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Prevention of hospital-acquired infections
A practical guide
2nd edition

World Health Organization
Department of Communicable Disease,
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Prevention of hospital-acquired infections

A PRACTICAL GUIDE

2nd edition

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Introduction

Anosocomial infection – also called "hospital-acquired infection" can be defined as:

An infection acquired in hospital by a patient who was admitted for a reason other than that infection (1). An infection occurring in a patient in a hospital or other health care facility in whom the infection was not present or incubating at the time of admission. This includes infections acquired in the hospital but appearing after discharge, and also occupational infections among staff of the facility (2).

Patient care is provided in facilities which range from highly equipped clinics and technologically advanced university hospitals to front-line units with only basic facilities. Despite progress in public health and hospital care, infections continue to develop in hospitalized patients, and may also affect hospital staff. Many factors promote infection among hospitalized patients: decreased immunity among patients; the increasing variety of medical procedures and invasive techniques creating potential routes of infection; and the transmission of drug-resistant bacteria among crowded hospital populations, where poor infection control practices may facilitate transmission.

Frequency of infection

Nosocomial infections occur worldwide and affect both developed and resource-poor countries. Infections acquired in health care settings are among the major causes of death and increased morbidity among hospitalized patients. They are a significant burden both for the patient and for public health. A prevalence survey conducted under the auspices of WHO in 55 hospitals of 14 countries representing 4 WHO Regions (Europe, Eastern Mediterranean, South-East Asia and Western Pacific) showed an average of 8.7% of hospital patients had nosocomial infections. At any time, over 1.4 million people worldwide suffer from infectious complications acquired in hospital (3). The highest frequencies of nosocomial infections were reported from hospitals in the Eastern Mediterranean and South-East Asia Regions (11.8 and 10.0% respectively), with a prevalence of 7.7 and 9.0% respectively in the European and Western Pacific Regions (4).

The most frequent nosocomial infections are infections of surgical wounds, urinary tract infections and lower respiratory tract infections. The WHO study, and others, have also shown that the highest prevalence of nosocomial infections occurs in intensive care units and in acute surgical and orthopaedic wards. Infection rates are higher among patients with increased susceptibility because of old age, underlying disease, or chemotherapy.

Impact of nosocomial infections

Hospital-acquired infections add to functional disability and emotional stress of the patient and may, in some cases, lead to disabling conditions that reduce the quality of life. Nosocomial infections are also one of the leading causes of death (5). The economic costs are considerable (6,7). The increased length of stay for infected patients is the greatest contributor to cost (8,9,10). One study (11) showed that the overall increase in the duration of hospitalization for patients with surgical wound infections was 8.2 days, ranging from 3 days for gynaecology to 9.9 for general surgery and 19.8 for orthopaedic surgery. Prolonged stay not only increases direct costs to patients or payers but also indirect costs due to lost work. The increased use of drugs, the need for isolation, and the use of additional laboratory and other diagnostic studies also contribute to costs. Hospital-acquired infections add to the imbalance between resource allocation for primary and secondary health care by diverting scarce funds to the management of potentially preventable conditions.

The advancing age of patients admitted to health care settings, the greater prevalence of chronic diseases among admitted patients, and the increased use of diagnostic and therapeutic procedures which

affect the host defences will provide continuing pressure on nosocomial infections in the future. Organisms causing nosocomial infections can be transmitted to the community through discharged patients, staff, and visitors. If organisms are multiresistant, they may cause significant disease in the community.

Factors influencing the development of nosocomial infections

The microbial agent

The patient is exposed to a variety of microorganisms during hospitalization. Contact between the patient and a microorganism does not by itself necessarily result in the development of clinical disease – other factors influence the nature and frequency of nosocomial infections. The likelihood of exposure leading to infection depends partly on the characteristics of the microorganisms, including resistance to antimicrobial agents, intrinsic virulence, and amount (inoculum) of infective material.

Many different bacteria, viruses, fungi and parasites may cause nosocomial infections. Infections may be caused by a microorganism acquired from another person in the hospital (cross–infection) or may be caused by the patient's own flora (endogenous infection). Some organisms may be acquired from an inanimate object or substances recently contaminated from another human source (environmental infection).

Before the introduction of basic hygienic practices and antibiotics into medical practice, most hospital infections were due to pathogens of external origin (foodborne and airborne diseases, gas gangrene, tetanus, etc.) or were caused by microorganisms not present in the normal flora of the patients (e.g. diphtheria, tuberculosis). Progress in the antibiotic treatment of bacterial infections has considerably reduced mortality from many infectious diseases. Most infections acquired in hospital today are caused by microorganisms which are common in the general population, in whom they cause no or milder disease than among hospital patients (*Staphylococcus aureus*, coagulase–negative staphylococci, enterococci, Enterobacteriaceae).

Patient susceptibility

Important patient factors influencing acquisition of infection include age, immune status, underlying disease, and diagnostic and therapeutic interventions. The extremes of life – infancy and old age – are associated with a decreased resistance to infection. Patients with chronic disease such as malignant tumours, leukaemia, diabetes mellitus, renal failure, or the acquired immunodeficiency syndrome (AIDS) have an increased susceptibility to infections with opportunistic pathogens. The latter are infections with organism(s) that are normally innocuous, e.g. part of the normal bacterial flora in the human, but may become pathogenic when the body's immunological defences are compromised. Immunosuppressive drugs or irradiation may lower resistance to infection. Injuries to skin or mucous membranes bypass natural defence mechanisms. Malnutrition is also a risk. Many modern diagnostic and therapeutic procedures, such as biopsies, endoscopic examinations, catheterization, intubation/ventilation and suction and surgical procedures increase the risk of infection. Contaminated objects or substances may be introduced directly into tissues or normally sterile sites such as the urinary tract and the lower respiratory tract.

Environmental factors

Health care settings are an environment where both infected persons and persons at increased risk of infection congregate. Patients with infections or carriers of pathogenic microorganisms admitted to hospital are potential sources of infection for patients and staff. Patients who become infected in the hospital are a further source of infection. Crowded conditions within the hospital, frequent transfers of patients from one unit to another, and concentration of patients highly susceptible to infection in one area (e.g. newborn infants, burn patients, intensive care) all contribute to the development of nosocomial infections. Microbial flora may contaminate objects, devices, and materials which subsequently contact susceptible body sites of patients. In addition, new infections associated with bacteria such as waterborne bacteria (atypical mycobacteria) and/or viruses and parasites continue to be identified.

Bacterial resistance

Many patients receive antimicrobial drugs. Through selection and exchange of genetic resistance elements, antibiotics promote the emergence of multidrug-resistant strains of bacteria; microorganisms in the normal human flora sensitive to the given drug are

suppressed, while resistant strains persist and may become endemic in the hospital. The widespread use of antimicrobials for therapy or prophylaxis (including topical) is the major determinant of resistance. Antimicrobial agents are, in some cases, becoming less effective because of resistance. As an antimicrobial agent becomes widely used, bacteria resistant to this drug eventually emerge and may spread in the health care setting. Many strains of pneumococci, staphylococci, enterococci, and tuberculosis are currently resistant to most or all antimicrobials which were once effective. Multiresistant *Klebsiella* and *Pseudomonas aeruginosa* are prevalent in many hospitals. This problem is particularly critical in developing countries where more expensive second-line antibiotics may not be available or affordable (*12*).

Nosocomial infections are widespread. They are important contributors to morbidity and mortality. They will become even more important as a public health problem with increasing economic and human impact because of:

- Increasing numbers and crowding of people.

- More frequent impaired immunity (age, illness, treatments).

- New microorganisms.

- Increasing bacterial resistance to antibiotics (*13*).

Purpose of this manual

This manual has been developed to be a practical, basic, resource which may be used by individuals with an interest in nosocomial infections and their control, as well as those who work in nosocomial infection control in health care facilities. It is applicable to all facilities, but attempts to provide rational and attainable recommendations for facilities with relatively limited resources. The information should assist administrators, infection control personnel, and patient care workers in such facilities in the initial development of a nosocomial infection control programme, including specific components of such programmes. Additional reading in specific areas is provided in the list of WHO relevant documents and infection control texts at the end of the manual (Annex 1), as well as relevant references in each chapter.

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Epidemiology of nosocomial infections

Studies throughout the world document that nosocomial infections are a major cause of morbidity and mortality (*1–13*). A high frequency of nosocomial infections is evidence of a poor quality of health service delivery, and leads to avoidable costs. Many factors contribute to the frequency of nosocomial infections: hospitalized patients are often immunocompromised, they undergo invasive examinations and treatments, and patient care practices and the hospital environment may facilitate the transmission of microorganisms among patients. The selective pressure of intense antibiotic use promotes antibiotic resistance. While progress in the prevention of nosocomial infections has been made, changes in medical practice continually present new opportunities for development of infection. This chapter summarizes the main characteristics of nosocomial infections, based on our current understanding.

1.1 Definitions of nosocomial infections

Nosocomial infections, also called "hospital–acquired infections", are infections acquired during hospital care which are not present or incubating at admission. Infections occurring more than 48 hours after admission are usually considered nosocomial. Definitions to identify nosocomial infections have been developed for specific infection sites (e.g. urinary, pulmonary). These are derived from those published by the Centers for Diseases Control and Prevention (CDC) in the United States of America (*14,15*) or during international conferences (*16*) and are used for surveillance of nosocomial infections. They are based on clinical and biological criteria, and include approximately 50 potential infection sites.

Nosocomial infections may also be considered either endemic or epidemic. Endemic infections are most common. Epidemic infections occur during outbreaks, defined as an unusual increase above the baseline of a specific infection or infecting organism.

Changes in health care delivery have resulted in shorter hospital stays and increased outpatient care. It has been suggested the term nosocomial infections should encompass infections occurring in patients receiving treatment in any health care setting. Infections acquired by staff or visitors to the hospital or other health care setting may also be considered nosocomial infections.

Simplified definitions may be helpful for some facilities without access to full diagnostic techniques (*17*). The following table (Table 1) provides definitions for common infections that could be used for surveys in facilities with limited access to sophisticated diagnostic techniques.

TABLE 1. **Simplified criteria for surveillance of nosocomial infections**

Type of nosocomial infection	Simplified criteria
Surgical site infection	Any purulent discharge, abscess, or spreading cellulitis at the surgical site during the month after the operation
Urinary infection	Positive urine culture (1 or 2 species) with at least 10^5 bacteria/ml, with or without clinical symptoms
Respiratory infection	Respiratory symptoms with at least two of the following signs appearing during hospitalization: — cough — purulent sputum — new infiltrate on chest radiograph consistent with infection
Vascular catheter infection	Inflammation, lymphangitis or purulent discharge at the insertion site of the catheter
Septicaemia	Fever or rigours and at least one positive blood culture

1.2 Nosocomial infection sites

An example of the distribution of sites of nosocomial infections is shown in Figure 1.

FIGURE 1. **Sites of the most comon nosocomial infections: distribution according to the French national prevalence survey (1996)***
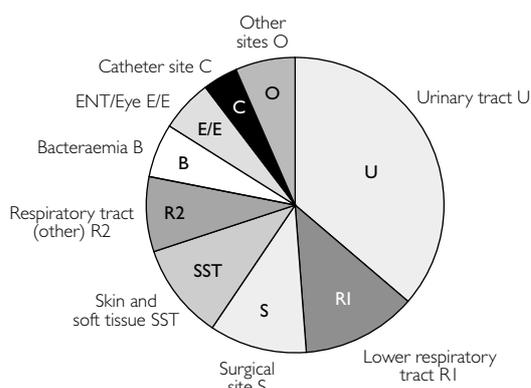
* Adapted fom Enquête nationale de prévalence des infections nosocomiales, 1996. *BEH*, 1997, 36:161–163.

1.2.1 Urinary infections

This is the most common nosocomial infection; 80% of infections are associated with the use of an indwelling bladder catheter (*1,2,3*). Urinary infections are associated with less morbidity than other nosocomial infections, but can occasionally lead to bacteraemia and death. Infections are usually defined by microbiological criteria: positive quantitative urine culture ($\geq 10^5$ microorganisms/ml, with a maximum of 2 isolated microbial species). The bacteria responsible arise from the gut flora, either normal (*Escherichia coli*) or acquired in hospital (multiresistant *Klebsiella*).

1.2.2 Surgical site infections

Surgical site infections are also frequent: the incidence varies from 0.5 to 15% depending on the type of operation and underlying patient status (*18,19,20*). These are a significant problem which limit the potential benefits of surgical interventions. The impact on hospital costs and postoperative length of stay (between 3 and 20 additional days) (*21,22,23,24*) is considerable.

The definition is mainly clinical: purulent discharge around the wound or the insertion site of the drain, or spreading cellulitis from the wound. Infections of the surgical wound (whether above or below the aponeurosis), and deep infections of organs or

organ spaces are identified separately. The infection is usually acquired during the operation itself; either exogenously (e.g. from the air, medical equipment, surgeons and other staff), endogenously from the flora on the skin or in the operative site or, rarely, from blood used in surgery. The infecting microorganisms are variable, depending on the type and location of surgery, and antimicrobials received by the patient. The main risk factor is the extent of contamination during the procedure (clean, cleancontaminated, contaminated, dirty), which is to a large part dependent on the length of the operation, and the patient's general condition (*25*). Other factors include the quality of surgical technique, the presence of foreign bodies including drains, the virulence of the microorganisms, concomitant infection at other sites, the use of preoperative shaving, and the experience of the surgical team.

1.2.3 Nosocomial pneumonia

Nosocomial pneumonia occurs in several different patient groups. The most important are patients on ventilators in intensive care units, where the rate of pneumonia is 3% per day. There is a high casefatality rate associated with ventilator–associated pneumonia, although the attributable risk is difficult to determine because patient comorbidity is so high. Microorganisms colonize the stomach, upper airway and bronchi, and cause infection in the lungs (pneumonia): they are often endogenous (digestive system or nose and throat), but may be exogenous, often from contaminated respiratory equipment.

The definition of pneumonia may be based on clinical and radiological criteria which are readily available but non–specific: recent and progressive radiological opacities of the pulmonary parenchyma, purulent sputum, and recent onset of fever. Diagnosis is more specific when quantitative microbiological samples are obtained using specialized protected bronchoscopy methods. Known risk factors for infection include the type and duration of ventilation, the quality of respiratory care, severity of the patient's condition (organ failure), and previous use of antibiotics.

Apart from ventilator–associated pneumonia, patients with seizures or decreased level of consciousness are at risk for nosocomial infection, even if not intubated. Viral bronchiolitis (respiratory syncytial virus, RSV) is common in children's units, and influenza and secondary bacterial pneumonia may occur in institutions for the elderly. With highly

immunocompromised patients, *Legionella* spp. and *Aspergillus* pneumonia may occur. In countries with a high prevalence of tuberculosis, particularly multiresistant strains, transmission in health care settings may be an important problem.

1.2.4 Nosocomial bacteraemia

These infections represent a small proportion of nosocomial infections (approximately 5%) but case–fatality rates are high – more than 50% for some microorganisms. The incidence is increasing, particularly for certain organisms such as multiresistant coagulase–negative *Staphylococcus* and *Candida* spp. Infection may occur at the skin entry site of the intravascular device, or in the subcutaneous path of the catheter (tunnel infection). Organisms colonizing the catheter within the vessel may produce bacteraemia without visible external infection. The resident or transient cutaneous flora is the source of infection. The main risk factors are the length of catheterization, level of asepsis at insertion, and continuing catheter care.

1.2.5 Other nosocomial infections

These are the four most frequent and important nosocomial infections, but there are many other potential sites of infection. For example:

- Skin and soft tissue infections: open sores (ulcers, burns and bedsores) encourage bacterial colonization and may lead to systemic infection.

- Gastroenteritis is the most common nosocomial infection in children, where rotavirus is a chief pathogen: *Clostridium difficile* is the major cause of nosocomial gastroenteritis in adults in developed countries.

- Sinusitis and other enteric infections, infections of the eye and conjunctiva.

- Endometritis and other infections of the reproductive organs following childbirth.

1.3 Microorganisms

Many different pathogens may cause nosocomial infections. The infecting organisms vary among different patient populations, different health care settings, different facilities, and different countries.

1.3.1 Bacteria

These are the most common nosocomial pathogens. A distinction may be made between:

- **Commensal bacteria** found in normal flora of healthy humans. These have a significant protective role by preventing colonization by pathogenic microorganisms. Some commensal bacteria may cause infection if the natural host is compromised. For example, cutaneous coagulase–negative staphylococci cause intravascular line infection and intestinal *Escherichia coli* are the most common cause of urinary infection.

- **Pathogenic bacteria** have greater virulence, and cause infections (sporadic or epidemic) regardless of host status. For example:

  – Anaerobic Gram–positive rods (e.g. *Clostridium*) cause gangrene.

  – Gram–positive bacteria: *Staphylococcus aureus* (cutaneous bacteria that colonize the skin and nose of both hospital staff and patients) cause a wide variety of lung, bone, heart and bloodstream infections and are frequently resistant to antibiotics; beta–haemolytic streptococci are also important.

  – Gram–negative bacteria: Enterobacteriacae (e.g. *Escherichia coli*, *Proteus*, *Klebsiella*, *Enterobacter*, *Serratia marcescens*), may colonize sites when the host defences are compromised (catheter insertion, bladder catheter, cannula insertion) and cause serious infections (surgical site, lung, bacteraemia, peritoneum infection). They may also be highly resistant.

  – Gram–negative organisms such as *Pseudomonas* spp. are often isolated in water and damp areas. They may colonize the digestive tract of hospitalized patients.

  – Selected other bacteria are a unique risk in hospitals. For instance, *Legionella* species may cause pneumonia (sporadic or endemic) through inhalation of aerosols containing contaminated water (air conditioning, showers, therapeutic aerosols).

1.3.2 Viruses

There is the possibility of nosocomial transmission of many viruses, including the hepatitis B and C viruses (transfusions, dialysis, injections, endoscopy), respiratory syncytial virus (RSV), rotavirus, and

enteroviruses (transmitted by hand–to–mouth con–tact and via the faecal–oral route). Other viruses such as cytomegalovirus, HIV, Ebola, influenza viruses, herpes simplex virus, and varicella–zoster virus, may also be transmitted.

1.3.3 Parasites and fungi

Some parasites (e.g. *Giardia lamblia*) are transmitted easily among adults or children. Many fungi and other parasites are opportunistic organisms and cause infections during extended antibiotic treatment and severe immunosuppression (*Candida albicans, Aspergillus* spp., *Cryptococcus neoformans, Cryptosporidium*). These are a major cause of systemic infections among immunocompromised patients. Environmental con–tamination by airborne organisms such as *Aspergil–lus* spp. which originate in dust and soil is also a concern, especially during hospital construction.

Sarcoptes scabies (scabies) is an ectoparasite which has repeatedly caused outbreaks in health care facilities.

