C6 Influence of Facility Design on Healthcare-Associated Infection

Summary

The design of a healthcare facility can influence the transmission of healthcare-associated infections by air, water and contact with the physical environment. Key design features that minimise the transmission of infection include:

- surface finishes that are easy to maintain and clean (floors, walls, benches, fixtures and fittings);
- ventilation, air conditioning, cooling towers and water systems that meet Australian standards for the facility they are to service;
- the ability to isolate patients:
  - in a single room (infectious patients) or negative pressure room (to prevent transmission of airborne pathogens)
  - positive pressure rooms or use of laminar airflow filtration (LAF) for immunocompromised patients
- triaging of patients in waiting rooms with separation of infectious patients;
- appropriate workplace design:
  - separation of procedural and cleaning areas
  - movement of workflow systems
  - ready access to hand hygiene facilities
  - adequate storage for all patient-care items;
  - easily accessible storage for PPE;
  - adequate waste management procedures and linen handling; and
- involvement in demolition, construction and renovation projects of a multidisciplinary team that includes infection prevention and control staff to coordinate preventive measures.

C6.1 Facility Design and its Impact on Infection Prevention and Control

Infection prevention and control requirements are critical to the planning of a healthcare facility and need to be incorporated into plans and specifications. All areas of a healthcare facility should be designed, constructed, furnished and equipped to minimise the risk of transmission of infection. In particular, the design and layout of the facility should facilitate the application of standard and transmission-based precautions by all staff.

C6.1.1 Evidence on the influence of environmental design on healthcare-associated infection

There are few randomised controlled trials relevant to the effects of specific design features or interventions on health outcomes. However, from case reports, published literature relating to outbreaks and from a theoretical risk-management perspective, it is clear that the design of buildings can have an impact on rates of HAI. Reliable patterns across several studies emerged, which were broadly consistent with predictions based on established knowledge and theory concerning environment and healthcare outcomes.

However, it is difficult to distinguish the independent effect of any environmental factor, as most changes of the physical environment in healthcare settings alter several environmental factors simultaneously. For example, renovating an intensive care unit with two-bed patient rooms to create single-bed rooms would be likely to alter not only the number of patients per room, but also the ratio of hand-hygiene sinks per bed and possibly the room ventilation or air quality.

C6.2 Mechanisms for Influencing Healthcare-Associated Infection Through Environmental Design
Many studies indicate that infection rates are lower when there is very good air and water quality, greater physical separation of patients and greater space per patient (with isolation where appropriate).

### C6.2.1 Reducing airborne transmission

Reservoirs for airborne pathogens include (Ulrich & Wilson 2006):

- dust (e.g. spores of *C. difficile* or *Aspergillus*);
- aerosols (e.g. TB, severe acute respiratory syndrome [SARS], influenza, chickenpox), and
- skin scales shed by patients infected with MRSA.

Airborne transmission has also been implicated in outbreaks of other infections such as *Acinetobacter* and *Pseudomonas* spp. (Beggs 2003; Beggs et al 2008).

Most pathogens in healthcare settings originate from patients, staff and visitors within the buildings. Other pathogens can enter buildings from outside air through dust that harbours pathogens such as *Aspergillus*, streptococci or staphylococci (Beggs 2003). There are also less common sources of airborne infections; for example, bird droppings or aerosols from contaminated water in a warm-water therapy pool (Angenent et al 2005).

### Approaches to airborne transmission

Approaches to reducing airborne transmission include:

- installation of effective air filtration;
- specifying appropriate ventilation systems and air change rates (eg negative airflow pressure);
- employing monitoring and control measures during construction or renovation; and
- using single-bed instead of multi-bed rooms.

In dental practices, engineering rules state there must be separation between inlet air for compressors and air conditioning outlets (ADA 2008).

### Filtration

An effective way to prevent infections is to control the source of pathogens. Heating, ventilation and air-conditioning systems control the concentration of airborne particulates in high risk areas, to minimise the risk of infection by means of air pressure, flow control and air filtration (the physical removal of particulates from air). The level of control should be proportional to the risk.

In acute healthcare settings, a commonly used approach to filtration is the HEPA filter (Streifel 1999). There is evidence that there is a lower incidence of infection when immunocompromised and other high-acuity patients are housed in HEPA-filtered isolation rooms. HEPA filters must comply with AS 1324 and AS 4260.

### Ventilation systems and airflow control

Optimal ventilation rates, airflow patterns and humidity can help to minimise the spread of infection.

