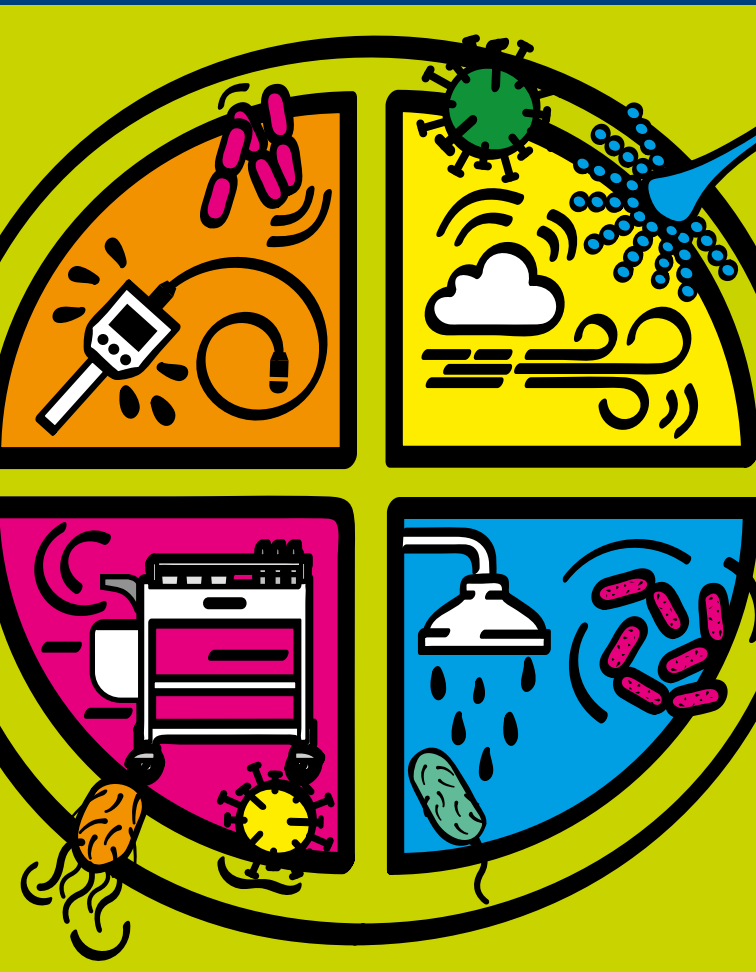
BIOMÉRIEUX

ENVIRONMENTAL INFECTION CONTROL IN HOSPITALS



PIONEERING DIAGNOSTICS

PREFACE

After decades of focusing on the control of environmental contamination, fostered by the use of multi-usage high-risk items and devices, two major breakthroughs significantly reduced the environmental risk in the eighties and nineties: firstly, the universal use of sterile single-use medical devices, and secondly, the introduction of alcohol-based handrubs for hand hygiene in the healthcare setting. Both innovative measures were key for limiting cross-transmission and preventing environmental contamination.

However, recent evidence is growing on the importance of environmental contamination as a reservoir for healthcare-associated infection (HAI): airborne transmission of aspergillosis is a high risk for immunosuppressed patients; water contamination may be a reservoir for acquisition of high-risk pathogens such as *Pseudomonas aeruginosa*, *Legionella pneumophila* or carbapenemase-producing Enterobacterales; the survival of resistant bacteria on dry surfaces has been responsible for transmission of multidrug-resistant organisms and *Clostridiodes difficile.*

To respond to these evolving risks, new rapid molecular techniques have allowed a better understanding of the role of the environment in the epidemiology of resistant pathogens. Large, multicenter cluster-randomized studies have been conducted to assess the impact of preventive measures, such as the use of various surface and airborne disinfectants, the role of architecture for limiting the environmental risk, or the critical role of thorough environmental cleaning and disinfection.

But where do we go now? It is clear that environmental contamination must be systematically included in programs for preventing cross-transmission and HAI, and that environmental cleaning should be part of "standard precautions", in addition to hand hygiene and the prevention of blood-borne pathogens.

