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# Infection control

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Despite healthcare-associated infections (HAIs) being preventable, the incidence is increasing, leading to morbidity, mortality and increased healthcare costs. The aim of infection control practices is to prevent the transmission of infections between patients and healthcare providers. The earliest published infection control reference in anaesthesia was in 1873.

Infection prevention and control involves every corner of the hospital. From environmental and equipment cleaning and decontamination to infection control precautions when managing infectious patients to the most basic of effective interventions, hand hygiene. There are additional sources of risk in anaesthesia practice; injection and drug administration practices, the insertion of invasive lines, surgical antibiotic prophylaxis and the performance of regional and neuraxial anaesthesia. Anaesthetists should endeavour to be part of the solution and not part of the problem.

Modest changes in our daily infection control practices, such as appropriate and adequate hand hygiene; surface, environmental and equipment decontamination; correct handling and use of drugs, fluids, intravenous administration sets; and meticulous care to sterility and cleanliness when performing invasive procedures can have a significant impact on patient outcomes. Knowledge of local infection prevention and control guidelines is the first step to adherence and building the central pillars to minimise the risk of HAIs.

HAIs increase morbidity, mortality and healthcare expenses. These infections are avoidable and yet the incidence is increasing. Surgical site infections (SSIs) are the most common HAIs with the highest expenditure, increasing hospital stay by up to 11 days.[1] The World Health Organization (WHO)[2] reports that 3.5–12% of hospitalised patients in developed countries will develop an HAI and this is almost doubled in developing countries at 5.7–19.1%. The GlobalSurg Collaborative[3] found the prevalence of SSIs in lower-and-middle income countries (LMICs) to be 2–20 times higher than in higher income countries (HICs). In South Africa, one in seven patients is at risk of developing an HAI.[4]

**Keywords:** healthcare-associated infections, infection control, decontamination, antimicrobial prophylaxis

## What is infection control?

As the Centers for Disease Control (CDC)[5] so aptly states, 'infection control prevents or stops the spread of infections in healthcare settings'.

## The history of infection control in anaesthesia

The earliest published reference to the risk of cross-infection in anaesthesia was in 1873 by Thomas Skinner.[6] His words were definitive: "If there be one evil more crying, more disgusting than another, in the practice of inducing anaesthesia, it is the use of inhalers. … I for one throw out a decided protest against being required to inhale through any instrument which has been used for a similar purpose, by any other man, woman, or child. …after twenty-five years' experience of medicine by inhalation, we remain the merest barbarians, everyone breathing after his neighbour, and through the same instrument." And in such a way, the principles of infection control and prevention (IPC) were born. Almost 150 years after Skinner's tantrum, a plethora of guidelines exist on this issue.

## Definitions

Table I lists several commonly used terms, definitions and classifications in infection prevention and control (IPC).

## Infection control guidelines

Guidelines on IPC or specific aspects of IPC exist from global authorities, e.g. WHO,[10,14-17] the CDC,[18-20] the National Institute for Health and Care Excellence (NICE);[11] colleges, e.g. Royal College of Anaesthetists (RCOA);[21] and locally associated societies, e.g. the South African Society of Anaesthesiologists (SASA),[7,22] the Australian and New Zealand College of Anaesthetists (ANZCA),[23] the Association of Anaesthetists of Great Britain and Ireland (AAGBI).[24]

## How is the anaesthetist involved?

The prevention of the transmission of pathogens from patient-to-patient and between patients and healthcare providers (HCPs) is the main goal of IPC. Anaesthetists, the anaesthesia work area (AWA), our equipment and our possessions have previously all been implicated in the outbreaks of various pathogenic microorganisms. Anaesthetists are part of the healthcare system and are therefore a part of the problem and a part of the solution.