- The ventilation rate is a measure used to control indoor air quality, and in healthcare facilities is usually expressed as room air changes per hour (ACH). The peak efficiency for particle removal in the air space often occurs between 12 ACH and 15 ACH — Australian guidelines recommend that isolation rooms have a minimum of 12 ACH or 145L/sec whichever is greater (NSW Health 2007), and other rooms in Australian healthcare facilities are required to comply with AS1688.2 (1991). However, there is a lack of consistency in the minimum ventilation requirements needed for effective prevention of infections.

  A study of 17 Canadian hospitals found that the risk of healthcare workers acquiring TB was strongly linked with exposure to infected patients in rooms with low ACH rates, such as waiting areas (Menzies et al 2000).

- Airflow direction is also important:
  - **Negative airflow pressure** is preferred for rooms housing infectious patients to prevent the dispersion of pathogen-laden aerosols (e.g. measles [rubeola], TB, chickenpox [varicella], dust and skin scales from the locus of the infected patient to other spaces. A review of 40 studies concluded that there is strong evidence to support and recommend the use of negatively pressurised isolation rooms (Li et al 2007).
  - **Positive airflow pressure** is desirable to safeguard them from aerial pathogens entering from adjacent spaces in the care of immunocompromised patients (e.g. surgical patients, patients with underlying chronic lung disease, or dialysis patients) or immunosuppressed patients (e.g. transplant patients or cancer patients).
  - **Laminar air flow (LAF)** is HEPA-filtered air blown into a room at a rate of $27 \pm 3$ m/min in a unidirectional pattern with 100–400 ACH (Sehulster et al 2004). LAF can reduce air contamination to the lowest possible level and is therefore recommended for operating rooms.
and areas with ultraclean room requirements (e.g. immunocompromised patients) (Alberti et al 2001; Arlet et al 1989; Dharan & Pittet 2002; Friberg et al 2003; Hahn et al 2002; Sherertz et al 1987).

**Maintenance systems**

Ventilation and airflow control systems need to be maintained regularly by suitably qualified staff according to an agreed maintenance plan, and accurate documented in a maintenance record.

**Maintaining air quality during construction or renovation**

Effective control and prevention measures are necessary during construction and renovation within a healthcare facility, because such activities have been frequently implicated in outbreaks of airborne infection. The key to eliminating infections is to minimise the dust generated during the construction activity and to prevent dust infiltration into patient-care areas near the construction. Examples of such measures include installing barriers between patient-care areas and construction/renovation areas, generating negative air pressure for construction/renovation areas relative to patient-care areas, using portable HEPA filters and sealing patient windows.

For more information, refer to Public Health Agency of Canada guidelines from 2001, Construction-related Nosocomial Infections in Patients in Health Care Facilities: Decreasing the Risk of Aspergillus, Legionella and Other Infections, which contain a risk assessment and preventive measures checklist.

**C6.2.2 Reducing infections spread through the physical environment**

The prevention of contact-spread infections is of paramount importance in healthcare settings. Contact contamination is generally recognised as the principal transmission route of healthcare acquired infections, including pathogens such as MRSA, *C. difficile* and VRE, which survive well on environmental surfaces and other reservoirs.

Environmental routes of contact-spread infections include direct person-to-person contact and indirect transmission via environmental surfaces.

**Reducing surface contamination through hand-hygiene compliance**

Healthcare workers' hands play a key role in both direct and indirect transmission (see Sections B1.1 and C3.4). Given the importance of maximising hand-hygiene compliance, it is absolutely essential that all areas of the facility are designed to facilitate compliance with hand-hygiene requirements.

**Accessibility**

Conveniently located alcohol-based product dispensers, sinks and basins can facilitate healthcare worker compliance with hand-hygiene requirements (Grayson et al 2009).

Hand-hygiene compliance can be increased by providing a greater number of alcohol-based product dispensers, particularly if they are placed in appropriate locations (where clinical care is provided [e.g. bedside] or where indirect care tasks are performed). Other aspects of design that may increase compliance include automated dispensers of hand-hygiene products, electronic monitoring and computerised voice prompts.

Alcohol-based handrub dispensers need to be suitably located out of the reach of children, or in supervised locations. Placement of dispensers must be carefully considered in mental health facilities and alcohol withdrawal units. Further guidance is available from HHA.

Consideration needs to be given to ensuring availability of basins for healthcare workers that are separate from patient bathrooms. As well as being installed in all patient-care areas, hand-hygiene facilities should be placed in all areas where careful attention to hygiene is essential, such as kitchens, laundries, pharmacies, laboratories and staff amenities areas (e.g. bathrooms, toilets and change rooms).

