Antisepsis, asepsis and skin preparation

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Abstract
Infection is still one of the most frequent causes of morbidity and mortality following surgery. In the era of multi-resistant organisms it is essential that all surgeons have a clear understanding of the techniques used to prevent surgical infections. This article outlines the factors which contribute to infections in surgical practice and details of some of the techniques employed to decrease their incidence.

Antiseptic and aseptic techniques play a key role in the reduction of surgical infection. Patient, surgeon and environmental factors all contribute to surgical-site infections (SSIs).

Keywords antisepsis; asepsis; sterilization; wound infection

Introduction
The terms antisepsis and asepsis are used widely but misunderstood frequently. Antisepsis derived from the Greek “against putrefaction” and its use in modern medicine is most frequently linked to the work of Lister. It refers to the use of solutions for disinfection. Asepsis is defined as the absence of infectious organisms. Aseptic techniques are those aimed at the elimination of all infectious micro-organisms during procedures.

Historical perspective
In the late eighteenth and early nineteenth centuries operative outcomes were poor. Wounds were allowed to heal by secondary intention and morbidity and mortality were associated largely with surgical-site infections (SSIs). A number of discoveries resulted in a reduction in postoperative infection and, with the advent of anaesthetic techniques, allowed a period of rapid progress in surgical practice.

In the mid-nineteenth century Oliver Wendell Holmes and Ignaz Semmelweis observed high mortality rates in women hospitalized with puerperal fever. Semmelweis noted it was especially high in women treated by students who had come straight from the mortuary and postulated that infection was being transmitted directly. The instigation of a strict hand-washing regime resulted in a decrease in mortality from 11.4% in 1846 to 1.3% in 1848. Louis Pasteur’s discovery that bacteria were the cause of ‘spoilt wine’ prompted the work of Joseph Lister who applied Pasteur’s ideas to human disease. Lister’s carbolic spray and wound preparation reduced infection rates from 45% to 15%. In 1889 Halstead at Johns Hopkins Hospital noted that his theatre nurse was allergic to the corrosive hand preparation and asked the Goodyear Rubber Company to manufacture gloves for her to wear. Soon after this the use of gloves and gowns became standard practice; first to protect the patient from the surgeon (in aseptic ritual), but later to protect the surgeon from risk of blood-borne viruses from the patient.

The next advance in aseptic technique came with the discovery of antimicrobial agents and the use of prophylactic antibiotics. The use of positive pressure laminar airflow systems reduced infection rates from surgical procedures further.

Asepsis and antisepsis
The principles of antisepsis and asepsis are used to decrease the rate of SSIs. Postoperative wound infections have a considerable morbidity and mortality that lead to increased costs. The risk of postoperative infection can be estimated by considering the type of surgical wound (Table 1). Any wound with purulent discharge and erythema should be considered to be infected. Microbiological confirmation of the organism responsible should be sought to direct therapy, but the diagnosis is clinical. The source of infection is either exogenous (transmitted from another source) or endogenous (caused by the person’s own microbial flora). Endogenous flora can be classified as transient (isolated following exposure to a new microbial environment) or resident (isolated consistently from the person).

Both antiseptic and aseptic procedures are used to reduce wound infection. Factors contributing to asepsis in theatre can be broadly considered under the following headings:

- prevention on the surgical ward
- preparation of the patient
- preparation of the surgical instruments
- preparation of the surgeon
- preparation of the operating theatre
- antibiotic prophylaxis
- surgical technique.

Prevention on the surgical ward
The recognition of the importance of healthcare-associated infections (HCAI) and cross-contamination between patients from healthcare workers has resulted in a dramatic change in practice in recent years. Measures to improve hospital environmental hygiene and hand washing have been the main focus. Hand hygiene has been highlighted as an important factor in reducing infection and the national ‘cleansyourhands® Campaign’ led by the National Patient Safety Agency has helped raise awareness with both the public and the profession. Hands should be decontaminated immediately before and after every episode of direct patient contact. For convenience alcohol-based hand rubs are acceptable but visibly soiled hands should be washed with soap and water. After several applications of hand rub, hands should also be washed. Further information can be found in the Epic2 Guidelines.
The patient’s own bacterial flora is the principle source of infection in surgical wounds. The preparation of the patient begins with the preoperative assessment. Any focal source of infection should be treated prior to surgery and swabs taken for methicillin-resistant Staphylococcus aureus (MRSA). Eradication (suppression) therapy should be given as necessary. The length of preoperative hospital stay should be kept to a minimum (preferably same-day admission) as a significant increase in wound infection rates is seen in those patients with a long preoperative stay. A Cochrane review has shown that the use of preoperative showering with chlorhexidine has no clear evidence of benefit to patients in the prevention of SSI.

