Optimising ventilation for infection prevention and control in healthcare settings

Why is ventilation important for infection prevention and control in health care?

Good indoor air quality and effective ventilation helps to reduce circulating infectious particles in the air. In turn, this minimises the risk of potential exposure to respiratory particles containing infectious agents, such as COVID-19, measles, tuberculosis, varicella (chicken pox) or other transmissible respiratory pathogens.[1-3]

An effective indoor ventilation system should maintain indoor air temperature and humidity control and improve air quality by[1-5]:

- facilitating the supply and movement of clean air (e.g., outdoor or recirculated) within or between spaces
- cleaning the air (e.g., by filtering particles from outside air or from air that is recirculated by a heating, ventilation and air-conditioning system using High-efficiency particulate air [HEPA] filters)
- removing contaminated air
- increasing the dilution efficiency of air.

This guidance has been developed to assist health service organisations to:

- understand the importance of effective ventilation in infection prevention and control and patient and workforce safety
- recognise immediate risks with current ventilation systems
- identify optimal ventilation strategies for new buildings, as well as current infrastructure
- consider environmental sustainability when procuring, upgrading and operating ventilation systems.

Specific guidance for ventilation in operating theatres is outside the scope of this guidance. Specialised guidance is available for this setting including the Australasian Health Facility Guidelines, state and territory engineering and ventilation technical advice, and the ACORN Standards for Operating Theatres.

Ventilation requirements for Australian health service organisations

Health service organisations accredited to the National Safety and Quality Health Service Standards must comply with Action 3.08 of the Preventing and Controlling Infections Standard. This action requires environmental control measures, such as effective ventilation systems, to be in place to reduce the risk of infection transmission.[6,7]

The design, installation and commissioning of ventilation systems for new builds, or upgrades to current infrastructure, requires technical expertise from qualified biomechanical or ventilation engineers who are also responsible for the operation, maintenance and monitoring of these systems.

Ventilation systems should comply with the following minimum requirements [1-4,8-10]:

- The Australasian Health Facility Guidelines
- National, state or territory building design, ventilation and engineering and technical advice guidelines
- AS 1668.1-2015 - The use of ventilation and air conditioning in buildings Part 1: Fire and smoke control in buildings

- AS1668.2-2012 – The use of ventilation and air conditioning in buildings - Part 2: Mechanical ventilation in buildings
- National Construction Code
- Relevant work health and safety (WH&S) and fire safety legislation.

Location of ventilation systems must be clearly outlined in facility documentation floorplans with instructions for use, including contingencies for outbreak management (e.g., isolation of heating, ventilation and air conditioning systems).[2,3]

Types of ventilation and considerations for use are included in **Table 1**.

Risk management for ventilation systems

Health service organisations should use risk management principles that are consistent with the current edition of the Australian Guidelines for the Prevention and Control of Infection in Healthcare. The Commission's guidance for health service organisations on COVID-19 infection prevention and control risk management may also be useful.

A risk assessment should be carried out to determine the appropriateness of a ventilation system as part of capital works planning and procurement for new builds and upgrades to current infrastructure. Careful consideration of cost, design, maintenance, and potential impact on airflow to other parts of the healthcare facility is required when considering upgrades to existing infrastructure.[1-3]

The risk assessment should consider local requirements, current infrastructure, risk factors for infection transmission and factors which may impede effective ventilation, such as [1-6,8-12]:

- The risk rating of the clinical area and patient cohort
- Density of patients, staff and visitors within clinical areas or spaces
- The air exchange rate (i.e. the number of times per hour the air in a room is replaced with clean, filtered air)
- The number of effective air exchanges required in different areas
- The direction of airflow within or between spaces (also known as airflow directionality) and the risk this poses to other areas (e.g. contaminated air moving or exhausted into corridors or other patient rooms)
- The number, location and type of supply diffusers and return/exhaust grills
- The distribution of air throughout the room from floor to ceiling
- Temperature and humidity
- Requirements to ensure system is fit for use before commissioning (e.g. filter changes, air testing, or purge cycles).