**Personal protective equipment**

It is also essential that all areas of the facility are designed to facilitate appropriate use of PPE. All rooms should have dedicated and accessible areas for storage of gowns, aprons, gloves, masks and protective eyewear.

**C6.2.3 Control of surface contamination through material selection**

Ease of cleaning should be a key consideration in selecting appropriate floor and furniture coverings. Several design-related factors should be considered to minimise the risk of infection stemming from contaminated surfaces:

- the nature and type of contamination that is likely to occur; and
- if a suitable cleaning method for that surface can be performed.

Areas that may be in direct contact with blood and body substances (e.g. surfaces such as floors and bench tops) need to be made of impervious
material that is smooth and easy to clean.

Healthcare flooring

A wide range of floor covering materials is used in healthcare settings. These include but are not limited to: ceramic tiling, linoleum, rubber, textile floor covering, vinyl, sheet terrazzo, cork, timber laminates, mats and matting, cementitious toppings, seamless coatings and outdoor flooring.

Floor coverings have not been generally related to healthcare associated infection. Some studies have identified carpeting as susceptible to contamination by fungi and bacteria (Anderson et al 1982; Boyce et al 1997; Skoutelis et al 1994; Beyer & Belsito 2000).

When selecting floor covering for a health care setting consideration needs to be given to the following:

- Who is at risk of acquiring infection?
- What is the risk of exposure to the infectious agents?
- What is the nature of the possible infectious agents?
- How can the agent be transmitted? (eg airborne; through cleaning techniques; through contact especially in environments in which there are young children)

In terms of infection prevention and control, the advantages of hard floor coverings include:

- being easier to clean;
- being easier to disinfect where required;
- allowing use of the most appropriate disinfectant, rather than a product that is suitable for use on carpet;
- costing less, as disinfectant is less expensive than steam cleaning, and steam cleaning may not be readily available;
- there is less surface area so hard floor coverings are less likely to act as a reservoir of infectious agents than carpet; and
- when additional cleaning is required, hard floor surfaces are easier to clean than carpet.

However, carpeting may offer advantages unrelated to infection prevention and control, including noise reduction (Philbin & Gray 2002). Textile floor finishes should not be considered unless there is a comprehensive maintenance and replacement program in place complying with AS/NZS 3733. Care and maintenance of floor covering need to consider manufacturer’s recommendations.

Carpeting should be avoided in areas where (Sehulster & Chinn 2003):

- spills are likely to occur (e.g. around sinks or in isolation or soiled utility/holding areas);
- patients may have direct contact with contaminated carpets (e.g. children/babies crawling on the floor); and
- patients are at greater risk of airborne infections.

Furnishings


A study comparing the performance of a variety of furniture upholstery types with respect to VRE and *Pseudomonas aeruginosa* (PSAE) contamination (Lankford et al 2006) found that performance was similar across different furniture coverings in terms of reductions in VRE and PSAE after cleaning and the transfer of VRE and PSAE to hands through contact. However, while there were no differences in the ability of different upholstery types to harbour PSAE, the VRE pathogen survived less well or for shorter periods on vinyl (Lankford et al 2006).

The CDC/HICPAC guidelines (Sehulster & Chinn 2003) recommend minimising the use of upholstered furniture in areas housing immunocompromised patients.

Blinds and curtains should be easy to clean and discourage the accumulation of dust.

C6.2.4 Reducing water-borne transmission

Compared with airborne and contact transmission of infection, fewer studies were identified on waterborne transmission in relation to healthcare facility design factors. The literature nonetheless is clear that waterborne infections can be a serious threat to patient safety. Many bacterial and some protozoal microorganisms can proliferate or remain viable in moist environments or aqueous solutions in healthcare settings (Sehulster et al 2004).

Contaminated water systems in healthcare settings (such as inadequately treated wastewater) may lead to the pollution of municipal water systems, enter surface or ground water, and affect people in the community (Iversen et al 2004).
Sources of water contamination

The CDC/HICPAC guidelines (Sehulster & Chinn 2003) identify the following categories of environmental routes or sources of waterborne transmission:

- direct contact, such as hydrotherapy (Angenent et al 2005);
- ingestion of water, such as drinking water (Conger et al 2004; Squier et al 2000);
- inhalation of aerosols dispersed from contaminated water sources, such as improperly cleaned or maintained cooling towers, showers (Mineshita et al 2005), respiratory therapy equipment and room air humidifiers; and
- aspiration of contaminated water.