Postoperative patients are at risk of developing a variety of HAIs, including surgical site infections (SSIs), pulmonary and urinary tract infections and intravascular catheter-related infections.[25] The operating theatre (OT) environment and

**Table I:** Definitions and classifications used in IPC[7]

| | |
|---|---|
| Causative agent[7] | Bacteria, viruses, fungi and protozoa that cause infection in patients. |
| Droplet spread[8] | Droplets are heavy particles and disperse within a maximum 2 m radius after coughing and sneezing by an infected patient. Spread can occur during airway instrumentation, e.g. intubation, suctioning and extubation. |
| Airborne or aerosol spread[9] | Aerosols are miniscule respiratory particles (< 5 µm) that remain suspended in the air for prolonged periods, are able to travel beyond 2 m from the source patient and penetrate or circumnavigate standard surgical masks. Spread can occur during airway instrumentation, e.g. intubation, suctioning and extubation. |
| Decontamination[4,7] | A process of removing pathogenic MOs from an object or surface so that it is no longer capable of transmitting infectious particles. It is a combination of the processes of cleaning, disinfection, and/or sterilisation. |
| Cleaning[4,7] | The removal of foreign material, e.g. soil, organic or inorganic material, from objects, accomplished using water and detergents or enzymatic products. Thorough cleaning is required before high-level disinfection or sterilisation as materials that remain on surfaces or instruments/devices interfere with the effectiveness of these processes. Cleaning is considered the most important step in the reprocessing of an instrument/device. |
| Disinfection[4,7] | Disinfection significantly reduces the number of pathogenic MOs on instruments by removing and/or killing them. Disinfection may involve chemical or thermal means. There are three categories of disinfection.<br>• High-level disinfection (HLD) destroys all MOs (mycobacteria, vegetative bacteria, viruses and fungal spores), except large numbers of bacterial spores in a relatively short exposure time. *Examples of disinfectants:* Glutaraldehyde, ortho-phthalaldehyde, hydrogen peroxide and peracetic acid. Used for semi-critical instrument decontamination.<br>• Intermediate-level disinfection (ILD) destroys mycobacteria, vegetative bacteria, most viruses, and most fungi, but does not kill bacterial spores. *Examples of disinfectants:* 70% isopropyl alcohol, iodophor and phenolic compounds, concentrated quaternary ammonium compounds, e.g. hospital cleaners and disinfectants with a tuberculocidal claim. Used for non-critical instruments and environmental surfaces when a tuberculocidal agent is necessary.<br>• Low-level disinfection (LLD) destroys lipid or medium-sized viruses, some fungal spores and vegetative bacteria. *Examples of disinfectants:* Diluted quaternary ammonium compounds, e.g. hospital cleaners and disinfectants without a tuberculocidal claim. Used for non-critical items and surfaces when a tuberculocidal agent is not needed. |
| Sterilisation[4,7] | A process whereby all types of MOs including bacterial endospores are eliminated. Sterilisation must be preceded by cleaning and disinfection. *Examples of methods:* pressurised steam (autoclaves) or low-temperature sterilisation methods, e.g. ethylene oxide and hydrogen peroxide plasma, and hot air ovens. It is used for critical instrument decontamination. |
| Surgical site infection (SSI)[10] | An infection of a surgical incision or organ or space that occurs after surgery and is diagnosed within 30 days of the operation, or within one year if an implanted device was inserted. |
| Altemeier classification of surgical wounds[11] | *Clean:* Skin is intact before surgical incision and surgery does not involve the gastrointestinal (GIT), genitourinary, respiratory or oropharyngeal tracts. SSI risk < 1%.<br>*Clean-contaminated:* Surgical incision enters GIT, genitourinary, respiratory or oropharyngeal tract under controlled conditions and without any contamination. SSI risk 2–5%.<br>*Contaminated:* An operation whereby gross soiling from the GIT occurs, or opening of infected genitourinary or biliary tracts. SSI risk 5–10%.<br>*Dirty:* An operation in which viscera are perforated or acute inflammation with pus is present. SSI risk > 10%. |
| Aerosol-generating procedures (AGPs) | No consensus on which procedures are AGPs.[9] Examples include tracheal intubation, noninvasive ventilation (NIV), high-flow nasal oxygen (HFNO), bronchial suctioning, bronchoscopy, tracheotomy, sputum induction, cardiopulmonary resuscitation (CPR).[9,12,13] The SARS-CoV-2 pandemic has added many procedures to this list by a variety of professional societies[12] without sufficient epidemiological studies: nasogastric tube placement, thoracocentesis, oesophagogastroduodenoscopy, colonoscopy, cardiac catheterisation, exercise tolerance tests, pulmonary function tests, percutaneous gastric tube placement, facial surgery, second stage of labour. |

