needles, introducers, tubes, etc. There was lack of control by the sterilization method and many single-use instruments were re-sterilized 15 times or more [222]. Today, "single use" means that the instrument is discarded after one use in all hospitals in our country.

Work with sterile instruments relies on a comprehensive approach to the complete process. Dancer and co-workers described an outbreak of SSIs in approximately 20 elective orthopaedic patients, associated with deficiencies in autoclaving and drying and lack of control "all the way," from the sterile central to the operating room [223]. Visually discoloured and partly wet instrument sets were delivered to the surgical department. Among 20 sets, half were discoloured exteriorly and more than half had bacteria on the interior surfaces. A total of 11 patients had to be reoperated because of SSIs [224].

Prion diseases such as Creutzfeldt-Jakob disease (CJD) and variant CJD (vCJD) transmitted from animals, like bovine spongiform encephalopathy (BSE—"mad cow disease"), must always be remembered, concerning cleaning,

disinfection and sterilization of instruments and other equipment in contact with/ perforation of the mucosa and perforation of the skin. There is a limited efficacy of steam sterilization, 134–137 °C for 3 min to inactivate vCJD [224]. Recently, dura mater graft-associated Creutzfeldt-Jakob disease in 154 cases was published from Japan [225]. A Lyodura dura mater product was associated with 140 of the cases [225].

See the chapters on disinfection and sterilization; 59–61.

33.5.11.12 Antibacterial Prophylaxis

Risk for SSIs depends on:

1: (a) Amount of bacteria in the wound, virulence and antibiotic resistance, (b) tissue damage around the wound and (c) foreign material in the wound.

2: (a) The patient's general condition and local immunity and (b) antibiotic prophylaxis.

In a study from Europe (2010), 17% of the total consumption of antibiotics in hospitals were used for surgical prophylaxis [226]. Among 1650 agents used in surgical prophylaxis, the cephalosporins dominated (first generation, 27%; second generation, 20%), followed by combinations of penicillins, 13%, and imidazole agents, 9%. Resistance driving and very important therapeutic agents, like fluoroquinolones, third-generation cephalosporins and aminoglycosides, were in sum used for almost 20% of the cases (8%, 5.7% and 4.4%, respectively) [226]. This is a serious development with regard to the use of resistance-driving antibiotics.

Effect of prophylaxis is evidenced in caesarean section in which the introduction of pre-incision antibiotics reduced SSIs from 10.8% to 2.8% [227]. Problems with the development of resistance is often associated with inappropriate use of antibiotics, including antibiotic prophylaxis [228, 229].

In a study from Switzerland, antibiotics were used inappropriate in half of surgical wards because of no indication for use; 30.3%, wrong choice of agents; 10.9%, not proper timing, dosage, duration etc.; 9.5% [230]. By changing the prophylaxis treatment to include a new dose at the duration of surgery for 3 h and reducing the duration of the treatment to 1.6 days (from previously 2.4 days), an intervention study found a significant reduction of SSIs with resistant gram-negative rods and MRSA [231]. New guidelines are more restrictive [232].

Antibiotic prophylaxis has many positive aspects but is a continuous risky excuse to relax in hygiene, cleaning and infection control, and while the bacterial resistance is easily selected, it happens little on the antibiotic front.

33.5.11.13 Planning of Surgery on Infected Patients

During surgery, precautions for contact transmission often may include precautions for airborne transmission when in direct work with infectious tissue. Dedicated operating rooms for patients with infections should be placed nearby the entrance to the operating department. It should be "stripped" of excess equipment, large enough,

sturdy and robust for chemical disinfectants and easy to clean. Positive pressure must be turned off and ventilation valves closed, and the room should preferably have a complete separate ventilation (not shared with other operating theatres). Negative pressure and possibility of gas disinfection of rooms and input and output channel after the operation should be recommended. Procedures should be established for gas disinfection of the inner machine parts for medical equipment that draws air from the room and that cannot be disinfected inside by chemical liquids [179, 233]. Introduction room should be used as a sluice with the same ventilation system as the operating room.

The patient is brought in a clean bed with clean linen directly from the isolate to the operating room in accordance with applicable isolation regime. Transport bed/stretcher is treated as infectious—after having handed over the patient. New, clean bed/stretcher is retrieved to postoperative transport. It is an advantage that the patient wakes up in the operating room and then brought directly to isolate in the postoperative phase. Operation at the end of the day or in an empty department may be required with very dangerous infective agents [233].

The severity of the infections determines the use of PPE. Note that airborne infection is a risk factor in patients with blood-borne infections (HIV, hepatitis, prions, etc.) and for infections in tissue (tuberculosis, etc.). This applies especially to the use of diathermy, "drilling" and suction. In England, there is recommended less use of diathermy because of the risk of prion disease.

33.5.11.14 Gas Disinfection After Surgery on Patient with Infection

Gas disinfection may be implemented, using mobile devices, preprogrammed for the volume of the room, and which is measuring the gas concentration down to 0 ppm—before the room is opened [180, 181, 234]. Dry hydrogen peroxide 5% may be used where high water vapour concentration may damage—corrode—instruments. Three disinfection cycles and spore test are used routinely to check the effects; spores will be killed by the gas [180, 181]. Disinfection time is 3–5 h. No gas type has been proven effective against *Mycobacterium tuberculosis*.

Surgical hand hygiene—see separate Chap. 34.

Operations department—operational activity—see separate Chap. 35.

References

1. Cruse PJ, Foord R. The epidemiology of wound infections. A 10-year prospective study of 69,939 wounds. Surg Clin North Am. 1980;60:27–40.
2. Haley RW, Culver DH, White JW, et al. The efficacy of infection surveillance and control programs in preventing nosocomial infections in university hospitals. Am J Epidemiol. 1985;121:182–205.
3. Garner JS, Jarvis WR, Emori TG, Horan TC, Hughes JM. CDC definitions for nosocomial infections, 1988. Am J Infect Control. 1998;16:128–40.

4. Mangram AJ, Horan TC, Pearson ML, Silver LC, Jarvis WR. Guideline for prevention of surgical site infection, 1999. Hospital Infection Control Practices Advisory Committee. Infect Control Hosp Epidemiol. 1999;20:250–78.

5. Anonymous. Prevention of surgical site Infections. In: Prevention and control of healthcare-associated Infections in Massachusetts. Massachusetts Dep Publ Health, 31 Jan 2008. p. 61–8.

6. Anonymous. Surgical site infection; prevention and treatment of surgical site infection. Nation Coll Center Wom Child Health, Oct 2008.

7. Horan TC, Andrus M, Dudeck M. CDC/NHSN surveillance definition of healthcare-associated infection and criteria for specific types of infection in the acute care setting. Am J Infect Control. 2008;36:309–32.

