14 Hospital hygiene and infection control

14.1 Objective

Management of health-care waste is an integral part of hospital hygiene and infection control. Health-care waste should be considered as a reservoir of pathogenic microorganisms, which can cause contamination and give rise to infection. If waste is inadequately managed, these microorganisms can be transmitted by direct contact, in the air, or by a variety of vectors. Infectious waste contributes in this way to the risk of nosocomial infections, putting the health of hospital personnel, and patients, at risk. The practices described in Chapters 6 to 10 of this handbook for the proper management of health-care waste should therefore be strictly followed as part of a comprehensive and systematic approach to hospital hygiene and infection control.

This chapter outlines the basic principles of prevention and control of the infections that may be acquired in health-care facilities (but does not address other aspects of hospital hygiene and safety such as pressure sores and the risk of falls). It should be stressed here that other environmental health considerations, such as adequate water-supply and sanitation facilities for patients, visitors, and health-care staff, are of prime importance.

14.2 Epidemiology of nosocomial infections

Nosocomial infections—known also as hospital-acquired infections, hospital-associated infections, and hospital infections—are infections that are not present in the patient at the time of admission to hospital but develop during the course of the stay in hospital. There are two forms:

- *Endogenous infection, self-infection, or auto-infection.* The causative agent of the infection is present in the patient at the time of admission to hospital but there are no signs of infection. The infection develops during the stay in hospital as a result of the patient's altered resistance.
- *Cross-contamination followed by cross-infection.* During the stay in hospital the patient comes into contact with new infective agents, becomes contaminated, and subsequently develops an infection.

While there is no clinically significant difference between the endogenous self-infection and the exogenous cross-infection, the distinction is important from the standpoint of epidemiology and prevention.

Healthy people are naturally contaminated. Faeces contain about 10^{13} bacteria per gram, and the number of microorganisms on skin varies between 100 and 10 000 per cm^2. Many species of microorganisms live on mucous membranes where they form a normal flora. None of these tissues, however, is infected. Microorganisms that penetrate the skin or the mucous membrane barrier reach subcutaneous tissue, muscles, bones, and body cavities (e.g. peritoneal cavity, pleural cavity, bladder), which are normally sterile (i.e. contain no detectable organisms). If a general or local reaction to this contamination develops, with clinical symptoms, there is an infection.

14.2.1 The transition from contamination to infection

Whether or not a tissue will develop an infection after contamination depends upon the interaction between the contaminating organisms and the host.

Healthy individuals have a normal *general resistance* to infection. Patients with underlying disease, newborn babies, and the elderly have less resistance and will probably develop an infection after contamination. Health-care workers are thus less likely to become infected than patients.

Local resistance of the tissue to infection also plays an important role: the skin and the mucous membranes act as barriers in contact with the environment. Infection may follow when these barriers are breached. Local resistance may also be overcome by the long-term presence of an irritant, such as a cannula or catheter; the likelihood of infection increases daily in a patient with an indwelling catheter.

The most important determinants of infection, however, are the nature and number of the contaminating organisms. Microorganisms range from the completely innocuous to the extremely pathogenic: the former will never cause an infection, even in immunocompromised individuals, while the latter will cause an infection in any case of contamination. A classification of conventional, conditional, and opportunistic pathogens is given in Box 14.1.

When only a few organisms are present on or in a tissue, an infection will not necessarily develop. However, when a critical number is exceeded, it is very likely that the tissue will become infected. For every type of microorganism, the *minimal infective dose* can be determined; this is the lowest number of bacteria, viruses, or fungi that cause the first clinical signs of infection in a healthy individual. For most causative agents of nosocomial infections, the minimal infective dose is relatively high. For *Klebsiella* and *Serratia* spp. and other Enterobacteriaceae, for example, it is more than 100 000, but for hepatitis B virus it is less than 10.

14.2.2 The sources of infection

In a health-care facility, the sources of infection, and of the preceding contamination, may be the personnel, the patients, or the inanimate environment.