MOs – microorganisms

drug preparation methods utilised increase the risk of syringe and stopcock contamination with resultant postoperative morbidity and mortality.[26] Potentially pathogenic microorganisms (MOs) can be found on any surface, item, inside drug vials and on our hands. Decontamination of the AWA and hand hygiene are important factors in decreasing nosocomial infections and mortality.[26] IPC in the OT is a team effort. Almost all aspects of anaesthesia are potential sources for MO transmission.

The following aspects of IPC for anaesthetists will be addressed in this article: 1) General principles of infection control, 2) Safe injection and drug administration practices, 3) Hand hygiene, 4) Anaesthetic equipment decontamination, 5) Prevention of central venous line-associated infections, 6) Infection control recommendations for regional anaesthesia, 7) Antimicrobial prophylaxis for surgical procedures, 8) Environmental considerations in IPC, 9) Infection control precautions for the infectious patient (including SARS-CoV-2).

### *General principles of infection control[7]*

Basic starting points include a liaison officer and regular training programmes of local IPC guidelines, including monitoring and audits. Decontamination recommendations from the manufacturers should always be taken into consideration. The risks and benefits, including the cost implications, of single-use devices should be considered carefully. Staff exchanges within an operating theatre and during a procedure should be kept to a minimum. Hand hygiene is one of the most effective techniques for reducing cross-infection.

### *Safe injection and drug administration practices[7]*

Needles and syringes are single use, including single-patient use. These items are contaminated when they come into contact with the patient, the infusion bag or intravascular (IV) administration set. Medication from a single syringe should not

be shared among multiple patients. A used syringe, even with a new clean needle, should never be reinserted into a medication vial or solution bag. Reuse of syringes utilised for infusions or the infusion solution, with or without a non-return valve on the administration set, and/or syringe driver is not permitted. Always recap all needles and syringes after use. Do not place syringes in pockets for transport.

Single-dose (or preservative-free) ampoules and vials are single-dose and single-patient items; these are preferred over multi-dose vials. Do not save unused contents for later use and do not share ampoules/vials between patients. Drugs are to be drawn after hand hygiene and gloving and should be used immediately after being drawn. Before opening glass ampoules or inserting a needle into the rubber stopper of a vial, wipe the neck or stopper with isopropanol 70% (alcohol swab) and allow to dry. Use a new sterile syringe and needle each time the vial is used. Do not leave needles inserted in the rubber stopper as this leaves a direct path for contamination.

Any item in contact with the vascular system is single-patient use. Do not use common source IV solutions for multiple patients, e.g. phenylephrine and saline flush; use single-dose, single-use containers or bags as flush solutions for a single patient. Before injecting into IV ports, use an alcohol swab to clean the port; however, caution should be exercised in neonates who can develop toxicity.

Prepared drugs should be used within one hour from the time of preparation. However, there is insufficient evidence to provide a clear timeframe. It is recommended that most drugs can be used throughout the duration of a case and should then be discarded. Unused propofol should be discarded within six hours of ampoule opening and if used as an infusion, the unused propofol, syringe and administration tubing should be discarded after 6–12 hours.

Extreme care should be used when ointments and lubricating gels that are not single use are available; make sure not to contaminate the containers. Wipe the top of the anaesthetic workstation and cart between patients.

