

# A review of nosocomial infections: epidemiology, transmission and control measures

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## Abstract

The increasing virulence and pathogenicity of viruses, bacteria and fungi in healthcare facilities has led to a consistent rise in nosocomial infections. These facts demand actions that ensure that healthcare workers and the general public are not unduly exposed to potentially preventable infections. This article explores the use of various infection control measures that can be used to decrease the risk of acquiring infections in healthcare facilities.

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## Introduction

The recent focus on infections acquired in healthcare facilities in both developing and developed countries has highlighted the importance of improving infection control. Healthcare professionals, patients and the general public are regularly being exposed to a multitude of bacterial, viral and fungal pathogens in outpatient and inpatient settings. These infections are referred to as nosocomial infections, hospital-acquired infections or healthcare-associated infections.<sup>1</sup>

The World Health Organisation (WHO) raises the following points regarding nosocomial infections<sup>2</sup>:

- A nosocomial infection is one that occurs in a patient in a hospital or other healthcare facility in whom the infection was not present or incubating at the time of admission.
- A nosocomial infection is one acquired in hospital by a patient who was admitted for a reason other than that infection.
- Infections that occur more than 48 hours after admission are usually considered nosocomial.
- This includes infections acquired in the hospital but appearing after discharge as well as occupational infections among staff of the facility.
- Nosocomial infections may also be considered either endemic or epidemic.

In-patient facilities and in particular intensive care units (ICUs) have been frequently identified as the epicentres of hospital-acquired infections. The risks however have extended to outpatient facilities such as waiting areas, clinics and pharmacies. Furthermore, nosocomial infections can appear after the infected individuals have left the facilities.

The United States (US) Centres for Disease Control and Prevention estimated that annually approximately 1.7 million hospital-associated infections caused or contributed to the deaths of 99 000 Americans each year. Furthermore, surveys of healthcare facilities in Europe estimate that up to 25 000 deaths occur annually from nosocomial infections.<sup>3</sup> Recent data published in the New England Journal of Medicine in 2014 showed that one in 25 patients developed at least one hospital-acquired infection.<sup>4</sup>

In South Africa approximately one in seven patients entering a healthcare facility are at high risk of acquiring nosocomial infections. Of these patients approximately 80% acquire the following infections<sup>5</sup>:

- Lower respiratory tract infections
- Urinary tract infections
- Bloodstream infections
- Post-surgical infections

There is extensive evidence revealing the negative impact of nosocomial infections on patient mortality and morbidity as well as rising healthcare costs. This has been compounded by the development of antimicrobial resistance and the paucity of newer antimicrobial agents.

## Transmission

Infections are transmitted to people in healthcare facilities in the following ways<sup>6,7</sup>:

- Droplet transmission
- Airborne transmission
- Contact transmission (direct or indirect)

### Droplet transmission

Droplets greater than five microns in diameter are dispersed via coughing, sneezing, talking or during the performance of procedures such as suctioning or bronchoscopy. Due to their relatively large size they travel only distances of two metres or less.<sup>7</sup>

Organisms commonly associated with droplet transmission are:

- Respiratory viruses (e.g. *influenza*, *parainfluenza virus*, *adenovirus*, *respiratory syncytial virus*, *human metapneumovirus*)
- *Bordetella pertussis*
- *Streptococcus pneumoniae*: the most common cause of bacterial pneumonia
- *Neisseria meningitidis*: associated with an aggressive form of bacterial meningitis

### Airborne transmission

Small pathogens of less than five microns in diameter are transmitted via coughing or sneezing. These particles travel greater distances and remain in the air for longer periods of time. They are also most likely to reach the alveoli as compared to larger particles and are therefore associated with increased pathogenicity.