The hospital environment can be contaminated with pathogens. *Salmonella* or *Shigella* spp., *Escherichia coli* O157 : H7, or other pathogens may be present in the food and cause an outbreak of disease just as they can in a community outside the hospital. If the water distribution system breaks down, waterborne infections may develop. In more sophisticated premises the water cooling system of air conditioning equipment may

Box 14.1 Classification of pathogenic germs[1]

Conventional pathogens
Cause disease in healthy individuals in the absence of specific immunity.
Examples:
Staphylococcus aureus, *Streptococcus pyogenes*, *Salmonella* spp., *Shigella* spp., *Corynebacterium diphtheriae*, *Mycobacterium tuberculosis*, *Bordetella pertussis*, hepatitis A and B viruses, rubella virus, rotaviruses, human immunodeficiency virus (HIV).

Conditional pathogens
Cause disease, other than trivial local infections, only in persons with reduced resistance to infection (including newborn infants) or when implanted directly into tissue or a normally sterile body area.
Examples:
Streptococcus agalactiae, *Enterococcus* spp., *Clostridium tetani*, *Escherichia coli*, *Klebsiella* spp., *Serratia marcescens*, *Acinetobacter baumanii*, *Pseudomonas aeruginosa*, *Candida* spp.

Opportunistic pathogens
Cause generalized disease, but only in patients with profoundly diminished resistance to infection.
Examples:
atypical mycobacteria, *Nocardia asteroides*, *Pneumocystis carinii.*

[1]Source: Parker (1978).

become contaminated with *Legionella pneumophilia*, causing Legionnaires' disease in susceptible patients. Pharmaceuticals may become contaminated during production or preparation; an outbreak of infection with, for example, *Pseudomonas aeruginosa*, *Burkholderia cepacia*, or *Serratia marcescens*, may occur as a consequence. In all these examples, it may be possible to isolate the same causative agent in several patients, which would suggest a common source. All possible measures should be taken to prevent the recurrence of such incidents.

The source of an outbreak of nosocomial infection may also be a health worker who is infected or colonized (a carrier). The symptoms of frank infection will make the potential of transmission apparent to the health worker and/or to managerial staff, and infected personnel are usually dismissed from patient care duties. A symptomless carrier, however, is contaminated or colonized by potentially pathogenic organisms but does not develop any infection. A typical example is *Staphylococcus aureus*, which may be carried in the nasal passages of 30–60% of personnel. Faecal carriage of enteropathogens such as *Salmonella* spp. also occurs frequently, but the prevalence varies according to the region. Other conventional pathogens that can be found in symptomless carriers include *Streptococcus pyogenes*, *Corynebacterium diphtheriae*, *Neisseria meningitidis*, hepatitis B virus, and cytomegalovirus. Contamination of patients by carriers can give rise to an outbreak of disease. Careful investigation and isolation of the same organisms from a cluster of patients should reveal the cause of the outbreak.

The source of most hospital epidemics is infected patients, i.e. patients contaminated with pathogenic microorganisms. These microorganisms are often released into the environment in very high numbers, exceeding the minimal infective dose, and contaminate other patients who subsequently develop hospital-acquired infections.

14.2.3 The routes of transmission

Microorganisms can be transmitted from their source to a new host through direct or indirect contact, in the air, or by vectors.

Vector-borne transmission is typical of countries in which insects, arthropods, and other parasites are widespread. These become contaminated by contact with excreta or secretions from an infected patient and transmit the infective organisms mechanically to other patients.

Airborne transmission occurs only with microorganisms that are dispersed into the air and that are characterized by a low minimal infective dose. Only a few bacteria and viruses are present in expired air, and these are dispersed in large numbers only as a result of sneezing or coughing.

Direct contact between patients does not usually occur in health-care facilities, but an infected health-care worker can touch a patient and directly transmit a large number of microorganisms to the new host.