1.4 Reservoirs and transmission

Bacteria that cause nosocomial infections can be acquired in several ways:

1. ***The permanent or transient flora of the patient*** (*endogenous infection*). Bacteria present in the nor–mal flora cause infection because of transmission to sites outside the natural habitat (urinary tract), damage to tissue (wound) or inappropriate anti–biotic therapy that allows overgrowth (*C. difficile*, yeast spp.). For example, Gram–negative bacteria in the digestive tract frequently cause surgical site infections after abdominal surgery or urinary tract infection in catheterized patients.

2. ***Flora from another patient or member of staff*** (*exogenous cross-infection*). Bacteria are transmitted between patients: (a) through direct contact be–tween patients (hands, saliva droplets or other body fluids), (b) in the air (droplets or dust con–taminated by a patient's bacteria), (c) via staff contaminated through patient care (hands, clothes, nose and throat) who become transient or per–manent carriers, subsequently transmitting bac–teria to other patients by direct contact during care, (d) via objects contaminated by the patient (including equipment), the staff's hands, visitors or other environmental sources (e.g. water, other fluids, food).

3. ***Flora from the health care environment*** (*endemic or epidemic exogenous environmental infections*). Several types of microorganisms survive well in the hos–pital environment:

   – in water, damp areas, and occasionally in sterile products or disinfectants (*Pseudomonas, Acinetobacter, Mycobacterium*)

   – in items such as linen, equipment and sup–plies used in care; appropriate housekeeping normally limits the risk of bacteria surviving as most microorganisms require humid or hot conditions and nutrients to survive

   – in food

   – in fine dust and droplet nuclei generated by coughing or speaking (bacteria smaller than 10 µm in diameter remain in the air for sev–eral hours and can be inhaled in the same way as fine dust).

People are at the centre of the phenomenon:

● as main reservoir and source of microorganisms

● as main transmitter, notably during treatment

● as receptor for microorganisms, thus becoming a new reservoir.

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Infection control programmes

Prevention of nosocomial infections is the responsibility of all individuals and services providing health care. Everyone must work cooperatively to reduce the risk of infection for patients and staff. This includes personnel providing direct patient care, management, physical plant, provision of materials and products, and training of health workers. Infection control programmes (1) are effective provided they are comprehensive and include surveillance and prevention activities, as well as staff training. There must also be effective support at the national and regional levels.

2.1 National or regional programmes

The responsible health authority should develop a national (or regional) programme to support hospitals in reducing the risk of nosocomial infections. Such programmes must:

- set relevant national objectives consistent with other national health care objectives

- develop and continually update guidelines for recommended health care surveillance, prevention, and practice

- develop a national system to monitor selected infections and assess the effectiveness of interventions

- harmonize initial and continuing training programmes for health care professionals

- facilitate access to materials and products essential for hygiene and safety

- encourage health care establishments to monitor nosocomial infections, with feedback to the professionals concerned.

The health authority should designate an agency to oversee the programme (a ministerial department, institution or other body), and plan national activities with the help of a national expert committee.

Professional and academic organizations must also be involved in this programme.

2.2 Hospital programmes

The major preventive effort should be focused in hospitals and other health care facilities (2). Risk prevention for patients and staff is a concern of everyone in the facility, and must be supported at the level of senior administration. A yearly work plan to assess and promote good health care, appropriate isolation, sterilization, and other practices, staff training, and epidemiological surveillance should be developed. Hospitals must provide sufficient resources to support this programme.

2.2.1 Infection Control Committee

An Infection Control Committee provides a forum for multidisciplinary input and cooperation, and information sharing. This committee should include wide representation from relevant programmes: e.g. management, physicians, other health care workers, clinical microbiology, pharmacy, central supply, maintenance, housekeeping, training services. The committee must have a reporting relationship directly to either administration or the medical staff to promote programme visibility and effectiveness. In an emergency (such as an outbreak), this committee must be able to meet promptly. It has the following tasks:

- to review and approve a yearly programme of activity for surveillance and prevention

- to review epidemiological surveillance data and identify areas for intervention

- to assess and promote improved practice at all levels of the health facility

- to ensure appropriate staff training in infection control and safety

- to review risks associated with new technologies, and monitor infectious risks of new devices and products, prior to their approval for use

- to review and provide input into investigation of epidemics

- to communicate and cooperate with other committees of the hospital with common interests such as Pharmacy and Therapeutics or Antimicrobial Use Committee, Biosafety or Health and Safety Committees, and Blood Transfusion Committee.

2.2.2 Infection control professionals (infection control team)

Health care establishments must have access to specialists in infection control, epidemiology, and infectious disease including infection control physicians and infection control practitioners (usually nurses) (2). In some countries, these professionals are specialized teams working for a hospital or a group of health care establishments; they may be administratively part of another unit, (e.g. microbiology laboratory, medical or nursing administration, public health services). The optimal structure will vary with the type, needs, and resources of the facility. The reporting structure must, however, ensure the infection control team has appropriate authority to manage an effective infection control programme. In large facilities, this will usually mean a direct reporting relationship with senior administration.

The infection control team or individual is responsible for the day-to-day functions of infection control, as well as preparing the yearly work plan for review by the infection control committee and administration. These individuals have a scientific and technical support role: e.g. surveillance and research, developing and assessing policies and practical supervision, evaluation of material and products, control of sterilization and disinfection, implementation of training programmes. They should also support and participate in research and assessment programmes at the national and international levels.

2.2.3 Infection control manual

A nosocomial infection prevention manual (3), compiling recommended instructions and practices for patient care, is an important tool. The manual should be developed and updated by the infection control team, with review and approval by the committee.

It must be made readily available for patient care staff, and updated in a timely fashion.

2.3 Infection control responsibility

2.3.1 Role of hospital management

The administration and/or medical management of the hospital must provide leadership by supporting the hospital infection programme. They are responsible for:

- establishing a multidisciplinary Infection Control Committee

- identifying appropriate resources for a programme to monitor infections and apply the most appropriate methods for preventing infection

- ensuring education and training of all staff through support of programmes on the prevention of infection in disinfection and sterilization techniques

- delegating technical aspects of hospital hygiene to appropriate staff, such as:
  – nursing
  – housekeeping
  – maintenance
  – clinical microbiology laboratory

- periodically reviewing the status of nosocomial infections and effectiveness of interventions to contain them

- reviewing, approving, and implementing policies approved by the Infection Control Committee

- ensuring the infection control team has authority to facilitate appropriate programme function

- participating in outbreak investigation.

2.3.2 Role of the physician

Physicians have unique responsibilities for the prevention and control of hospital infections:

- by providing direct patient care using practices which minimize infection

- by following appropriate practice of hygiene (e.g. handwashing, isolation)

- serving on the Infection Control Committee

- supporting the infection control team.

Specifically, physicians are responsible for:

- protecting their own patients from other infected patients and from hospital staff who may be infected

- complying with the practices approved by the Infection Control Committee

- obtaining appropriate microbiological specimens when an infection is present or suspected

- notifying cases of hospital–acquired infection to the team, as well as the admission of infected patients

- complying with the recommendations of the Antimicrobial Use Committee regarding the use of antibiotics

- advising patients, visitors and staff on techniques to prevent the transmission of infection

- instituting appropriate treatment for any infections they themselves have, and taking steps to prevent such infections being transmitted to other individuals, especially patients.

2.3.3 Role of the microbiologist (4)

The microbiologist is responsible for:

- handling patient and staff specimens to maximize the likelihood of a microbiological diagnosis

- developing guidelines for appropriate collection, transport, and handling of specimens

- ensuring laboratory practices meet appropriate standards

- ensuring safe laboratory practice to prevent infections in staff

- performing antimicrobial susceptibility testing following internationally recognized methods, and providing summary reports of prevalence of resistance

- monitoring sterilization, disinfection and the environment where necessary

- timely communication of results to the Infection Control Committee or the hygiene officer

- epidemiological typing of hospital microorganisms where necessary.

2.3.4 Role of the hospital pharmacist (5)

The hospital pharmacist is responsible for:

- obtaining, storing and distributing pharmaceutical preparations using practices which limit potential transmission of infectious agents to patients

- dispensing anti–infectious drugs and maintaining relevant records (potency, incompatibility, conditions of storage and deterioration)

- obtaining and storing vaccines or sera, and making them available as appropriate

- maintaining records of antibiotics distributed to the medical departments

- providing the Antimicrobial Use Committee and Infection Control Committee with summary reports and trends of antimicrobial use

- having available the following information on disinfectants, antiseptics and other anti–infectious agents:

  - active properties in relation to concentration, temperature, length of action, antibiotic spectrum

  - toxic properties including sensitization or irritation of the skin and mucosa

  - substances that are incompatible with antibiotics or reduce their potency

  - physical conditions which unfavourably affect potency during storage: temperature, light, humidity

  - harmful effects on materials.

The hospital pharmacist may also participate in the hospital sterilization and disinfection practices through:

- participation in development of guidelines for antiseptics, disinfectants, and products used for washing and disinfecting the hands

- participation in guideline development for reuse of equipment and patient materials

- participation in quality control of techniques used to sterilize equipment in the hospital including selection of sterilization equipment (type of appliances) and monitoring.

2.3.5 Role of the nursing staff

Implementation of patient care practices for infection control is the role of the nursing staff. Nurses should be familiar with practices to prevent the occurrence and spread of infection, and maintain appropriate practices for all patients throughout the duration of their hospital stay.

The senior nursing administrator is responsible for:

- participating in the Infection Control Committee

- promoting the development and improvement of nursing techniques, and ongoing review of aseptic nursing policies, with approval by the Infection Control Committee

- developing training programmes for members of the nursing staff

- supervising the implementation of techniques for the prevention of infections in specialized areas such as the operating suite, the intensive care unit, the maternity unit and newborns

- monitoring of nursing adherence to policies.

The nurse in charge of a ward is responsible for:

- maintaining hygiene, consistent with hospital policies and good nursing practice on the ward

- monitoring aseptic techniques, including hand-washing and use of isolation

- reporting promptly to the attending physician any evidence of infection in patients under the nurse's care

- initiating patient isolation and ordering culture specimens from any patient showing signs of a communicable disease, when the physician is not immediately available

- limiting patient exposure to infections from visitors, hospital staff, other patients, or equipment used for diagnosis or treatment

- maintaining a safe and adequate supply of ward equipment, drugs and patient care supplies.

The nurse in charge of infection control is a member of the infection control team and responsible for :

- identifying nosocomial infections

- investigation of the type of infection and infecting organism

- participating in training of personnel

- surveillance of hospital infections

- participating in outbreak investigation

- development of infection control policy and review and approval of patient care policies relevant to infection control

- ensuring compliance with local and national regulations

- liaison with public health and with other facilities where appropriate

- providing expert consultative advice to staff health and other appropriate hospital programmes in matters relating to transmission of infections.

2.3.6 Role of the central sterilization service

A central sterilization department serves all hospital areas, including the operating suite. An appropriately qualified individual must be responsible for management of the programme. Responsibility for day-to-day management may be delegated to a nurse or other individual with appropriate qualifications, experience, and knowledge of medical devices.

The responsibilities of the *central sterilization service* are to clean, decontaminate, test, prepare for use, sterilize, and store aseptically all sterile hospital equipment. It works in collaboration with the Infection Control Committee and other hospital programmes to develop and monitor policies on cleaning and decontamination of:

- reusable equipment

- contaminated equipment

  including

  – wrapping procedures, according to the type of sterilization

  – sterilization methods, according to the type of equipment

  – sterilization conditions (e.g. temperature, duration, pressure, humidity) (see Chapter V).

The *director of this service* must:

- oversee the use of different methods – physical, chemical, and bacteriological – to monitor the sterilization process

- ensure technical maintenance of the equipment according to national standards and manufacturers' recommendations

- report any defect to administration, maintenance, infection control and other appropriate personnel

- maintain complete records of each autoclave run, and ensure long-term availability of records

- collect or have collected, at regular intervals, all outdated sterile units

- communicate, as needed, with the Infection Control Committee, the nursing service, the operating suite, the hospital transport service, pharmacy service, maintenance, and other appropriate services.

2.3.7 Role of the food service (see Chapter VIII)

The *director of food services* must be knowledgeable in food safety, staff training, storage and preparation of foodstuffs, job analysis, and use of equipment.

The *head of catering services* is responsible for:

- defining the criteria for the purchase of foodstuffs, equipment use, and cleaning procedures to maintain a high level of food safety

- ensuring that the equipment used and all working and storage areas are kept clean

- issuing written policies and instructions for handwashing, clothing, staff responsibilities and daily disinfection duties

- ensuring that the methods used for storing, preparing and distributing food will avoid contamination by microorganisms

- issuing written instructions for the cleaning of dishes after use, including special considerations for infected or isolated patients where appropriate

- ensuring appropriate handling and disposal of wastes

- establishing programmes for training staff in food preparation, cleanliness, and food safety

- establishing a Hazard Analysis of Critical Control Points (HACCP) programme, if required.

2.3.8 Role of the laundry service (see Chapter VIII)

The laundry is responsible for:

- selecting fabrics for use in different hospital areas, developing policies for working clothes in each area and group of staff, and maintaining appropriate supplies

- distribution of working clothes and, if necessary, managing changing rooms

- developing policies for the collection and transport of dirty linen

- defining, where necessary, the method for disinfecting infected linen, either before it is taken to the laundry or in the laundry itself

- developing policies for the protection of clean linen from contamination during transport from the laundry to the area of use

- developing criteria for selection of site of laundry services:

    - ensuring appropriate flow of linen, separation of "clean" and "dirty" areas

    - recommending washing conditions (e.g. temperature, duration)

    - ensuring safety of laundry staff through prevention of exposure to sharps or laundry contaminated with potential pathogens.

2.3.9 Role of the housekeeping service (see 5.3)

The housekeeping service is responsible for the regular and routine cleaning of all surfaces and maintaining a high level of hygiene in the facility. In collaboration with the Infection Control Committee it is responsible for :

- classifying the different hospital areas by varying need for cleaning

- developing policies for appropriate cleaning techniques

    - procedure, frequency, agents used, etc., for each type of room, from highly contaminated to the most clean, and ensuring that these practices are followed

- developing policies for collection, transport and disposal of different types of waste (e.g. containers, frequency)

- ensuring that liquid soap and paper towel dispensers are replenished regularly

- informing the maintenance service of any building problems requiring repair: cracks, defects in the sanitary or electrical equipment, etc.

- caring for flowers and plants in public areas

- pest control (insects, rodents)

- providing appropriate training for all new staff members and, periodically, for other employees, and specific training when a new technique is introduced

- establishing methods for the cleaning and disinfection of bedding (e.g. mattresses, pillows)

- determining the frequency for the washing of curtains, screening curtains between beds, etc.

- reviewing plans for renovations or new furniture, including special patient beds, to determine feasibility of cleaning.

There should be a continuing programme for staff training. This programme should stress personal hygiene, the importance of frequent and careful washing of hands, and cleaning methods (e.g. sequence of rooms, correct use of equipment, dilution of cleaning agents, etc.). Staff must also understand causes of contamination of premises, and how to limit this, including the method of action of disinfectants. Cleaning staff must know to contact staff health if they have a personal infection, especially infections of the skin, digestive tract and respiratory tract.

2.3.10 Role of maintenance

Maintenance is responsible for:

- collaborating with housekeeping, nursing staff or other appropriate groups in selecting equipment and ensuring early identification and prompt correction of any defect

- inspections and regular maintenance of the plumbing, heating, and refrigeration equipment, and electrical fittings and air conditioning; records should be kept of this activity

- developing procedures for emergency repairs in essential departments

- ensuring environmental safety outside the hospital, e.g. waste disposal, water sources.

Additional special duties include:

- participation in the choice of equipment if maintenance of the equipment requires technical assistance

- inspection, cleaning and regular replacement of the filters of all appliances for ventilation and humidifiers

- testing autoclaves (temperature, pressure, vacuum, recording mechanism) and regular maintenance (cleaning the inner chamber, emptying the tubes)

- monitoring the recording thermometers of refrigerators in pharmacy stores, laboratories, the blood bank and kitchens

- regularly inspecting all surfaces – walls, floors, ceilings – to ensure they are kept smooth and washable

- repairing any opening or crack in partition walls or window frames

- maintaining hydrotherapy appliances

- notifying infection control of any anticipated interruption of services such as plumbing or air conditioning.

2.3.11 Role of the infection control team (hospital hygiene service)

The infection control programme is responsible for oversight and coordination of all infection control activities to ensure an effective programme.

The hospital hygiene service is responsible for:

- organizing an epidemiological surveillance programme for nosocomial infections

- participating with pharmacy in developing a programme for supervising the use of anti-infective drugs

- ensuring patient care practices are appropriate to the level of patient risk

- checking the efficacy of the methods of disinfection and sterilization and the efficacy of systems developed to improve hospital cleanliness

- participating in development and provision of teaching programmes for the medical, nursing, and allied health personnel, as well as all other categories of staff

- providing expert advice, analysis, and leadership in outbreak investigation and control

- participating in the development and operation of regional and national infection control initiatives

- the hospital hygiene service may also provide assistance for smaller institutions, and undertake research in hospital hygiene and infection con-

trol at the facility, local, national, or international level.

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Nosocomial infection surveillance

The nosocomial infection rate in patients in a facility is an indicator of quality and safety of care. The development of a surveillance process to monitor this rate is an essential first step to identify local problems and priorities, and evaluate the effectiveness of infection control activity. Surveillance, by itself, is an effective process to decrease the frequency of hospital–acquired infections (1,2,3).

- improvements in health care with increased quality and safety

  but

- changes in care with new techniques, new pathogens or changes in resistance, increased patient acuity, ageing population, etc.

  =

- need for active surveillance to monitor changing infectious risks

  and

- identify needs for changes in control measures.

3.1 Objectives

The ultimate aim is the reduction of nosocomial infections, and their costs.

The specific objectives of a surveillance programme include:

- to improve awareness of clinical staff and other hospital workers (including administrators) about nosocomial infections and antimicrobial resistance, so they appreciate the need for preventive action

- to monitor trends: incidence and distribution of nosocomial infections, prevalence and, where possible, risk–adjusted incidence for intra– and inter–hospital comparisons

- to identify the need for new or intensified prevention programmes, and evaluate the impact of prevention measures

- to identify possible areas for improvement in patient care, and for further epidemiological studies (i.e. risk factor analysis).

3.2 Strategy

A surveillance system must meet the following criteria (Table 1):

- simplicity, to minimize costs and workload, and promote unit participation by timely feedback

- flexibility, to allow changes when appropriate

- acceptability (e.g. evaluated by the level of participation, data quality)

- consistency (use standardized definitions, methodology)

- sensitivity, although a case–finding method with low sensitivity can be valid in following trends, as long as sensitivity remains consistent over time and cases identified are representative

- specificity, requiring precise definitions and trained investigators.

TABLE 1. **Desired characteristics of a nosocomial infection surveillance system***

Characteristics of the system:
- timeliness, simplicity, flexibility
- acceptability, reasonable cost
- representativeness (or exhaustiveness)

Quality of the data provided:
- sensitivity, specificity
- predictive value (positive and negative)
- usefulness, in relation to the goals of the surveillance (quality indicators)

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* Adapted from Thacker SB, 1988 (4).