### *Hand hygiene*[7]

Hand washing is one of the most effective and simplest techniques employed in infection control but has poor compliance rates. A plethora of studies over several decades, including a locally conducted study,[27] have found that hands of HCPs are contaminated and can be directly linked to postoperative infection. Gloves do not prevent contamination especially if soiled. Hand hygiene is a constant and continuous practice: before and after direct patient contact, before donning sterile gloves, any contact with body fluids and wound dressings, between tasks and before making contact with a clean site after touching a contaminated site, after touching high-touch surfaces and equipment, after removing gloves, before and after eating and drinking and after using the bathroom.[1]

Plain soap is used for routine standard hand washing. Antimicrobial soap is used for contamination of hands with blood or body fluids. Alcohol-based hand rubs are used only if hands are not visibly soiled; a volume of 15 ml is required with a contact time of one minute and the forearms should also be rubbed. Dispensers should be kept within the AWA. Keep nails short and clean. Do not use nail brushes during hand washing as these can damage skin and increase the risk of contamination and cross-infection. Non-sterile gloves should be used when there is contact with blood, body fluids, mucous membranes, non-intact skin and potentially infectious materials. Gloves should be changed between procedures and tasks, even on the same patient and should never be reused. The concept "bare below the elbow" is a contentious issue with conflicting evidence.

### *Anaesthetic equipment decontamination*[7,28]

Reusable equipment requires the removal and inactivation of MOs. Decontamination involves three steps: cleaning, disinfection and sterilisation. Over 50 years ago, Spaulding[28] developed a classification to determine the level of contamination on equipment and thereby determine the required decontamination technique. Critical items are in contact with sterile body cavities or the vascular system, e.g. surgical instruments, implants, and have a risk of contamination. These items should be sterilised. Airway equipment, e.g. laryngoscope handles and blades meet the criteria for critical instruments. The manufacturer's recommendations should be adhered to. Semi-critical items contact intact mucosa and skin, e.g. endoscopes and respiratory equipment, and carry an intermediate risk of contamination. Most of these items are now considered critical items. Semi-critical items require, as a minimum, high-level disinfection (HDL). All semi-critical items should be packaged and stored to prevent contamination and should not be left unwrapped on work surfaces. Non-critical items contact only intact skin, e.g. blood pressure cuffs and oximetry probes, anaesthesia machine knobs, and carry a low risk of contamination. Cleaning and intermediate- or low-level disinfection (ILD or LLD) and drying, after each patient is adequate.

Single-use/disposable laryngoscope blades are preferred. If disposable medical items are to be reused, informed consent must be obtained from the patient. Reusable laryngoscope blades should undergo HLD as a minimum with a defined instructional protocol, but should preferably be sterilised. Laryngoscope handles should be decontaminated after each use by sterilisation, HLD or ILD. Breathing circuits may be used for up to seven days if a high efficiency heat-and-moisture-exchange filter (HMEF), with a 0.1–0.2 µm pore size, has been used and the circuit has been decontaminated daily as per the manufacturer's recommendations. If the circuit is visibly soiled or has been used on a confirmed or potentially infected patient, it should be discarded. The HMEF should be placed between the airway device (endotracheal tube, supraglottic airway device or tracheostomy tube) and the elbow connector or catheter mount. Oxygen tubing and masks and nasal prongs are single-use items. Bag-mask valve resuscitators should have a HMEF placed between the valve and the mask/airway device. Resuscitators may be used on the same patient but if to be used on a different

patient, the resuscitator must be disassembled and all the parts washed and disinfected and allowed to dry before sterilisation and reassembly.

### *Prevention of central venous line-associated infections*[7]

The subclavian site is preferred over the internal jugular or femoral sites for insertion of central venous catheters (CVCs) to decrease the risk of sepsis and thrombosis. The use of ultrasound-guided cannulation, with a sterile probe sheath, is recommended whenever possible. Insertion of CVCs is a sterile procedure requiring scrubbing and full sterile precautions, including a mask, sterile gown and gloves, skin preparation and sterile draping. A sterile dressing must be used; either a transparent semipermeable polyurethane dressing or gauze can be used. Gauze dressings must be replaced every two days and transparent dressing every seven days, unless visibly soiled or loose, in which case it should be replaced immediately. Placement of arterial catheters requires strict hand hygiene, sterile gloves and site skin preparation. Peripheral venous catheters can be inserted with clean (versus sterile) gloves and skin preparation is required.