Approaches to reducing waterborne transmission

Water supply system

The water supply system should be designed and maintained with proper temperature and adequate pressure; stagnation and back flow should be minimised and dead-end pipes should be avoided.

To prevent the growth of *Legionella* and other bacteria, the CDC/HICPAC guidelines recommend that healthcare facilities maintain cold water at a temperature below 20°C, store hot water above 60°C, and circulate hot water with a minimum return temperature of 51°C (Sehulster & Chinn 2003).

When the recommended standards cannot be achieved because of inadequate facilities that are unable to be renovated, other measures such as chlorine treatment, copper-silver ionisation, or ultraviolet lights are recommended to ensure water quality and prevent infection (Sehulster & Chinn 2003).

Point-of-use fixtures

Water fixtures such as sinks, faucets, aerators, showers, and toilets have been identified as potential reservoirs for pathogenic microorganisms (Blanc et al 2004; Conger et al 2004; Mineshita et al 2005; Squier et al 2000). Such fixtures produce aerosols that can disperse microbes and they have wet surfaces on which moulds and other microorganisms can proliferate. However, empirical evidence linking these fixtures to HAIs is still limited; no consensus has been reached regarding the disinfection or removal of these devices for general use (Sehulster et al 2004).

Regular cleaning, disinfection and preventative maintenance programs should be provided, especially in areas housing immunocompromised patients.

Ice machines

Ice storage receptacles and ice-making machines should be properly maintained and regularly cleaned. Ice and ice-making machines may be contaminated through improper handling of ice by patients and/or staff. Ice for human consumption should be differentiated from ice for first aid or storage of clinical specimens. Pharmaceuticals or medical solutions should not be stored on ice intended for consumption.

Machines that dispense ice are preferable to those that require ice to be removed from bins or chests with a scoop. Ice machines and their dispensers should be flushed and cleaned if they have not been disconnected before anticipated lengthy water disruptions.

All ice-storage chests should be cleaned, disinfected, and maintained on a regular basis as per manufacturers instructions.

Suggested steps to avoid improper handling of ice include (Sehulster & Chinn 2003):

- avoiding handling ice directly by hand;
- washing hands before obtaining ice;
- using a smooth-surface ice scoop to dispense ice;
- keeping the ice scoop on a chain short enough that the scoop cannot touch the floor, or keeping the scoop on a clean, hard surface when not in use; and
- avoiding storing the ice scoop in the ice bin.

Water features

Despite the absence of empirical documentation linking properly maintained fountains to healthcare-acquired infections, the AIA & FGI Guidelines (2006) recommend that fountains not be installed in enclosed spaces in healthcare facilities.

C6.3 the Benefits of Single-Bed Rooms for Patient Isolation
The three routes of transmission often overlap, and environmental approaches may influence more than one transmission route. For example, single rooms play a key role in preventing a patient with a contagious or aerial spread infection from infecting others, and also protect immunocompromised patients in nearby patient-care areas from airborne pathogens.

- Studies of cross-infection for contagious airborne diseases (such as TB, measles [rubeola], and chickenpox [varicella]) indicate that placing patients in single rooms, single-bed cubicles with partitions, isolation rooms, or rooms with fewer beds and more space between patients, is safer than housing them in multi-bed spaces with more patients.
- Surfaces near infected patients quickly become contaminated, creating numerous reservoirs that can transfer pathogens to patients and staff.
- Screening for MRGs or specific pathogens is effective but results may not be available on admission; placing MRO colonised/infected patients with non-colonised/infected patients in multi-bed rooms increases the spread of MROs.
- Single-bed rooms can facilitate greater frequency of cleaning and decontamination, as there is limited impact on neighbouring patients.
- Hand-hygiene compliance is likely to be improved through greater prominence of sinks or hand hygiene dispensers.
- Ensuite bathrooms are a key factor in preventing the spread of *C. difficile* and other infectious agents that spread via enteric and contact mechanisms.

International bodies including the American Institute of Architects recommend that acute-care facilities have 80% single-bed rooms. This recommendation is being implemented in a number of current hospital redevelopments (e.g. Royal Canberra Hospital, Royal Perth Hospital) and should be considered during planning for redevelopment of any acute healthcare facility.

### Anterooms

Anterooms enable visitors and healthcare workers to change into and dispose of appropriate PPE when caring for an infectious patient. Anterooms increase the effectiveness of isolation rooms by reducing the potential escape of airborne infectious particles into the corridor.

Ideally the pressure in the anteroom is lower than that of ambient pressure in the adjacent corridor (AusHFG).