Organisms commonly associated with airborne transmission are:

- *Mycobacterium tuberculosis*
- *Rubella virus* (German measles)
- *Varicella-zoster virus* (chickenpox/shingles)

Airborne transmission can be further categorised into obligate or preferential airborne transmission.<sup>8</sup>

- Obligate airborne transmission refers to pathogens that are transmitted only by deposition of droplet nuclei under natural conditions (e.g. pulmonary tuberculosis).
- Preferential airborne transmission refers to pathogens that can initiate infection by multiple routes, but are predominantly transmitted by droplet nuclei (e.g. measles, chickenpox).

### Contact transmission (direct or indirect)

Direct contact transmission involves the transfer of microorganisms from one individual to another via direct physical contact. Doctors and nurses are at high risk during their physical examinations of patients.

Indirect contact transmission refers to the transfer of microorganisms initially to objects or surfaces within facilities and thereafter to other patients or healthcare workers. Objects most frequently associated with this form of infection include bed linen, furniture, bedpans and urinals, and examination equipment such as thermometers, blood pressure cuffs and stethoscopes.

In the era of antibiotic resistant microbes, the organisms that are of great concern in this form of transmission include:

- Extended spectrum beta-lactamase (ESBL)-producing Gram negative bacteria

- Methicillin resistant *Staphylococcus aureus* (MRSA)
- Vancomycin resistant enterococci
- *Clostridium difficile*

### Infection control

Numerous methods are used to decrease the rates of infections. Selecting the optimal infection control method is dependent on which pathogens or modes of transmission the patient and/or the healthcare professional are exposed to or are anticipated to be exposed to.

Standard precautions include:

- Hand hygiene
- Disinfection or sterilisation
- Adequate ventilation
- Injection safety

Thereafter, protection can be improved by adding the following interventions:

- Droplet and airborne transmission routes:
  - Personal protective equipment such as masks, face shields or goggles
  - Mechanical ventilation
  - Ultraviolet germicidal irradiation (UVGI)
- Direct contact transmission
  - Personal protective equipment such as gloves, gowns, aprons, masks, face shields or goggles
- Indirect contact transmission
  - Personal protective equipment such as gloves, gowns, aprons and masks

### Hand hygiene

Hand hygiene is still regarded as one of the cheapest and yet most important methods of infection control. Guidelines have been developed on this method of infection control emphasising simple steps, such as washing hands under running water, the use of antiseptic products and drying techniques.<sup>9</sup> The knowledge of correct handwashing techniques is also suboptimal amongst healthcare workers.<sup>10</sup>

The bacteria cultured on the unwashed hands of healthcare workers included<sup>11</sup>:

- *Methicillin-resistant staphylococcus aureus* (MRSA)
- *Vancomycin-resistant enterococci* (VRE)
- *Pseudomonas aeruginosa*

Hand sanitisers have become common in healthcare settings. Research has shown that washing with soap and water is more effective than alcohol swabs.<sup>12</sup> This must be balanced against the convenience of the alcohol swabs and sprays. The effectiveness of any hand hygiene techniques is linked to its knowledge, convenience and frequency of use.

### Disinfection and sterilisation

Disinfection uses chemicals on surfaces and at room temperature to kill disease-causing microorganisms. This process does not kill all possible pathogens, but does significantly decrease the microbial count.

Sterilisation is a process used to kill all possible pathogens. This level of microbicide requires more specialised process and equipment.<sup>13</sup> Methods used to achieve sterilisation of disinfection include:

- Specialised equipment such as autoclaves and steam sterilisers
- Chemicals such as alcohols, glutaraldehyde, formaldehyde and hydrogen peroxide

It is vitally important to clean the countertops and surfaces where medication preparation occurs at least daily and when visibly soiled. In a pharmacy or hospital dispensary, this includes trays or other devices for counting solid dosage forms. Contaminated items must not be placed in or near the medication preparation area. In the event of blood or body fluids being spilled, clean the visible matter with appropriate absorbent material followed by immediate disposal into a biohazard container or bin. The area will thereafter require disinfection.