Fluid administration sets need to be replaced at 4–7-day intervals. Blood administration sets need to be changed after completion of each unit or every four hours. Administration sets for fat emulsions need to be changed every 24 hours or with each new container.

### *Infection control recommendations for regional anaesthesia*[7,22]

Aseptic techniques should be employed during preparation and performance of central neuraxial blocks, including caudal anaesthesia. Jewellery should be removed and a cap and surgical mask should be worn. Hand hygiene, sterile gown and sterile gloves, as well as sterile draping after skin preparation are required to perform central neuraxial blocks. The solution for skin preparation should be allowed to dry before performing the neuraxial. A sterile occlusive dressing is used to cover the puncture site. If the patient has known or suspected bacteraemia, preprocedural prophylactic antibiotics should be considered.

Peripheral nerve blocks do not require maximal sterile barrier precautions, unless inserting a perineural catheter or in a severely immunocompromised patient. Jewellery should be removed, hand hygiene performed and sterile gloves should be donned. Skin preparation, a sterile drape and a sterile probe sheath are required.

### *Antimicrobial prophylaxis for surgical procedures*[7,10,29]

During any procedure, the surgical wound is likely to be contaminated by resident skin MOs.[25] Limiting the progression of this contamination to clinical infection is determined by a myriad of perioperative factors and events. The CDC,[29] WHO[10,15] and NICE[11] provide guidance on preoperative bathing, hair removal, surgical hand preparation, operating site skin preparation, perioperative oxygenation and maintaining normothermia, normovolaemia and normoglycaemia.

Antimicrobial prophylaxis is indicated in procedures associated with a high rate of infection; clean procedures with the insertion of prosthesis or implants, clean-contaminated and contaminated procedures. Dirty wounds require treatment and this dose should not be omitted perioperatively. The choice of antibiotic is determined by the local pathogens and antibiotic resistance and the activity spectrum against the MOs causing SSI in the specific procedure. Prophylactic antibiotics should have as narrow a spectrum as possible. The optimal timing of the antibiotic dose

**Table II:** Recommended antibiotic prophylaxis for various procedures[7,30]

| Procedure | Recommended prophylaxis |
|---|---|
| Neurosurgery: craniotomy, VPS, spinal surgery<br>Maxillofacial: ORIF mandible, facial plastic surgery | Cefazolin<br>ORIF mandible: add metronidazole or amoxycillin/clavulanate |
| ENT: ear surgery, endoscopic sinus surgery, Ts and As, benign head and neck surgery | NOT RECOMMENDED |
| ENT: clean malignant neck dissection, contaminated/ clean-contaminated | Cefazolin<br>Cefazolin + metronidazole or amoxycillin/clavulanate |
| Thorax: breast cancer +/- implants, open heart surgery, lung resection<br>Upper GIT: oesophageal surgery, stomach and duodenal surgery | Cefazolin |
| Hepatobiliary: bile duct, pancreas, liver | Cefazolin + metronidazole or amoxycillin/clavulanate |
| Lower GIT: appendicectomy, colorectal | Amoxycillin/clavalunate, cefazolin + metronidazole or amoxycillin/ clavulanate |
| Abdomen: hernia repair, diagnostic endoscopy, ERCP | Only for ERCP: cefazolin + metronidazole or amoxycillin/clavulanate |
| Obstetrics and gynaecology: hysterectomy, caesarean section, evacuation of uterus | Cefazolin<br>Nil for evac |
| Urology: endoscopic stone fragmentation, transrectal prostate biopsy, TURP, TURBT, circumcision | Gentamicin, ciprofloxacin<br>Nil: TURBT, circumcision |
| Limb surgery: open fracture, closed fracture, arthroplasty, ortho surgery w/o implant, amputation, vascular surgery | Treat, cefazolin, cefazolin + metronidazole or amoxycillin/clavulanate<br>Nil: no implants |