Other factors to consider when designing a ventilation system include:

- Ability to change system settings to respond to increased outdoor temperature, humidity or increased outbreak risk
- Ability of the system to restrict air movement or leakage of air in and between various rooms or departments, in line with WH&S and fire safety legislation
- Inclusion of alarm systems to ensure system breakdowns can be recognised and be acted on promptly
- Cost and frequency required for routine maintenance of the system
- Forecasting length of downtime (e.g. room to be closed during maintenance)
- Other safety risks (e.g. exposure to ultraviolet light)

Table 1: Types of ventilation and considerations for use[1-6,8-12]

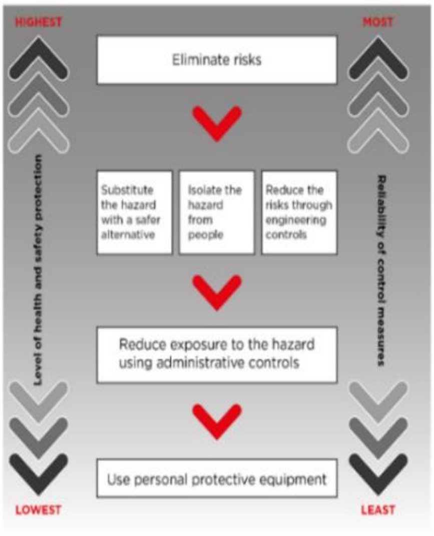
	Mechanism of action	Considerations for use
Mechanical ventilation		
Heating, ventilation and air conditioning (HVAC) systems	Supplies clean air by diluting and filtering air (from outdoor or recirculated air) and removes contaminated air by filtering and/or exhausting it to the outdoor environment or to adjacent spaces.[6]	• The type of system influences the extent that air mixes in and between various rooms or departments, with certain systems designed to limit mixing of air (e.g. negative pressure rooms)[7] • Direction of air movement from patient areas may impact on the safety of occupants (e.g. when air exhausts to a corridor or is recirculated in and between various rooms or departments) • Use of HEPA filters or filters with a high Minimum Efficiency Reporting Values (MERV) rating within centralised heating, ventilation and air conditioning systems may improve removal of infectious particles from the air. The impacts of these filters on airflow should be assessed before use.
Split systems	Recirculates air within a space. Can also be used for cooling.	• Use of split systems should be avoided in patient care areas. If use of split system air conditioning units is unavoidable, the effects on air flow into or within common spaces (e.g. shared rooms or corridors) should be considered, and health service organisations should follow a schedule for maintenance and filter changes.[6-8]
Other ventilation methods		
Natural ventilation	Aims to introduce outdoor air and encourage removal of contaminated air through open windows and doors or air vents. Effectively designed natural ventilation systems aim to reduce areas of stagnant air within indoor zones.	• Natural ventilation should only be used if there are no other mechanical ventilation solutions to improve air quality. This is because: 1) airflow, wind currents and air movement and external weather conditions, such as rain or dust, cannot be controlled, and 2) air cannot be filtered to minimise the risk of exposure to respiratory particles containing infectious agents. • The capacity for and quality of natural ventilation is affected by external environmental conditions (e.g. rain, humidity, heat) and air quality (e.g. dust). • Natural ventilation does not permit temperature or humidity control or filter incoming air, which has implications for the comfort of patients and staff, and for the management of sterile stock

	Mechanism of action	Considerations for use
		• When used in combination with mechanical ventilation, open windows and doors may impact the effectiveness of split systems (e.g. reduced air movement, cooling, and higher condensate levels) and increase system running costs. Where natural ventilation is used, insect screens should also be considered[1,2] • It may be necessary to explain to patients and other consumers that mechanical ventilation: is more effective than natural ventilation for minimising the risk of exposure to respiratory particles containing infectious agents and for temperature control; and may be necessary in adverse weather conditions.
Hybrid ventilation	Uses a combination of mechanical (usually split systems) and natural ventilation.[1,5]	Consider the issues stated above for split systems and natural ventilation.
Emerging technologies to filter and clean the air These technologies should only be used in combination with mechanical, natural or hybrid ventilation. Use of these technologies may also be considered in situations where other ventilation strategies are not immediately possible.		
Air filtration devices and air scrubbers/ cleaners. May be fixed or mobile	Draws air through a series of filters, to provide purified air that may or may not be recirculated.	Before these technologies are used: • undertake a local risk assessment that considers impacts on air flow and WH&S requirements for electrical equipment • review state or territory guidance • develop local protocols for use based on manufacturer's Instructions For Use • ensure protocols for maintenance (e.g. filter replacement) are in place.[2,11,12,13]
Personal ventilation hoods	A portable or mobile transparent, plastic cover fitted over a frame of a hospital bed or the upper body of a patient. The hood contains expelled respiratory particles and draws the contaminated air out of the hood through a HEPA filtered fan.	
Ultraviolet germicidal irradiation (UVGI)	Uses ultraviolet (UV) energy to remove particles from the air.	• If the HVAC system allows for efficient filtration or provides outdoor airflow above minimum requirements, ultraviolet germicidal irradiation may add little benefit.[14] • Risk assessment is required prior to considering use of ultraviolet germicidal irradiation (e.g. risks of exposure to ultraviolet radiation, cost, and time)