8. Owens CD, Stoessel K. Surgical site infections: epidemiology, microbiology and prevention. J Hosp Infect. 2008;70:3–10.

9. Umscheid CA, Agarwal RK, Brennan PJ, Healthcare Infection Control Practices Advisory C. Updating the guideline development methodology of the Healthcare Infection Control Practices Advisory Committee (HICPAC), CDC. Am J Infect Control. 2010;38:264–73.

10. Uckay I, Hoffmeyer P, Lew D, Pittet D. Prevention of surgical site infections in orthopedic surgery and bone trauma: state-of-the-art update. J Hosp Infect. 2013;84:5–12.

11. Anderson DJ, Podgorny K, Berrios-Torres SI, et al. Strategies two preventable surgical site infections in acute care hospitals: 2014 update. Infect Control Hosp Epidemiol. 2014;35:605–27.

12. Berrios-Torres SI, Umscheid CA, Bratzler DW, et al. Draft of guidelines for the prevention of surgical site infection. CDC. 2014.

13. Berrios-Torres SI, Umscheid CA, Bratzler DW, et al. Healthcare Infection Control Practices Advisory Committee. Centers for Disease Control and Prevention guideline for prevention of surgical site infection, 2017. JAMA Surg. Published online 3 May 2017. https://doi.org/10.1001/jamasurg.2017.0904.

14. Regulations on infection control in health institutions – hospital infections – with annotations, of 5 July 1996 was replaced by the Regulation on infection control in health services by 17 July 2005. The regulations is associated to the Communicable Diseases Act § 4-7 and § 7-11 in the Law of Aug 5, 1994 No. 55 on the protection against infectious diseases.

15. Andersen BM, Holta Ringertz SH, Petersen Gullord T, Hermansen W, Lelek M, Norman BI, Tilrem Nystad M, Anderson Rød K, Røed RT, Smidesang IJ, Solheim N, Tandberg S, Halsnes R, Høystad MW. A three-year survey of nosocomial and community- acquired infections, antibiotic treatment and re-hospitalization in a Norwegian health region. J Hosp Infect. 2000;44:214–23.

16. Andersen BM, Rasch M, Tollefsen T, Kvist J, Bentsen L. Point prevalence studies during 10 years; − study of nosocomial Infections in a tertiary university hospital in Norway. J Hosp Infect. 2006;64(Suppl 1):70. Abstract

17. Andersen BM, Rasch M, Hochlin K, Tollefsen T, Sandvik L. Hospital-acquired infections before and after healthcare reorganization in a tertiary University Hospital in Norway. J Public Health. 2009;7:1–7.

18. National Institute of Public Health. Prevalence of infections and use of antibiotics in health care institutions (PIAH): Monitoring guidelines for hospitals, Norway. 2010.

19. Worth LJ, Bull AL, Spelman T, Brett J, Richards MJ. Diminishing surgical site infections in Australia: time trends in infection rates, pathogens and antimicrobial resistance overusing a comprehensive Victorian surveillance program, 2002–2013. Infect Control Hosp Epidemiol. 2015;36:409–16.

20. Rioux C, Grandbastien B, Astagneau P. Impact of a six-year control program on surgical site infections in France: results of the INCISO surveillance. J Hosp Infect. 2007;66:217–23.

21. Astagnneau P, L'Hériteau F, Daniel F, Parneix P, et al. Reducing surgical site infection incidence through a network: results from the French ISO RAISIN surveillance system. J Hosp Infect. 2009;72:127–34.

22. Coignard B. Raisin. National NI prevalence surveys results, 2001–2006. http://www.invs.sante.fr/raisin.

23. CDC. National and State Healthcare Associated infections (HAI). Progress report. Feb 2015.
24. Pennsylvania Healthcare. Healthcare-associated infections in Pennsylvania. 2005, 2006, 2007, 2012 Report. 2014.
25. SPRI-Report, 179/1988, Stockholm.
26. Valentini L, Casali C, Chatenoud L, et al. Surgical site infections after elective neurosurgery: a survey and 1747 patients. Neurosurgery. 2008;62:88–96.
27. National Academy of Sciences-National Research Council. Postoperative wound infections: the influence of ultraviolet irradiation of the operating room and various other factors. Ann Surg. 1964;160(Suppl 2):1–132.
28. Olson M, O'Connor M, Schwartz ML. Surgical wound infections. A 5-year prospective study of 20,193 wounds at the Minneapolis VA Medical Center. Ann Surg. 1984;199:253–9.
29. Culver DH, Horan TC, Gaynes RP, et al. Surgical wound infection rates by wound class, operative procedure, and patient risk index. Am J Med. 1991;91:152–7.
30. Charnley J. Postoperative infection after total hip replacement with special reference to air contamination in the operating room. Clin Orthop. 1972;87:167–87.
31. Lidwell OM, Lowbury EJL, Whyte W, Blowers R, Stanley SJ, Lowe D. Airborne contamination of wounds in joint replacement operations: the relationship to sepsis rates. J Hosp Infect. 1983;4:111–31.
32. Ventilation of operating theaters. Center for Health Technology Assessment, SINTEF UNIMED, Oslo. 2001.
33. Dohmen PM. Antibotics resistance in common pathogens reinforces the need-to minimize surgical site infections. J Hosp Infect. 2008;70:15–20.
34. Bruun JN. Surgical wound infections. Tidsskr Nor Legeforen. 1972;92:97–100.
35. Bruun JN. Postoperative wound infections. Predisposing factors and the effect of a reduction in the dissemination of staphylococci. Acta Med Scand. 1970;514:1–89.
36. Hovig B. Detection of hospital infections. Rikshospitalet. The Hospital. 1977;40:321–7.
37. Sander J. Postoperative wound infections in a general surgical department with infection ward. Tidsskr Nor Legeforen. 1979;99:1177–9.
38. Hygiene Group of the Eastern region of Norway. Nosocomial infections. Guidelines for the prevention and control of postoperative surgical site infections. Tidsskr Nor Legeforen. 1985;105:41–6.
39. Simmons BP. CDC guideline for prevention of surgical wound infections. Infect Control. 1982;3:187–96.
40. Centers for Disease Control. Guideline for prevention of surgical wound Infections, 1985. CDC. 1985.
41. National Institute of Public Health, Norway. The prevalence of healthcare-associated infections and antibiotic use (PAIH) – autumn 2014.
42. Andersen BM. Spread of SARS in aircraft and weakness of the evidence-based medicine. Dagens Medicine, 21 Aug 2003.
43. Andersen BM. The Ebola virus. Handbook of hygiene and infection control in hospitals. Part 1: Microbiology and infection control. Fagbokforlaget. 2014:292–293.
44. Nichols RL. Preventing surgical site infections: a surgeon's perspective. Emerg Infect Dis. 2001;7:220–4.
45. Leaper D, Tanner J, Kiernan M. Surveillance of surgical site infection: more accurate definitions and intensive recording needed. J Hosp Infect. 2013;83:83–6.
46. Reese SM, Knepper BC, Price CS, Young HL. An evaluation of surgical site infection surveillance methods for colon surgery and hysterectomy in Colorado Hospitals. Infect Control Hosp Epidemiol. 2015;36:353–5.
47. Tanner J, Padley W, Kiernan M, Leaper D, Norrie P, Baggott R. A benchmark too far: findings from a national survey of surgical site infection surveillance. J Hosp Infect. 2013;83:87–91.
48. Tanner J, Padley W, Davey S, Murphy K, Brown B. Patient narratives of surgical site infection: Implications for practice. J Hosp Infect. 2013;83:41–5.
49. Grammatico-Guillon L, Rusch E, Astagneau P. Surveillance of prosthetic joint infections: international overview and new insights for hospital databases. J Hosp Infect. 2015;89:90–8.