The extent to which these characteristics are met will vary among different institutions.

3.2.1 Implementation at the hospital level

Ensuring a valid surveillance system is an important hospital function. There must be specific objectives (for units, services, patients, specific care areas) and defined time periods of surveillance for all partners: e.g. clinical units and laboratory staff, infection control practitioner (ICP)/nurse, and director, administration.

Initially, discussion should identify the information needs, and the potential for the chosen indicators to support implementation of corrective measures (what or who is going to be influenced by the data). This discussion will include:

- the patients and units to be monitored (defined population)

- the type of infections and relevant information to be collected for each case (with precise definitions)

- the frequency and duration of monitoring

- methods for data collection

- methods for data analysis, feedback, and dissemination

- confidentiality and anonymity.

FIGURE 1. **"Surveillance is a circular process"**
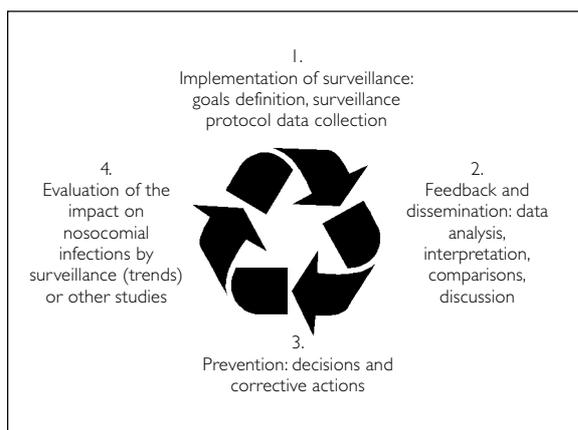
The optimal method (Figure 1) is dependent on hospital characteristics, the desired objectives, resources available (computers, investigators) and the level of support of the hospital staff (both administrative and clinical).

The surveillance programme must report to hospital administration, usually through the Infection Control Committee (ICC), and must have a dedicated budget to support its operation.

3.2.2 Implementation at the network (regional or national) level

Hospitals should share nosocomial infection data, on a confidential basis, with a network of similar facilities to support standards development for inter-facility comparisons (5), and to detect trends. Local, regional, national or international networks may be developed. The advantages include:

- technical and methodological assistance

- reinforcing compliance to existing guidelines and clinical practices

- evaluating the importance of surveillance (more legitimacy) to encourage participation

- facilitating the exchange of experiences and solutions

- promoting epidemiological research, including analysis of the impact of interventions

- assisting nation/states in scope and magnitude estimates to help with resource allocation nationally and internationally

- the key advantage: possibility of developing valid inter-hospital comparisons using standardized methods and adjusted rates.

3.3 Methods

Simply counting infected patients (numerator) provides only limited information which may be difficult to interpret. Further data are necessary to fully describe the problem on a population basis, to quantify its importance, to interpret variations, and to permit comparisons. Risk factor analysis requires information for both infected and non-infected patients. Infection rates, as well as risk-adjusted rates, can then be calculated.

"Passive surveillance" with reporting by individuals outside the infection control team (laboratory-based surveillance, extraction from medical records post-discharge, infection notification by physicians or nurses) is of low sensitivity. Therefore some form of active surveillance for infections (prevalence or incidence studies) is recommended (Table 2).

TABLE 2. **Key points in the process of surveillance for nosocomial infection rates**

- Active surveillance (prevalence and incidence studies)
- Targeted surveillance (site-, unit-, priority-oriented)
- Appropriately trained investigators
- Standardized methodology
- Risk-adjusted rates for comparisons

3.3.1 Prevalence study (cross-sectional/transverse)

Infections in all patients hospitalized at a given point in time are identified (point prevalence) in the entire hospital, or on selected units. Typically, a team of trained investigators visits every patient of the hospital on a single day, reviewing medical and nursing charts, interviewing the clinical staff to identify infected patients, and collecting risk factor data. The outcome measure is a prevalence rate.

Prevalence rates are influenced by duration of the patient's stay (infected patients stay longer, leading to an overestimation of patient's risk of acquiring an infection) and duration of infections.

Another problem is determining whether an infection is still "active" on the day of the study.

In small hospitals, or small units, the number of patients may be too few to develop reliable rates, or to allow comparisons with statistical significance.

A prevalence study is simple, fast, and relatively inexpensive. The hospital-wide activity increases awareness of nosocomial infection problems among clinical staff, and increases the visibility of the infection control team. It is useful when initiating a surveillance programme to assess current issues for all units, for all kinds of infections, and in all patients, before proceeding to a more focused continuing active surveillance programme. Repeated prevalence surveys can be useful to monitor trends by comparing rates in a unit, or in a hospital, over time.

3.3.2 Incidence study (continuous/longitudinal)

Prospective identification of new infections (incidence surveillance) requires monitoring of all patients within a defined population for a specified time period. Patients are followed throughout their stay, and sometimes after discharge (e.g. post-discharge surveillance for surgical site infections). This type of surveillance provides attack rates, infection ratio and incidence rates (Table 3). It is more effective in detecting differences in infection rates, to follow trends, to link infections to risk factors, and for inter-hospital and inter-unit comparisons (6).

This surveillance is more labour-intensive than a prevalence survey, more time-consuming, and costly. Therefore, it is usually undertaken only for selected high-risk units on an ongoing basis (i.e. in intensive care units), or for a limited period, focusing on selected infections and specialties (i.e. 3 months in surgery) (7,8,9,10).

Recent trends in "targeted surveillance" include:

- **Site-oriented surveillance**: priorities will be to monitor frequent infections with significant impact in mortality, morbidity, costs (e.g. extra-hospital days, treatment costs), and which may be avoidable.

  Common priority areas are:

  - ventilator-associated pneumonia (a high mortality rate)

  - surgical site infections (first for extra-hospital days and cost)

  - primary (intravascular line) bloodstream infections (high mortality)

  - multiple-drug resistant bacteria (e.g. methicillin-resistant *Staphylococcus aureus*, *Klebsiella* spp. with extended-spectrum beta-lactamase).

  This surveillance is primarily laboratory-based. The laboratory also provides units with regular reports on distribution of microorganisms isolated, and antibiotic susceptibility profiles for the most frequent pathogens.

- **Unit-oriented surveillance**: efforts can focus on high-risk units such as intensive care units, surgical units, oncology/haematology, burn units, neonatalogy, etc.

- **Priority-oriented surveillance**: surveillance undertaken for a specific issue of concern to the facility (i.e. urinary tract infections in patients with urinary catheters in long-term care facilities).

  While surveillance is focused in high-risk sectors, some surveillance activity should occur for the rest of the hospital. This may be most efficiently performed on a rotating basis (laboratory-based or repeated prevalence studies).

TABLE 3. **Prevalence and incidence rates** (11,12)

Prevalence rate	Examples
Number of infected patients* at the time of study / Number of patients observed at the same time ×100 (*or number of infections)	*Prevalence (%) of nosocomial infections (NI) for 100 hospitalized patients* *Prevalence (%) of urinary tract infections (UTI) for 100 hospitalized patients*
Number of infected patients at the time of the study / Number of patients exposed at the same time ×100	*Prevalence (%) of UTI for 100 patients with a urinary catheter*
Attack rate (cumulative incidence rate)	
Number of new infections acquired in a period / Number of patients observed in the same period ×100	*Attack rate (%) of UTI for 100 hospitalized patients*
Number of new infections acquired in a period / Number of patients exposed in the same period ×100	*Attack rate (%) of surgical site infections (SSI) for 100 operated patients*
Incidence rate	
Number of new nosocomial infections acquired in a period / Total of patient-days for the same period ×1000	*Incidence of bloodstream infection (BSI) for 1000 patient-days*
Number of new device-associated nosocomial infections in a period / Total device-days for the same period ×1000	*Incidence of ventilator-associated pneumonia for 1000 ventilation-days*

3.3.3 Calculating rates

Rates are obtained by dividing a numerator (number of infections or infected patients observed) by a denominator (population at risk, or number of patient–days of risk). The frequency of infection can be estimated by prevalence and incidence indicators (Table 3).

For multiple–drug resistant bacteria surveillance, the three main indicators used are :

● percentage of antimicrobial resistant strains within isolates of a species, e.g. percentage of *Staphylococcus aureus* resistant to methicillin (MRSA)

● attack rate (i.e. number of MRSA/100 admissions)

● incidence rate (MRSA/1000 patient–days).

For both prevalence and incidence rates, either the global population under surveillance, or only patients with a specific risk exposure, may be the denominator.

Attack rates can be estimated by the calculation of a simplified infection ratio using an estimate of the denominator for the same period of time (i.e. number of admissions or discharges, number of surgical procedures).

Incidence rates are encouraged as they take into account the length of exposure, or the length of stay (and/or follow–up) of the patient; this gives a better reflection of risk and facilitates comparisons. Either patient–day rates or device–associated rates can be used.

3.4 Organization for efficient surveillance

Nosocomial infection surveillance includes data collection, analysis and interpretation, feedback leading to interventions for preventive action, and evaluation of the impact of these interventions (see Figure 1 earlier in this chapter). The director (physician and/or nurse from the infection control team,

the unit under surveillance, or from the Infection Control Committee) must be a trained professional specifically responsible for surveillance, including training of personnel for data collection. A written protocol must describe the methods to be used, the data to be collected (e.g. patient inclusion criteria, definitions), the analysis that can be expected, and preparation and timing of reports (*13*).

3.4.1 Data collection and analysis

3.4.1.1 Sources

Data collection requires multiple sources of infor–mation as no method, by itself, is sensitive enough to ensure data quality. Trained data extractors (train–ing should be organized by the infection control team or the supervisor) performing active surveillance will increase the sensitivity for identifying infections. Techniques for case–finding include:

- **Ward activity**: looking for clues such as:

  – the presence of devices or procedures known to be a risk for infection (indwelling urinary and intravascular catheters, mechanical ven–tilation, surgical procedures)

  – record of fever or other clinical signs consist–ent with infection

  – antimicrobial therapy

  – laboratory tests

  – medical and nursing chart review.

- **Laboratory reports**: isolation of microorgan–isms potentially associated with infection, anti–microbial resistance patterns, serological tests. Microbiology laboratory reports have low sensi–tivity because cultures are not obtained for all infections, specimens may not be appropriate, some infectious pathogens may not be isolated (e.g. virus), and the isolation of a potential patho–gen may represent colonization rather than infection (e.g. for surgical site infections, pneu–monia). Laboratory reports are, however, reliable for urinary tract infection, bloodstream infections, and multiple–drug resistant bacteria surveillance, because the definitions for these are essentially microbiological.

- **Other diagnostic tests**: e.g. white blood counts, diagnostic imaging, autopsy data.

- **Discussion of cases** with the clinical staff dur–ing periodic ward visits.

Continuing collaboration among infection control staff, the laboratory, and clinical units will facilitate an exchange of information and improve data qual–ity (*14*). The patient is monitored throughout the hospital stay, and in some cases (e.g. for surgical site infections), surveillance includes the post–discharge period (*15*). The progressive reduction of the aver–age length of stay with recent changes in health care delivery increases the importance of identifying post-discharge infections.

3.4.1.2 Data elements

Some examples of data collection forms for a preva–lence study and for surgical site infection surveil–lance are given in Figures 2 and 3. One form is completed for each patient. Simple, validated, and standardized definitions (*16,17*) are essential for cred–ibility of the surveillance system and to ensure data quality. A complete guide for data collection should include:

- patient inclusion criteria

- precise definitions for each variable to be collected (not only definitions for infections)

- lists of codes for each variable, including specific codes for missing data.

This data collection guide is also useful in training data extractors.

The information to be collected should include:

- administrative data (e.g. hospital number, admis–sion date)

- additional information describing demographic risk factors (e.g. age, gender, severity of underly–ing illness, primary diagnosis, immunological status) and interventions (e.g. device exposure, surgical procedure, treatments) for infected and for non–infected patients

- presence or absence of infection: date of onset, site of infection, microorganisms isolated, and antimicrobial susceptibility.

Data validation is essential to ensure correct inter–pretation and meaningful comparisons. Validation is a continuous process which may incorporate vari–ous methods:

- before data input, information validated by a second extractor

- if computerized data collection is used, the soft–ware should include input checks (each variable

FIGURE 2. **Example of a minimum data collection form for prevalence study**

Date (dd/mm/yy)	— — — — — —
Hospital	— —
Unit	— —
Unit specialty	— —

Patient	
Patient identification	— — — — —
Age (years)	— — —
Gender ☐ male ☐ female	—
Date of admission in the hospital (dd/mm/yy)	— — — — — —

Patient exposure	
Surgical procedure (during the last month) ☐ Yes ☐ No	—
Urinary catheter ☐ Yes ☐ No	—
Mechanical ventilation ☐ Yes ☐ No	—
Intravascular catheter ☐ Yes ☐ No	—
Antibiotic ☐ Yes ☐ No	—
If yes, prescription for	
☐ Prophylaxis ☐ Therapy ☐ Other/unknown	—

Nosocomial infection	
☐ Yes ☐ No	—
If yes, fill the following items	
Surgical site infection ☐ Yes ☐ No	—
Urinary tract infection ☐ Yes ☐ No	—
Bloodstream infection ☐ Yes ☐ No	—
Pneumonia ☐ Yes ☐ No	—
Other respiratory infection ☐ Yes ☐ No	—
Line-related infection ☐ Yes ☐ No	—
Other nosocomial infection ☐ Yes ☐ No	—

FIGURE 3. **Example of a data collection form for surgical site infection surveillance**

Hospital		— —
Unit		— —

Patient		
Patient identification		— — —
Age	(years)	— — —
Gender	☐ male ☐ female	—
Date of admission (in the hospital)	(dd/mm/yy)	— — — — — —
Date of discharge (from the unit)	(dd/mm/yy)	— — — — — —

Operation		
Date of operation	(dd/mm/yy)	— — — — — —
Main procedure	(code)	
Wound class	☐ Clean ☐ Contaminated	
	☐ Clean-contaminated ☐ Dirty/infected	—
ASA score	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5	—
Duration of operation	(minutes)	— — —
Urgent	☐ Yes ☐ No	—
Prosthesis/implant	☐ Yes ☐ No	—
Multiple procedures	☐ Yes ☐ No	—
Coeliosurgery	☐ Yes ☐ No	—

Antibiotics		
Antimicrobial prophylaxis	☐ Yes ☐ No	—
Starting date	(dd/mm/yy)	— — — — — —
Duration	(days)	— —

Surgical site infection		
Surgical site infection	☐ Yes ☐ No	—
Date of infection	(dd/mm/yy)	— — — — — —
Infection site	☐ superficial ☐ deep ☐ organ/space	—
Microorganism 1		— — —
Microorganism 2		— — —
Date of last contact	**(dd/mm/yy)**	— — — — — —

collected must be coded according to the proto-col)

- before analysis, a retrospective data validation performed to identify missing values, inconsistencies, outliers/possible errors, unexpected values or codes.

3.4.1.3 Analysis

Information should be collected only if it will be used in the analysis.

Analysis includes the description of the population, frequency of risk exposure and infections, calculation of rates, comparisons of patient groups (with significance testing), comparisons of rates over time, etc.

For adequate sample size, and monitoring long-term trends, continuous surveillance or surveillance undertaken at periodic intervals of sufficient length is recommended.

Inclusion of risk factors allows stratification of patients by risk, and risk-adjusted rates for accurate comparisons. A single overall nosocomial infection rate is not useful for inter-hospital comparisons. Adjusted rates will enable the unit or the hospital to compare its performance over time with its own previous results, and with other similar units/hospitals, or with populations of patients with similar risk levels.

Computerization of data collection and analysis should be considered, if possible, as it will ensure rapid feedback and better data quality. Low-cost computers and different types of software are now widely available to facilitate analysis for the epidemiologist. Information already collected and accessible through the hospital computer system should be used, wherever possible. Integration of nosocomial infection surveillance into routine data handling should be encouraged by defining specific requirements for hospital information systems.

3.4.2 Feedback/dissemination

To be effective, feedback must be prompt, relevant to the target group, i.e. the people directly involved in patient care, and with the potential for maximal influence on infection prevention (i.e. surgeons for surgical site infection, physicians and nurses in intensive care units). Reporting may include meetings for sharing of information and discussion, micro-

biological review, and summary or graphic presentations on a notice board in the unit. Dissemination of information is also organized through the Infection Control Committee to other units, management, and laboratories.

Reports should not identify individual patients. Codes must also be assigned to hospitals, units and responsible physicians, to ensure anonymity. Reports must be returned or disposed of confidentially following established procedures.

3.4.3 Prevention and evaluation

An effective surveillance system must identify priorities for preventive interventions and improvement in quality of care (*18*).

By providing quality indicators, surveillance enables the infection control programme, in collaboration with patient care units, to improve practice, and to define and monitor new prevention policies. The final aim of surveillance is to decrease nosocomial infections and reduce costs.

Surveillance is a continuous process which needs to evaluate the impact of interventions to validate the prevention strategy, and determine if initial objectives are attained.

3.5 Evaluation of the surveillance system

A surveillance system must be continuing if it is to be credible. Periodic contacts with staff will also help to maintain a high level of compliance. Once the surveillance system is functioning, a validation of the surveillance methods and data should be undertaken at regular intervals, considering the following criteria:

3.5.1 Evaluation of the surveillance strategy

Review whether the surveillance system meets the required characteristics (*19,20*):

- simplicity/flexibility/acceptance
- timeliness (is the feedback prompt enough to be useful?)
- utility (in terms of priorities, impact, etc.)
- efficacy/efficiency

Evaluation can be undertaken, for example, through a questionnaire study exploring how feedback is

perceived and how results are used by different groups.

3.5.2 Feedback evaluation

Specific issues which may be addressed are:

● Confidentiality: is it respected? Is it compatible with an optimum use of the results for prevention?

● Exchanges and publication: are the results discussed adequately in the units and the hospital, are inter-facility results reviewed in the context of the relevant literature?

● Comparability

– representativity: is the population under surveillance representative of the hospital, or of the specific patient group?

– risk adjustment/stratification: are these appropriate?

– sample size: the length of the surveillance period may be adjusted to obtain a sufficient number of patients for valid analysis.

3.5.3 Validity/data quality

A data quality evaluation should be periodically undertaken, with criteria such as (19):

● For the denominator:

– exhaustiveness (missing patients)

TABLE 4. **Data quality for the numerator**

| | **Condition PRESENT (patient infected)** | |
	YES	NO
Detected by surveillance YES	A (true positive)	B (false positive)
NO	C (false negative)	D (true negative)

Sensitivity
= proportion of patients detected as being infected who actually are infected (true positive) among infected patients = (A/A+C)

Specificity
= proportion of patients detected as "non-infected" who actually are non-infected (true negative) among non-infected patients = (D/B+D)

Predictive value positive
= proportion of patients detected as being infected who actually are infected (true positive) among "infected patients" detected by the surveillance = (A/A+B)

– completeness (missing data)

– correctness (wrong data).

