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Antimicrobial Resistance and Healthcare Associated Infection

NHS National Services Scotland

Transmission Based Precautions Literature Review: Definitions of Transmission Based Precautions

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This literature review will be updated in real time if any significant changes are found in the professional literature or from national guidance/policy.

Version	Date	Summary of changes
1.0	June 2014	Final for publication
2.0	October 2017	'Airborne transmission from the environment' added to the 'Which infectious agents are transmissible by the airborne route?' box. Airborne dissemination/Environmental transmission, in regard to construction/renovation added. AGP section moved to RPE (link added). Definitions for TBPs: 'airborne dissemination' added.
3.0	October 2020	Update of the literature review. The question set was reviewed and the following objectives added: • How long do aerosols remain suspended in the air? • How long do droplets remain suspended in the air?

Approvals

Version	Date	Name
3.0	September 2020	Steering (Expert Advisory) Group for SICPs and TBPs)

HPS ICT Document Information Grid	
Title:	Transmission Based Precautions Literature Review: Definitions of Transmission Based Precautions
Purpose:	To inform the Transmission Based Precautions section of the National Infection Prevention and control manual in order to facilitate the prevention and control of HAIs in NHS Scotland hospital settings.
Target audience:	All NHS Scotland staff involved in the prevention and control of infection in the hospital setting.
Circulation list:	Infection Control Managers, Infection Prevention and Control Teams, Public Health Teams
Description:	This literature review examines the available professional literature on the definitions of Transmission Based Precautions.
Update/review schedule:	Updated as new evidence emerges, with changes made to recommendations as required.
Cross reference:	National Infection Prevention and Control Manual (NIPCM) NIPCM: Chapter 1 - Standard Infection Control Precautions (SICPs) NIPCM: Chapter 2 – Transmission Based Precautions (TBPs) NIPCM: A-Z Pathogens NIPCM: Appendix 11 - Best Practice - Aide Memoire for Optimal Patient Placement and Respiratory Protective Equipment (RPE) for Infectious agents whilst a patient is in hospital NIPCM Literature review: Aerosol Generating Procedures (AGPs)
Update level:	Practice – ***No significant change to practice*** Research – ***No significant change***

Contents

1. Objectives

The aim is to review the extant scientific literature to produce standard definitions for Transmission Based Precautions.

The specific objectives of the review are to determine:

- What are Transmission Based Precautions (TBPs)?
- When should TBPs be applied?
- What is airborne transmission?
- How long do aerosols remain suspended in the air?
- Which activities result in airborne transmission?
- Which infectious agents are transmissible by the airborne route?
- What is droplet transmission?
- How long do droplets remain suspended in the air?
- Which activities result in droplet transmission?
- Which infectious agents are transmissible by the droplet route?
- What is contact transmission?
- Which activities result in contact transmission?
- Which infectious agents are transmissible by the contact route?
- Are there any other definitions for cross transmission of infectious agents in health and care settings?

N.B. Transmission Based Precautions (TBPs) are measures that may be required **in addition to Standard Infection Control Precautions (SICPs).** It is assumed, for the purpose of this literature review, that all SICPs are adhered to, and therefore are not the focus of this literature review and the associated recommendations**.**

2. Methodology

This systematic literature review was produced using a defined methodology as described in the National Infection Prevention and Control Manual: Methodology.

3. Discussion

3.1 Implications for Practice

What are Transmission Based Precautions (TBPs)?

Transmission Based Precautions (TBPs) are a set of infection prevention and control measures that should be implemented as required when patients are known or suspected to be infected with an infectious agent[1-3] in addition to Standard Infection Control Precautions (SICPs) in all care settings to prevent onwards transmission of infection.[2] TBPs are categorised according to the route of transmission of the infectious agent i.e. airborne, droplet or contact transmission.[1-3] The routes of transmission depend on the type of organism; some infectious agents may have multiple routes of transmission and therefore require more than one type of precautions e.g. *Mycobacterium tuberculosis*.[3] For a list of pathogens, see the National Infection Prevention and Control Manual's (NIPCM) A-Z of Pathogens.

When should TBPs be applied?

TBPs should be applied in addition to SICPs when caring for patients with active (known) infection(s) and asymptomatic patients who are suspected to be infectious or incubating an infection.[2, 3] Since the infectious agent may not be known until laboratory-confirmed, TBPs must be implemented based on the clinical presentation and likely pathogen and then modified when the pathogen is identified or a likely cause is ruled out.[2, 3] For a guide outlining the required TBPs for a number of infectious agents/diseases see the NIPCM's Appendix 11 – Best Practice – Aide Memoire for Optimal Patient Placement and Respiratory Protective Equipment (RPE) for Infectious agents whilst a patient is in hospital to be used in conjunction with the NIPCM's A-Z of Pathogens.