50. Wilson J, Rambo I, Suetens C, et al. Hospitals in Europe Link for infection control through surveillance (helices). Inter-country comparison of rates of surgical site infection - opportunities and limitations. J Hosp Infect. 2007;65:165–70.
51. Mishriki SF, Law DJW, Jeffery PJ. Factors affecting the incidence of postoperative wound infection. J Hosp Infect. 1990;16:223–30.
52. Wurtz R, Wittrock B, Lavin MA, Zawacki. Do new surgeons have higher surgical-site infection rates? Infect Control Hosp Epidemiol. 2001;22:375–7.
53. Sherlaw-Johnson C, Wilson APR, Keogh B, Gallivan S. Monitoring the occurrence of wound infections after cardiac surgery. J Hosp Infect. 2007;65:307–13.
54. Woodhead K, Taylor EW, Bannister G, Chesworth T, Hoffman P, Humphreys H. Behaviors and rituals in the operating theater. J Hosp Infect. 2002;51:41–255.
55. King C, Aylin P, Moore LSP, Pavlu J, Holmes A. Syndromic surveillance of surgical site infections – a case study in coronary artery bypass graft patients. J Infect. 2014;68:23–31.
56. Calderwood MS, Kleinman K, Bratzler DW, et al. Use of Medicare claims to identify US hospitals with a high rate of surgical site infection after hip athroplasty. Infect Control Hosp Epidemiol. 2013;34:31–9.
57. Anderson D, Hartwig MG, Pappas T, et al. Surgical volume and the risk of surgical site infection in community hospitals: size matters. Ann Surg. 2008;247:343–9.
58. Mu Y, Edwards JR, Horan TC, Berrios-Torres SI, Fridkin SK. Improving risk-adjusted measures of surgical site infection for the National Healthcare Safety Network. Infect Control Hosp Epidemiol. 2011;32:970–86.
59. Delgado-Rodriguez M, Gomez-Ortega A, Llorca J. Nosocomial infection, indices of intrinsic infections risk, and in-hospital mortality in general surgery. J Hosp Infect. 1999;41:203–11.
60. McGarry SA, Enger Mann JJ, Schmader K, Sexton DJ, Kaye KS. Surgical-site infection due to *Staphylococcus aureus* among elderly patients: mortality, duration of hospitalization, and costs. Infect Control Hosp Epidemiol. 2004;25:461–7.
61. Dohmen PM. Influence of skin flora and preventive measures on surgical site infection during cardiac surgery. Surg Infect. 2006;7:S13–7.
62. Bauman Z, Gassner M, Host H, et al. Causes of surgical mortality: is it pathology or hospital harms? Crit Care Med. 2013;41 Abstract 31
63. de Lissovy D, Fraeman K, Hutchins V, Murphy D, Song S, Vaughn BB. Surgical site infection: incidence and impact on hospital utilization and treatment costs. Am J Infect Control. 2009;37(5):387–97.
64. Rosenthal VD, Richtmann R, Singh S, et al. Surgical site infections, international nosocomial infection control consortium (INICC) report, data summary of 30 countries, 2005–2010. Infect Control Hosp Epidemiol. 2013;34:597–604.
65. Hovig B, Lystad A, Osjøn H. A prevalence study of infections among hospitalized patients in Norway. NIPH Annals (Oslo). 1981;4:49–60.

Orthopaedics

66. Houtari K, Lyytikäinen O, Seitsalo S. Patient outcomes after simultaneous bilateral total hip and knee joint replacements. J Hosp Infect. 2007;65:219–25.
67. Lindgren V, Godon M, Wretenberg P, Karrholm J, Garellick G. Deep infection after total hip replacement: a method for national incidence surveillance. Infect Control Hosp Epidemiol. 2014;35:1491–6.
68. Furnes A, Havelin LI, Engesæter LB, Lie SA. Quality control of replacement surgery knee, ankle, toe, shoulder, elbow, and finger joints in Norway 1994. Tidsskr Nor Legeforen. 1996;116:1777–81.
69. Reigstad A. The safety of arthroplasty. Tidsskr Nor Legeforen. 1996;116:1777–6.
70. Dale H. Artificial hip joints – infections in Norway from 1987 to 2011. Orthopedic Clinic Haukeland Hospital, Norway.

Hernia

71. Olsen MA, Nickel KB, Wallace AE, et al. Stratification of surgical site infection by operational factors and comparison of infection rates after hernia repair. Infect Control Hosp Epidemiol. 2015;36:329–35.

Caesarean Section

72. Olsen MA, Butler AM, Willers DM, et al. Risk factors for surgical site infecxtion after low transverse cesarean section. Infect Control Hosp Epidemiol. 2008;29:477–84.
73. Ward VP, Charlett A, Fagan J, Crawwshaw SC. Enhanced surgical site infection surveillance following caesarean section: experience of a multicentre collaborative post-discharge system. J Hosp Infect. 2008;70:166–73.
74. Wilson J, Włoch C, Saei A, et al. Inter-hospital comparison of rates of surgical site infection following caesarean section delivery: evaluation of a multicentre surveillance study. J Hosp Infect. 2013;84:44–51.
75. Vedeler M. Infections after caesarean section during the period 2009–2011. Aftenposten, 27 Feb 2013.

Hysterectomy

76. Meltomaa SS, Makinen JI, Taalikka MO, Helenius HY. Incidence, risk factors and outcome of infection in a 1-year hysterectomy cohort: a prospective follow-up study. J Hosp Infect. 2000;45:211–7.

Transplants

77. Harris AD, Fleming B, Bromberg JS, et al. Surgical site infection after renal transplantation. Infect Control Hosp Epidemiol. 2015;36:417–23.