Preparation of the patient
The patient should be transferred to the theatre wearing a clean gown in a clean bed or trolley. The best time to perform preoperative shaving, if at all deemed necessary, is immediately prior to the surgeon scrubbing and should be done by a suitable, trained person to avoid skin abrasions. The use of electric clippers and depliation cream has been advocated but has cost implications. Shaving on the wards prior to transfer to theatre encourages colonization of skin abrasions with bacteria, increasing wound infection rates. There is level I evidence that clipping hair shortly before surgery using a sterile, disposable head relates to a low rate of SSI and this has been advocated in a recent NICE clinical guideline.

Preoperative skin preparation with iodophors (povidone iodine; betadine) and chlorhexidine is standard practice. The iodophors are highly complexed iodine compounds which have a sustained release, are non-staining and stable. These complexes are less irritant than iodine solutions with a wide spectrum of antimicrobial activity. They should be applied using a sponge and from the area of incision outwards. The most heavily contaminated areas should be treated after clean areas. The contaminated sponge should be discarded immediately. Pooling beneath the patient should be avoided in order to prevent diathermy burns. If a stoma is present it should be treated prior to skin preparation and covered with a sterile swab. The solutions should be allowed to dry.

Reusable or disposable surgical drapes are used to isolate the prepared operative site. Reusable drapes are either chemically treated cotton or cotton-polyester. They decrease transmission from the skin below and protect against abrasion. They can be secured around the operative site with non-penetrating clips. Disposable drapes are synthetic and offer a greater resistance to the penetration of microbes but can be affected by volatile liquids and punctured by instruments. The use of disposable drapes is particularly important in operations where prosthetic implants are used. Adhesive operative drapes do not decrease the incidence of wound infections, unless they are impregnated with an antimicrobial, such as povidone iodine, but do allow for the securing of drapes around a site especially in areas of difficult anatomy. Only the area of the drape above the table can be considered sterile.

Preparation of the surgical instruments
Surgical instruments used during operative procedures are prepared by cleaning, disinfection and sterilization (Table 2).

Cleaning: Removal of organic debris must be undertaken prior to disinfection or sterilization to prevent the transmission of infection. It is undertaken using detergents or by simple washing but is vital.

Disinfection: This is usually undertaken using automated washing processes. These are outlined in Table 3. Disinfectants are chemicals employed to disinfect inanimate objects. They are classified according to their activity into high-, intermediate- and low-level disinfectants. High-level disinfectants destroy all microbes except bacterial spores. Intermediate level disinfectants are active against all microbes except bacterial spores. Low-level disinfectants are active only against some...
viruses and bacteria. Certain viruses and prions are not affected by disinfectants.

Sterilization: This process can be undertaken by:
- steam
- hot air
- ethylene oxide
- steam and formaldehyde
- irradiation.

Steam: this method allows for the eradication of viruses, bacteria including Mycobacterium tuberculosis and heat-resistant spores. An autoclave is required and this should be operated and maintained only by trained personnel. A centrally placed autoclave within the central sterile supply department (CSSD) is used for wrapped instruments whilst smaller autoclaves within the operating theatre can be used for unwrapped single items. All instruments are cleaned prior to sterilization. A combination of temperature, pressure and hold-time is responsible for the elimination of microbes. The steam used in sterilization should contain less than 3% water to be effective; ideally, a steam quality of 100% is required. The lower temperatures required to destroy microbes in the presence of steam is accounted for by the increased rate of denaturation of proteins in the presence of moisture. The most common cycles used are:
- 134 °C (at a pressure of 2 kPa) for a hold-time of 3 min
- 121 °C (at a pressure of 1 kPa) for a hold-time of 15 min.