● For the numerator: see Table 4.

Validation methods used will depend on timeliness, areas of surveillance, and resources (e.g. parallel prospective collection with a trained "expert" investigator for a short period, retrospective validation of a random sample of registered records by an investigator considered as a "gold standard").

The four principal points for nosocomial infection surveillance:

● valid quality indicators (risk-adjusted rates, etc.)

● effective, timely feedback (rapid, useful)

● appropriate implementation of interventions

● evaluation of the impact of interventions by continued surveillance (trends), and other studies

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CHAPTER IV
Dealing with outbreaks

An outbreak is defined as an unusual or unexpected increase of cases of a known nosocomial infection or the emergence of cases of a new infection. Outbreaks of nosocomial infection should be identified and promptly investigated because of their importance in terms of morbidity, costs and institutional image. Outbreak investigation may also lead to sustained improvement in patient care practices.

4.1 Identifying an outbreak

Early identification of an outbreak is important to limit transmission among patients by health care workers or through contaminated materials. A potential problem may be initially identified by nurses, physicians, microbiologists, or any other health care worker, or through a nosocomial infection surveillance programme. Appropriate investigations are required to identify the source of the outbreak, and to implement control measures. The control measures will vary depending on the agent and mode of transmission, but may include isolation procedures or improvements in patient care or environmental cleaning.

4.2 Investigating an outbreak

Systematic planning and implementation of an outbreak investigation is necessary.

4.2.1 Planning the investigation

- Notify the appropriate individuals and departments in the institution of the problem; establish terms of reference for the investigation. This must include development of an outbreak team and clear delineation of authority.

- Infection control staff must be part of the outbreak team.

- Confirm whether there is an outbreak by reviewing preliminary information on the number of potential cases, available microbiology, severity of the problem, and demographic data of person(s), place and time.

4.2.2 Case definition

A case definition should be developed. It must include a unit of time and place and specific biological and/or clinical criteria. The inclusion and exclusion criteria for cases must be precisely identified. A gradient of definition (as definite, probable or possible case) is often helpful. The definition should also differentiate between infection or colonization. Specific criteria to identify the index case may also be developed if relevant information is available.

> **Example of case definition**: A definite case patient will be defined as a patient hospitalized in the geriatric ward in January, with diarrhoea, cramps, vomiting and in whom routine culture of faeces identifies enterotoxin-producing staphylococci.

The case definition can change with time as new information becomes available, or with additional diagnostic information.

A data collection form for case–finding should be developed, and include:

- demographic characteristics (e.g. age, sex, cause of admission/leading diagnosis, date of admission, date of any surgery, prior antimicrobials)

- clinical data (e.g. onset of symptoms and signs, frequency and duration of clinical features associated with the outbreak, treatments, devices)

- any other potentially relevant data.

The form must be straightforward to use. It is completed with information extracted from medical charts, microbiology reports, pharmacy reports and log books of affected wards. The data collected must also be checked for validity.

The clinical diagnosis will usually be confirmed microbiologically. Optimal diagnostic specimens to be obtained from cases should be described. It may be appropriate to store selected biological materials for future analysis in anticipation that new diagnostic methods may become available.

To verify the outbreak, the number of cases or isolates observed during the putative outbreak period is compared with the number of cases (or isolates) reported during the previous period, or with the number of cases (or isolates) reported in the same period of time one month or one year earlier.

4.2.3 Describing the outbreak

The detailed description includes person(s), place, and time. Cases are also described by other characteristics such as gender, age, date of admission, transfer from another unit, etc. The graphic representation of the distribution of cases by time of onset is an epidemic curve. The epidemic curve should distinguish between definite and probable cases. The shape

FIGURE 2. **Epidemic curve in case of ongoing transmission***
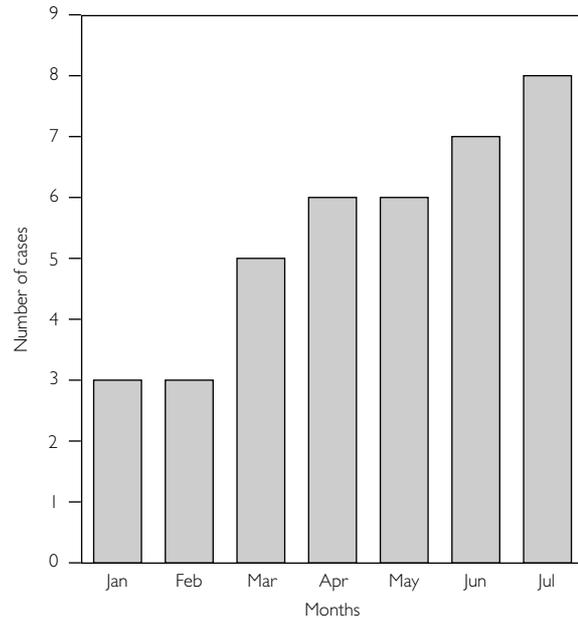
* Adapted from Astagneau P. Duneton P. Management of epidemics of nosocomial infections. *Pathol Biol* (Paris) 1998, 46:272–278.

of the epidemic curve may suggest a single point source (Figure 1), ongoing transmission (Figure 2), or an intermittent source (Figure 3).

These data allow the calculation of an attack rate, defined by:

$$\frac{\text{Number of people at risk who are infected}}{\text{Total number of people at risk}}$$

The attack rate can also be calculated stratified by relevant characteristics such as sex, age, location, or specific exposure (ventilation, catheterization, operating rooms, occupational exposure).

At the end of the descriptive analysis, it should be possible to:

● formulate a hypothesis on the type of infection (exogenous, endogenous)

● tentatively identify the source and route of infection

● suggest and implement initial control measures.

4.2.4 Suggesting and testing a hypothesis

This includes identifying a potential exposure (type and route) for the outbreak and testing this hypothesis using statistical methods. A review of the cur–

FIGURE 1. **Epidemic curve in case of single point source outbreak***

* Adapted from Astagneau P. Duneton P. Management of epidemics of nosocomial infections. *Pathol Biol* (Paris) 1998, 46:272–278.

FIGURE 3. **Epidemic curve in case of intermittent source***
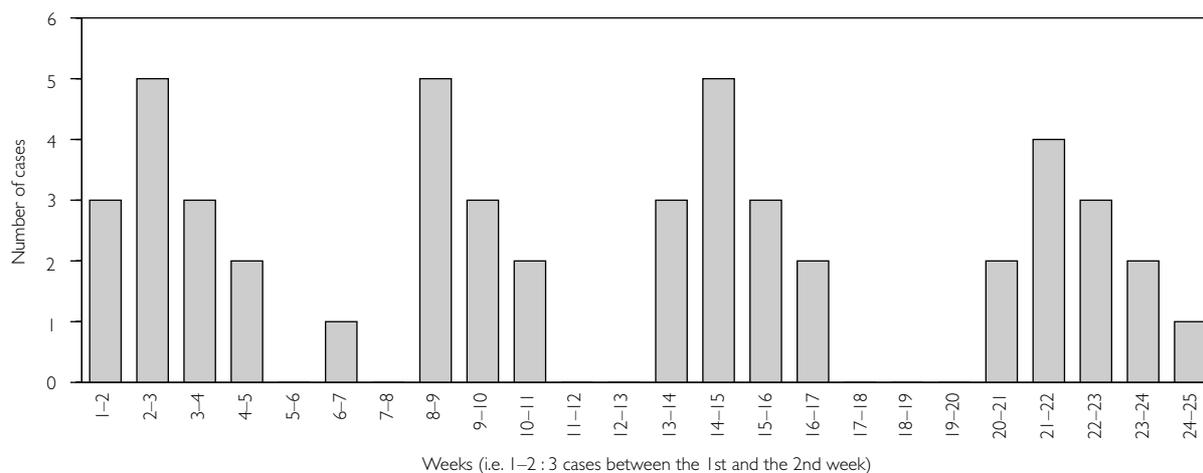
Weeks (i.e. 1–2 : 3 cases between the 1st and the 2nd week)

* adapted from Astagneau P, Duneton P. Management of epidemics of nosocomial infections. *Pathol Biol* (Paris) 1998, 46:272–278.

rent literature may help identify possible routes of infection for the suspected or known infecting agents.

A case–control study is the most common approach to hypothesis testing. This compares the frequency of a risk factor in a group of cases (i.e. individuals with the nosocomial infection) and in a group of controls (i.e. individuals without the infection). Controls must be carefully selected to limit bias. Two or more controls for each case may be necessary to provide sufficient statistical power. By definition, the controls are not–cases (individuals without the nosocomial infection or colonization). Further in–depth discussion of the selection of controls is described in several other sources (*1,2,3*).

The strength of association between exposure and disease is quantified by the odds ratio in case-control studies (or the relative risk for cohort studies), with a 95% confidence interval. The role of chance, confounding, and bias should be considered in interpreting results.

4.2.5 Control measures and follow-up

The aims are:

● to control the current outbreak by interrupting the chain of transmission

● to prevent future occurrence of similar outbreaks.

The selection of control measures (Table 1) is determined by results of the initial analysis in consultation with appropriate professionals (infection control staff, epidemiologist, clinicians, microbiologists, nursing). This is also an opportunity to initiate or improve a surveillance system to facilitate evaluation of the efficacy of the control procedures instituted. Continuous surveillance may be implemented in high–risk units (see Chapter III).

4.2.6 Communication

During the investigation of an outbreak, timely, up–to–date information must be communicated to the

TABLE 1. **Immediate control measures for outbreak management**

Type of transmission suspected	Suggested action
Cross-transmission (transmission between individuals)	Patient isolation and barrier precautions determined by infectious agent(s)
Hand transmission	Improvements in handwashing; cohorting
Airborne agent	Patient isolation with appropriate ventilation
Agent present in water, waterborne agent	Checking of water supply and all liquid containers Use of disposable devices
Foodborne agent	Elimination of the food at risk

hospital administration, public health authorities, and, in some cases, to the public. Information may be provided to the public and to the media with agreement of the outbreak team, administration and local authorities.

A final report on the outbreak investigation should be prepared. It should describe the outbreak, interventions, and effectiveness, and summarize the contribution of each team member participating in the investigation. It should also make recommendations to prevent future occurrence. This report can be published in the medical literature, and may be considered as a legal document.

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Prevention of nosocomial infection

Prevention of nosocomial infections requires an integrated, monitored, programme which includes the following key components:

- limiting transmission of organisms between patients in direct patient care through adequate handwashing and glove use, and appropriate aseptic practice , isolation strategies, sterilization and disinfection practices, and laundry

- controlling environmental risks for infection

- protecting patients with appropriate use of prophylactic antimicrobials, nutrition, and vaccinations

- limiting the risk of endogenous infections by minimizing invasive procedures , and promoting optimal antimicrobial use

- surveillance of infections, identifying and controlling outbreaks

- prevention of infection in staff members

- enhancing staff patient care practices, and continuing staff education.

Infection control is the responsibility of all health care professionals – doctors, nurses, therapists, pharmacists, engineers and others.

5.1 Risk stratification (1)

Acquisition of nosocomial infection is determined by both patient factors, such as degree of immunocompromise, and interventions performed which increase risk. The level of patient care practice may differ for patient groups at different risk of acquistion of infection. A risk assessment will be helpful to categorize patients and plan infection control interventions.

Tables 1 and 2 provide an example of an approach which could be customized to a particular facility. Table 1 stratifies the risk for different patient groups, and Table 2 provides a hierarchy of patient care practice for different levels of patient risk.

5.2 Reducing person-to-person transmission

5.2.1 Hand decontamination

The importance of hands in the transmission of hospital infections has been well demonstrated (2), and can be minimized with appropriate hand hygiene (3,4,5). Compliance with handwashing, however, is frequently suboptimal. This is due to a variety of reasons, including: lack of appropriate accessible equipment, high staff-to-patient ratios, allergies to

TABLE 1. **Differential nosocomial infection risk by patient and interventions**

Risk of infection	Type of patients	Type of procedures
1 Minimal	Not immunocompromised; no significant underlying disease	Non-invasive No exposure to biological fluids *
2 Medium	Infected patients, or patients with some risk factors (age, neoplasm)	Exposure to biological fluids or Invasive non-surgical procedure (e.g. peripheral venous catheter, introduction of urinary catheter)
3 High	Severely immunocompromised patients, (<500 WBC per ml); multiple trauma, severe burns, organ transplant	Surgery or High-risk invasive procedures (e.g. central venous catheter, endotracheal intubation)

* Biological fluids include blood, urine, faeces, CSF, fluid from body cavities.

TABLE 2. **Aseptic measures appropriate for different levels of risk of infection**

Risk of infection	Asepsis	Antiseptics	Hands	Clothes	Devices*
1 Minimal	Clean	None	Simple handwashing or hand disinfection by rubbing	Street clothes	Clean or disinfected at intermediate or low level
2 Medium	Asepsis	Standard antiseptic products	Hygienic handwashing or hand disinfection by rubbing	Protection against blood and biological fluids, as appropriate	Disinfected at sterile or high level
3 High	Surgical asepsis	Specific major products	Surgical handwashing or surgical hand disinfection by rubbing	Surgical clothes: dress, mask, caps, sterile gloves	Disinfected at sterile or high level

*All devices entering sterile body cavities must be sterile.

handwashing products, insufficient knowledge of staff about risks and procedures, too long a duration recommended for washing, and the time required.

5.2.1.1 Optimal "hand hygiene" requirements

For handwashing:

- running water: large washbasins which require little maintenance, with antisplash devices and hands–free controls

- products: soap or antiseptic depending on the procedure

- facilities for drying without contamination (disposable towels if possible).

For hand disinfection:

- specific hand disinfectants: alcoholic rubs with antiseptic and emollient gels which can be applied to physically clean hands.

5.2.1.2 Procedures

There must be written policies and procedures for handwashing. Jewellery must be removed before washing. Simple hygiene procedures may be limited to hands and wrists; surgical procedures include the hand and forearm.

Procedures will vary with the patient risk assessment (Table 3):

- ***routine care (minimal)***:

  – handwashing with non–antiseptic soap

  – or quick hygienic hand disinfection (by rubbing) with alcoholic solution

- ***antiseptic handcleaning (moderate) — aseptic care of infected patients***:

  – hygienic handwashing with antiseptic soap following manufacturers instructions (e.g. one minute)

  – or quick hygienic hand disinfection: as previously

- ***surgical scrub (surgical care)***:

  – surgical hand and forearm washing with antiseptic soap and sufficient time and duration of contact (3–5 minutes)

  – or surgical hand and forearm disinfection: simple handwash and drying followed by two applications of hand disinfectant, then rub to dry for the duration of contact defined by the product.

5.2.1.3 Resource availability

Equipment and products are not equally accessible in all countries or health care facilities. Flexibility in products and procedures, and sensitivity to local needs, will improve compliance. Table 3 provides suggestions to adapt handwashing for different availability of resources. In all cases, the maximum procedure possible should be instituted.

TABLE 3. **Hand care and economic constraints**

Level	Good resources	Limited resources	Very limited resources
1 **Routine** **(minimal)**	*Simple handwashing:* Equipment: large wash-basin, water and automatically distributed washing agent, liquid soap, disposable towels *Hygienic hand disinfection by rubbing:* Specified duration of contact between hand and disinfectant, rub to dry	*Simple handwashing:* Equipment: large wash-basin, water and locally made soap (dry), individual towels *Hygienic hand disinfection by rubbing:* Specified duration of contact with hand disinfectant or alcohol, rub to dry	*Simple handwashing:* Equipment: clean water, locally made soap (dry), towels washed daily *Hygienic hand disinfection by rubbing:* Specified duration of contact with alcohol and rub to dry
2 **Antiseptic** **hand cleaning**	*Hygienic (or antiseptic) handwashing:* Equipment: large wash-basin, water and automatically distributed washing agent, antiseptic scrub (one-minute contact), disposable towels *Hygienic hand disinfection by rubbing:* Specified duration of hand-disinfectant contact, rub to dry	*Hygienic (or antiseptic) handwashing:* Equipment: large wash-basin, water and locally made soap (dry) if antisepsis is undertaken after the washing. Otherwise: antiseptic scrub (1 minute contact), individual towels *Hygienic hand disinfection by rubbing:* Specified duration of contact with disinfectant or alcohol, rub to dry	*Simple handwashing:* Equipment: clean water, locally made soap (dry), towels washed daily *Hygienic hand disinfection by rubbing:* Associated with alcohol antisepsis, contact and rub to dry
3 **Surgical scrub** **(maximal)**	*Surgical hand-forearm-washing:* Equipment: large wash-basin, water and automatically distributed washing agent, good antiseptic scrub (contact 3 to 5 minutes), sterile disposable towels *Surgical hand disinfection by rubbing:* Equipment as for level 2: good soft soap, specific hand disinfectant, repeated twice.	*Simple hand-forearm-washing:* Equipment: large wash-basin, water and locally made soap (dry), individual towels *Hygienic hand disinfection by rubbing:* Associated with antisepsis: specific hand disinfectant, repeated twice	*Simple hand-forearm-washing:* Equipment: clean water, locally made soap (dry), towels washed daily *Hygienic hand disinfection by rubbing:* Associated with alcohol antisepsis, repeated twice

5.2.2 Personal hygiene

All staff must maintain good personal hygiene. Nails must be clean and kept short. False nails should not be worn. Hair must be worn short or pinned up. Beard and moustaches must be kept trimmed short and clean.

5.2.3 Clothing

Working clothes

Staff can normally wear a personal uniform or street clothes covered by a white coat. In special areas such as burn or intensive care units, uniform trousers and a short–sleeved gown are required for men and women. In other units, women may wear a short–sleeved dress.

The working outfit must be made of a material easy to wash and decontaminate. If possible, a clean out–fit should be worn each day. An outfit must be changed after exposure to blood or if it becomes wet through excessive sweating or other fluid expo–sure.

Shoes

In aseptic units and in operating rooms, staff must wear dedicated shoes, which must be easy to clean.

Caps

In aseptic units, operating rooms, or performing selected invasive procedures, staff must wear caps or hoods which completely cover the hair.

5.2.4 Masks (6)

Masks of cotton wool, gauze, or paper are ineffective. Paper masks with synthetic material for filtration are an effective barrier against microorganisms.

● Masks are used in various situations; mask requirements differ for different purposes.

● Patient protection: staff wear masks to work in the operating room, to care for immuno–compromised patients, to puncture body cavities. A surgical mask is sufficient.

● Staff protection: staff must wear masks when caring for patients with airborne infections, or when performing bronchoscopies or similar examination. A high–efficiency mask is recommended.

● Patients with infections which may be transmitted by the airborne route must use surgical masks when outside their isolation room.

5.2.5 Gloves (6)

Gloves are used for:

● Patient protection: staff wear sterile gloves for surgery, care for immunocompromised patients, invasive procedures which enter body cavities.

● Non–sterile gloves should be worn for all patient contacts where hands are likely to be contaminated, or for any mucous membrane contact.