What is airborne transmission?

Airborne transmission is the transmission of infectious airborne particles or droplet nuclei (aerosols) in the respirable size range.3-8 Particles of this size can remain suspended in the air for long periods of time and may be dispersed by air currents (> 1 metre).5-8 Transmission of respiratory diseases was traditionally thought to occur via one of two distinct routes: droplet route for large droplets and aerosol or airborne route for small droplets based on the World Health Organization's (WHO)9 definition which used a cut-off size of 5 µm to delineate between droplets (>5 µm in diameter) and aerosols (≤ 5 µm in diameter). This dichotomy of respiratory particles into droplets or aerosols has important practical implications for infection control measures with different interventions (e.g. droplet or airborne precautions) based on this simplified classification. While this definition is useful, recent studies have demonstrated that exhaled respiratory droplets exist across a continuum of sizes10-13 and transmission by the airborne route is dependent on the interplay of several factors such as size of the emitted inoculum, infective dose of pathogens and their ability to survive desiccation and other stresses of aerosolisation and airborne transport, environmental factors (e.g. humidity and temperature) and host defences.[4, 7, 8, 11, 14] Infectious particles may be inhaled by susceptible hosts who may develop infection without having close contact with infectious individuals.[2, 3]

"Droplet nuclei" are aerosols formed from the rapid evaporation/desiccation of larger droplet particles when expelled/exhaled from the respiratory tract (see Droplet Transmission).[3, 5, 6, 8, 15] Studies have shown that expelled respiratory droplets evaporate to around one half (1/2)[4] or one third (1/3)[14] of its original diameter and these 'droplet nuclei' will have a range of final size typically 0.5 – 12 µm in diameter.[6] Aerosols formed from droplet particles in this way behave as other aerosols, such as those generated from environmental sources or aerosol generating procedures (AGPs).[5, 6] Aerosols can deposit along the respiratory tract down to the alveolar level.[4, 5, 8]

How long do aerosols remain suspended in the air?

Due to their small particle size, aerosols including droplet nuclei have a slow settling velocity, thus they remain suspended in the air and can travel distances in the airflow.[5-7]

Literature regarding airborne transmission has been underpinned by the early seminal studies of Wells[16] and Duguid[17] who used Stoke's Law to describe the settling of expelled particles in undisturbed air as being a function of evaporation, size, and time. They calculated that particles larger than 4 µm remain suspended for 90 minutes while smaller nuclei (< 4 µm) remained airborne for much longer periods approximately 17 -30 hours.[16, 17] Later studies of aerosol formation and behaviour utilised modern methodologies/technologies such as laser light observation,[18] computational fluid dynamics,[19] Collison nebulizers,[20] sensitive air samplers,[20] and assays using reverse transcription polymerase chain reaction (RT-PCR).[7] Results of aerosol settling times vary depending on the methodology used and estimates range widely from minutes (8 min,[18] 9 min,[10] 45 min[21]) to hours (1 hour[4], 3 hours[22]). However, there is a general consensus in the literature that aerosols can remain suspended in the air for prolonged periods of time.[4, 7, 14]

Which activities result in airborne transmission?

Airborne particles can be generated from:

- The respiratory tract through breathing, coughing, sneezing, talking and laughing.[5, 23] Experimental studies found that healthy individuals can produce aerosols from coughing and during speech[10, 18] while results from another study showed that the amount of particles (measuring approximately 1 µm) emitted during speech is correlated with the loudness (amplitude) of vocalizations.[24] Infectious influenza virus was recovered from aerosol samples collected from the exhaled breaths and coughs generated by infected individuals[25] while experimental cough studies demonstrated that some cystic fibrosis patients produced aerosols containing viable *Pseudomonas aeruginosa*,[26] gram-negative bacteria and *Staphylococcus aureus*.[21] While the concept of aerosol transmission for tuberculosis, measles and chickenpox is generally accepted,[3, 7, 8, 15] transmission of other infectious agents by this type of aerosol route is complex and difficult to prove; more research is needed.
- In addition, certain clinical activities and procedures termed 'aerosol generating procedures' (AGPs) can generate aerosols, and create the potential for airborne transmission of infections that may otherwise only be transmissible by the droplet route.5, 15, 27 For a list of AGPs see the NIPCM's Literature Review: Aerosol Generating Procedures (AGPs).