Heart

78. Hall JC, Hall JL, Edwards MG. The time of presentation of wound infection after cardiac surgery. J Qual Clin Pract. 1998;18:227–31.
79. Roy MC, Herwald LA, Embrey R, et al. Does the Centers for Disease Control's NNIS system risk index stratify patients undergoing cardiothoracic operations by their risk of surgical-site infections? Infect Control Hosp Epidemiol. 2000;21:186–90.
80. Cristofolini M, Worlitzch D, Wienke A, Silber RE, Borneff-Lipp M. Surgical site infection and coronary artery bypass graft surgery: incidence, perioperative hospital stay, readmission, and revision surgeries. Infection. 2012;40:397–404.
81. Bouza E, Hortal J, Munoz P, et al. Postoperative infections after major heart surgery and prevention of ventilator-associated pneumonia: a one-day European prevalence study (ESGNI-008). J Hosp Infect. 2006;64:224–30.
82. Yavuz S, Tarcin AZ, Ada S, et al. Incidence, etiology, and control of sternal surgical site infections. J Hosp Infect. 2013;85:206–12.

83. Olafsen K, Hotvedt R, Andersen BM, Almdahl SM, Sørlie D. Nosocomial infection with resistant *Enterobacter cloacae*. Impact on disease progression and treatment. Tidsskr Nor Legeforen. 1989;109:332–6.

84. Andersen BM, Sørlie D, Hotvedt D, Almdahl SM, Olafsen K, George RC, Gilfillian A. Multiply beta-lactam resistant. *Enterobacter cloacae* infections linked to the environmental flora in a unit of cardiothoracic and vascular surgery. Scand J Infect Dis. 1989;21:181–91.

85. Breathnach AS, Riley PA, Shad S, et al. An outbreak of wound infection in cardiac surgery patients caused by *Enterobacter cloacae* arisings from cardioplegic ice. J Hosp Infect. 2006;64:124–8.

86. Kanemitsu K, Endo S, Oda K, et al. An increased incidence of *Enterobacter cloacae* in a cardiovascular ward. J Hosp Infect. 2007;66:130–4.

87. Mekontso-Dessap A, Kirs M, Brun-Buisson C, Loisance D. Poststernotomy mediastinitis due to *Staphylococcus aureus*: comparison of methicillin-resistant and methicillin-susceptible cases. Clin Infect Dis. 2001;32:877–83.

88. Hussey LC, Hynan L, Leeper B. Risk factors for sternal wound infection in men versus women. Am J Crit Care. 2001;10:112–6.

89. Boeken U, Eisner J, Feind P, Petzold TH, Schulte HD, Gams E. Does the time of re-sternotomy for bleeding have any influence on the incidence of sternal infections, septic courses or further complications? Thorac Cardiovasc Surg. 2001;49:45–8.

90. Bitkover CY, Marcusson E, Ransjö U. Spread of coagulase-negative staphylococci during cardiac operations in a modern operating room. Ann Thorac Surg. 2000;69:1110–5.

91. Tegnell A, Aren C, Ohman L. Coagulase-negative staphylococci and sternal infections after cardiac operation. Ann Thorac Surg. 2000;69:1104–9.

92. De Feo M, Renzulli A, Ismeno G, et al. Variables predicting adverse outcome in patients with deep sternal wound infection. Ann Thorac Surg. 2001;71:324–32.

93. Tollefsen T, Andersen BM, Veng ØA. Surgical site infections after cardiac surgery in Oslo, Norway. J Hosp Infect. 2006;64(Suppl 1):70. Abstract- poster

Colorectal Surgery

94. Flatmark K, Nilsen BH. Postoperative wound infections by elective colorectal surgery. Tidsskr Nor Legeforen. 2000;120:2761–3.

95. Limon E, Shaw E, Badia JM, et al. Post-discharge surgical site infections after uncomplicated elective colorectal surgery: impact and risk factors. The experience of the VINCat Program. J Hosp Infect. 2014;86:127–32.

96. Kirby A, Santorini N. Antibiotic resistance in *Enterobacteriaceae*: what impact on the efficacy of antibiotic prophylaxis in colorectal surgery *?* J Hosp Infect. 2015;89:259–63.

Neurosurgery

97. Humphreys H, Jenks PJ. Surveillance and management of venticulitis following neurosurgery. J Hosp Infect. 2015;89:281–6.

Robot-Assisted Surgery

98. Hermsen ED, Hinze T, Sayles H, Sholtz L, Rupp M. Incidence of surgical site infection associated with robotic surgery. Infect Control Hosp Epidemiol. 2010;31:822–7.

NOIS Incidence

99. NOIS-annual reports – in 2011 and 2013, the National Institute of Public Health, Norway.

SSIs After Discharge

100. Lecuona M, Torres-Lana A, Delgado-Rodriguez M, Llorca J, Sierra A. Risk factors for surgical site infections diagnosed after hospital discharge. J Hosp Infect. 1998;39:71–4.
101. Lankiewicz JD, Yokoe DS, Olsen MA, Onufrak F, Fraser VJ, Huang KS. Beyond 30 days: does limiting the duration of surgical site infection follow-up limit detection? Infect Control Hosp Epidemiol. 2012;33:202–4.
102. Rosenthal R, Weber WP, Marti WR, et al. Surveillance of surgical site infections by surgeons: biased underreporting or useful epidemiological data. J Hosp Infect. 2010;75:178–82.
103. Bryce E, Forrester L. How long is long enough? Determining the optimal surgical site infection surveillance period. Infect Control Hosp Epidemiol. 2012;33:1178–9.
104. Swenne CL, Lindholm C, Borowiec J, Carlsson M. Surgical-site infections within 60 days of coronary artery by-pass graft surgery. J Hosp Infect. 2004;57:14–24.
105. Koek MB, Wille JC, Voss A, van Benthem BH. Post-discharge surveillance (PDS) for surgical site infections: a good method is more important than a long duration. Euro Surveill. 2015;20:21042.
106. Hall L, Halton K, Bailey ES, et al. Post-discharge surveillance (PDS) – where to from here? J Hosp Infect. 2013;84:266–70.

Adverse Events

107. NPE. Lost equipment during operation. Tidsskr Nor Legeforen. 2013;133:1572.
108. Nordstrøm P, Gustafson Y, Michaelsson K, Nordstrøm A. Length of hospital stay after hip fracture and short term risk of death after discharge: a total cohort study in Sweden. BMJ. 2015;350:h696.