Environmental cleaning, supported by simple techniques for assessing its quality, and microbiological environmental control driven by a comprehensive and thoughtful approach to its usefulness, should be integrated in the arsenal of infection prevention and control measures.

I hope that this booklet will inform, encourage and support healthcare professionals who wish to improve environmental control and reduce antimicrobial resistance.

Professor Jean-Christophe LUCET
Head, Infection Control Unit,
Bichat University Hospital,
Assistance Publique - Hopitaux de Paris,
France

Most of the recommendations in this booklet have been extracted from the literature and have been cited where relevant.
The recommendations also assume availability of resources which may not be accessible in some countries, or in smaller or regional healthcare institutions.

For more information and guidelines on Environmental Infection Control, consult the following dedicated web resources:

CDC

Infection Control
https://www.cdc.gov/infectioncontrol/

Guidelines for Environmental Infection Control in Health-Care Facilities
https://www.cdc.gov/infectioncontrol/guidelines/environmental/index.html

ECDC

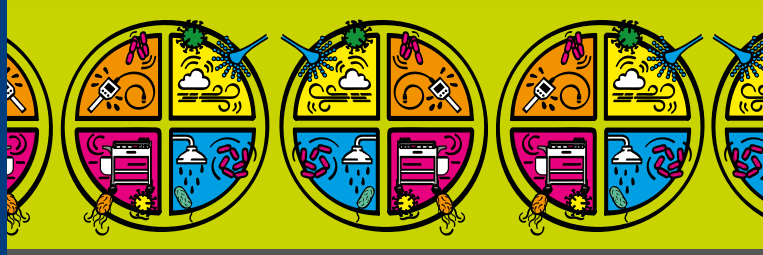
Directory of online resources for the prevention and control of antimicrobial resistance (AMR) and healthcare-associated infections (HAI)
https://www.ecdc.europa.eu/en/publications-data/directory-online-resources-prevention-and-control-antimicrobial-resistance-amr

Organisation of infection prevention and control in healthcare settings
https://www.ecdc.europa.eu/en/publications-data/directory-guidance-prevention-and-control/measures-in-hospitals

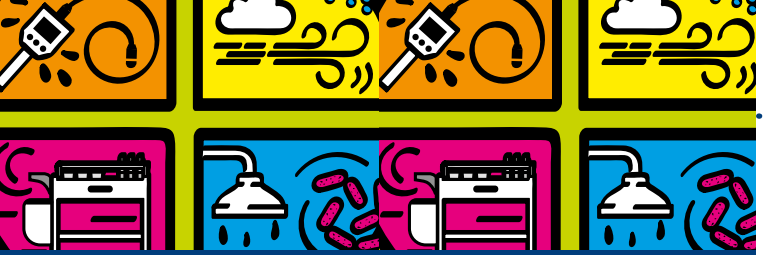
WHO

Practical guidelines for infection control in health care facilities
https://www.who.int/water_sanitation_health/emergencies/infcontrol/en/

Environmental Management Practices
https://www.who.int/water_sanitation_health/hygiene/envsan/inf-controlenv_mgmt.pdf?ua=1



CONTENTS



INTRODUCTION

The hospital environment may be contaminated with various environmental pathogens and with more virulent microorganisms transmitted from colonized or infected patients or staff.

Infection may occur by direct inoculation into wounds or other sites. More frequently, commensal flora, mostly skin and digestive microbiota, may first become colonized with subsequent invasive infection when patient defences are compromised.