The most frequent route of transmission, however, is indirect contact. The infected patient touches—and contaminates—an object, an instrument, or a surface. Subsequent contact between that item and another patient is likely to contaminate the second individual who may then develop an infection.

During general care and/or medical treatment, the hands of health-care workers often come into close contact with patients. The hands of the clinical personnel are thus the most frequent vehicles for nosocomial infections. Transmission by this route is much more common than vector-borne or airborne transmission or other forms of direct or indirect contact.

The spread of nosocomial infections is summarized and illustrated in Fig. 14.1.

14.3 The prevention of nosocomial infection

14.3.1 Principles

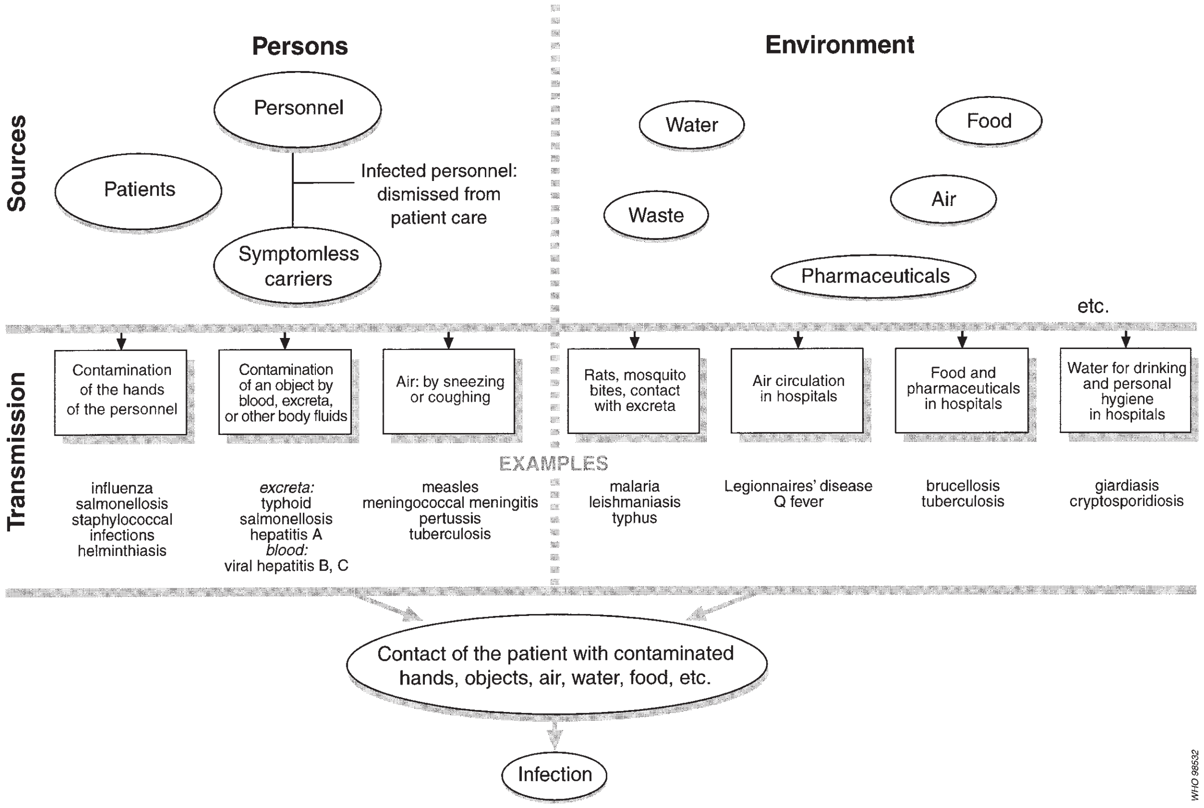
Two basic principles govern the main measures that should be taken in order to prevent the spread of nosocomial infections in health-care facilities:

- separate the infection source from the rest of the hospital;
- cut off any route of transmission.