The adequacy of sterilization is determined using Bowie–Dick test (a test of adequacy of vacuum initiation), Browne’s tubes or impregnated tapes and markers. The purpose of indicator tapes is to differentiate externally that an item has been sterilized. It is the responsibility of the person unpacking the instruments to check these. There should be a proactive quality control protocol within the CSSD with records of cycle lengths, pressures and hold-times.

Sterilization by hot air: this is an inefficient method of sterilization. However, all micro-organisms are killed by dry heat of 160 °C for a hold time of 2 h. This method is advantageous when treating non-aqueous liquids, air tight containers and non-stainless steel instruments with fine cutting edges where corrosion is to be avoided (e.g. ophthalmic instruments). It cannot be used on aqueous fluids or in materials which are liable to heat damage (plastics and rubber).

Sterilization by ethylene oxide: this method is used largely by industry and relies on the broad-spectrum action of the non-corrosive gas. It is used for heat-sensitive items such as endoscopes and electrical equipment. It is not used for ventilatory equipment or items soiled with organic matter. The gas itself is toxic, carcinogenic and flammable.

Sterilization by low-temperature steam and formaldehyde: This method uses dry saturated steam and formaldehyde at 73 °C. It has a cidal action against bacteria, spores and most viruses. The lower temperatures allow for its use with heat-sensitive items or those items with integral plastic parts. It cannot be used on soiled components as fixed protein deposits are produced and it is not used with endoscopes as they have fine lumens which may trap formaldehyde.

Sterilization by irradiation: this is an industrial process used to sterilize batches of single-use products such as sutures, syringes and catheters. Delivery of gamma rays or accelerated electrons at a dose of 25 kGy is accepted as giving adequate sterilization.

Preparation of the surgeon
Hand washing: Preoperative washing of hands is aimed at decreasing the number of normal and transient flora on the hands. It should also inhibit the growth of bacteria under the glove during the procedure. Prior to entering the operating room all jewellery should be removed. Nails should be kept short and free of nail polish with no false nails. A single-use disposable nail brush should be used only on the fingernails but not the skin to avoid micro-trauma which increases surface bacterial numbers. Studies have demonstrated no difference in infection rates between a scrub time of 3 min and 5 min. The person scrubbing should wash from the fingertips to the elbows (Table 4). Chlorhexidine gluconate 4% (Hibiscrub) with soap is an ideal agent with a prolonged effect whereas povidone–iodine (Betadine) soap solutions have a shorter duration of action, but both have a wide spectrum of activity. A number of alcohol-based hand rubs have been licensed for use preoperatively. The World Health Organisation (WHO) suggests that if alcohol-based hand rubs are used, a prior wash with non-medicated soap should be used on entering the operating room followed by at least three applications of hand rub for a period of 3–5 min. The alcohol-based hand rubs have been shown to reduce resident skin flora levels rapidly and the reduction is so great that it takes up to 6 h to return to baseline. There are clear advantages, therefore, for the use of alcohol-based hand rubs but their use is not yet widespread.
Amended WHO procedural steps for surgical ‘scrub’

Start timing. ‘Scrub’ each side of each finger, between the fingers, and the back and front of the hand for 2 min. Use a brush only (or ‘orange stick’) on the nails.

Proceed to ‘scrub’ the arms, keeping the hand higher than the arm at all times. This helps to avoid recontamination of the hand.

Wash each side of the arm from wrist to the elbow for 1 min.

Repeat the process on the other hand and arm, keeping hands above elbows at all times. If the hand touches anything at any time, the ‘scrub’ should be lengthened by 1 min.

Rinse hands and arms passing them through the water in one direction only, from fingertips to elbow.

Keep hands above elbows.

At all times try to prevent splashing of water onto surgical attire.

Hands and arms should be dried using a sterile towel and aseptic technique.

Table 4

Gloves: the use of surgical gloves forms an integral part of asepsis and universal precautions. There is little evidence to suggest that glove puncture increases surgical wound infection, which suggests that hand washing is of great importance. Most surgical gloves are made of latex and are disposable; various alternatives are available to those with allergies. Studies suggest that an average of 18% (range: 5–82%) of gloves are punctured and 90% of these occur in operations lasting longer than 2 h. Approximately 40,000 organisms can pass through a glove pin hole in a 20 min period. The most commonly punctured finger is the left index finger. Double gloving affords a greater protection to the surgeon, but at the cost of decreased dexterity and comfort. Even with double gloving puncture is still observed in 4% of cases after the procedure.