### Injection safety

Injection safety refers to the appropriate steps involving the preparation and/or administration of the following interventions:

- Injections and infusions
- Phlebotomy (for laboratory blood tests)
- Lumbar punctures
- Finger prick tests (e.g. glucose monitoring devices)

The devices in question include needles, lancets, syringes, glucose-monitoring devices, intravenous tubing, medication vials, and parenteral solutions. These practices are intended to prevent the transmission of infectious diseases between patients or between a patient and healthcare professionals. These safety measures are of increasing importance to pharmacists as the number of patients visiting pharmacies for vaccinations, family planning, various blood or urine monitoring tests, including those for glucose and cholesterol, has increased significantly in recent years.

Recommendations from the United States' Centres for Disease Control and Prevention regarding injection safety include the following measures<sup>14</sup>:

- Use aseptic technique when preparing and administering chemotherapy infusions or other parenteral medications
- Whenever possible, use commercially manufactured or pharmacy-prepared prefilled syringes
- Avoid prefilling and storing batch-prepared syringes except in accordance with pharmacy standards
- Avoid unwrapping syringes prior to the time of use
- Never administer medications from the same syringe to

multiple patients, even if the needle is changed or the injection is administered through an intervening length of intravenous tubing

- Never leave a needle inserted into the septum of a medication vial for multiple draws
- Do not reuse a syringe to enter a medication vial or solution
- Do not administer medications from single-dose or single-use vials, ampoules, or bags or bottles of intravenous solution to more than one patient (e.g. do not use a bag of saline as a common source supply for multiple patients)
- Cleanse the access diaphragms of medication vials with 70% alcohol and allow the alcohol to dry before inserting a device into the vial
- Dedicate multi-dose vials to a single patient whenever possible. If multi-dose vials must be used for more than one patient, they are restricted to a dedicated medication preparation area and should not enter the immediate patient treatment area (e.g. exam room, chemotherapy suite)
- Dispose of used syringes and needles at the point of use in a sharps container that is closable, puncture-resistant, and leak-proof
- Do not use fluid infusion or administration sets (e.g. intravenous tubing) for more than one patient
- Use single-use, disposable finger stick devices (e.g. lancets) to obtain samples for checking a patient's blood glucose, cholesterol, etc and dispose of them after each use

### Ventilation

The risk of exposure to airborne pathogens decreases in the presence of adequate ventilation.<sup>15</sup> The general purpose of ventilation in buildings is to provide healthy air for breathing by both diluting and removing the pollutants and pathogens from the indoor area. The three factors that affect the efficiency of the ventilation system in use are the ventilation rate, airflow direction and airflow distribution.<sup>16</sup>

Natural ventilation involves natural forces such as wind or thermal buoyancy (warmer air rising) to drive exchanges between outdoor and indoor air through openings such as windows, doors, solar chimneys and wind towers.<sup>17</sup>

Mechanical ventilation involves the use of fans to drive the air exchange process. Mechanical ventilation systems can deliver the predetermined ventilation rate, airflow direction and airflow distribution regardless of the outdoor weather conditions. Mechanical ventilation units can be installed with pathogen and/or pollutant filters and integrated into air-conditioning ducts where the indoor air temperature and humidity can also be controlled.<sup>14</sup>

Hybrid ventilation models employ the use of both natural and mechanical ventilation systems.<sup>18</sup>

### Personal protective equipment (PPE)

These items offer barrier protection mainly to healthcare workers. This equipment includes, but is not limited to masks, respirators, gowns, aprons, face shields or goggles.

When selecting the appropriate PPE, the following must be taken into consideration<sup>19</sup>:

- *Type of transmission*

Is it droplet, airborne, direct contact or indirect contact transmission?

In what area is this transmission occurring? Is it a consulting room, pharmacy, hospital ward, TB clinic or other area?

- *The anticipated type of pathogen*

Is it from a patient with an infectious disease such as tuberculosis or chicken pox, for example? This information may not always be readily available.

This is of particular relevance when choosing N95 respirators over conventional facemasks.<sup>20</sup>

Facemasks with or without a face shield are loose-fitting physical barriers between the mouth and nose of the wearer and potential contaminants in the immediate environment.