● Staff protection: staff wear non–sterile gloves to care for patients with communicable disease transmitted by contact, to perform bronchoscopies or similar examinations.

● Hands must be washed when gloves are removed or changed.

● Disposable gloves should not be reused.

● Latex or polyvinyl–chloride are the materials most frequently used for gloves. Quality, i.e. absence of porosity or holes and duration of use vary considerably from one glove type to another. Sensitivity to latex may occur, and the occupational health programme must have policies to evaluate and manage this problem.

5.2.6 Safe injection practices

To prevent transmission of infections between patients with injections:

● eliminate unnecessary injections

● use sterile needle and syringe

● use disposable needle and syringes, if possible

● prevent contamination of medications

● follow safe sharps disposal practices (Chapter VII, 8.5).

For more information, refer to the WHO guide "Best infection control practices for skin–piercing intra–dermal, subcutaneous, and intramuscular needle injections" (7).

5.3 Preventing transmission from the environment

To minimize the transmission of microorganisms from equipment and the environment, adequate methods for cleaning, disinfecting and sterilizing must be in place. Written policies and procedures which are updated on a regular basis must be developed for each facility.

5.3.1 Cleaning of the hospital environment (5,6,8)

● Routine cleaning is necessary to ensure a hospital environment which is visibly clean, and free from dust and soil.

● Ninety per cent of microorganisms are present within "visible dirt", and the purpose of routine cleaning is to eliminate this dirt. Neither soap nor detergents have antimicrobial activity, and the cleaning process depends essentially on mechanical action.

● There must be policies specifying the frequency of cleaning and cleaning agents used for walls, floors, windows, beds, curtains, screens, fixtures, furniture, baths and toilets, and all reused medical devices.

● Methods must be appropriate for the likelihood of contamination, and necessary level of asepsis. This may be achieved by classifying areas into one of four hospital zones (8):

    – *Zone A*: no patient contact. Normal domestic cleaning (e.g. administration, library).

– *Zone B*: care of patients who are not infected, and not highly susceptible, cleaned by a pro-cedure that does not raise dust. Dry sweeping or vacuum cleaners are not recommended. The use of a detergent solution improves the qual-ity of cleaning. Disinfect any areas with visible contamination with blood or body fluids prior to cleaning.

– *Zone C*: infected patients (isolation wards). Clean with a detergent/disinfectant solution, with separate cleaning equipment for each room.

– *Zone D*: highly–susceptible patients (protective isolation) or protected areas such as operating suites, delivery rooms, intensive care units, premature baby units, casualty departments and haemodialysis units. Clean using a deter-gent/disinfectant solution and separate clean-ing equipment.

All horizontal surfaces in zones B, C and D, and all toilet areas should be cleaned daily.

● Bacteriological testing of the environment is not recommended except in selected circumstances such as:

– epidemic investigation where there is a sus-pected environmental source

– dialysis water monitoring for bacterial counts, as required by standards (see Chapter VIII)

– quality control when changing cleaning prac-tices.

5.3.2 Use of hot/superheated water

An alternative to disinfection for environmental cleaning for some objects is hot water (Table 4).

TABLE 4. **Disinfection with hot water**

	Temperature	Duration
1. Sanitary equipment	80 °C	45–60 seconds
2. Cooking utensils	80 °C	1 minute
3. Linen	70 °C 95 °C	25 minutes 10 minutes

5.3.3 Disinfection of patient equipment

Disinfection removes microorganisms without com-plete sterilization to prevent transmission of organ-isms between patients. Disinfection procedures must (*5,9,10*):

● meet criteria for killing of organisms

● have a detergent effect

● act independently of the number of bacteria present, the degree of hardness of the water, or the presence of soap and proteins (that inhibit some disinfectants).

To be acceptable in the hospital environment, they must also be:

● easy to use

● non–volatile

● not harmful to equipment, staff or patients

● free from unpleasant smells

● effective within a relatively short time.

For further recommendations, see Tables 5 and 6. In using a disinfectant, manufacturers recommenda-tions must always be followed. Different products or processes achieve different levels of disinfection. These are classified as high–, intermediate– or low–level disinfection (*11*); Table 5 provides charac-teristics of the three levels, and Table 6 makes recommendations for the level of disinfection for dif-ferent patient care activity.

High-level disinfection (critical) – this will destroy all microorganisms, with the exception of heavy con-tamination by bacterial spores.

Intermediate disinfection (semi–critical) – this inactivates *Mycobacterium tuberculosis*, vegetative bacteria, most viruses and most fungi, but does not necessarily kill bacterial spores.

Low-level disinfection (non–critical) – this can kill most bacteria, some viruses and some fungi, but can-not be relied on for killing more resistant bacteria such as *M. tuberculosis* or bacterial spores.

These levels of disinfection are attained by using the appropriate chemical product in the manner appro-priate for the desired level of disinfection.

5.3.4 Sterilization (*5–13*)

Sterilization is the destruction of all microorganisms. Operationally this is defined as a decrease in the

TABLE 5. **Spectrum of activity achieved of the main disinfectants**

Level of disinfection required	Spectrum of activity of desinfectant	Active ingredients potentially capable of satisfying these spectra of activity	Factors affecting the efficacy of a disinfectant
High	• Sporicidal • Mycobactericidal • Virucidal • Fungicidal • Bactericidal	• Peracetic acid • Chlorine dioxide • Formaldehyde • Glutaraldehyde • Sodium hypochlorite • Stabilized hydrogen peroxide • Succinaldehyde (succinic aldehyde)	• Concentration • Contact time • Temperature • Presence of organic matter • pH • Presence of calcium or magnesium ions (for example, hardness of the water used for dilution)
Intermediate	• Tuberculocidal • Virucidal • Fungicidal • Bactericidal	• Phenol derivatives • Ethyl and isopropyl alcohols	• Formulation of the disinfectant used
Low	• Bactericidal	• Quaternary ammonium • Amphiprotic • Amino acids	

TABLE 6. **Level of disinfection for patient equipment in relation with type of care** *(11,12)*

Devices use	Class	Level of risk	Level of disinfection
Into vascular system, into sterile cavity, into sterile tissues: Surgical instrumentation, e.g. athro-scopes, biopsies, instrumentation, etc.	• critical	• high	• sterilization or high-level disinfection
Mucous membrane contact, non-intact skin: e.g. gastroscopy, etc.	• semi-critical	• medium	• disinfection of median level
Intact skin or without contact with patient: e.g. beds, sink, etc.	• non-critical	• low	• disinfection of low level

microbial load by 10^{-6}. Sterilization can be achieved by either physical or chemical means (Table 7).

● Sterilization is required for medical devices penetrating sterile body sites, as well as all parenteral fluids and medications.

● For reprocessed equipment, sterilization must be preceded by cleaning to remove visible soil.

● The object must be wrapped for sterilization. Only a wrapped sterilized object should be described as sterile:

Materials for packaging include:

– *paper* which prevents contamination if intact, maintains sterility for a long period, can act as a sterile field, and can also be used to wrap dirty devices after the procedure

TABLE 7. **Principal sterilization methods**

Thermal sterilization

• Wet sterilization: exposure to steam saturated with water at 121 °C for 30 minutes, or 134 °C for 13 minutes in an autoclave; (134 °C for 18 minutes for prions).

• Dry sterilization: exposure to 160 °C for 120 minutes, or 170 °C for 60 minutes; this sterilization process is often considered less reliable than the wet process, particularly for hollow medical devices.

Chemical sterilization

• Ethylene oxide and formaldehyde for sterilization are being phased out in many countries because of safety and greenhouse gas emission concerns.

• Peracetic acid is widely used in the United States and some other countries in automatic processing systems.

- – *selected plastics*; only polyethylene and poly-propylene are suitable for sterilization with ethylene oxide

  – *non-woven disposable textiles*

  – *containers* can be used only if they contain material intended for a single treatment procedure for a single patient. They must be provided with a filter and a valve, which must be monitored regularly.

- Packaging systems for sterile items shall meet local legislation and/or regulations, but must nevertheless:

  – provide adequate seal integrity and be tamper-proof

  – provide an adequate barrier to particulate matter

  – withstand physical conditions of the sterilization process

  – provide an adequate barrier to fluids

  – permit adequate air removal

  – allow penetration and removal of sterilant

  – protect package content from physical damage

  – resist tears and punctures

  – be free of holes

  – be free of toxic ingredients

  – have a low lint content

  – have a positive cost/benefit ratio

  – be used according to the manufacturers' written instructions

  – be dated.

- Proper storage conditions are essential to maintain the integrity of sterilized items.

- The end–user must check the integrity of the package before use.

- The sterilization of endoscopes, minimally invasive instruments, and robotic instrumentation is necessary, but may present a particular challenge because of the configuration of these instruments.

- Quality control parameters for the sterilization process must record information on the sterilization processing cycle including:

  – load number

  – load content

  – temperature and time exposure record chart

  – regular (at least daily) physical/chemical testing

  – regular (at least weekly) biological testing

  – steam processing (*Bacillus stearothermophilus*)

  – ethylene oxide processing (*Bacillus subtilis v. niger*).

- Regular maintenance must be performed and documented. The following records must be maintained for all sterilization:

  – date of service

  – model and serial number

  – location

  – descriptions of replaced parts

  – biological testing records

  – Bowie–Dick test

  – name and signature of controller.

Endoscope reprocessing

Endoscopes are medical devices which may be problematic to clean and disinfect (long narrow channels, complex internal design, etc.). Products and/or processes used (chemical or thermo-chemical disinfection) may not be as reliable as sterilization methods.

To reduce nosocomial transmission of microorganisms by endoscopy a standard reprocessing procedure must be systematically followed.

1. Immediately after use, the air-water channel should be cleared with forced air, and tap water or detergent suctioned or pumped through the aspiration/biopsy channel(s) to remove organic debris.

2. All detachable parts (e.g. hoods and suction valves) should be removed and soaked in a detergent solution, and the external parts of the endoscopes gently wiped.

3. All accessible channels should then be irrigated with tap water or detergent solution, brushed (using sterile or single use brush) and purged.

4. Before any immersion, the endoscope must be leak-tested.

Endoscope reprocessing continued

After pre-treatment and mechanical cleaning the endoscope should be cleaned and disinfected, either manually or automatically. In both cases, the complete cycle includes several stages:

5. Cleaning using an approved detergent (this solution cannot be reused).

6. Rinsing (tap water is sufficient for this in-between rinsing stage).

7. Disinfection. Using an approved, high level disinfectant.

   Regarding CJD risk, a disinfectant with protein-fixative properties (i.e. aldehyde-based products) should not be used. A non-fixative desinfectant should be selected.

8. Rinsing: The level of microbial purity of the water used depends on the further use of the endoscope (bacteriologically controlled water or sterile water).

9. Drying: If the endoscope is not stored, this drying stage includes only air-blowing the channel to remove residual water.

Note: new French guidelines regarding variant Creutzfeldt-Jakob (CJD) risk recommend to clean and rinse the endoscope twice before disinfection.

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Prevention of common endemic nosocomial infections

The four most common nosocomial infections are urinary tract infections, surgical wound infections, pneumonia, and primary bloodstream infection. Each of these is associated with an invasive medical device or invasive procedure. Specific policies and practices to minimize these infections must be established, reviewed and updated regularly, and compliance monitored (Table 1).

6.1 Urinary tract infections (UTI)

Urinary tract infections are the most frequent nosocomial infections (*1*); 80% of these infections are associated with an indwelling urethral catheter (Figure 1). Interventions effective in preventing nosocomial urinary infection include (*2,3,4*):

● avoiding urethral catheterization unless there is a compelling indication

TABLE 1. **Measures for prevention of infection**

Infection	Proven effective	Proven not effective
Urinary tract infections	Limit duration of catheter Aseptic technique at insertion Maintain closed drainage	Systemic antibiotic prophylaxis Bladder irrigation or instillation of normal saline antiseptic or antibiotic Antiseptic added to drainage bag Antimicrobial-coated catheter Daily antiseptic perineal cleaning
Surgical site infections	Surgical technique Clean operating environment Staff attire Limiting preoperative hospital stay Preoperative shower and local skin preparation of patient Optimal antibiotic prophylaxis Aseptic practice in operating room Surgical wound surveillance	Fumigation Preoperative shaving

Pneumonia	Ventilator-associated
	    Aseptic intubation and suctioning
	    Limit duration
	    Non-invasive ventilation
	Others
	    Influenza vaccination for staff
	    Isolation policy
	    Sterile water for oxygen and aerosol therapy
	    Prevention of *Legionella* and *Aspergillus*
	        during renovations
		Digestive decontamination for all patients
		Changes of ventilator circuit every 48 or
		    72 hours

Vascular device infections	All catheters
	    Closed system
	    Limit duration
	    Local skin preparation
	    Aseptic technique at insertion
	    Removal if infection suspected
	Central lines
	    Surgical asepsis for insertion
	    Limitation of frequency of dressing change
	    Antibiotic-coated catheter for short term
		Antimicrobial creams for skin preparation

FIGURE I. **Portals of entry for microorganisms in urinary drainage systems: the urethral meatus-catheter junction; the catheter-drainage tubing junction; the drainage tubing-bag junction; and the outlet that drains urine from the bag**

Urethral meatus–catheter junction

Catheter–drainage tubing junction

Drainage–tubing bag junction

Outlet

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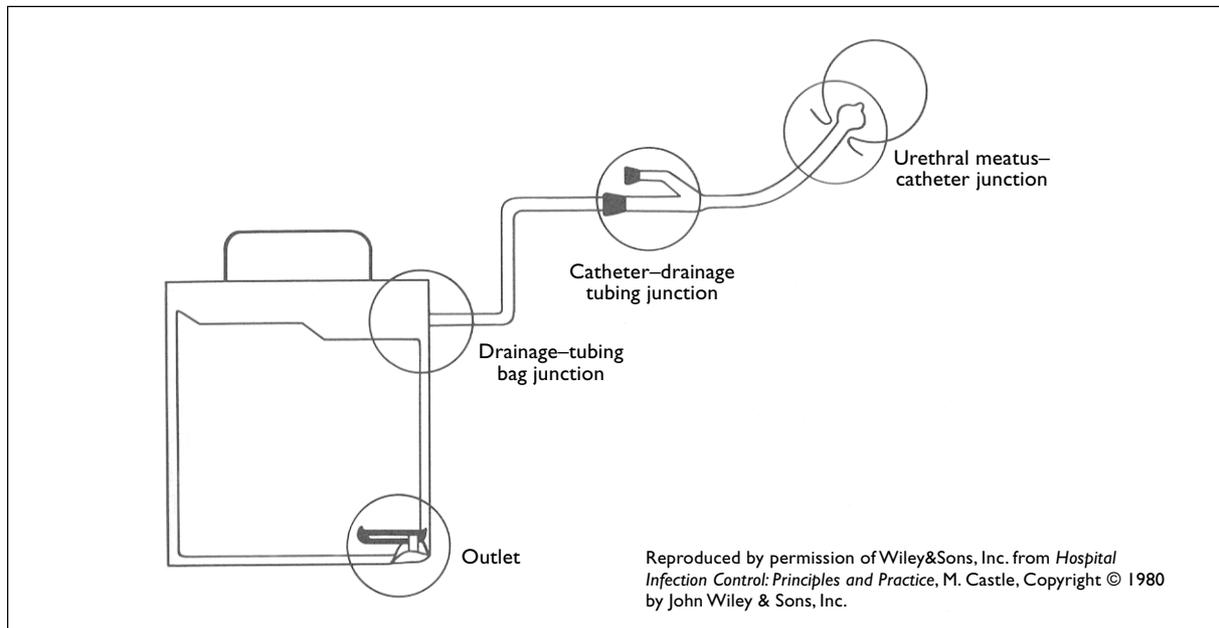
- limiting the duration of drainage, if catheterization is necessary

- maintaining appropriate aseptic practice during urinary catheter insertion and other invasive urological procedures (e.g. cystoscopy, urodynamic testing, cystography)

- hygienic handwash or rub prior to insertion and following catheter or drainage bag manipulation (Chapter V)

- sterile gloves for insertion

- perineal cleaning with an antiseptic solution prior to insertion

- non–traumatic urethral insertion using an appropriate lubricant

- maintaining a closed drainage system.

Other practices which are recommended, but not proven to decrease infection include:

- maintaining good patient hydration

- appropriate perineal hygiene for patients with catheters

- appropriate staff training in catheter insertion and care

- maintaining unobstructed drainage of the bladder to the collection bag, with the bag below the level of the bladder.

Generally, the smallest diameter catheter should be used. Catheter material (latex, silicone) does not influence infection rates.

For patients with a neurogenic bladder:

- avoid an indwelling catheter if possible

- if assisted bladder drainage is necessary, clean intermittent urinary catheterization should be used.

6.2 Surgical wound infections (surgical site infections)

Factors which influence the frequency of surgical wound infection include (*5,6,7,8*):

- surgical technique

- extent of endogenous contamination of the wound at surgery (e.g. clean, clean–contaminated)

- duration of operation

- underlying patient status

- operating room environment

- organisms shed by the operating room team.

A systematic programme for prevention of surgical wound infections (*5*) includes the practice of optimal surgical technique, a clean operating room environment with restricted staff entry and appropriate

staff attire, sterile equipment, adequate preoperative preparation of the patient, appropriate use of preoperative antimicrobial prophylaxis, and a surgical wound surveillance programme. Surgical wound infection rates are decreased by standardized surveillance for infection with reporting of rates back to individual surgeons.

6.2.1 Operating room environment

Airborne bacteria must be minimized, and surfaces kept clean. A recommended schedule for cleaning and disinfection of the operating theatre is:

- *every morning before any intervention*: cleaning of all horizontal surfaces

- *between procedures*: cleaning and disinfection of horizontal surfaces and all surgical items (e.g. tables, buckets)

- *at the end of the working day*: complete cleaning of the operating theatre using a recommended disinfectant cleaner

- *once a week*: complete cleaning of the operating room area, including all annexes such as dressing rooms, technical rooms, cupboards.

All items used within a sterile field must be sterile. Sterile drapes must be placed on the patient and on any equipment included in the sterile field; these drapes must be handled as little as possible. Once a sterile drape is in position, it must not be moved; shifting or moving the sterile drape compromises the sterile field.

For selected high-risk surgery (e.g. orthopaedic procedures with implants, transplantation) further specific measures for operating room ventilation may be considered (Chapter VIII).

6.2.2 Operating room staff

6.2.2.1 Handwashing

A surgical hand disinfection should be performed by all persons participating in the operative procedure (Chapter V).

6.2.2.2 Operating room attire

Operating staff must wear sterile gloves. The reported occurrence of glove punctures ranges from 11.5% to 53% of procedures (*9*), and double gloving is therefore advisable for procedures with a high risk of

puncture, such as total joint arthroplasty. Double gloving is also recommended when operating on patients known to be infected with bloodborne pathogens such as the human immunodeficiency virus (HIV), hepatitis B, or hepatitis C (*10*). Gloves should be changed immediately after any accidental puncture.