The separation of the source has to be interpreted in a broad sense. It includes not only the isolation of infected patients but also all "aseptic techniques"—the measures that are intended to act as a barrier between

Fig. 14.1 *The spread of nosocomial infections*

Notes: Many of the listed diseases can spread by more than one route. The figure shows only a few of the many diseases that may be transmitted within a hospital setting.



infected or potentially contaminated tissue and the environment, including other patients and personnel.

In recent years, increasing attention has been paid to the protection of the personnel, in particular against the transmission of bloodborne infections, e.g. AIDS and viral hepatitis B and C. Preventive measures are known as “universal” or “standard” precautions.

It is impossible to avoid all contact with infected tissue or potentially contaminated body fluids, excreta, and secretions. Even when they are not touched with the bare hands, they may come in contact with instruments, containers, linen, etc. **All objects that come in contact with patients should be considered as potentially contaminated.** If an object is disposable, it should be discarded as waste. If it is reusable, transmission of infective agents must be prevented by cleaning, disinfection, or sterilization.

Despite the continuing concern of hospital managers and all attempts at improvement, many health-care establishments are unable to achieve adequate levels of prevention, particularly in developing countries. An international survey of the prevalence of hospital-acquired infections was conducted in 14 countries in different regions of the world between 1983 and 1985. The results of this survey, which covered 47 hospitals of size ranging from 227 to 1502 beds (mean 614) showed a wide range of nosocomial infections, with prevalence varying from 3% to 21% (mean 8.4%) in individual hospitals. This work emphasizes the importance of the public health problem.

14.3.2 *Isolation of infected patients and standard precautions*

The first essential measure in preventing the spread of nosocomial infections is *isolation* of infected patients. The term isolation covers a broad domain of measures. The strictest form of isolation is applied in case of very infectious diseases (e.g. haemorrhagic fever, diphtheria); less stringent precautions can be taken in case of diseases such as tuberculosis, other respiratory infections, and infectious diarrhoea. Isolation of any degree is expensive, labour-intensive, and usually inconvenient or uncomfortable for both patients and health-care personnel; its implementation should therefore be adapted to the severity of the disease and to the causative agent. Disease-specific precautions should include details of all the measures (private room, wearing of masks or gowns, etc.) to be taken in the case of a specific disease caused by a defined organism.

The so-called standard precautions, summarized in Box 14.2, essentially protect health-care workers from bloodborne infections caused by human immunodeficiency virus and hepatitis B and C viruses.

14.3.3 *Cleaning*

One of the most basic measures for the maintenance of hygiene, and one that is particularly important in the hospital environment, is cleaning. The principal aim of cleaning is to remove visible dirt. It is essentially a mechanical process: the dirt is dissolved by water, diluted until it is no longer visible, and rinsed off. Soaps and detergents act as solubility-promoting agents. The microbiological effect of cleaning is also essentially mechanical: bacteria and other microorganisms are suspended in the cleaning fluid and removed from the surface. The efficacy of the cleaning process depends completely on this mechanical action, since neither soap nor detergents possess any antimicrobial activity. Thorough cleaning will remove more than 90% of microorganisms. However, careless and superficial cleaning is much less effective; it is even possible that it has a negative effect, by dispersing the microorganisms over a greater surface and increasing the chance that they may contaminate other objects. Cleaning has therefore to be carried out in a standardized manner or, better, by automated means that will guarantee an adequate level of cleanliness.

Diluting and removing the dirt also removes the breeding-ground or culture medium for bacteria and fungi. Most non-sporulating bacteria and viruses survive only when they are protected by dirt or a film of organic matter; otherwise they dry out and die. Non-sporulating bacteria are unlikely to survive on clean surfaces.

The effectiveness of disinfection and sterilization is increased by prior or simultaneous cleaning.