Healthcare

109. Haamann F, Dulon M, Nienhaus A. MRSA as an occupational disease: a case series. Int Arch Occup Health. 2011;84:259–66.
110. Wang JT, Chang SC, Koh WJ, Chang YY, Chen ML, Pan HJ, Luh KT. A hospital-acquired outbreak of methicillin-resistant *Staphylococcus aureus* infection initiated by a surgeon carrier. J Hosp Infect. 2001;47:104–9.
111. Kolmos HJ, Svendsen RN, Nielsen SV. The surgical team as a source of postoperative wound infection caused by *Streptococcus pyogenes*. J Hosp Infect. 1997;35:207–14.
112. Wenger PN, Brown JM, McNei MM, Jarvis WR. *Nocardia farcina* sternotomy site infections in patients following open heart surgery. J Infect Dis. 1998;178:1539–43.

Expenses

113. Olsen MA, Chu-Ongsakul S, Brandt KE, et al. Hospital-associated costs due to surgical site infection after breast surgery. Arch Surg. 2008;143:53–60.

114. Andersen BM. Economic consequences of hospital infections in a 1000 bed University Hospital in Norway. Infect Control Hosp Epidemiol. 1998;19:805–7.
115. Reilly J, Twaddle S, McIntosh J, Kean L. An economic analysis of surgical wound infection. J Hosp Infect. 2001;49:245–9.
116. Whitehouse JD, Friedman D, Kirkland KB, Richardson WJ, Sexton DJ. The impact of surgical site infections following orthopedic surgery at a community hospital and a university hospital: adverse quality of life, excess length of stay, and extracost. Infect Control Hosp Epidemiol. 2002;23:183–9.
117. Perencevich EN, Sands KE, Cosgrove SE, Guadagnoli E, Meara E, Platt R. Health and economic impact of surgical site infections diagnosed after hospital discharge. Emerg Infect Dis. 2003;9:196–203.
118. Graves N, Halton K, Curtis M, et al. Costs of surgical site infections that appear after hospital discharge. Emerg Infect Dis. 2006;12:831–4.
119. Broex ECJ, Van Asselt ADI, Bruggeman CA, van Tiel FH. Surgical site infections: how high are the costs? J Hosp Infect. 2009;72:193–201.

Microbes and Transmission Routes

120. Reichel M, Heisig P, Kampf G. Identification of variables for aerobic bacterial density that clinically relevant skin sites. J Hosp Infect. 2011;78:5–10.
121. Jenkins PJ, Clement ND, Gaston P, Breusch S, Simpson H, Dave J. Invasive group B streptococcal disease in an orthopedic unit. J Hosp Infect. 2010;76:231–3.
122. Klevens RM, Morrison MA, Nadle J, et al. Invasive, methicillin-resistant *Staphylococcus aureus* infections in the United States. JAMA. 2007;298:1763–72.
123. Dantes R, Mu Y, Belflower R, et al. National burden of methicillin-resistant *Staphylococcus aureus* infections, United States, 2011. JAMA Intern Med. 2013;173:1970–8.
124. Anderson DJ, Kaye KS, Chen LF, et al. Clinical and financial outcomes due to methicillin-resistant *Staphylococcus aureus* surgical site infection: a multi-center matched outcome study. PLoS One. 2009;4:e8305. Anderson et al ICAAC 2008, K-597
125. Pan A, Lee A, Cooper B, et al. Risk factors for previously unknown methicillin-resistant *Staphylococcus aureus* carriage on admission to 13 surgical wards in Europe. J Hosp Infect. 2013;83:107–13.
126. Andersen BM, Røed RTH, Solheim N, Levy F, Bratteberg A, Kristoffersen K, Moløkken I. Air quality and microbiological contamination in operating theaters and non-laminar flow. Tidsskr Nor Legeforen. 1998;20:3148–51.
127. Andersen BM, Solheim N. Occlusive scrub suits in operating theaters during cataract surgery; effect on airborne contamination. Infect Control Hosp Epidemiol. 2002;23:218–20.
128. Crusz SA, Yates C, Holden S, Kearns A, Boswell T. Prolonged outbreak of *Staphylococcus aureus* surgical site infection traced to a healthcare worker with psoriasis. J Hosp Infect. 2014;86:42–6.
129. Sreeramoju PV, Garcia-Houchins S, Bova J, Patterson JE. Correlation between respiratory colonization with gram-negative bacteria and development of gram-negative bacterial infection after cardiac surgery. Infect Control Hosp Epidemiol. 2008;29:546–8.

Air Contamination

130. Whyte W, Hambraes A, Laurell G, Hoborn J. The relative importance of the routes and sources of wound contamination during general surgery. II Airborne. J Hosp Infect. 1992;22:41–54.

131. Lidwell OM, Lowbury EJL, Whyte W, Blowers R, Stanley SJ, Lowe D. Infection and sepsis after operations for total hip or knee-joint replacement: influence of ultra clean air, prophylactic antibiotis and other factors. J Hyg (Lond). 1984;93:505–29.

132. Friberg B, Friberg S, Östensson R, Burman LG. Surgical area contamination-comparable bacterial counts using disposable head and mask and helmet aspirator system, but dramatic increase upon omission of head-gear: an experimental study in horizontal laminar air flow. J Hosp Infect. 2001;47:110–5.

133. Hambraeus A, Bengtsson S, Laurell G. Bacterial contamination in a modern operating suite. 3. Importance of floor contamination as a source of airborne bacteria. J Hyg (Lond). 1978;80:169–74.

134. Gastmeier P, Breier AC, Brandt C. Influence of laminar airflow on prosthetic joint infections: a systematic review. J Hosp Infect. 2012;81:73–8.

135. Tammelin A, Domicel P, Hambreus A, Ståhle E. Dispersal of methicillin-resistant *Staphylococcus epidermidis* by staff in an operating suite of thoracic and cardiovascular surgery: relation two skin carriage and clothing. J Hosp Infect. 2000;44:119–26.

136. Owers KL, James E, Bannister GC. Source of bacterial shedding in laminar flow theaters. J Hosp Infect. 2004;58:230–2.

137. Scaltriti S, Cencetti S, Rovesti S, Marchesi I, Bargellini A, Borella P. Risk factors for particulate and microbial contamination of air in operating theaters. J Hosp Infect. 2007;66:320–6.

138. Lawrence JC, Lilly HA, Kidson A. Wound dressings and airborne dispersal of bacteria. Lancet. 1992;339:807.

139. Fox BC, Chamberlin L, Kılıch P, Rae EJ, Webster LR. Heavy contamination of operating room air with *Penicillum* species. Identification of the source and attempts at decontamination. Am J Infect Control. 1990;8:300–6.

140. Schulz-Stubner S, Danner K, Hauer T, Tabori E. Psychodidiae (Drain fly) infestation in an operating room. Infect Control Hosp Epidemiol. 2015;36:366–7.