All persons entering the surgical theatre must wear surgical attire restricted to being worn only within the surgical area. The design and composition of surgical attire should minimize bacterial shedding into the environment.

All head and facial hair, including sideburns, and neckline, must be covered. All personnel entering in the operating suite must remove any jewellery; nail polish or artificial nails must not be worn.

Full coverage of the mouth and nose area with a surgical mask for everyone entering the operating suite (*11*).

Sterile surgical gowns must be worn by all persons participating directly in the operation. Waterproof gowns or aprons should be worn for procedures at high risk of blood contamination.

6.2.2.3 Operating room activitiy

- The number of persons entering the theatre during an operation should be minimized.

- Unnecessary movement or conversation should be avoided.

6.2.3 Pre-intervention preparation of the patient

For elective procedures, any existing infections should be identified and treated before surgery. The preoperative stay should be minimized. Any malnourished patient should have nutrition improved before elective surgery.

The patient should normally be bathed or showered on the evening before the intervention, using an antimicrobial soap. If hair removal is required, this should be done by clipping or with a depilatory rather than by shaving (*5,12*).

The operative site must be washed with soap and water, then an antimicrobial preoperative skin preparation applied from the centre to the periphery. The area prepared must be large enough to include the entire incision and adjacent skin sufficient for

the surgeon to work without contacting unprepared skin.

The patient must be covered with sterile drapes; no part is uncovered except the operating field and areas needed for the administration and maintenance of anaesthesia.

6.2.4 Antimicrobial prophylaxis (see Chapter IX)

6.2.5 Surgical wound surveillance (see also Chapter III)

- Prospective surgical wound surveillance should be undertaken for selected procedures.

- Infection rates should be stratified by the extent of endogenous bacterial contamination at surgery: clean, clean–contaminated, or dirty.

- Surgical wound infection rates may also be stratified by duration of operation and underlying patient status.

- Individual surgeons should be provided their own surgical wound infection rates in a confidential manner, with a comparator of overall rates for the facility or region.

6.3 Nosocomial respiratory infections (13)

Nosocomial respiratory tract infections occur in different patient groups (10). In some cases, the hospital environment may play a significant role (see Chapter VIII). Recommendations to prevent these infections include:

6.3.1 Ventilator-associated pneumonia in the intensive care unit

- Appropriate disinfection and in–use care of tubing, respirators, and humidifiers to limit contamination.

- No routine changes of respirator tubing.

- Avoid antacids and H2 blockers.

- Sterile tracheal suctioning.

- Nurse in head–up position.

6.3.2 Medical units

- Limit medications which impair consciousness (sedatives, narcotics).

- Position comatose patients to limit the potential for aspiration.

- Avoid oral feeds in patients with swallowing abnormalities.

- Prevent exposure of neutropenic or transplant patients to fungal spores during construction or renovation (Chapter VIII).

6.3.3 Surgical units

- All invasive devices used during anaesthesia must be sterile.

- Anaesthetists must use gloves and mask when undertaking invasive tracheal or venous or epidural care. Disposable filters (for individual use) for endotracheal intubation effectively prevent the transmission of microorganisms among patients by ventilators.

- Preoperative physiotherapy prevents postoperative pneumonia in patients with chronic respiratory disease.

6.3.4 Neurological patients with tracheostomy (with or without ventilation)

- Sterile suctioning at appropriate frequency.

- Appropriate cleaning and disinfection of respiratory machines and other devices.

- Physiotherapy to assist with drainage of secretions.

6.4 Infections associated with intravascular lines (3,14–16)

Local (exit site, tunnel) and systemic infections may occur (Figure 2). They are most common in intensive care units (14). Key practices for all vascular catheters include:

- avoiding catheterization unless there is a medical indication

- maintaining a high level of asepsis for catheter insertion and care

- limiting the use of catheters to as short a duration as possible

- preparing fluids aseptically and immediately before use

- training of personnel in catheter insertion and care.

FIGURE 2. **Portals of entry for microorganisms in IV systems**

During manufacture

Additives

Hairline cracks or punctures

Bottle (bag)–tubing junction

Medication port

Stopcock

Insertion site

Secondary infection from other side

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6.4.1 Peripheral vascular catheters

● Hands must be washed before all catheter care, using hygienic handwash or rub (Chapter V).

● Wash and disinfect skin at the insertion site with an antiseptic solution.

● Intravenous line changes no more frequently than change of catheters, with the exception of line changes after the transfusion of blood or intralipids, and for discontinuous perfusions.

● A dressing change is not normally necessary.

● If local infection or phlebitis occurs, the catheter should be removed immediately.

6.4.2 Central vascular catheters

● Clean the insertion site with an antiseptic solution.

● Do not apply solvents or antimicrobial ointment to the insertion site.

● Mask, cap, and sterile gloves and gown must be worn for insertion.

● The introduction of the catheter and the subsequent catheter dressings require a surgical hand wash or rub.

● Follow appropriate aseptic care in accessing the system, including disinfecting external surfaces of hub and ports.

● Change of lines should normally not occur more often than once every three days. A change of line is necessary, however, after the transfusion of blood, blood products, or intralipids, and for discontinuous perfusions.

● Change dressing at the time of the change of lines, following surgical asepsis.

● Use a sterile gauze or transparent dressing to cover the catheter site.

● Do not replace over a guide wire if infection is suspected.

● An increased number of catheter lumens may increase the risk of infection. A single lumen catheter is preferred wherever possible.

● Antimicrobial impregnated catheters may decrease infection in high–risk patients with short–term (<10 days) catheterization.

● Use the subclavion site in preference to jugular or femoral sites.

● Consider using a peripherally inserted central catheter, if appropriate.

6.4.3 Central vascular totally implanted catheters

Implantable vascular access devices should be considered for patients who require long–term (>30 days) therapy. Additional preventive practices for these patients include:

● a preoperative shower and implantation under surgical conditions in an operating room

● local preparation includes washing and antisepsis with major antiseptic solution as for other surgical procedures

● mask, hat, and sterile gloves and gown must be worn; the introduction of a catheter and the dressing require a surgical handwash or rub

● maintain a closed system during the use of the

device; a change of lines should normally occur every 5 days for continuous use, and at each intervention for intermittent use; a change of line is necessary after the transfusion of blood, and for discontinuous perfusions.

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Infection control precautions in patient care

Selected patients may require specific precautions to limit transmission of potential infecting organisms to other patients.

Recommended isolation precautions depend on the route of transmission (*1*). The main routes are:

- **Airborne infection**: the infection usually occurs by the respiratory route, with the agent present in aerosols (infectious particles <5 μm in diameter).

- **Droplet infection**: large droplets carry the infectious agent (>5 μm in diameter).

- **Infection by direct or indirect contact**: infection occurs through direct contact between the source of infection and the recipient or indirectly through contaminated objects.

7.1 Practical aspects

Isolation and other barrier precautions must be clearly written policies which are standardized, and adaptable to the infectious agent and the patients. These include:

- standard or routine precautions to be followed for all patients

- additional precautions for selected patients.

7.1.1 Standard (routine) precautions (*1,2*)

To be applied to the care of all patients. This includes limiting health care worker contact with all secretions or biological fluids, skin lesions, mucous membranes, and blood or body fluids. Health care workers must wear gloves for each contact which may lead to contamination, and gowns, mask and eye protection where contamination of clothes or the face is anticipated.

Standard precautions for all patients (*3,4*)

- Wash hands promptly after contact with infective material

- Use no touch technique wherever possible

- Wear gloves when in contact with blood, body fluids, secretions, excretions, mucous membranes and contaminated items

- Wash hands immediately after removing gloves

- All sharps should be handled with extreme care

- Clean up spills of infective material promptly

- Ensure that patient-care equipment, supplies and linen contaminated with infective material is either discarded, or disinfected or sterilized between each patient use

- Ensure appropriate waste handling

- If no washing machine is available for linen soiled with infective material, the linen can be boiled.

Considerations for protective clothing include:

- gown: should be of washable material, buttoned or tied at the back and protected, if necessary, by a plastic apron

- gloves: inexpensive plastic gloves are available and usually sufficient

- mask: surgical masks made of cloth or paper may be used to protect from splashes.

7.1.2 Additional precautions for specific modes of transmission (*1,2*)

The following precautions are used for selected patients in addition to those described above:

Airborne precautions (droplet nuclei <5 μm) (e.g. tuberculosis, chickenpox, measles) (5,6)

The following is required:

- individual room with adequate ventilation; this includes, where possible, negative pressure; door closed; at least six air exchanges per hour; exhaust to outside away from intake ducts

- staff wearing high-efficiency masks in room

- patient to stay in room.

Droplet precautions (droplet nuclei >5 μm) (e.g. bacterial meningitis, diphtheria, respiratory syncytial virus)

The following procedures are required:

- individual room for the patient, if available

- mask for health care workers

- restricted circulation for the patient; patient wears a surgical mask if leaving the room.

Contact precautions

These are required for patients with enteric infections and diarrhoea which cannot be controlled, or skin lesions which cannot be contained.

- individual room for the patient if available; cohorting of patients if possible

- staff wear gloves on entering the room; a gown for patient contact or contact with contaminated surfaces or material

- wash hands before and after contact with the patient, and on leaving the room

- restrict patient movement outside the room

- appropriate environmental and equipment cleaning, disinfection, and sterilization.

Absolute (strict) isolation (e.g. haemorrhagic fever, vancomycin-resistant S. aureus) (7,8)

Such isolation is required where there is risk of infection by a highly virulent or other unique agent of concern where several routes of transmission are implicated.

- individual room, in an isolation ward if possible

- mask, gloves, gowns, cap, eye protection for all entering the room

- hygienic handwashing at entry to and exit from the room

- incineration of needles, syringes

- disinfection of medical instruments

- incineration of excreta, body fluids, nasopharyngeal secretions

- disinfection of linen

- restrict visitors and staff

- daily disinfection and terminal disinfection at the end of the stay

- use of disposable (single-use) equipment

- appropriate transport and laboratory management of patient specimens.

7.2 Antimicrobial-resistant microorganisms

The increased occurrence of antimicrobial-resistant microorganisms (i.e. methicillin-resistant *S. aureus* (9,10) or vancomycin-resistant enterococci [VRE]) (11,12) is a major medical concern. The spread of multiresistant strains of *S. aureus* and VRE is usually by transient carriage on the hands of health care workers.

The following precautions are required for the prevention of spread of epidemic MRSA:

- minimize ward transfers of staff and patients

- ensure early detection of cases, especially if admitted from another hospital; screening of high-risk patients may be considered

- isolate infected or colonized patients in a single room, isolation unit or cohorting in a larger ward

- re-enforce handwashing by staff after contact with infected or colonized patients; consider using an antiseptic handwashing agent

- use gloves for handling MRSA-contaminated materials, or infected or colonized patients

- wear gown or apron when handling contaminated materials or infected or colonized patients

- consider treating nasal carriers with mupirocin

- consider antiseptic detergent daily wash or bath for carriers or infected patients

- ensure careful handling and disposal of medical devices, linen, waste, etc.

- develop guidelines specifying when isolation measures can be discontinued.

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Environment

The discussion of the environment will include building features, ventilation, water, food and wastes. Housekeeping and equipment are discussed in Chapter V.

8.1 Buildings

Health services – including public and private hospital services – must meet quality standards (ISO 9000 and ISO 14000 series) (*1*). It is recognized that older facilities, and facilities in developing countries, may not be able to achieve these standards. However, the principles underlying these standards should be kept in mind for local planning and, where possible, renovations should attempt to achieve standards.

8.1.1 Planning for construction or renovation (2,11)

An infection control team member should participate on the planning team for any new hospital construction or renovation of existing facilities. The role of infection control in this process is to review and approve construction plans to ensure they meet standards for minimizing nosocomial infections. Considerations will usually include:

- traffic flow to minimize exposure of high–risk patients and facilitate patient transport

- adequate spatial separation of patients

- adequate number and type of isolation rooms

- appropriate access to handwashing facilities

- materials (e.g. carpets, floors) that can be adequately cleaned

- appropriate ventilation for isolation rooms and special patient care areas (operating theatres, transplant units)

- preventing patient exposure to fungal spores with renovations

- appropriate potable water systems to limit *Legionella* spp.

8.1.2 Architectural segregation

It is useful to stratify patient care areas by risk of the patient population for acquisition of infection. For some units, including oncology, neonatology, intensive care, and transplant units special ventilation may be desirable.

Four degrees of risk may be considered:

> A – Low-risk areas: e.g. administrative sections
>
> B – Moderate-risk areas: e.g. regular patient units
>
> C – High-risk-areas: e.g. isolation unit, intensive care units
>
> D – Very-high-risk areas: e.g. operating rooms

Infected patients must be separated from immuno–compromised patients. Similarly, in a central sterilization unit or in a hospital kitchen, contaminated areas must not compromise non–contaminated areas.

8.1.3 Traffic flow (3)

A room or space, whatever its purpose, is never completely separate. However, a distinction can be made between high–traffic and low–traffic areas. One can consider general services (food and laundry, sterile equipment, and pharmaceutical distribution), specialized services (anaesthesiology, medical imaging, medical or surgical intensive care) and other areas. A hospital with well–defined areas for specific activities can be described using flowcharts depicting the flow of in– or outpatients, visitors, staff (physicians, nurses and paramedics), supplies (expendable, sterile, catering, clothing, etc.) as well as

the flow of air, liquids and wastes. Other traffic patterns may also be identified. Building or rebuilding a hospital requires consideration of all physical movements and communications, and where contamination may occur.

In this context, rather than considering a "clean" and a "dirty" circuit, consider only circuits where the different flows can cross without risk provided material is properly protected. An elevator can accommodate hospital staff, sterile equipment, visitors and waste, as long as each of these is treated appropriately. Both sterile products and waste must be sealed in safe containers, and the outside of those containers must present no risk of biological contamination.

8.1.4 Materials

The choice of construction materials – especially those considered in the covering of internal surfaces – is very important. Floor coverings must be easy to clean and resistant to disinfection procedures. This also applies to all items in the patient environment.

All of this calls for:

1. Definition of needs (planning)

2. Definition of the level of risk (segregation)

3. Description of functional flow patterns (flows and isolation)

4. Building or rebuilding (materials)

8.2 Air

8.2.1 Airborne contamination and transmission

Infection may be transmitted over short distances by large droplets, and at longer distances by droplet nuclei generated by coughing and sneezing (4). Droplet nuclei remain airborne for long periods, may disseminate widely in an environment such as a hospital ward or an operating room, and can be acquired by (and infect) patients directly, or indirectly through contaminated medical devices.

Housekeeping activity such as sweeping, using dry dust mops or cloths, or shaking out linen, can aerosolize particles that may contain microorganisms. Similarly, *Legionella pneumophila*, the organism responsible for legionellosis (Legionnaires' disease; Pontiac fever), can become airborne during the evaporation

of water droplets from air conditioning cooling towers or with aerosolization in patient showers, and subsequently may be inhaled by patients at risk of infection.

The number of organisms present in room air will depend on the number of people occupying the room, the amount of activity, and the rate of air exchange. Bacteria recovered from air samples usually consist of Gram-positive cocci originating from the skin. They can reach large numbers if dispersed from an infected lesion, particularly an infected exfoliative skin lesion. However, since the contaminated skin scales are relatively heavy, they do not remain suspended in the air for long. Gram-negative bacteria are usually found in the air only when associated with aerosols from contaminated fluids, and tend to die on drying.

Droplets projected from the infected upper respiratory tract may contain a wide variety of microrganisms, including viruses, and many infections can be spread by this route (i.e. respiratory viruses, influenza, measles, chickenpox, tuberculosis). In most cases, these are spread by large droplets, and an infective dose will rarely move more than a few feet from the source patient. Varicella-zoster (chickenpox), tuberculosis, and a few other agents, however, may be transmitted over large distances in droplet nuclei.

8.2.2 Ventilation

Fresh filtered air, appropriately circulated, will dilute and remove airborne bacterial contamination. It also eliminates smells. Desirable ventilation rates, expressed in air changes per hour, vary with the purpose of a particular area (5). High-risk hospital areas (operating rooms, nurseries, intensive care units, oncology, and burn units) should have air with minimal bacterial contamination.

● Adequate ventilation systems require proper design and maintenance to minimize microbial contamination. All outdoor air inlets must be located as high as possible above ground level; inlets must be remote from ventilation discharge outlets, incinerators, or boiler stacks.

● Within rooms, the location of air inlets and exhaust outlets influences the movement of air. High wall or ceiling inlets and low wall outlets allow clean air to move downward through the area toward the contaminated floor where it is removed through the low exhaust. This pattern is for all

areas where high-risk patients receive care, and in areas subject to heavy contamination.

- Filters used in the ventilation systems must meet standards for the patient care activity of the area. High-efficiency filters must be provided in systems serving areas where patients are particularly susceptible to infection (haematology/oncology units) or where some clinical procedures subject patients to unusual hazard (for instance surgical procedure, particularly transplantation).

- Regular inspection and maintenance of filters, humidifiers, and grills in the ventilation system must be performed and documented.

- Cooling towers and humidifiers should be regularly inspected and cleaned to prevent aerosolization of *Legionella* spp.

- Zoning of air systems may confine the air of a department to that department alone. A design that enables air pressure to control air movement into or out of a specific room or area will control the spread of contamination. Positive air pressure is recommended for areas which must be as clean as possible. It is achieved by supplying more air into an area than can be removed by the exhaust ventilation system. This produces an outflow around doors and other openings, and decreases entry of air from more contaminated areas. Negative air pressure is recommended for contaminated areas, and is required for isolation of patients with infections spread by the airborne route. It is achieved by supplying less air to the area than can be removed by the ventilation system. Negative air pressure produces an inflow around openings and reduces the movement of contaminated air out of the area. For effective air pressurization all doors must be kept closed except for essential entrances and exits.

8.2.3 Operating theatres

Modern operating rooms which meet current air standards are virtually free of particles larger than 0.5 μm (including bacteria) when no people are in the room. Activity of operating room personnel is the main source of airborne bacteria, which originate primarily from the skin of individuals in the room. The number of airborne bacteria depends on eight factors (Table 1). Conventional operating rooms are ventilated with 20 to 25 changes per hour of high-efficiency filtered air delivered in a vertical flow. High-efficiency particulate air (HEPA) systems re-

move bacteria larger than 0.5 to 5 μm in diameter and are used to obtain downstream bacteria-free air. The operating room is usually under positive pressure relative to the surrounding corridors, to minimize inflow of air into the room.

TABLE I. **Factors influencing airborne contamination in operating theatres**

1. Type of surgery
2. Quality of air provided
3. Rate of air exchange
4. Number of persons present in operating theatre
5. Movement of operating room personnel
6. Level of compliance with infection control practices
7. Quality of staff clothing
8. Quality of cleaning process

8.2.4 Ultra-clean air

- For minimizing airborne particles, air must be circulated into the room with a velocity of at least 0.25 m/sec through a high-efficiency particulate air (HEPA) filter, which excludes particulate matter of defined size. If particles 0.3 microns in diameter and larger are removed, the air entering the room will be essentially clean and free of bacterial contaminants.