- During construction/renovation. These activities have been associated with outbreaks of *Aspergillus spp*. within health and care settings, with severely immunocompromised patients more at risk of developing aspergillosis.[3, 6, 28, 29] Aerosolised water which is contaminated with infectious agents, such as *Legionella*, has been implicated in outbreaks.[30] Equipment identified as producing aerosols include: showers/toilets, cooling towers, water-cooled air conditioning systems and humidifiers.[3, 15, 30-32]

Which infectious agents are transmissible by the airborne route?

Airborne transmission from the patient

Only a small number of infectious agents are known to be transmissible primarily by the airborne route. These include *Mycobacterium tuberculosis*, measles virus and varicella-zoster virus (chicken pox).[1, 3, 7, 8, 15] However, short distance transmission to susceptible persons near the patient by small particle aerosols generated under specific circumstances has also been shown e.g. transmission of SARS-CoV has been associated with endotracheal intubation, cardiopulmonary resuscitation and non-invasive positive pressure ventilation.[3, 7] Reports from gastroenteritis outbreaks has suggested that norovirus may be transmitted through aerosolisation of infectious particles from vomitus; the infectious particles are thought to be inhaled and subsequently swallowed however evidence is limited.[3, 4] Influenza viruses are transmitted primarily through close contact with infectious respiratory droplets,[3, 7] however there are a growing number of studies assessing the possibility of airborne transmission of influenza.[3, 7, 8] Despite this, consensus has not been reached and transmission of influenza virus remains droplet.

Airborne transmission from the environment

Some infectious agents do not usually involve person-to person transmission but are derived from environmental sources, these include spores of environmental fungi such as *Aspergillus spp*. and anthrax spores.[3] *Legionella* is transmitted to humans through a common aerosolised contaminated water source such as cooling towers.[3, 30]

What is droplet transmission?

Droplet transmission is the transmission of droplets (5µm to approximately 200 µm diameter) from the respiratory tract of an infectious individual to susceptible mucosal surface or conjunctiva (eyes, nose, mouth) of another individual.[1, 4, 5, 7] Droplets do not readily penetrate the lower (alveolar) respiratory system.[5, 6, 15] Large droplets (> 20 µm diameter) rapidly fall to the ground or environmental surfaces following a ballistic trajectory.[2, 8, 14] The maximum distance for cross transmission from droplets has not been fully determined, although a distance of approximately 1 metre (3 feet) around the infected individual has frequently been reported in the literature as the highest area of risk.[3-7, 14] Droplets can become aerosols through evaporation[14] (see Airborne Transmission).

How long do droplets remain suspended in the air?

The length of time droplets remain suspended in the air is determined by the types of infectious agent within the particles, particle size, settling velocity, temperature, relative humidity and airflow.[2] Large particles typically remain suspended in the air for a limited time before settling to

the ground or environmental surfaces usually within 1 metre (3 feet) from the source.[7, 10] Small droplets with aerodynamic diameter of around 5 µm to 20 µm takes minutes (approximately 4 to 17 minutes) to fall to the ground[4, 7, 14] whereas larger droplets > 20 µm in diameter fall out of suspension within seconds.[10, 14]

Which activities result in droplet transmission?

Droplets are produced from the respiratory tract through talking, coughing or sneezing, and can be generated from healthcare procedures that may cause splashing or spraying of body fluids e.g. open suctioning, endotracheal intubation and cough induction by chest physiotherapy.[3, 5, 10]

Which infectious agents are transmissible by the droplet route?

Examples of infectious agents transmissible by the droplet route include *Bordetella pertussis* (whooping cough), influenza virus, adenovirus, rhinovirus, *Mycoplasma pneumoniae*, coronavirus and *Neisseria meningitides*.[1, 3, 7] The emerging evidence for the novel betacoronavirus SARS-CoV-2 is also suggestive of droplet transmission mainly through respiratory droplets generated by coughing and sneezing.[33, 34]

What is contact transmission?

Contact transmission is the most common route of transmission, and consists of two distinct types: direct contact and indirect contact.[1, 3] Direct contact transmission occurs when infectious agents are transmitted directly from an infectious individual to another individual without the involvement of another contaminated person or object (fomite).[3] Indirect contact transmission occurs when infectious agents are transmitted from an infectious individual to another individual via a contaminated object or person (fomite) or person.[3]

Which activities result in contact transmission?

Examples of ways in which direct contact transmission can occur include: blood and/or body fluids from an infected individual directly entering another individual's body through contact with a mucous membrane or via cuts and abrasions to the skin; scabies mites transmitted from an infected individual to another individual by direct skin-to-skin contact.[3] Examples of ways in which indirect contact transmission can occur in health and care settings include: via healthcare worker hands if hand hygiene is not performed between touching an infected or colonised body site or a contaminated object and then touching another individual; via shared patient care equipment contaminated with blood and/or body fluids that are not adequately cleaned or disinfected between use; shared contaminated toys; and via surgical instruments or equipment that have not been adequately sterilised or disinfected between use.[2, 3]

Which infectious agents are transmissible by the contact route?