Masks, visors, hair cover: masks have traditionally been thought to reduce bacterial contamination of wounds but in modern practice they are best regarded as protective to the surgeon. Approximately 36 bacteria are emitted per 100 spoken words. Masks are usually only effective for short periods. Their filtering qualities decrease rapidly as they become increasingly moist. Evidence now suggests that there is no increase in SSIs after operations carried out by surgeons without masks, except in the presence of a respiratory tract infection where bacterial numbers increase in the oropharynx. The use of a mask has been shown to decrease bacterial numbers at the operative site in prosthetic operations but no correlation has been shown with SSI. Masks should now be worn as part of universal precautions to prevent the possible spread of blood-borne viruses. Their use is especially important in operations in which fine sprays are produced. A number of masks are now fitted with visors which give added protection. Hair should be covered in its entirety. It is not a common source of infection but the scalp can carry *Staphylococcus aureus*.

Gowns: the use of theatre scrubs decreases the possible bacterial contamination. Wearing scrubs decreases the number of desquamated skin flakes. Cotton has a pore size of 100 μm whilst skin squames are 5–60 μm. Therefore, contamination is only marginally decreased. For optimal decrease of these particles elasticated wristlets should be used. The most important aspect of a gown is its ability to be moisture impermeable as this decreases the transmission of bacteria from the skin surface. It is advised that for short duration (less than 2 h) and minimal blood loss (less than 100 ml) a 1 ply gown be used. For longer procedures lasting 2–4 h or with 100–500 ml of blood loss or operations in the chest or abdominal cavity a 2 ply reinforced gown should be used. For even longer operations an impervious gown should be used. Gowns are considered sterile from the shoulders down to the level of the sterile field and from just below the elbows.

Preparation of the operating theatre

Design: the theatres should be close to Accident and Emergency Department, with easy access to ITU and Radiology. Ideally all should be on the same level. The theatre should have a double door entrance to the anaesthetic room with a double door exit to the corridor. A dirty area should be present. A single entrance should connect the room to the scrub area. A clean preparation area and store should also be connected. The temperature should be regulated between 19 and 22 °C and humidity between 45 and 55%. The anaesthetic room should be well stocked with working suction and a cardiac arrest trolley. The walls and floor should be made of a robust material which is continuous and easy to clean. Any joins should be amenable to cleaning. Adjustable lighting should be present.

One of the key factors in postoperative wound infections is the number of bacteria in the theatre air. To reduce these numbers air should be filtered ideally through a 5 mm filter and cycled through theatre between 20 and 25 times an hour. Air should flow across the operating table and be exhausted from the theatre at floor level. The theatre should be maintained at a positive pressure compared to adjacent corridors. In orthopaedics the use of ultra-clean air systems (laminar flow) is of paramount importance in reducing postoperative infection. In these air is filtered through high-efficiency filters and directed down over the patient to prevent recirculation of air. These systems allow a two- to four-fold decrease in postoperative infection. Turbulence is further decreased by limiting the number and movement of personnel in theatre and ensuring doors are closed.

Prophylactic antibiotics

Prophylactic antibiotics should be given in any instance where contamination of a wound may be anticipated. They are not advocated in clean procedures except for the placement of a prosthesis where infection would be disastrous. The antibiotic
chosen should be effective against the likely infecting pathogens. Intravenous dosing is advised to ensure good tissue penetration.

Antibiotics are usually given one hour before the procedure or 15 min prior to the induction of anaesthesia or inflation of tourniquets. A second dose should be administered if a procedure lasts more than 4 h. No evidence exists to support the use of long-term prophylactic antibiotics and it is generally considered that no benefit is conferred after 24 h, even after prosthetic surgery unless there is excessive blood loss or excessive contamination.

**Surgical technique**

Poor tissue handling and inadequate haemostasis result in devitalization of tissues and haematoma formation. Necrotic tissue and haematomas provide a medium for bacterial growth and increase wound infection rates. Surgical drains should be used judicially as they result in increased wound infection rates.

**Summary**

The prevention of wound infection is multi factorial. It is only through an understanding of antiseptic and aseptic techniques that reduction in wound infection rates can be achieved.

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**FURTHER READING**