141. Dettenkofer M, Scherrer M, Hoch V, Glaser G, Schwarzer G, Zetner J, Daschner FD. Shutting down operating theater ventilation when the theater is not in use: infection control and environmental aspects. Infect Control Hosp Epidemiol. 2003;24:596–600.

Routine Errors, Accidents and Failures

142. D'Agata EM, Wise S, Stewart A, Lefkowitz LB. Nosocomial transmission of *Mycobacterium tuberculosis* from an extrapulmonary site. Infect Control Hosp Epidemiol. 2001;22:10–2.

143. Richet HM, Craven PC, Brown JM, et al. A cluster of *Rhodococcus* (Gordona) *bronchialis* after coronary-artery bypass surgery. N Engl J Med. 1991;324:104–9.

144. Kalmeijer MD, van Nieuwland-Bollen E, Bogaers-Hofman D, de Baere GAJ, Kluytmans JAJW. Nasal carriage of *Staphylococcus aureus* is a major risk factor for surgical-site infections in orthopedic surgery. Infect Control Hosp Epidemiol. 2000;21:319–23.

145. Passaro DJ, Waring L, Armstrong R, et al. Postoperative *Serratia marcescens* wound infections traced two an out-of-hospital source. J Infect Dis. 1997;175:992–5.

146. DeVries JJC, Baas WH, Van Der Ploeg K, et al. Outbreak of *Serratia marcescens* colonization and infection traced to a healthcare worker with long-term carriage on hands. Infect Control Hosp Epidemiol. 2006;27:1153–8.

147. Haille C, Fletcher S, Archer R, et al. Prolonged outbreak of methicillin-resistant *Staphylococcus aureus* in a cardiac surgery unit linked to a single colonized healthcare worker. J Hosp Infect. 2013;83:219–25.

148. Bajolet O, Ciocan D, Vallet C, et al. Gastroscopy-associated transmission of extended-spectrum beta-lactamase-producing *Pseudomonas aeruginosa*. J Hosp Infect. 2013;83:341–3.

149. Ulu-Kilic A, Parkan O, Ersoy S, et al. Outbreak of postoperative empyema caused by *Serratia marcescens* in a thoracic surgery unit. J Hosp Infect. 2013;85:226–9.

150. Bruins MJ, Wijshake D, de Vries-van Rossum OR, et al. Otitis externa following irrigation linked to instruments contaminated with *Pseudomonas aeruginosa*. J Hosp Infect. 2013;84:222–6.
151. Lowry PW, Blankenship RJ, Gridley W, Troup NJ, Tompkins LA. A cluster of *Legionella* sternal wound infections due to postoperative topical exposure two contaminated tap water. N Engl J Med. 1991;324:109.
152. Vucovic D, Parezanovic V, Savic B, et al. *Mycobacterium fortuitum* endocarditis associated with cardiac surgery, Serbia. Emerg Infect Dis. 2013;19:517–9.

Risk

153. Smyth ETM, Emmerson AM. Surgical site infection surveillance. J Hosp Infect. 2000;45:173–84.
154. Geubbles ELPE, Mintjes-de Groot AJ, Martin J, van der Berg J, de Boer AS. Operating surveillance system of surgical-site infections in the Netherlands: results of the Prezi National Surveillance Network. Infect Control Hosp Epidemiol. 2000;21:311–8.
155. DeBoer AS, Mintjes-de Groot J, Severijns AJ, van der Berg JM, van Pelt W. Risk assessment for surgical-site infections in orthopedic patients. Infect Control Hosp Epidemiol. 1999;20:402–7.
156. Kluytmans J, Voss A. Prevention of postsurgical infections: some like it hot. Curr Opin Infect Dis. 2002;15:427–32.
157. SHEA. 2008. ICHE, October.
158. Turiainen J, Saimanen EI, Partio TJ, et al. Supplemental postoperative oxygen in the prevention of surgical wound infection after lower limb vascular surgery: a randomized controlled trial. World J Surg. 2011;35:1387–95.

Risk Factors

159. Altemeier WA, Culbertson WR, Hummel RP. Surgical considerations of endogenous infection sources, types, and methods of control. Surg Clin North Am. 1968;48:227–40.
160. Daneman N, Lu H, Redelmeier DA. Discharge after discharge: predicting surgical site infections after patients leave hospital. J Hosp Infect. 2010;75:188–94.
161. Latham R, Lancaster AD, Covington JF, Pirolo JS, Thomas CS Jr. The association of diabetes and glucose control with surgical site infections among cardiothoracic surgery patients. Infect Control Hosp Epidemiol. 2001;22:607–12.
162. Wilson SJ, Sexton DJ. Elevated preoperative fasting serum glucose levels increase the risk of postoperative mediastinitis in patients undergoing open heart surgery. Infect Control Hosp Epidemiol. 2003;24:776–8.
163. Sharma M, Berriel-Cass D, Baran J Jr. Sternal surgical-site infection following coronary artery bypass graft: prevalence, microbiology, and complications during a 42-month period. Infect Control Hosp Epidemiol. 2004;25:468–71.
164. Greif R, Aca O, Horn E-P, et al. Supplemental perioperative oxygen to reduce the incidence of surgical-wound infection. Crit Care. 2000;342:161–7.

Preoperative Phase

165. Biant LC, Teare EL, Williams WW, et al. Eradication of methicillin resistant *Staphylococcus aureus* by "ring fencing" of elective orthopedic beds. BMJ. 2004;329:149–51.

Shaving, Shampoo

166. Seropian R, Reynolds BM. Wound infections after preoperative depilatory versus razor preparation. Am J Surg. 1971;121:251–4.
167. Kjønniksen I, Andersen BM, Søndenå V, Segadal L. Preoperative hair removal – a systematic literature review. AORN J. 2002;75:928–40.
168. Ng W, Alexander D, Kerr B, Ho MF, Amato M, Katz K. A hairy tale: successful patient education strategies to reduce prehospital hair removal by patients undergoing elective caesarean section. J Hosp Infect. 2013;83:64–7.
169. Wilhelmi I, Bernaldo De Quiros JCLB, Romero-Vivas J, Duarte J, Rojo E, Bouza E. Epidemic outbreak of *Serratia marcescens* infection in a cardiac surgery unit. J Clin Microbiol. 1987;25:1298–300.
170. Lewis AM, Stephenson JR, Garner J, Afshar F, Tabaqchali S. A hospital outbreak of *Serratia marcescens* in neurosurgical patients. Epidemiol Infect. 1989;102:69–74.
171. Leng P, Huang WL, Het T, Wang YZ, Zhang HN. Outbreak of *Serratia marcescens* postoperative infection traced two barbers and razors. J Hosp Infect. 2015;89:46–50.
172. Amemiya K, Taguchi F. Bacterial contamination of hair washing liquids. J Jpn Ass Infect Dis. 1994;68:177–82.
173. Madani TA, Alsaedi S, James L, et al. *Serratia marcescens*-contaminated baby shampoo causing an outbreak among newborns at King Abdulaziz University Hospital, Jeddah, Saudi Arabia. J Hosp Infect. 2011;78:16–9.