ORIF – open reduction and internal fixation, Ts and As – tonsillectomy and adenoidectomy, ERCP – endoscopic retrograde cholangiopancreatography, TURP – transurethral resection of prostate, TURBT – transurethral resection of bladder tumour

remains controversial with the latest CDC guidelines[29] considering this an unresolved issue; most guidelines recommend dosing within 30–60 minutes of incision, but the WHO[10] states within 120 minutes and SASA[7] recommends within 30 minutes. Cefazolin is recommended for most surgical procedures.[7,10,30] Vancomycin can be used as an alternative for penicillin/cephalosporin allergies but needs to be given as an infusion. A second dose is required if the procedure duration exceeds two half-lives of the drug. The duration of prophylaxis is for the duration of the procedure but there are recommendations to continue for 24 hours, especially if prosthesis or implants are used. However, antimicrobial prophylaxis should not be continued beyond that. A short summary of recommended prophylactic antibiotics is shown in Table II. A detailed list can be found in Appendix A of the SASA IPC guidelines.[7]

### *Environmental considerations in infection prevention and control[7]*

OT doors should remain closed. A central humidity ventilation and air-conditioning (HVAC) system is required in every OT complex, with 15–20 air changes per hour. Air should move from the ceiling to the floor and air exhausts located near the floor should not be obstructed. Laminar airflow ventilation has no benefit over conventional ventilation in reducing the incidence of SSI in hip and knee arthroplasty.[15] The ambient temperature of the OT should be 18–24 °C with humidity levels of 30–60%.

Surface cleaning with detergents is required. Work areas should be organised into clean and dirty areas and cleaned with disinfectant wipes during cases. Visibly soiled surfaces, especially with blood and body fluids, should be cleaned immediately and disinfected. OTs should be cleaned and disinfected between cases. Non-critical items should all be decontaminated. Terminal cleaning should take place once every 24 hours. There is increased usage of ultraviolet germicidal irradiation (UVGI) for airborne bacterial and viral infections, but no effect on fungal spores.

Scrubs that are soiled or potentially contaminated with infectious material should be changed. A waterproof apron should be worn under a surgical gown during procedures at high risk of contamination. Home laundering of scrubs is not recommended. A surgical mask covering all facial hair, the nose and mouth should be worn when sterile packs are open and for the duration of the procedure. Theatre caps should cover all hair. Dedicated OT shoes should be worn; shoe covers do not protect against SSIs.

### *Infection control precautions for the infectious patient (including SARS-CoV-2)[7]*

Infectious patients, especially airborne diseases such as tuberculosis (TB), requiring non-emergent surgery should be postponed until such time that they have been treated for a sufficient period to decrease the risk of transmission. Infectious patients should be isolated. Surgical lists containing an infectious patient require careful ordering of cases with the infected patient placed last on the list to allow for maximum air exchanges prior to OT reuse.

The level of precautions and personal protective equipment (PPE) required will depend on the infectivity of the MO and the mode of transmission. Droplet precautions constitute the wearing of a standard face mask by the infectious patient and standard PPE to be worn by HCPs. Airborne precautions also require a face mask to be worn by infectious patients, standard PPE, impermeable gown, eye protection and respiratory protection, e.g. N95 or higher respirator, are required for HCPs. Hand hygiene should be performed throughout donning and doffing procedures. During doffing, extreme care must be taken to avoid self-contamination.

The SARS-CoV-2 pandemic has created a heightened awareness of IPC. Several societies, organisations and directives have provided guidelines for PPE to be used when treating patients infected with SARS-CoV-2. Respiratory protection should include an N95/FFP2/FFP3 respirator, especially during AGPs. Disposable gowns, eye protection and double gloving are some of the other precautions advised[8,21,31]

## Conclusion

With even modest changes in infection control practices, such as hand hygiene, surface and environmental cleaning and appropriate handling of syringes, drugs, intravenous lines, administration sets and stopcocks, a significant difference can be made. Small improvements in our daily behaviours can go a long way for our patient outcomes. Knowledge of these guidelines and adherence to the recommendations provided are the central pillars at minimising the risk of HAIs.


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