- This principle has been applied to microbiology laboratories, pharmacies, special intensive care units, and operating rooms.

Workers in microbiology laboratories use special unidirectional airflow hoods to handle microbial cultures. These are particularly useful for certain highly infectious cultures. Hoods of this type protect the individual worker as well as the laboratory environment from contamination by the airborne route.

Similar hoods are used in pharmacies to prevent airborne contamination of sterile fluids when containers are opened. For example, when adding an antibiotic to a container of sterile glucose solution for intravenous use, or when preparing fluids for parenteral hyperalimentation.

In intensive care units, laminar flow units have been used in the treatment of immunosuppressed patients.

For operating theatres, a unidirectional clean airflow system with a minimum size of 9 m² (3 m x

3 m) and with an air speed of at least 0.25 m/s, protects the operating field and the instrument table. This ensures instrument sterility through-out the procedure. It is possible to reduce the costs of building and maintaining operating theatres by positioning such systems in an open space with several operating teams working together. This is particularly adapted to high-risk surgery such as orthopaedics, vascular surgery, or neurosurgery.

> Some nosocomial infections are due to airborne mi-croorganisms.
>
> Appropriate ventilation is necessary, and must be monitored within risk areas, e.g. orthopaedics, vascu-lar surgery and neurosurgery.
>
> Unidirectional airflow systems should be incorporated in appropriate areas in new hospital construction.

8.3 Water

The physical, chemical and bacteriological charac-teristics of water used in health care institutions must meet local regulations. The institution is responsi-ble for the quality of water once it enters the build-ing. For specific uses, water taken from a public network must often be treated for medical use (physi-cal or chemical treatment). Criteria for drinking-water is usually not adequate for medical uses of water.

8.3.1 Drinking-water

Drinking-water should be safe for oral ingestion. National norms and international recommendations define appropriate criteria for clean drinking-water. Unless adequate treatment is provided, faecal con-tamination may be sufficient to cause infection through food preparation, washing, the general care of patients, and even through steam or aerosol in-halation (*Legionella pneumophila*). Even water that con-forms to accepted criteria may carry potentially pathogenic microorganisms. Organisms present in tap water have frequently been implicated in noso-comial infections (Table 2). Guidance on drinking-water quality is provided in WHO guidelines (*6*).

These microorganisms have caused infection of wounds (burns, surgical wounds), respiratory tract, and other sites (semi-critical equipment such as endoscopes rinsed with tap water after they have been disinfected).

TABLE 2. **Some microorganisms causing waterborne nosocomial infections**

Gram-negative bacteria:

    Pseudomonas aeruginosa

    Aeromonas hydrophilia

    Burkholderia cepacia

    Stenotrophomonas maltophilia

    Serratia marcescens

    Flavobacterium meningosepticum

    Acinetobacter calcoaceticus

    Legionella pneumophila and other

Mycobacteria:

    Mycobacterium xenopi

    Mycobacterium chelonae

    Mycobacterium avium-intracellularae

Legionella spp. live in hot water networks where the temperature promotes their development within protozoan phagosomes; tap aerators facilitate pro-liferation of these and other microorganisms, such as *Stenotrophomonas maltophilia*. Equipment which uses tap water may be a risk in health care institutions: ice machines, dental units, eye- and ear-washing installations, etc. Water used for flowers and holy water has also been implicated in nosocomial infec-tions.

8.3.2 Baths

Baths can be used either for hygiene (patients, babies) or for specific purposes of care (burns, re-habilitation in swimming pools, lithotripsy). The main infectious agent in baths is *Pseudomonas aeruginosa* (*7*). It may cause folliculitis (generally benign), external otitis, which can become severe under certain conditions (diabetes, immunosuppres-sion), and wound infections. Baths can also transmit other pathogens (*Legionella*, atypical mycobacteria – with swimming pool granuloma, enterobacteria such as *Citrobacter freundii*).

Viral infections may also be transmitted in commu-nal baths (*Molluscum contagiosum*, papillomavirus) through contact with contaminated surfaces. Para-sitic infections such as cryptosporidiosis, giardiasis, and amoebiasis, and mycoses, especially *Candida*, may also be transmitted. National regulations for public swimming pools and baths is a basis for standards for health care institutions. Protocols for the disin-fection of equipment and material must be written,

and adherence to these practices monitored. Infected patients should be restricted from using communal baths. Potential entry points for organisms to cause infection in patients, such as percutaneous devices, must be protected with waterproof occlusive dressings.

8.3.3 Pharmaceutical (medical) water

There are physical, chemical, bacteriological, and biological parameters which must be met for water used for medical purposes.

Pharmaceutical waters include (8):

- purified water – sterile water used for the preparation of drugs that normally do not need to be sterile, but must be pyrogen-free

- water used for injectable preparations, which must be sterile

- dilution water for haemodyalisis.

  In the case of dialysis, contamination may induce infections (bacteria passing from the dialysate into the blood) or febrile reactions due to pyrogenic endotoxins from the degradation of the membranes of Gram-negative bacteria. The CDC recommends that the water for haemodyalisis contain:

  – less than 200 coliforms/ml for water used for dilution

  – less than 2000 coliforms/ml for dialysate.

  The levels of organisms in dialysate should be monitored once a month. The coliform recommendations may be revised downwards with improvements in water production, use of dialysis membranes with improved permeability, and increasing knowledge of the role of bacterial products in the complications of long-term dialysis. New techniques (haemofiltration, haemodialysis filtration on line) require stricter guidelines for water dilution and for haemodialysis solutions (9).

8.3.4 Microbiological monitoring

Regulations for water analysis (at the national level for drinking-water, in the Pharmacopoeia for pharmaceutical waters) define criteria, levels of impurities, and techniques for monitoring. For water use for which regulations are not available, parameters should be appropriate for the planned use and the requirements of users (including risk factors for patients).

Methods used for monitoring must suit the use. Bacteriological, medical and biochemical methods are not necessarily adapted to environmental analyses, and may lead to falsely reassuring conclusions. Two points which must be considered for water ecosystems are: (1) biofilm, (2) level of stress for the microorganism (nutrients, exposure to physical or chemical antibacterial agents).

Biofilm consists of microorganisms (dead or alive) and macromolecules of biological origin, and accumulates as a complex gel on the surfaces of conduits and reservoirs. It is a dynamic ecosystem with a wide variety of organisms (bacteria, algae, yeasts, protozoa, nematodes, insect larvae, molluscs) starting with the biodegradable organic matter of water. This biofilm is a dynamic reservoir for microorganisms (including pathogenic agents such as *Legionella* and *Pseudomonas aeruginosa*). Individual organisms may be freed into circulation through shearing at the surface of the biofilm or through the mechanical impact of vibrations (such as may occur during construction).

Bacteriological tests may not always give true estimates of contamination because of the presence of agents such as disinfectants.

> Water is used in health care institutions for many very different uses.
>
> The use determines characteristics needed for the water. These usually differ from those of tap water.
>
> Infections attributable to water are usually due to failure to meet water quality standards for the specific use.
>
> Infection control/hygiene teams must have written, valid policies for water quality to minimize risk of adverse outcomes attributable to water in health care settings.

8.4 Food

Quality and quantity of food are key factors for patient convalescence. Ensuring safe food is an important service delivery in health care.

8.4.1 Agents of food poisoning and foodborne infections

Bacterial food poisoning (acute gastroenteritis) is an infection or intoxication manifested by abdominal pain and diarrhoea, with or without vomiting or fever. The onset of symptoms may range from less than one to more than 48 hours after eating contaminated food. Usually, large numbers of organisms actively growing in food are required to initiate symptoms of infection or intoxication. Water, milk, and solid foods are all vehicles for transmission.

Table 3 is a non-exhaustive listing of organisms that may cause food poisoning.

TABLE 3. **Microbiological agents causing food poisoning**

Bacteria

Salmonella species	Campylobacter jejuni
Staphylococcus aureus	Yersinia enterocolitica
Clostridium perfringens	Vibrio parahaemolyticus
Clostridium botulinum	Vibrio cholerae
Bacillus cereus and other aerobic spore-forming bacilli	Aeromonas hydrophilia
	Streptococcus species
	Listeria monocytogenes
Escherichia coli	

Viruses	**Parasites**
Rotavirus	Giardia lamblia
Caliciviruses	Entamoeba histolytica

8.4.2 Factors contributing to food poisoning

The frequency of foodborne illness is increasing. This may be due to increasing complexity in modern food handling, particularly in mass-catering, as well as increasing importation of potentially contaminated food products from other countries.

For individuals to develop food poisoning, the number of organisms in food must be of a sufficient level. There must also be adequate nutrients, moisture, and warmth for multiplication of organisms, or toxin production to occur between preparation and consumption of the food.

Many inappropriate food handling practices permit contamination, survival and growth of infecting bacteria. The most common errors which contribute to outbreaks include:

– preparing food more than a half day in advance of needs

– storage at room temperature

– inadequate cooling

– inadequate reheating

– use of contaminated processed food (cooked meats and poultry, pies and take-away meals) prepared in premises other than those in which the food was consumed

– undercooking

– cross-contamination from raw to cooked food

– contamination from food handlers.

Hospital patients may be more susceptible to foodborne infection, and suffer more serious consequences than healthy people. Thus, high standards of food hygiene must be maintained. A hospital surveillance system must be able to identify potential foodborne outbreaks early (Chapter III), and prompt outbreak investigation and control must be initiated if an outbreak is suspected (Chapter IV).

8.4.3 Prevention of food poisoning

The following food preparation practices must be hospital policy, and rigorously adhered to:

● Maintain a clean work area.

● Separate raw and cooked food to avoid cross-contamination.

● Use appropriate cooking techniques and follow recommendations to prevent growth of micro-organisms in food.

● Maintain scrupulous personal hygiene among food handlers, especially handwashing, as hands are the main route of contamination (see Chapter 6).

● Staff should change work clothes at least once a day, and keep hair covered.

● Avoid handling food in the presence of an infectious disease (cold, influenza, diarrhoea, vomiting, throat and skin infections), and report all infections.

Other factors important for quality control are:

● Purchased food must be of good quality (controlled), and bacteriologically safe.

● Storage facilities must be adequate, and correspond to requirements for the food type.

● The quantity of perishable goods should not exceed an amount corresponding to one day's consumption.

- Dry goods, preserves, and canned food should be stored in dry, well–ventilated storerooms, and stocks rotated.

- Frozen food storage and preparation must follow producers instructions, and be kept at temperatures of at least –18 °C (–0.4 °F); do not refreeze.

- The catering system environment must be washed often and regularly with tap water and appropriate detergents (and/or disinfectants).

- Samples of prepared food should be stored for a specified time period, to allow retrieval for testing should an outbreak occur.

- Food handlers should receive continuing instruction in safe practices.

Food poisoning can be avoided by basic principles of food care:

- Limiting contamination from source, hands, raw food, and environment
- Purchasing
- Storage
- Refrigeration
- Cooking
- Personal hygiene
- Clean up
- Pest control

8.5 Waste

Health care waste is a potential reservoir of pathogenic microorganisms, and requires appropriate handling. The only waste which is clearly a risk for transmission of infection, however, is sharps contaminated with blood. Recommendations for classification and handling of different types of waste should be followed (*10*).

8.5.1 Definition and classification (*10*)

Health care waste includes all waste generated by health care establishments, research facilities, and laboratories.

Between 75% to 90% of this waste is non–risk or "general" health care waste, comparable to domestic waste. This comes from the administrative and housekeeping functions of health care facilities. The remaining 10–25% of health care waste is regarded as hazardous, and may create some health risks (Table 4).

Infectious waste is suspected to contain pathogens (bacteria, viruses, parasites, or fungi) in sufficient concentrations or quantities to cause disease in susceptible hosts. This category of waste includes:

- cultures and stocks of infectious agents from laboratory work

TABLE 4. **Categories of health care waste**

Waste category	Description and examples
Infectious waste	Waste suspected to contain pathogens, e.g. laboratory cultures; waste from isolation wards; tissues (swabs), materials, or equipment that have been in contact with infected patients; excreta
Pathological waste	Human tissues or fluids, e.g. body parts; blood and other body fluids; fetuses
Sharps	Sharp waste, e.g. needles; infusion sets; scalpels; knives; blades; broken glass
Pharmaceutical waste	Waste containing pharmaceuticals, e.g. pharmaceuticals that are expired or no longer needed; items contaminated by or containing pharmaceuticals (bottles, boxes)
Cytotoxic waste	Waste containing substances with genotoxic properties, e.g. waste containing cytostatic drugs (often used in cancer therapy); genotoxic chemicals
Chemical waste	Waste containing chemical substances, e.g. laboratory reagents; film developer; disinfectants that are expired or no longer needed; solvents
Wastes with high content of heavy metals	Batteries; broken thermometers; blood pressure gauges; etc.
Pressurized containers	Gas cylinders; gas cartridges; aerosol cans
Radioactive waste	Waste containing radioactive substances, e.g. unused liquids from radiotherapy or laboratory research; contaminated glassware, packages, or absorbent paper; urine and excreta from patients treated or tested with unsealed radionuclides; sealed sources

- waste from surgery and autopsies on patients with infectious diseases (e.g. tissues, and materials or equipment that have been in contact with blood or other body fluids)

- waste from infected patients in isolation wards (e.g. excreta, dressings from infected or surgical wounds, clothes heavily soiled with human blood or other body fluids)

- waste that has been in contact with infected patients undergoing haemodialysis (e.g. dialysis equipment such as tubing and filters, disposable towels, gowns, aprons, gloves and laboratory coats)

- infected animals from laboratories

- any other instruments or materials that have been contaminated by infected persons or animals.

8.5.2 Handling, storage and transportation of health care waste

All waste disposal practices must meet local regulations. The following practices are recommended as a general guide:

- For safety and economic reasons, health care institutions must organize a selective collection of hospital waste, differentiating between medical waste, general waste and some specific wastes (sharp instruments, highly infectious waste, cytoxic waste).

- General health care waste may be disposed in the stream of domestic refuse.

- Sharps should be collected at source of use in puncture-proof containers (usually made of metal or high-density plastic) with fitted covers. Containers should be rigid, impermeable, and puncture proof. To discourage abuse, containers should be tamper-proof (difficult to open or break). Where plastic or metal containers are unavailable or too costly, containers made of dense cardboard are recommended – these fold for ease of transport and may be supplied with a plastic lining.

- Bags and other containers used for infectious waste must be marked with the international infectious substance symbol.

- Infectious health care waste should be stored in a secure place with restricted access.

- Microbiological laboratory waste should be sterilized by autoclaving. It must be packaged in bags compatible with the process: red bags, suitable for autoclaving, are recommended.

- Cytotoxic waste, most of which is produced in major hospital or research facilities, must be collected in strong, leak-proof containers clearly labelled "Cytotoxic wastes".

- Small amounts of chemical or pharmaceutical waste may be collected together with infectious waste.

- Large quantities of obsolete or expired pharmaceuticals stored in hospital wards or departments must be returned to the pharmacy for disposal. Other pharmaceutical waste generated at the wards, such as spilled or contaminated drugs, or packaging containing drug residues must **not** be returned because of the risk of contaminating the pharmacy; it must be deposited in the correct container at the point of generation.

- Large quantities of chemical waste must be packed in chemical-resistant containers and sent to specialized treatment facilities (if available). The identity of the chemicals must be clearly marked on the containers: hazardous chemical wastes of different types should never be mixed.

- Waste with a high content of heavy metals (e.g. cadmium or mercury) must be collected and disposed of separately.

- Pressurized containers may be collected with general health care waste once they are completely empty, provided that the waste is not destined for incineration.

- Low-level radioactive infectious waste (e.g. swabs, syringes for diagnostic or therapeutic use) may be collected in yellow bags or containers for infectious waste if these are destined for incineration.

- Health care personnel and other hospital workers should be informed about the hazards related to health care waste and trained in appropriate waste management practices.

- Additional information on collection, handling, storage and disposal of health care wastes, as well as personal protection and training issues is provided in a referenced document (10).

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CHAPTER IX

Antimicrobial use and antimicrobial resistance

Following the discovery and widespread use of sulfonamides and penicillin in the mid–20th century, the years between 1950 and 1970 saw a "golden age" of antimicrobial discovery (Table 1) . Many infections that were once serious and potentially fatal could now be treated and cured. However, these successes encouraged the overuse and misuse of antibiotics. Currently many microorganisms have become resistant to different antimicrobial agents, and in some cases to nearly all agents. Resistant bacteria may cause increased morbidity and death, particularly among patients with significant underlying diseases or who are immunocompromised. Resistance to antimicrobial agents is a problem in the community as well as health care facilities, but in hospitals, transmission of bacteria is amplified because of the highly susceptible population.

Resistance and its spread among bacteria is generally the result of selective antibiotic pressure (1,2). Resistant bacteria are transmitted among patients, and resistance factors are transferred between bacteria, both occurring more frequently in health care settings. The continuous use of antimicrobial agents increases selection pressure favouring the emergence, multiplication, and spread of resistant strains. Inappropriate and uncontrolled use of antimicrobial agents including overprescribing, administration of suboptimal doses, insufficient duration of treatment, and misdiagnosis leading to inappropriate choice of drug, contribute to this. In health care settings, the spread of resistant organisms is facilitated when handwashing, barrier precautions, and equipment cleaning are not optimal. The emergence of resistance is also favoured by underdosing due to shortage of antibiotics, where lack of microbiological laboratories results in empiric prescribing, and where the lack of alternate agents compounds the risk of therapeutic failure.

TABLE I. **Commonly used antimicrobials by class**

Class	Antibiotics
Aminoglycosides	Streptomycin, kanamycin, tobramycin, gentamicin, neomycin, amikacin
Beta-lactams	
• Penicillins	Benzylpenicillin (penicillin G), procaine-benzyl penicillin, benzathine-benzyl penicillin, phenoxymethylpenicillin (penicillin V), ampicillin, amoxycillin, methicillin, cloxacillin
• Penicillin/beta-lactamase inhibitors	amoxicillin/clavulanic acid, piperacillin/tazobactam
• Cephalosporins	1st generation: cephalexin, cephalothin 2nd generation: cefuroxime, cefoxitin, cefaclor 3rd generation: cefotaxime, ceftriaxone, ceftazidime
Other beta-lactams	Aztreonam,
• Carbapenems	Imipenem, meropenem
• Glycopeptides	Vancomycin, teicoplanin
• Macrolides/azolides	Erythromycin, oleandomycin, spiramycin, clarithromycin, azithromycin
• Tetracyclines	Tetracycline, chlortetracycline, minocycline, doxycycline, oxytetracycline
• Quinolones	Nalidixic acid, ciprofloxacin, norfloxacin, pefloxacin, sparfloxacin, fleroxacin, ofloxacin, levofloxacin, gatifloxacin, moxifloxacin
• Oxazolidinone	linezolid
• Streptogramin	Quinupristin/dalfopristin
• Others	Bacitracin, cycloserine, novobiocin, spectinomycin, clindamycin, nitrofurantoin
Sulfonamides and trimethoprim	Trimethoprim, trimethoprim/ sulfamethoxazole

9.1 Appropriate antimicrobial use

Each health care facility should have an antimicrobial use programme (*3,4*). The goal is to ensure effective economical prescribing to minimize the selection of resistant microorganisms. This policy must be implemented through the Antimicrobial Use Committee.