Body Wash and Disinfection

174. Byrne DJ, Napier A, Cuschieri A. Rationalizing whole body disinfection. J Hosp Infect. 1990;15:183–7.
175. Webster J, Osborne S. Preoperative bathing or showering with skin antiseptics to prevent surgical infections. Cochran Database Syst Rev. 2012;9:CD004985.
176. Kampf G, Degenhadt S, Lackner S, Jesse K, von Baum H, Ostermeyer C. Poorly processed reusable surface disinfection tissue dispensers may be a source of infection. BMC Infect Dis. 2014;14:37.

Cleaning, Disinfection and Environmental

177. Andersen BM, Rasch M, Kvist J, Tollefsen T, Lukkassen R, Sandvik L, Welo A. Floor cleaning: effect on bacteria and organic materials in hospital rooms. J Hosp Infect. 2009;71:57–65.
178. Carling P, Po JL, Jefferson J, Parry MM. Objectively improving operating theater disinfection cleaning in 12 hospitals. Boston University. 2010;
179. Operation Department. Cleaning. In: Handbook of hygiene and infection control for hospitals. Oslo: Ullevaal University Hospital; 2008. p. 530–3. and 536–537.
180. Andersen BM, Rasch M, Hochlin K, Jensen F-H, Wismar P, Fredriksen JE. Decontamination of rooms, medical equipment and ambulances, using a dry mist of hydrogen peroxide disinfectant. J Hosp Infect. 2006;62:149–55.
181. Andersen BM, Hochlin K, Daling JP. Cleaning and decontamination of reusable medical equipments, including the use of hydrogen peroxide dry-mist gas decontamination. J Microbiol Biochem Technol. 2012;4:57–62.
182. Andersen BM, Syversen G, Thoresen H, Rasch M, Hochlin K, Seljordslia B, Snevold I, Berg E. Failure of dry mist of hydrogen peroxide 5% to kill *Mycobacterium tuberculosis*. J Infect Hosp. 2010;76:80–3.

183. Andersen BM. Does "airborne" hydrogen peroxide kill *Mycobacterium tuberculosis*? J Hosp Infect. 2011;77:83–5.
184. Andersen BM, Bånrud H, Boe E, Bjordal O, Drangsholt F. Comparison of UVC light and chemicals for disinfection of surfaces in hospital isolation units. Infect Control Hosp Epidemiol. 2006;27:729–35.
185. Andersen BM, Teige B, Hochlin K, Elsebutangen N, Fagerbakke L, Seljordslia B, Syversen G. Failure of ionised water produced by Activeion Ionator to kill harmful bacteria. Microbiol Biochem Technol. 2012;4:3.
186. Alfa MJ, Oslo N, Murray B-L. Adenosine tri-phosphate (ATP) based cleaning monitoring in healthcare: how rapidly does environmental ATP deteriorate? J Hosp Infect. 2015;90:59–66.
187. Munoz-Price L, Birnbach DJ, Lubarsky DA, et al. Decreasing operating room environmental pathogen contamination through improved cleaning practices. Infect Control Hosp Epidemiol. 2012;333:897–904.
188. Jewett DL, Heinsohn P, Bennett C, Rosen A, Neuilly C. Blood-containing aerosols generated by surgical techniques: a possible infectious hazard. Am Ind Hyg Assoc J. 1992;53:228–31.

Unclean Equipments

189. Fellowes C, Kerstein R, Clark J, Azadian BS. MRSA on tourniquets and keyboards. J Hosp Infect. 2006;64:86–8.
190. Messina G, Ceriale E, Burgassi S, et al. Impact of a disinfecting technique on microbial contamination of computer keyboards and telephone handset. J Hosp Admin. 2013;2:1–6.
191. Brady RR, Fraser SF, Dunlop MG, Paterson-Brown S, Gibb AP. Bacterial contamination of mobile communication devices in the operational environment. J Hosp Infect. 2007;66:397–8.
192. Hope CK, Malton LV. Concerning the survival of saliva-borne oral bacteria on patient notes. J Hosp Infect. 2009;73:282.
193. Ranawat VS, Dowell JK, Teare EL. Pressure sore prevention pads as an infective source in orthopedic theaters. J Infect Hosp. 2004;56:318–20.
194. Burton C. Forgie S, Rennie R, Turnbull DS. Can skin marker pens, used pre-operatively to mark surgical site, transfer bacteria? In: Annual ICAAC/IDSA, Washington, DC, 25–28 Oct 2008; K-583.
195. Cooke RPD, Unsworth B. Oesophageal manometers should be managed as single-use instruments. J Hosp Infect. 2007;66:398–9.
196. Kanemitsu K, Endo S, Oda K, et al. An increased incidence of *Enterobacter cloacae* in a cardiovascular ward. J Hosp Infect. 2007;66:130–4.
197. Moretti B, Larocca AMV, Napoli C, et al. Active warming systems to maintain perioperative normothermia in hip replacement surgery: a therapeutic aid or a vector of infection? J Hosp Infect. 2009;73:58–63.

Anaesthesia Machine and Equipment

198. Koff MD, Loftus RW, Buchman CC, et al. Reduction of intra-operative bacterial contamination of peripheral intra-venous tubing through the use of a novel devise. Anesthesiology. 2009;110:978–85.
199. Fukada T, Iwakiri H, Ozaki M. Anaesthetists' role in computer keyboards contamination in an operating room. J Hosp Infect. 2008;70:148–53.

200. Loftus RW, Muffly MK, Brown JR, et al. Hand contamination of anesthesia providers is an important risk factor for intraoperative bacterial transmission. Anesth Analg. 2011;112:98–105.
201. Mahida N, Levi K, Kearns A, Snape S, Moppett I. Investigating the impact of clinical anesthetic practice on bacterial contamination of intravenous fluids and drugs. J Hosp Infect. 2015;90:70–5.
202. Negri de Sousa AC, Levy CE, Freitas MIP. Laryngoscope blades and handles as sources of cross-infection: an integrative review. J Hosp Infect. 2013;83:269–75.