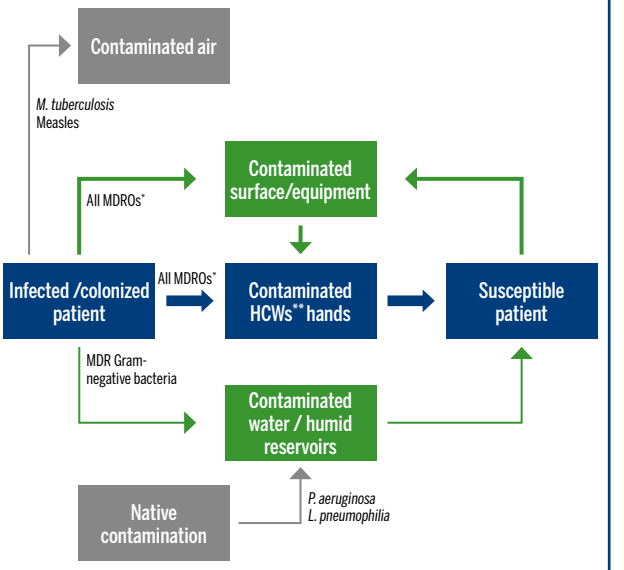
Infection control therefore includes the prevention of contamination and colonization as well as direct infection, to limit the spread of infections.

Transmission routes of infections are complex and often involve the environment, either directly or indirectly (**Figure 1**). Environmental routes and sources include:

- Air
- Water
- Medical devices and equipment
- Environmental surfaces
- Food and drink

Figure 1. Routes of transmission of healthcare-associated pathogens

Adapted from Otter JA, et al. *Infect. Control Hosp. Epidemiol.* 2011;32(7):687-699



* MDRO: Multidrug-resistant organism
** HCW: Healthcare worker

1 AIRBORNE AND DROPLET TRANSMISSION

Airborne microorganisms can be inhaled, fall directly onto wounds or instruments or survive on surfaces and then be indirectly transmitted to patients. Some pathogens are especially likely to be shed from patients or carriers, resist drying, survive in dust or droplets and then be spread via the air.

Conceptually, airborne transmission includes two main routes: **airborne transmission** per se and **droplet transmission.** Airborne transmission occurs when a patient inhales droplet nuclei of less than 10 microns or small particles containing microorganisms. These small particles can be dispersed over long distances. Microorganisms with a human reservoir transmitted via the airborne route include *M. tuberculosis*, measles, varicella and pox virus. Airborne transmission from the environment includes *Legionella* spp. and *Aspergillus* spp.

Droplet transmission occurs with large droplets of more than 10 microns. They originate mainly from oropharyngeal secretions and the upper respiratory tract, and contaminate a susceptible host either by impaction on mucous membranes at short distances, less than 1.5 m, or indirect transmission via contaminated fomites. Microorganisms with a human reservoir transmitted via droplet transmission include most viruses (influenza, RSV, norovirus, coronaviruses...), *Streptococcus pyogenes*, *Neisseria meningitidis*, *Bordetella pertussis*,...

For influenza virus and high-risk coronaviruses (MERS-CoV, SARS-CoV-1/SARS-CoV-2), there is strong evidence that transmission mostly occurs via droplets. However, given the potential severity of these viruses, the recommended level of precautions can be heightened to airborne precautions in certain situations at risk of generating small particle aerosols.

The main air/droplet-borne microorganisms in the hospital setting include:

- *Staphylococcus aureus* (droplet)
- Coagulase-negative Staphylococci (CoNS) (droplet)
- *Streptococcus pyogenes* (droplet)
- *Mycobacterium tuberculosis* (airborne)
- Influenza virus and respiratory syncytial virus (RSV) (droplet)
- Norovirus (droplet)
- High-risk coronaviruses: MERS-CoV, SARS-CoV-1/SARS-CoV-2 (mainly droplet, airborne in some circumstances)
- *Aspergillus* spp. (airborne)

The contaminated environment can originate from contaminated hands or from sedimentation of airborne pathogens at close proximity to the infected patient.

1.1 *Staphylococcus aureus*

Methicillin-sensitive *S. aureus* (MSSA) and methicillin-resistant *S. aureus* (MRSA) strains are major pathogens of surgical wounds, and skin and soft tissue infections.