Ventilation and the hierarchy of controls

The hierarchy of controls (**Figure 1**) ranks risk controls from most to least reliable. If eliminating risks is not reasonably practical, then risks must be minimised, as far as is reasonably practical, by using one or a combination of substitution, isolation, or engineering controls, followed by administrative controls and personal protective equipment (PPE).[6]

The Preventing and Controlling Infections Standard requires use of the hierarchy of controls in conjunction with infection prevention and control systems to identify and manage risks associated with infections.[7]



Source: Safe Work Australia. How to manage work health and safety risks: code of practice. Canberra: SWA; 2018:19, 'Hierarchy of control measures' licensed under CC BY-NC 4.0.

Figure 1. Hierarchy of Controls

Table 2 provides examples of strategies to manage risks and optimise ventilation, using the hierarchy of controls. Implementation of the below strategies needs consideration of the safety of patients, staff, visitors and contractors and determine impact or possible adverse consequences of strategies for quality safe patient care.

Strategies to improve ventilation are one control to reduce the risks associated with exposure to respiratory particles containing infectious agents. In accordance with the hierarchy of controls, ventilation is most effective when used in combination other risk control interventions, including appropriate patient placement, standard and transmission-based precautions (where appropriate), safe use of PPE and vaccination.[1-5]

Other resources

This resource should be used alongside existing state and territory or other local guidance, where available. In addition, see:

- National Safety and Quality in Health Service (NSQHS) Standards
- Australian Guidelines for the Prevention and Control of Infection in Healthcare
- COVID-19 infection prevention and control risk management - Guidance for health service organisations
- WHO Natural Ventilation for Infection Control in Health-Care Settings
- International Health Facility Guidelines
- WHO Roadmap to improve and ensure good indoor ventilation in the context of COVID-19
- Centers for Disease Control and Prevention Guidelines for Environmental Infection Control in Health-Care Facilities

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Table 2: Example strategies* to optimise ventilation in healthcare settings[1-21]

Controls	Examples strategies
Elimination: Remove the infection risk entirely	• Avoid recirculating air within enclosed spaces, where possible • Minimise crowding within indoor spaces and aim for an indoor density of one person per four square metres[17] • Minimise the use of small and enclosed spaces (e.g. encourage staff to go to an outside space for breaks) • Do not obstruct supply diffusers or return/exhaust grills (e.g. with furniture) • Avoid use of Class P rooms with positive pressure† airflow for patients with infectious diseases, such as COVID-19, measles, tuberculosis, and varicella (chicken pox), unless mitigating engineering solutions, including negative pressure anterooms, have been installed.
Substitution: Substitute infection hazard with a safer alternative	• Install heating, ventilation, and air conditioning systems to replace split systems • Install higher grade heating, ventilation, and air conditioning (HEPA) filters on systems. A G4/F8 filter is the minimum grade typically used in clinical areas.[11]

Isolation	• Ensure appropriate room placement for patients with infectious diseases, such as COVID-19, tuberculosis, measles, varicella:
	  ○ Isolation of patients into single rooms should be based on risk assessment (e.g. current ventilation infrastructure, room types and numbers of single rooms)
	  ○ Prioritise negative pressure§ (Class N room) or single room with negative airflow placement (if available) based on the level of infection and transmission risk (e.g. patient with COVID-19 exhibiting aerosol-generating behaviours or requiring aerosol-producing procedures).

Engineering controls: Reduce the infection risk through engineering controls	• Ensure that supply and exhaust systems meet minimum air exchange requirements[2,11,18]:
	  ○ At least six air changes per hour for standard rooms
	  ○ At least twelve air changes per hour for rooms where patients are requiring airborne precautions or aerosol-producing procedures are being performed
	  ○ At least ten air changes per hour for dirty utility rooms for odour control.
	• In consultation with staff from infection prevention and control and qualified biomechanical or ventilation engineers, use a pre- and post- occupancy purge cycle, based on air changes/hour (ACH) and time required for airborne-contaminant removal by efficiency
	• Increase heating, ventilation, and air conditioning airflow to occupied spaces by increasing air exchanges or exhaust to the highest setting possible to increase intake of outside air (up to 100% outside air), in accordance with manufacturer's Instructions for Use and a risk assessment of:
	  ○ the level of infection risk for the specific area
	  ○ environmental conditions (e.g. prolonged periods of increased outdoor temperature or humidity, air quality [e.g. building works and increased dust])
	  ○ sustainability considerations (e.g. energy requirements and avoidance of overheating of system)
	  ○ safety of increasing air movement within or between spaces in relation to air directionality and position of exhaust grills (e.g. contaminated air moving or exhausted into corridors or other patient rooms).