Technique and Complications

203. McHugh SM, Hill AD, Humphreys H. Intraoperative technique as a factor in the prevention of surgical site infection. J Hosp Infect. 2011;78:1–4.
204. Sønnergren HH, Strømbeck L, Aldenborg F, Faergmann J. Aerosolized spread of bacteria and reduction of bacterial wound contamination with three different methods of surgical wound debridement: a pilot study. J Hosp Infect. 2013;85:112–7.
205. Falk-Brynhildsen K, Söderquist B, Friberg Ø, Nilsson UG. Bacterial recolonization of the skin and wound contamination during cardiac surgery: a randomized controlled trial of the use of plastic adhesive drape compared with bare skin. J Hosp Infect. 2013;84:151–8.
206. Apisarnthanarak A, Singh N, Bandong AN, Madriga G. Tricolosan-coated sutures reduces the risk of surgical site infections: a systematic review and meta-analysis. Infect Control Hosp Epidemiol. 2015;36:169–79.

Diathermy and Suction

207. Lipscomb IP, Sihot AK, Keevil CW. Diathermy forceps and pencils: reservoirs for protein and prion contamination? J Hosp Infect. 2006;10:193–4.
208. Robinson AHN, Bentley G, Drew S, Anderson J, Ridgway GL. Suction tip contamination in the ultraclean-air operating theater. Ann R Coll Surg Engl. 1993;75:254–6.
209. Kaye KS, Marchaim D, Smialowicz C, Bentley L. Suction regulators: a potential vector for hospital-acquired pathogens. Infect Control Hosp Epidemiol. 2010;31:772–4.
210. Hodgson ES, Ruis-Frutos C. A care report of contaminated operating theater multipurpose equipment: a potential hazard for healthcare workers. Ann Occup Hyg. 1991;35:341–6.

Bandages

211. Walter CJ, Dumville JC, Sharp CA, Page T. Systematic review and meta-analysis of wound dressings in the prevention of surgical-site infections in surgical wounds healing by primary intention. Br J Surg. 2012;99:1185–94.

Disinfection and Sterilization

212. Southworth PM. Infections and exposures: reported incidents associated with unsuccessful decontamination of reusable surgical instruments. J Hosp Infect. 2014;88:127–31.

213. FDA. Reprocessing medical devices in healthcare settings: Validation methods and labeling. Guidance for industry and Food and Drug Administration staff. US Dep Health Hum Serv, 17 Mar 2015.

214. Pelaez B, Andrade R, et al. In-hospital evaluation: manual vs. automatic endoscope reprocessing. J Hosp Infect. 2010;76(Suppl 1):26. (P08.13). Poster and Abstract

215. Bou R, Aguilar A, Perpinan J, et al. Nosocomial outbreak of *Pseudomonas aeruginosa* infections related to a flexible bronchoscope. J Hosp Infect. 2006;64:129–35.

216. Kelley D, Post M, Pickens K, Langstaff K, Guzman Cottril YES. A *Burkholderia cepacia* surgical pseudo outbreak: what's lurking in your Surgeon's cupboards? In: 48th Annual ICAAC/ IDSA, Washington, DC, 25–28 Oct 2008; K-906.

217. Zimmerman SK, Chroneou A, Cook S et al. *Mycobacterium chelonae* in bronchoscopic LAVAGES: epidemiology of pseudo-outbreak with molecular typing. In: Annual ICAAC/ IDSA, Washington, DC, 25–28 Oct 2008; K-907.

218. Tosh PK, Disbot M, Duffy JM, et al. Outbreak of *Pseudomonas aeruginosa* surgical site infections after arthoscopic procedures: Texas, 2009. Infect Control Hosp Epidemiol. 2011;32:12.

219. Bajolet O, Ciocan D, Vallet C, et al. Gastroscopy-associated transmission of extended-spectrum betalactamase producing *Pseudomonas aeruginosa*. J Hosp Infect. 2013;83:341–3.

220. Promed-mail on 18 May 2015. Antibiotic-resistant *Enterobacteriaceae* – USA ERCP endoscopes, FDA update.

221. Bronowicki JP, Vénard V, Botte C, et al. Patient-to patient transmission of hepatitis C virus during coloscopy. N Engl J Med. 1997;337:237.

222. Christensen M, Haustveit G, Hoborn J, Jepsen OB, Ojajarvi J. Reuse of sterile single use medical devices: a survey of 100 hospitals in Denmark, Finland, Norway and Sweden (January 1998). Zentr Sterile. 1999;7:189–94.

223. Dancer SJ, Stewart M, Coulombe C, Gregori A, Virdi M. Surgical site infections linked to contaminated surgical instruments. J Hosp Infect. 2012;81:231–8.

224. Fernie K, Hamilton S, Somerville RA. Limited efficacy of steam sterilization to inactivate vCJD infectivity. J Hosp Infect. 2012;80:46–51.

225. Ae R, Hamaguchi T, Nakamura Y, et al. Update: dura mater graft-associated Creutzfeldt-Jakob disease—Japan, 1975–2017. Morb Mort Wkly Rep. 2018;67:274–8.

Antibacterial Prophylaxis

226. Zarb P, Coignard B, Griskeviciene J, et al. The European Center for Disease Prevention and Control (ECDC) pilot point prevalence survey of healthcare-associated infection and antimicrobial use. Euro Surveill. 2012;17 pii = 20316

227. Brown J, Thompson M, Sinnya S, et al. Pre-incision antibiotic prophylaxis reduces the incidence of post-caesarean surgical site infection. J Hosp Infect. 2013;83:68–70.

228. Norman BA, Bartsch SM, Duggan ASP, et al. The economics and timing of preoperative antibiotics for orthopedic procedures. J Hosp Infect. 2013;85:297–302.

229. Cakmakci M. Antibiotic stewardship programs and the surgeon's role. J Hosp Infect. 2015;89:264–6.

230. Cusini A, Rampini SK, Bansal V, et al. Different patterns of inappropriate antimicrobial use in surgical and medical units at a tertiary care hospital in Switzerland: a prevalence survey. PLoS One. 2010;5:e14011.

231. Takahashi Y, Takesue K, Nakajima K et al. Implementation of a hospital-wide project for appropriate antimicrobial prophylaxis. ICAAC 2008 K-1353. In: Annual ICAAC/IDSA, Washington, DC, 25–28 Oct 2008; K-907.

232. Bratzler DW, Dellinger EP, Olsen KM, Perl TM, Auwaerter PG, Bolon MK, Fish DN, Napolitano LM, Sawyer RG, Slain D, Steinberg JP, Weinstein RA. Clinical practice guidelines for antimicrobial prophylaxis in surgery. Am J Health Syst Pharm. 2013;70(3):195–283.
233. Øgrey T, Andersen BM. MDR TB operation. In: Handbook of hygiene and infection control for hospitals. Oslo: Ullevaal University Hospital; 2008. p. 546–9.
234. Fu TY, Gent P, Kumar V. Efficacy, efficiency and safety aspects of hydrogen peroxide vapor and hydrogen peroxide aerolized room disinfection systems. J Hosp Infect. 2012;80:199–205.