MSSA is a commensal of nose, perineum and other skin sites in about 30% of normal people and is shed on skin squames that float in the air before settling and surviving in dust. Air movement stirs up dust and *S. aureus* can then transmit to wounds and instruments, in particular in operating rooms. The proportion of transmission via the air or via direct contact to a wound remains largely unknown.

MRSA is carried much less frequently but spreads widely amongst hospital patients. It is mainly transmitted from colonized and infected patients through healthcare workers' hands, but environmental contamination and airborne spread may also be involved.

1.2 Coagulase-negative staphylococci (CoNS)

These are low virulence microorganisms that colonize the skin of normal people. Nearly all CoNS associated with healthcare are resistant to methicillin. They are also shed into the air and may settle on wounds and surgical instruments, leading to prosthetic infections, especially in orthopaedic and cardiac surgery.

1.3 *Streptococcus pyogenes*

This organism is carried in the throat of about 5% of healthy people and causes wound and skin and soft tissue infection with a similar epidemiology to *S. aureus*. It is mainly transmitted via respiratory droplets and skin contact.

PREVENTION AND CONTROL MEASURES

These measures involve the systematic implementation of **standard hygiene and cleaning precautions** (Sehulster, Chinn, CDC, & HICPAC, 2003) for the prevention and control of surface contamination (see page 30). The control of air contamination in high risk areas such as operating rooms involves strict environmental cleaning, frequent air changes and high efficiency air filtration (see below). In implant surgery, additional protection of the wound and surgical instruments from CoNS may be provided by delivery of ultraclean air from special ventilation canopies or hoods. The level and type of air filtration in the operating room however is a matter of debate. Recent recommendations suggest that ultraclean air ventilated with laminar airflow may no longer be required in clean orthopaedic surgery (Allegranzi et al., 2016; Bischoff et al., 2017).

MEASURES FOR PREVENTION OF AIRBORNE TRANSMISSION IN OPERATING ROOMS AND OTHER HIGH RISK ENVIRONMENTS

- **Repeated air changes**, air filtration and reduction of air turbulence.
- **Keeping staff to a minimum** throughout an operation and limiting door openings and movements in and out of the operating room.
- **Maintaining air flows** directed from clean areas such as operating rooms, intensive care units and treatment rooms (relatively positive pressure) to less clean general areas (relatively negative pressure).
- **Applying stricter measures** for higher risk environments. For example, six air changes/hr can be recommended for general wards, 10 air changes/hr for critical areas, 15 air changes/hr for day care operating rooms, and 25 air changes/hr for general operating rooms.
- **Using laminar flow filtered air** via canopies (ultra clean ventilation, UCV) for prosthetic implant surgery (Dharan & Pittet, 2002; Hoffman et al., 2002; Sehulster et al., 2003).

Although there are **no agreed standards for bacterial air sampling or its frequency**, many authorities agree on monitoring when:

- **A surgical room is newly commissioned.**
- **After building works or refurbishment** (Hoffman et al., 2002).

In addition, monitoring of adherence to cleaning practices is recommended.

CRITERIA FOR OPERATING ROOM AIR QUALITY

- **Empty operating room: <35 colony-forming units (CFU)/m^3**, with **<1 colony of *Clostridium perfringens* or *S. aureus* per m^3**.
- **During an operation**, total air counts: **<180 CFU/m^3** averaged over 5 minutes (Dharan & Pittet, 2002; Hoffman et al., 2002; Sehulster et al., 2003).

1.4 *Mycobacterium tuberculosis*

The most common form of tuberculosis is pulmonary. Such patients, who often cough up *M. tuberculosis* in sputum, can transmit the infection to others. Patient presenting with pulmonary tuberculosis are often nursed in hospitals, where they pose a risk of transmission via the airborne route to other patients, staff and visitors. Immunocompromised individuals are especially vulnerable to infection, including those with HIV/AIDS. Many outbreaks of hospital-acquired tuberculosis have been reported in the early nineties. **Protective respiratory equipment** including N95 (or FFP2) masks, and rapid suspicion and diagnosis at hospital admission have minimized the risk of transmission. The emergence of multidrug-resistant or even extra-resistant tuberculosis makes this a particularly important disease to control in healthcare facilities.