An N95 respirator is a close fitting facial respiratory protective device that achieves highly efficient filtration of airborne particles. The reference to "N95" is due to it filtering > 95% of particles tested. These masks are of particular benefit when treating patients with tuberculosis.

- *Type of exposure*

Is it contact, splashes or sprays, or large volumes of body fluids that might penetrate the clothing?

The durability, fit and appropriateness of the equipment is also of paramount importance.

This will affect, for example, whether a gown or apron that is selected for PPE needs to be fluid resistant or not.

In some countries, particularly in East Asia, it is culturally acceptable for the general public to wear masks.<sup>21</sup> This is used to protect the individual from air pollution as well as potential airborne pathogens. It is also culturally appropriate in those cultures for sick individuals to wear masks in order to prevent others from being infected.

### Ultraviolet germicidal irradiation

Ultraviolet germicidal irradiation (UVGI) is the use of ultraviolet energy to kill or inactivate viruses, bacteria, or fungi. UVGI provides protection against multiple pathogens and is effective against contact, droplet and airborne pathogen transmission.

Experiments conducted by Downes and Blunt during the 19<sup>th</sup> century described the effects of light as a germicidal agent.<sup>22</sup> Their later research revealed that sunlight was bactericidal and that these effects were dependent on intensity and duration of the exposure.<sup>23</sup> During the 1930s Wells described airborne infections and the use of ultraviolet light as a germicidal agent.<sup>24,25</sup>

More recent data has concluded that the effectiveness of UVGI is enhanced when installed with fans that facilitate air mixing.<sup>26,27,28,</sup> Up to 99% of tested bacteria were inactivated within 120 seconds of exposure to ultraviolet light. The pathogens tested included *Escherichia coli*, *Pseudomonas aeruginosa*, *Salmonella enteritidis*, *Listeria monocytogenes*, *Staphylococcus albus*, *Serratia marcescens*, *Mycobacterium phlei*, *Mycobacterium bovis* and *Mycobacterium tuberculosis*.<sup>29</sup> Ryan et al's research into "Effect of enhanced ultraviolet germicidal irradiation in the heating ventilation and air conditioning system on ventilator associated pneumonia in a neonatal intensive care unit" concluded that enhanced UVGI decreased heating ventilation and air conditioning system microbial colonisation. Furthermore there were significant reductions in ventilator-associated pneumonia and antibiotic use.<sup>30</sup>

There are however concerns over safety, with particular regard to overexposure to ultraviolet light. Ultraviolet light is potentially carcinogenic. UV-A and UV-B have been associated with skin cancers and corneal irritation and their longer wavelengths allow for greater skin penetration as compared to UV-C. UVGI lamps are designed to emit UV-C. The extremely low penetrating ability of UV-C is predominantly absorbed by the outer layer of skin. It is however noted that direct continuous exposure to the light is not recommended. Furthermore, it is imperative that the installation follows the norms and guidelines of regulatory bodies with regards to correct installation and safe exposure limits. Nardell et al evaluated the safety of upper-room ultraviolet germicidal air disinfection in their Tuberculosis Ultraviolet Shelter Study. The seven year study that occurred in six US cities revealed that "... careful application of upper-room UVGI can be achieved without an apparent increase in the incidence of the most common side-effects of accidental UV overexposure..."<sup>31</sup>

The evidence of the safety and effectiveness of UVGI reaffirms the value of this modality as an addition to existing infection control measures. Optimal adoption of UVGI will lead to the attenuation of contact, droplet and airborne transmission within healthcare facilities.

### Conclusion

Healthcare-associated infections are no longer within the confines of hospitals and clinics. Infections are readily spread across all healthcare facilities exposing patients, healthcare workers and the public to pathogens with increasing levels of virulence and resistance. There are currently numerous interventions available to attenuate these risks, however the implementation or utilisation of these interventions lies with educating all stakeholders on their benefits.

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