14.3.4 *Sterilization*

Self-evidently, an object should be sterile, i.e. free of microorganisms, after sterilization. However, sterilization is never absolute; by definition,

Box 14.2 Essentials of the standard precautions to be used in the care of all patients

A. **Hand washing**
- Wash hands after touching blood, secretions, excretions and contaminated items, whether or not gloves are worn. Wash hands immediately after gloves are removed, between patient contacts.
- Use a plain soap for routine hand washing.
- Use an antimicrobial agent for specific circumstances.

B. **Gloves**
- Wear gloves when touching blood, body fluids, secretions, excretions, and contaminated items. Put on clean gloves just before touching mucous membranes and non-intact skin.

C. **Mask, eye protection, face shield**
- Wear a mask and eye protection or a face shield during procedures and patient-care activities that are likely to generate splashes or sprays of blood, body fluids, secretions, and excretions.

D. **Gown**
- Wear a gown during procedures and patient-care activities that are likely to generate splashes or sprays of blood, body fluids, secretions, or excretions.

E. **Patient-care equipment**
- Ensure that reusable equipment is not used for the care of another patient until it has been cleaned and reprocessed appropriately.

F. **Environmental control**
- Ensure that the hospital has adequate procedures for the routine care, cleaning, and disinfection of environmental surfaces.

G. **Linen**
- Handle used linen, soiled with blood, body fluids, secretions, and excretions in a manner that prevents skin and mucous membrane exposures, and that avoids transfer of microorganisms to other patients and environments.

H. **Occupational health and bloodborne pathogens**
- Take care to prevent injuries when using needles, scalpels, and other sharp instruments or devices.
- Use ventilation devices as an alternative to mouth-to-mouth resuscitation methods.

I. **Place of care of the patient**
- Place a patient who contaminates the environment or who does not assist in maintaining appropriate hygiene in an isolated (or separate) room.

it effects a reduction in the number of microorganisms by a factor of more than 10^6 (i.e. more than 99.9999% are killed). Standard reference works, such as pharmacopoeias, often state that no more than one out of 1 000 000 sterilized items may still bear microorganisms. It is therefore important to minimize the level of contamination of the material to be sterilized. This is done by sterilizing only objects that are clean (free of visible dirt) and applying the principles of good manufacturing practice.

Sterilization can be achieved by both physical and chemical means. Physical methods are based on the action of heat (autoclaving, dry thermal or wet thermal sterilization), on irradiation (γ-irradiation), or on mechanical separation by filtration. Chemical means include gas sterilization with ethylene oxide or other gases, and immersion in a disinfectant solution with sterilizing properties (e.g. glutaraldehyde).

14.3.5 Disinfection

The term disinfection is difficult to define, as the activity of a disinfectant process can vary widely. The guidelines of the Centers for Disease Control (Garner & Favero, 1986) allow the following distinction to be made:

- *High-level disinfection*: can be expected to destroy all microorganisms, with the exception of large numbers of bacterial spores.
- *Intermediate disinfection*: inactivates *Mycobacterium tuberculosis*, vegetative bacteria, most viruses, and most fungi; does not necessarily kill bacterial spores.
- *Low-level disinfection*: can kill most bacteria, some viruses, and some fungi; cannot be relied on to kill resistant microorganisms such as tubercle bacilli or bacterial spores.

There is no ideal disinfectant and the best compromise should be chosen according to the situation. A disinfectant solution is considered appropriate when the compromise between the antimicrobial activity and the toxicity of the product is satisfactory for the given application. Another consideration may well be the cost. The more active disinfectants are automatically the more toxic ones; potentially toxic products can be applied to inanimate objects or surfaces, whereas for disinfection of human tissues only the less toxic disinfectants can be considered. For antisepsis, different disinfectants are used for application to the intact skin (e.g. alcoholic solutions) and to mucous membranes or wounds (only aqueous solutions of non-toxic substances). Cost is a less important consideration for an antiseptic than for a disinfectant.

The principal requirements for a good antiseptic are absence of toxicity and rapid and adequate activity on both the natural flora and, especially, pathogenic bacteria and other microorganisms after a very short exposure time. Essential requirements for a disinfectant are somewhat different: there must be adequate activity against bacteria, fungi, and viruses that may be present in large numbers and protected by dirt or organic matter. In addition, since disinfectants are applied in large quantities, they should be of low ecotoxicity.