Controls	Examples strategies
Engineering controls: Reduce the infection risk through engineering controls **continued**	• For new builds or when retrofitting current infrastructure, ensure systems are fully ducted, with contained air paths that are easy to clean, and ceilings designed to minimise leakage • Maximise air movement and direction by considering the location of supply louvres, exhaust air grills, and/or ability to alter damper settings during the design phase of new builds or retrofitting. Where possible, ensure that a clean air supply sweeps exhaled air away from the patient, to avoid recirculation or formation of stagnant pockets • Use dedicated exhaust systems as required in specialised settings, i.e., dirty utility rooms, negative pressure rooms • Clean vents and air grills regularly to remove dust build up and increase the amount of air being brought in from outside • Upgrade ventilation systems with HEPA filters • Use additional HEPA filters on outside air intakes to reduce exposure to infectious agents outside the building during at risk periods (e.g. during building works) • Ensure that recommissioning of heating, ventilation, and air conditioning systems meets relevant regulations and standards before restarting systems that have been temporarily shut down.
Administrative controls: Practices and policies that reduce or prevent exposure to infection hazards	• Designate an organisational lead who is responsible for the procurement and maintenance of the health service organisation's ventilation systems • Maintain an up-to-date schedule for the maintenance and testing of systems, including a schedule for changing HEPA filters[#], according to manufacturer's specifications • Ensure ventilation policies within each organisation are consistent with relevant standards and legislation • Ensure that all emerging devices are used according to manufacturers' Instructions for Use • Facilities should undertake an assessment of rooms and departments in relation to airflow, air changes per hour and airflow directionality • Assess rooms and departments as part of outbreak prevention and planning to determine risks associated with air movement (e.g. air pushing out to corridor) and air changes using air changes/hour (ACH) and time required for airborne-contaminant removal by efficiency. • Ensure pressures and alarms in negative pressure rooms are checked at the start of each shift, with a process in place for reporting and mitigating system failures • Ensure a risk assessment is undertaken by qualified persons, i.e., infection prevention and control staff and biomechanical or ventilation engineer, to determine risks (e.g. COVID-19 wards or during outbreaks) • Limit the number of people and duration of occupancy in buildings and spaces. During periods of increased risk (e.g. outbreaks), reduce room density by rostering only essential staff. • Schedule breaks between meetings to allow for the flushing of meeting spaces • Undertake capital works planning to install heating, ventilation, and/or air conditioning systems, if not currently in place

Controls	Examples strategies
Administrative controls: Practices and policies that reduce or prevent exposure to infection hazards **continued**	• Install monitoring systems to ensure correct temperature, humidity, room pressures and air flow direction • Monitor for plumbing risks which may lead to contamination of ventilation systems (e.g. aerosols containing legionella produced from shower sprays) • Conduct risk assessment of the ventilation impact of floor-to-ceiling barriers (e.g. room partitions) before installation • Avoid the use of fans, as fans may increase the risk of exposure to infectious agents. The use of fans in clinical areas should be based on a risk assessment that considers factors, such as the level of room occupancy, use of transmission-based precautions, type of clinical procedures being undertaken in the area and the likelihood of storage of sterile stock. If a fan is used, place the fan near open windows, if possible, and ensure that air is not blown directly from one person to another (e.g. from a patient to a staff member walking into the room).[9] • Assess impact of changing ventilation system settings to reduce energy consumption and whether these changes affect the safety of those within the healthcare setting.
Personal protective equipment (PPE): Effectiveness in preventing exposure to the infection hazard is dependent on access to appropriate PPE	• Ensure appropriate PPE for staff, visitors, and patients according to state and organisational guidelines • Ensure appropriate PPE is used during assessment, maintenance, and cleaning of ventilation systems • Ensure persons responsible for maintenance maintaining and cleaning ventilation systems are trained in the correct application and removal of PPE, including fit checking and fit testing, and use PPE as indicated by manufacturer's Instructions for Use or local protocols.

*__Note:__ The above ventilation strategies are examples only. Each health service organisation will need to develop its own approach and strategies, informed by the local context and guidance from qualified persons (i.e. qualified biomechanical or ventilation engineers).

†**Positive pressure:** The positive pressure air handling system within the room operates at a higher pressure, compared to adjacent rooms/spaces, and air supply is HEPA filtered.[15]

§**Negative pressure:** Air handling systems operates at a lower pressure compared toto adjacent areas such as anterooms and corridor and is exhausted to the outside.[2]

#**HEPA filters:** Filter air by physical removal of particulates from air.[3]

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