- Any antibiotic use must be justifiable on the basis of the clinical diagnosis and known or expected infecting microorganisms.

- Appropriate specimens for bacteriological examination must be obtained before initiating antibiotic treatment, to confirm the treatment is appropriate.

- The selection of an antibiotic must be based not only on the nature of the disease and that of the pathogenic agent(s), but on the sensitivity pattern, patient tolerance, and cost.

- The physician should receive timely, relevant information of the prevalence of resistance in the facility.

- An agent with as narrow a spectrum as possible should be used.

- Antibiotic combinations should be avoided, if possible.

- Selected antibiotics may be restricted in use.

- The correct dose must be used. Low dosages may be ineffective for treating infection, and encourage the development of resistant strains. On the other hand, excessive doses may have increased adverse effects, and may not prevent resistance.

Generally speaking, a course of antibiotics should be of limited duration (5–14 days), depending on the type of infection. There are selected indications for longer courses. As a rule, if an antibiotic has not been effective after three days of therapy, the antibiotic should be discontinued and the clinical situation reassessed.

9.1.1 Therapy

Empirical antimicrobial therapy must be based on careful clinical evaluation and local epidemiological data regarding potential pathogens and antibiotic susceptibility. Appropriate specimens for Gram stain, culture and, if available, sensitivity testing must be obtained before starting therapy. Therapy selected should be effective, limit toxicity, and be of the narrowest spectrum possible. The choice of parenteral, oral or topical antimicrobial formulations is made on the basis of clinical presentation (site and severity of infection). Oral administration is preferred, if possible. Combinations of antibiotics should be used selectively and only for specific indications such as enterococcal endocarditis, tuberculosis, and mixed infections.

The physician must decide whether antibiotic therapy is really necessary. In patients with fever, non-infectious diagnoses must be considered.

> The aim of antimicrobial therapy is to choose a drug that is selectively active against the most likely pathogen(s) and the least likely to cause adverse effects or promote resistance.

9.1.2 Chemoprophylaxis

Antibiotic prophylaxis is used only when it has been documented to have benefits which outweigh risks. Some accepted indications include:

- selected surgical prophylaxis (Table 2)

- endocarditis prophylaxis.

Where chemoprophylaxis is appropriate, antibiotics must be initiated intravenously within one hour prior to the intervention. It is often most efficient to order therapy given at call to the operating room or at the time of induction of anaesthesia. In most cases, prophylaxis with a single preoperative dose is sufficient. The regimen selected depends on the prevailing pathogen(s), the pattern of resistance in the surgical service, the type of surgery, the serum half-life of the antibiotic, and the cost of the drugs. Administration of prophylactic antibiotics for a longer period prior to the operation is counterproductive, as there will be a risk of infection by a resistant pathogen.

Antibiotic prophylaxis is not a substitute for appropriate aseptic surgical practice.

9.2 Antimicrobial resistance

Nosocomial infections are often caused by antibiotic-resistant organisms. Where transmission of these organisms in the health care setting is occurring, specific control measures are necessary (Table 3, Table 4). Antimicrobial restriction is also an important intervention.

TABLE 2. **Recommendations for antibiotic prophylaxis in surgery** (5,6,7,8)

Type of surgery	Prophylaxis

Gastrointestinal
Oesophageal,
gastric, duodenal
	Single dose:
	  cephalothin/cefazolin 2 g **or**
	  cefuroxime 1.5 g **or**
	  piperacillin 4 g **or**

Biliary tract	above **and** doxycycline 200 mg

Pancreatic, intestinal	any of above **and**
	  metronidazole 1 g **or**
	  tinidazole 800 mg

Urological
  Prostatectomy
	Single dose:
	  cefuroxime 1.5 g **or**
	  ciprofloxacin 500 mg **or**
	  norfloxacin 500 mg **or**
	  TMP/SMX* 160/800 mg

Enteric substitutes
Implanted prosthesis
Transrectal prostate
  biopsy
	same as intestinal
	cefuroxime 1.5 g
	ciprofloxacin 500 mg **or**
	  norfloxacin 400 mg

Gynaecological/
obstetrical
  Total hysterectomy
	Single dose:
	
	  cefuroxime 1.5 g **or**
	  cefazolin 2 g **or**
	  piperacillin 4 g

Orthopaedic
  Joint replacement
  Osteosynthes of
    trochanteric femur
    fractures
  Amputations
	3–4 doses over 24 hrs
	  cloxacillin/nafcillin
	    1–2 g/dose
	  cephalothin/cefazolin
	    1-2 g/dose **or**
	  clindamycin 600 mg/dose

Vascular
  Reconstructive
  Amputations
  Aortic graft stents
	cefuroxime 1.5 g q8h for
	  24 hours **or**
	ciprofloxacin 750 mg q12h for
	  24 hours **or**
	**vancomycin 1 g q12h for
	  24 hours

Thoracic
  Cardiac
  Implantation
    pacemaker/
    defibrillator
    (2 doses)
	3–4 doses over 24 hrs
	  cephalothin/cefazolin 2 g **or**
	  cloxacillin/nafcillin 2 g **or**
	  clindamycin 600 mg **or**
	  **vancomcyin 1 g IV

Pulmonary	cephalothin/cefazolin 2 g **or**
	  cefuroxime 1.5 g **or**
	  benzylpenicillin 3 g **or**
	  clindamycin 600 mg

* TMP/SMX: Trimethoprim/sulfamethoxazole

** For penicillin-allergic only

TABLE 3. **Infection control measures for containment of outbreaks with antimicrobial-resistant organisms**

Identify reservoirs

Colonized and infected patients

Environmental contamination

Halt transmission

Improve handwashing and asepsis

Isolate colonized and infected patients

Eliminate any common source; disinfect environment

Separate susceptible from infected and colonized patients

Close unit to new admissions, if necessary

Modify host risk

Discontinue compromising factors when possible

Control antibiotic use (rotate, restrict, or discontinue)

TABLE 4. **Control of endemic antibiotic resistance**

- Ensure appropriate use of antibiotics (optimal choice, dosage and duration of antimicrobial therapy and chemoprophylaxis based on defined hospital antibiotic policy, monitoring and antibiotic resistance, and up-to-date antimicrobial guidelines).

- Institute protocol (guidelines) for intensive infection control procedures and provide adequate facilities and resources, especially for handwashing, barrier precautions (isolation), and environmental control measures.

- Improve antimicrobial prescribing practices through educational and administrative methods.

- Limit use of topical antibiotics.

9.2.1 MRSA (methicillin–resistant Staphylococcus aureus)

Some strains of methicillin–resistant *Staphylococcus aureus* (MRSA) have a particular facility for nosocomial transmission. MRSA strains are often resistant to several antibiotics in addition to the penicillinase-resistant penicillins and cephalosporins, and occasionally are sensitive only to vancomycin and teicoplanin. MRSA infections are similar to those caused by sensitive strains of *S. aureus*, e.g. wound infections, lower respiratory and urinary tract infections, septicaemia, infections of sites for invasive devices, pressure sores, burns, and ulcers. Severe

infections are most common in the intensive care and other high–risk units with highly–susceptible patients (e.g. burn and cardiothoracic units). Epidemic spread of MRSA may occur; highly–transmissible strains tend to spread regionally and nationally to many hospitals. Factors increasing the likelihood of acquisition of resistant organisms are shown in the following box (*9*).

Patient risk factors for MRSA

- Possible sites of colonization or infection: nose, throat, perineum, inguinal folds, less frequently vagina or rectum; skin of buttocks area in immobile patients (superficial skin lesions, pressure sores, ulcers, dermatitis); surgical wounds and burns; invasive devices (intravascular and urinary catheters, stoma tubes, tracheostomy tubes).

- Prolonged hospital stay.

- Elderly patients, particularly with reduced mobility, immunosuppression or previous antibiotic therapy.

- Patients in special units, e.g. intensive care unit (ICU) and burns or referral hospitals.

- Frequent transfers of patients and staff between wards or hospitals.

- Excessive use of antibiotics in unit.

- Patient overcrowding.

- Staff shortages.

- Inadequate facilities for handwashing and appropriate isolation.

9.2.2 Enterococci

Some enterococci are now resistant to all antibiotics except vancomycin (VRE). The combination of peni–cillin and glycopeptide resistance in *Enterococcus faecium* causes infections which cannot be effectively treated. Fortunately, most VRE cause colonization, not infection. When infection does occur, it may not be treatable with antibiotics.

9.3 Antibiotic control policy

9.3.1 Antimicrobial Use Committee

The appropriate use of antimicrobial agents is facili–tated through the Antimicrobial Use Committee (*3,10*). This committee recommends antibiotics for the

formulary, prescribing policies, reviews and approves practice guidelines, audits antibiotic use, oversees education, and interacts with pharmaceutical repre-sentatives. The committee must be multidisciplinary, and should include: infectious disease physicians, surgeons, infection control nurses, pharmacists, microbiologists, and administration as well as other relevant professionals.

Each hospital will develop its own antibiotic policy, usually including classification of antimicrobial agents into the following categories:

- unrestricted (effective, safe and inexpensive, e.g. benzyl penicillin)

- restricted or reserved (to be used only in special situations by selected practitioners with exper-tise, for severe infection, with particular pattern of resistance, etc.)

- excluded (preparations without additional ben-efit to other, less costly alternatives).

The Antimicrobial Use Committee will usually be a subcommittee of the Pharmacy and Therapeutics Committee.

Hospitals should have a simple, flexible and regularly updated antibiotic-prescribing policy on a disease-specific basis, relying whenever possible on knowl-edge of prevailing antibiotic-sensitivity patterns and controlled use of reserve antibiotics. This should incorporate local practice guidelines.

9.3.2 Role of the microbiology laboratory

The microbiology laboratory has a major role in antimicrobial resistance. This includes:

- perform antibiotic susceptibility testing of appro-priate microbial isolates consistent with standards

- determine which antimicrobials are tested and reported for each organism

- provide additional antimicrobial testing for se-lected resistant isolates, as requested

- participate in activities of the Antimicrobial Use Committee

- monitor and report trends in prevalence of bac-terial resistance to antimicrobial agents

- provide microbiological support for investigations of clusters of resistant organisms

● notify infection control promptly of any unusual antimicrobial resistance patterns in organisms isolated from clinical specimens.

> One of the most important functions of the microbiology laboratory is to determine the antibiotic susceptibility of organisms isolated from infected patients, in order to assist the physician in the choice of treatment.

9.3.3 Monitoring antimicrobial use

Antimicrobial use in the facility must be monitored. This is usually performed by the pharmacy department, and should be reported in a timely manner to the Antimicrobial Use Committee and the Medical Advisory Committee. Specific elements to be monitored include the amount of different antimicrobials used during a given period and trends in antimicrobial use over time. In addition, the antimicrobial use in specific patient areas such as the intensive care units or haematology/oncology units should be analysed.

In addition to monitoring antimicrobial use, intermittent audits should be undertaken to explore the appropriateness of antimicrobial use. These audits should be undertaken under the auspices of the Antimicrobial Use Committee. The antimicrobial use to be audited will be based on changes observed in antimicrobial use, antimicrobial resistance of organisms, or concerns about poor patient outcomes. Physicians who are caring for patients must participate in planning the audit and analysis of data. Prior to undertaking the audit a series of appropriate guidelines for antimicrobial use should be developed and approved by the medical staff. A chart audit to determine to what extent the antimicrobials prescribed meet these criteria is then performed. If the criteria have not been met, reasons for inappropriate use should be identified.

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Preventing infections of staff

Health care workers are at risk of acquiring infection through occupational exposure (*1*). Hospital employees can also transmit infections to patients and other employees. Thus, a programme must be in place to prevent and manage infections in hospital staff.

Employees' health should be reviewed at recruitment, including immunization history and previous exposures to communicable diseases (e.g. tuberculosis) and immune status. Some previous infections (e.g. varicella–zoster virus [VZV]) may be assessed by serological tests.

Immunizations recommended for staff include: hepatitis A and B, yearly influenza, measles, mumps, rubella, tetanus, diphtheria. Immunization against varicella may be considered in specific cases. The Mantoux skin test will document a previous tuberculosis infection and must be obtained as a baseline.

Specific postexposure policies must be developed, and compliance ensured for: human immunodeficiency virus (HIV), hepatitis A virus, hepatitis B virus, hepatitis C virus, *Neisseria meningitidis*, *Mycobacterium tuberculosis*, varicella–zoster virus, hepatitis E virus, *Corynebacterium diphtheriae*, *Bordetella pertussis*, and rabies.

10.1 Exposure to human immunodeficiency virus (HIV) (*2,3,4*)

The probability of HIV infection following needlestick injury from an HIV–positive patient is 0.2% to 0.4% per injury (*1*). Risk reduction must be undertaken for all bloodborne pathogens, including:

- adherence to standard (routine) precautions with additional barrier protection as appropriate

- use of safety devices and a needle disposal system to limit sharps exposure

- continuing training for health care workers in safe sharps practice.

Factors associated with an increased likelihood of occupational acquisition of HIV infection following injury include:

- deep (intramuscular) injury

- visible blood on the injuring device

- injuring device used to enter a blood vessel

- source patient with high viral load

- hollow–bore needle

Information on preventive measures must be provided to all staff with potential exposure to blood and blood products. Policies must include screening of patients, disposal of sharps and wastes, protective clothing, managing inoculation accidents, sterilization and disinfection.

Hospital policy must include measures to promptly obtain serological testing of source patients where necessary. Postexposure prophylaxis should be started within four hours of exposure. The use of postexposure antiretroviral drugs is recommended. The combination of antiretroviral drugs, zidovudine (AZT), lamivudine (3TC), and indinavir is currently recommended, but local or national guidelines should be followed, if available.

A blood sample must be obtained for HIV testing from the health care worker as soon as possible after exposure, and at regular intervals to document a possible seroconversion. Health care workers must be informed of the clinical presentation of the acute retroviral syndrome, resembling acute mononucleosis, which occurs in 70% to 90% of patients with acute HIV infection, and immediately report any illness occurring within 3 months of injury.

An occupational exposure can occur at any time: counselling, testing and treatment must therefore be available 24 hours a day. Follow–up of an HIV exposure must be standardized, with repeated serological investigations for up to one year.

10.2 Exposure to hepatitis B virus *(3,4,5)*

Estimates of the probability of HBV infection by needlestick injury range from 1.9% to 40% per injury. With a sharps injury, the source person must be tested at the time of exposure to determine whether he or she is infected. Infection of the health care worker can occur when detection of hepatitis B surface antigen (HBsAg) or e antigen (HBeAg) is positive in the source person.

For previously immunized individuals with an anti-HBs antibody greater than 10 mlU/ml, no further treatment is required. For others, prophylaxis consists of the intramuscular injection of hepatitis B immune globulin, and a complete course of hepatitis B vaccine. Hepatitis B immunoglobulin must be given as soon as possible, preferably within 48 hours, and not later than a week after exposure. Post-immunization serology should be obtained to demonstrate an adequate serological response.

Delta hepatitis occurs only in individuals with hepatitis B virus infection, and is transmitted by similar routes. Preventive measures against hepatitis B are also effective for the delta agent.

10.3 Exposure to hepatitis C virus *(5)*

The routes of infection are similar to hepatitis B infection. No postexposure therapy is available for hepatitis C, but seroconversion (if any) must be documented. As for hepatitis B viral infection, the source person must be tested for HCV infection.

> For any occupational exposure to bloodborne pathogens, counselling and appropriate clinical and serological follow-up must be provided.

10.4 *Neisseria meningitidis* infection

N. meningitidis can be transmitted through respiratory secretions. Occupational infections are rare, but the severity of the disease warrants appropriate chemoprophylaxis for close contact between patients and health care workers. Close contact is defined as direct mouth–to–mouth contact as in resuscitation attempts. Recommended prophylaxis includes one of: rifampin (600 mg twice a day for two days), a single dose of ciprofloxacin (500 mg), or a single dose of ceftriaxone (250 mg) IM.

10.5 *Mycobacterium tuberculosis* *(6)*

Transmission to hospital staff occurs through air-borne droplet nuclei, usually from patients with pulmonary tuberculosis. The association of tuberculosis with HIV infection and multidrug–resistant tuberculosis are a current major concern. In the case of health care exposure, individuals with Mantoux conversion (≥10 mm induration) following exposure should be considered for isoniazid prophylaxis, depending on local recommendations.

10.6 Other infections (varicella, hepatitis A and E, influenza, pertussis, diphtheria and rabies) *(1)*

Transmission of these microorganisms may be uncommon, but policies to manage staff exposure should be developed. Vaccination of hospital staff against varicella and hepatitis A is recommended. Influenza vaccination should be given yearly. Rabies vaccination may be appropriate in some facilities in countries where rabies is endemic.

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Suggested further reading

World Health Organization

Indoor air quality: Biological contaminants. European Series No. 31, 1990. ISBN 92 890 1122 X, Order No. 1310031.

Hazard Analysis Critical Control Point Evaluation. A guide to identifying hazards and assessing risks associated with food preparation and storage, Bryan FL, 1992. ISBN 92 4 154433 3, Order No. 1150370.

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Wenzel RP, ed. *Prevention and control of hospital infections* (3rd ed). Philadelphia, Lippincott, Williams & Wilkins, 1997.

Internet resources

AIRHH: International Association for Research in Hospital Hygiene (Monaco)
    http://www.monaco.mc/assoc/airhh/

APIC: Association for Professionals in Infection Control and Epidemiology (USA)
    http://www.apic.org/

APSI: Associazione Controllo Infezioni (Italy)
    http://www.apsi.it

CDC: Centers for Disease Control and Prevention (USA)
    http://www.cdc.gov/cdc.htm

Health Canada: Division of Nosocomial and Occupational Infections
    http://www.hc–sc.gc.ca/hpb/lcdc/bid/nosocom/index.html

HELICS: Hospital in Europe Link for Infection Control through Surveillance
    http://helics.univ–lyon1.fr

Hospital Infection Society (UK)
    http://www.his.org.uk/

Infection Control Nurses Association (UK)
    http://www.icna.co.uk

IFIC: International Federation of Infection Control
    http://www.ific.narod.ru/

NNIS: National Nosocomial Infections Surveillance System (USA)
    http://www.cdc.gov/ncidod/hip/nnis/@nnis.htm

SFHH: Société Française d'Hygiène Hospitalière (France)
    http://sfhh.univ–lyon1.fr/

SHEA: Society for Healthcare Epidemiology of America (USA)
    http://www.shea–online.org