### C6.4 Construction and Renovation

Infection prevention and control precautions during construction and renovation should be integrated into the design and documentation of the facility from the beginning of the design stage. It is important that the dust control and infection prevention and control principles developed during the pre-design stage are integrated from the initial stages of design development until the completion of the activity.

Identification of the 'at risk' population, knowledge of the transmission route of a likely pathogen and location of the 'at risk' population all need to be taken into account in the planning stages.

### C6.4.1 Risk management

The risk-management approach should, as a minimum:

- identify the location of high-risk patients in relation to the site;
- identify ventilation system types and potential impact;
- determine air monitoring requirements, methodology and frequency;
- include taking of air quality samples to establish a baseline;
- identify possible contaminants and their locations (contaminants may be present in ceiling dust, service shafts (especially if dampness is present), spray-on fire retardants and bird droppings.

Refer to Section D of the Australasian Health Facility Guidelines (AusHFG) for further guidance and the definition of infection prevention and control risk, location/area table and infection prevention and control strategies.

### C7 Resources

#### C7.1 Management and Clinical Governance

- ACSQHC Resources
  - Measurement for improvement tool kit
  - Australian Charter of healthcare rights
  - HAI priority program. Building Capacity for Infection Control Professionals
  - Clinical Excellence Commission Quality Systems Assessment
C7.2 Staff Health and Safety

Occupational health and safety

Pre-employment screening and Immunisation

Legislation/ policy

Each state and territory has numerous legislation/ Acts relating to occupational health and safety, workers compensation and the employers responsibility to provide a safe work environment.

Immunisation of health care workers is an aspect of occupational health and safety in the health care setting. Each state has its own policies, examples are provided below:

- Immunisation for Health Care Workers (Revised October 2007) – DHS Victoria
- Health Department Policy Directive 2007_006 Occupational Assessment, Screening & Vaccination Against Specified Infectious Diseases

Guidelines

- National Immunisation Program Schedule – 2007 DoHA

Exposure to blood and blood products

Legislation/codes of practice


Each state has its own policies, examples are provided below:

- NSW
  - NSW Health Department Policy Directive 2005_311 HIV, Hepatitis B and Hepatitis C - Management of Health Care Workers Potentially Exposed

- WA

- QLD
  - Queensland Health Infection Control Guidelines and associated policies, recommended practices and advisories
  - Queensland Health Sharps Safety Programs

Post-exposure prophylaxis

Guidelines

C7.3 Education and Training

- ACORN Standard S24 visitors to the perioperative environment
- AICA
- Hand Hygiene Australia
- Australian Commission for Safety and Quality in Healthcare HAI program. Capacity building for Infection control professionals

C7.4 Surveillance


Policies

- National Notifiable Diseases Surveillance System

Notifiable diseases

- Department of Health and Ageing- Australian Notifiable Diseases
- Links page to state and territory Public Health Legislation, the Quarantine Act, and the National Health Security Act 2007

C7.5 Antimicrobial Stewardship

- National Antimicrobial Utilisation Surveillance Program (NAUSP)

C7.6 Facility Design

More detailed information on facility design is available from the following sources. State and territory department of health policies also provide information.

Guidelines

- NSW Health Department Guideline GL2007_003 Health Facility Guidelines - Use of Australasian Health Facility Guidelines (AUS HFG)
- Guidelines DHS, Victoria - Guidelines for the Classification and Design of Isolation Rooms in Health Care Facilities Victorian Advisory Committee on Infection Control 2007
- Victorian DHS Design Guidelines for Hospitals and Day Procedure Units 2005
- NSW Department of Health TS-7 Floor Coverings in Healthcare buildings
- Isolation room engineering requirements TS 11 Engineering and Sustainable Services. available in the NSW Health Infection Control Policy (Circular 2002/45, NSW Health 2002
- Hand Hygiene Australia manual

International literature

- CDC guidelines on tuberculosis, SARs and pandemic influenza
- CAS Z317.2-01 Special Requirements for Heating, Ventilation, and Air Conditioning (HVAC) Systems in Health Care Facilities
- CHICA position statement on construction and design for information related to this section
- Public Health Agency of Canada guidelines from 2001, Construction-related Nosocomial Infections in Patients in Health Care Facilities: Decreasing the Risk of Aspergillus, Legionella and Other Infections, which contain a risk assessment and preventive measures checklist
- American Institute of Architects and Facilities Guidelines Institute
- American Society of Heating, Refrigerating and Air-conditioning Engineers
C8 References