Infectious agents transmitted primarily by the contact route (both direct and indirect) include *Staphylococcus aureus*, herpes simplex virus (HSV) and *Clostridioides difficile*.[1, 3]

Are there any other definitions for cross transmission of infectious in health and care settings?

The literature also uses the term 'airborne dissemination'[35, 36] and 'aerosol dissemination'[35] when referring to airborne transmission of infectious organisms via environmental sources rather than patient to patient transmission. Jones et al used the terms airborne dissemination and aerosol dissemination to describe the possible mechanism for cross infection of *Pseudomonas aeruginosa* between cystic fibrosis (CF) patients in a CF centre in Manchester.[35] Epidemic *P. aeruginosa* strains were isolated from room air when patients performed spirometric tests, nebulisation, and airway clearance, but were not present in other areas of the inanimate environment of the CF centre; results suggest that cross infection of CF patients occurred by airborne dissemination.[35]

3.2 Implications for Research

The conventional definitions of airborne and droplet transmission based on particle size (i.e.< 5 µm for aerosol transmission and > 5 µm for droplet transmission) and distance (i.e. ≤ 1 metre from infectious source for droplet transmission and ≤ 1 metre for airborne transmission from infectious source) is currently debated. The World Health Organization recognises the limitations of this classification and as more studies broaden the understanding of disease transmission and host susceptibility, current definitions may need to evolve and be updated. This will have implications for infection prevention and control measures in the context of disease transmission and in supporting healthcare workers with choosing the appropriate transmission-based precautions to follow.

4. Recommendations

What are Transmission Based Precautions?

Transmission Based Precautions (TBPs) are a set of infection prevention and control measures that should be implemented when patients are known or suspected to be infected with an infectious agent. These should be implemented, as required, in addition to Standard Infection Control Precautions (SICPs) in all care settings.

TBPs are categorised according to the route of transmission of the infectious agent i.e.

- Airborne transmission
- Droplet transmission
- Contact transmission (further divided into 2 subgroups)
    - Direct transmission
    - Indirect transmission

(Category B)

When should TBPs be applied?

TBPs should be applied when caring for:

- Patients with active (known) infection(s);
- Asymptomatic patients who are suspected to be infectious or incubating an infection; and
- Patients colonised with an infectious agent.

(Category B)

What is airborne transmission?

Airborne transmission is the transmission of infectious airborne particles (aerosols) of small size (<5 µm diameter). Particles of this size can remain suspended in the air and may be dispersed over large distances by air currents.

“Droplet nuclei” are aerosols formed from the evaporation of larger droplet particles (see Droplet Transmission). Aerosols formed from droplet particles in this way behave as other aerosols, such as those generated from environmental sources or aerosol generating procedures (AGPs).

Aerosols can deposit along the respiratory tract down to the alveolar level.

(Category B)

How long do aerosols remain suspended in the air?

Due to their small size, aerosol particles can remain suspended in the air and can travel further distances in air currents. Estimated settling times of aerosols vary depending on the methodology used and they range from minutes (8 min, 9 min, 45 min) to hours (3 hrs). However, there is a general consensus in the literature that aerosols can remain suspended in the air for prolonged periods of time.

(Category B)

Which activities result in airborne transmission?

Airborne particles can be generated from:

- The respiratory tract through breathing, coughing, sneezing, talking and laughing.
- In addition, certain healthcare activities and procedures termed 'aerosol generating procedures' (AGPs) can generate aerosols, and create the potential for airborne transmission of infections that may otherwise only be transmissible by the droplet route. For a list of AGPs see NICPM Literature Review Aerosol Generating Procedures (AGPs).
- During construction/renovation. These activities have been associated with outbreaks of Aspergillus spp. within healthcare settings, with severely immunocompromised patients more at risk of developing aspergillosis. Aerosolised water which is contaminated with infectious agents, such as Legionella, have been implicated in outbreaks. Equipment identified as producing aerosols include: showers, cooling towers, water-cooled air conditioning systems and humidifiers.

(Category B)

Which infectious agents are transmissible by the airborne route?

Airborne transmission from the patient

Only a small number of infectious agents are known to be transmissible primarily by the airborne route. These include *Mycobacterium tuberculosis*, measles virus and varicella-zoster virus (chicken pox). There are, however, a number of other pathogens that are believed to be transmissible by the airborne (aerosol) route under certain circumstances. These include norovirus, influenza virus and coronavirus.