In general, use of the chosen disinfectant, at the appropriate concentration and for the appropriate time, should kill pathogenic microorganisms, rendering an object safe for use in a patient, or human tissue free of pathogens to exclude cross-contamination.

An overview of the characteristics of the main groups of disinfectants is given in Table 14.1.

Table 14.1 Characteristics of the main disinfectant groups

Disinfectants	Bactericidal activity	Tuberculocidal activity	Fungicidal activity	Virucidal activity	Sporicidal activity	Local human toxicity	Applications
Alcohol	Very active	Very active	Very active	Very active	Not active	Moderate	• Skin antisepsis • Disinfection of small surfaces
Chlorhexidine	Less active against Gram-negative bacilli	Not active	Less active	Not active	Not active	Low	• Skin and wound antisepsis
Chlorine compounds (chloramine, hypochlorite)	Very active	Active	Active	Very active	Less active	Moderate	• Skin and wound antisepsis • Water treatment • Surface disinfection
Formaldehyde	Very active	Very active	Very active	Very active	Less active	High	• Disinfection of inanimate objects and surfaces
Glutaraldehyde	Very active	Very active	Very active	Very active	Very active	High	• Disinfection of inanimate objects
Hydrogen peroxide	Less active against staphylococci and enterococci	Active	Active	Active	Less active	Low	• Wound antisepsis
Iodophore	Active	Active	Less active	Active	Not active	Moderate	• Skin and wound antisepsis
Peracetic acid	Very active	Active	Active	Active	Active	High	• Disinfection of inanimate objects
Phenolic compounds	Very active	Very active	Very active	Less active	Not active	High	• Disinfection of inanimate objects and surfaces
Quaternary ammonium compounds	Less active against Gram-negative bacilli	Not active	Less active	Less active	Not active	Low	• In combination with other compounds

14.3.6 Hand hygiene

As the hands of health-care workers are the most frequent vehicle of nosocomial infections, hand hygiene—including both hand washing and hand disinfection—is the primary preventive measure.

Thorough hand washing with adequate quantities of water and soap removes more than 90% of the transient, i.e. superficial, flora including all or most contaminants. An antimicrobial soap will further reduce the transient flora, but only if used for several minutes. Hand washing with (non-medicated) soap is essential when hands are dirty and should be routine after physical contact with a patient.

Killing *all* transient flora with all contaminants within a short time (a few seconds) necessitates hygienic hand disinfection: *only alcohol or alcoholic preparations act sufficiently fast.* Hands should be disinfected with alcohol when an infected tissue or body fluid is touched without gloves.

Table 14.2 The main forms of hand hygiene

Technique	Main purpose	Influence on hand flora	Agents	Rapidity of action	Residual effect
Social hand washing	Cleansing	Reduces transient flora	Non-medicated soap	Slow	Short
Careful hand washing	Cleansing after patient contact	Partly removes transient flora	Non-medicated soap	Slow	Short
Hygienic hand disinfection	Disinfection after contamination	Kills transient flora	Alcohol	Fast	Short
Surgical hand disinfection	Preoperative disinfection	Kills transient flora and inhibits resident flora	Antibacterial soap, alcoholic solutions	Slow (soap) or fast (alcohol)	Long

During a surgical intervention, a high proportion of gloves becomes perforated. Hands should therefore be disinfected with a long-acting disinfectant before gloves are put on. This will not only kill all the transient flora, but will also prevent the microorganisms of the resident (or deeper) flora from taking the place of the transient flora during the intervention. For this purpose, hands should be washed for 5–10 minutes with an antibacterial detergent containing chlorhexidine or an iodophore, or rubbed twice for 2 minutes with an alcoholic solution of one of these antiseptics.

An overview of the main forms of hand hygiene is given in Table 14.2.

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