Airborne transmission from the environment

Some infectious agents do not usually involve person-to person transmission but are derived from environmental sources, these include spores of environmental fungi such as A*spergillus* spp. and anthrax spores. *Legionella* is transmitted to humans through a common aerosolised contaminated water source.

(Category B)

What is droplet transmission?

Droplet transmission is the transmission of droplets (5 µm to approximately 200 µm diameter) from the respiratory tract of an infectious individual to susceptible mucosal surface or conjunctiva (eyes, nose, mouth) of another individual.

Droplets of less than 20 µm can remain suspended in the air for many minutes, while droplets of greater than 20 µm fall out of suspension in seconds.

Droplets do not readily penetrate the lower (alveolar) respiratory system.

The maximum distance for cross transmission from droplets has not been definitively determined, although a distance of approximately 1 metre (3 feet) around the infected individual has frequently been reported in the medical literature as the area of risk.

Droplets can become aerosols through evaporation (see Airborne Transmission).

How long do droplets remain suspended in air?

The length of time droplets remain suspended in the air is determined by the types of organism within the particles, particle size, settling velocity, temperature, relative humidity and airflow.

Small droplets with aerodynamic diameter of around 5 µm to 20 µm take minutes (approximately 4 to 17 minutes) to fall to the ground.

Larger droplets > 20 µm in diameter fall out of suspension within seconds.

(Category B)

Which activities result in droplet transmission?

Droplets are produced from the respiratory tract through talking, coughing or sneezing, and can be generated from healthcare procedures that may cause splashing or spraying of body fluids e.g. open suctioning, endotracheal intubation and cough induction by chest physiotherapy.

(Category B)

Which infectious agents are transmissible by the droplet route?

Examples of infectious agents transmissible by the droplet route include *Bordetella pertussis* (whooping cough), influenza virus, adenovirus, rhinovirus, *Mycoplasma pneumoniae*, coronavirus and *Neisseria meningitides*.

(Category B)

There is evidence that the emerging novel betacoronavirus SARS-CoV-2 is transmitted via the droplet route.

(Category C)

What is contact transmission?

Contact transmission is the most common route of transmission, and consists of two distinct types: direct contact and indirect contact.

Direct transmission occurs when microorganisms are transmitted directly from an infectious individual to another individual without the involvement of another contaminated person or object (fomite).

Indirect transmission occurs when microorganisms are transmitted from an infectious individual to another individual via a contaminated object or person (fomite).

(Category B)

Which activities result in contact transmission?

Examples of direct contact transmission include:

- Blood and/or body fluids from an infected individual directly entering another individual's body through contact with a mucous membrane or via cuts and abrasions to the skin;
- Scabies mites transmitted from an infected individual to another individual by direct skin-to-skin contact.

Examples of indirect contact transmission include:

- Via healthcare worker hands if hand hygiene is not performed between touching an infected or colonised body site or a contaminated object and then touching another individual;
- Via shared patient care equipment and devices contaminated with blood and/or body fluids that are not adequately cleaned or disinfected between use e.g. glucose monitoring devices and commodes;
- Via surgical instruments or equipment that have not been adequately sterilised or disinfected between use;
- Shared toys among paediatric patients.

(Category B)

Which infectious agents are transmissible by the contact route?

Microorganisms transmitted primarily by the contact route (both direct and indirect) include *Staphylococcus aureus*, herpes simplex virus (HSV) and *Clostridioides difficile.*

(Category B)

Are there any other definitions for cross transmission of infectious agents in health and care settings?

The literature also uses the terms ‘airborne dissemination’ and ‘aerosol dissemination’ when referring to airborne transmission of infectious organisms via environmental sources rather than patient to patient transmission.

(No recommendation)

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Appendix 1: Grades of recommendation

Final recommendations are given a grade to highlight the strength of evidence underpinning them, the NIPCM grades of recommendations are as follows:

Grade	Descriptor	Levels of evidence
Mandatory	Recommendations' that are directives from government policy, regulations or legislation	N/A
Category A	Based on high to moderate quality evidence	SIGN level 1++, 1+, 2++, 2+, AGREE strongly recommend
Category B	Based on low to moderate quality of evidence which suggest net clinical benefits over harm	SIGN level 2+, 3, 4, AGREE recommend
Category C	Expert opinion, these may be formed by the NIPC groups when there is no robust professional or scientific literature available to inform guidance.	SIGN level 4, or opinion of NIPC group
No recommendation	Insufficient evidence to recommend one way or another	N/A