PREVENTION AND CONTROL MEASURES

(Jensen et al., 2005; National Collaborating Centre for Chronic Conditions (UK) & Centre for Clinical Practice at NICE (UK), 2011).

- **Identify infected patients:** this is essential as undiagnosed patients with active pulmonary tuberculosis can spread the disease widely in institutions due to confined air and duration of contacts.
- **Assess risk** for drug resistance and HIV for all patients with tuberculosis. If multidrug-resistant tuberculosis is identified or suspected, special precautions should be implemented (see page 10).
- **Limit contact of patients with suspected active pulmonary tuberculosis with other individuals**, especially immunocompromised patients, until judged to be non-infectious. Patients with tuberculosis should be nursed in single rooms, either with negative pressure or vented to the outside of the building. Perform aerosol-generating procedures such as bronchoscopy, sputum induction or nebuliser treatment in an appropriately ventilated area.
- **Implement airborne or droplet precautions** by using protective respiratory equipment. Additional standard precautions should be strongly reinforced for healthcare workers caring for patients or people during aerosol-generating procedures associated with a high risk of tuberculosis transmission (aspiration, respiratory physiotherapy).
- **Inpatients with tuberculosis** should wear a surgical mask whenever they leave their rooms until they have are considered as non-infectious (usually two weeks after initiation of adequate drug treatment).

Multidrug-resistant Tuberculosis

Multidrug-resistant tuberculosis is a serious infection and special precautions should be implemented to prevent its spread:

- **Negative-pressure rooms** with continuously monitored air flows for patients with known or suspected multidrug-resistant tuberculosis, until they are judged non-infectious.
- **Higher level of respiratory protection** may be offered for staff and visitors while the patient is considered infectious. Masks should meet the standards summarized by the Health and Safety Executive guidelines (2013). Staff who are likely to nurse infected patients should be trained in the use of such masks and have their mask fit tested.

1.5 Influenza virus and respiratory syncytial virus (RSV)

Influenza is primarily a community-based infection that is spread from person to person mainly through transmission of large-particle respiratory droplets requiring close contact between source and recipient persons. In the hospital setting, spread of influenza virus can occur among patients, healthcare professionals (HCP), and visitors. In addition, HCP may acquire influenza from persons in their household or community. Airborne transmission over longer distances, such as from one patient room to another, has not been documented and is thought not to occur (CDC).

Respiratory syncytial virus (RSV) infection can cause a variety of respiratory illnesses mainly in infants and young children, but it can also occur in all age groups. It most commonly causes a cold-like illness but can also cause lower respiratory infections, such as bronchiolitis and pneumonia.

PREVENTION AND CONTROL MEASURES

The prevention and control of **influenza** in healthcare settings requires a multi-faceted approach, and **core prevention strategies** include ("https://www.cdc.gov/flu/professionals/infectioncontrol/healthcare-settings", s. d.):

- **Implementation of droplet precautions** for patients with suspected or confirmed influenza for 7 days after illness onset or until 24 hours after the resolution of fever and respiratory symptoms.
- **Appropriate management of symptomatic HCP.**
- **Administration of influenza vaccine.**

The prevention and control of **RSV infection** in hospitals depends largely on the following **key actions** (Groothuis et al., 2008):

- **Handwashing measures:** RSV is a labile virus that can be rapidly inactivated by alcohol, dishwashing detergents and antibacterial hand soaps.
- **Rapid screening and cohorting of patients on admission:** cohorting of infants with RSV on admission following prospective RSV diagnostic screening has been shown to be an effective method to reduce transmission of RSV.
- **Cohorting of ward staff and limiting family visits.**
- **Use of gloves and gowns.**

1.6 Norovirus

Norovirus is a highly contagious cause of diarrhoea and vomiting that is usually community-acquired. In hospitals, rapid transmission can produce large outbreaks involving both patients and staff and may lead to ward closures. The main transmission route is person-to-person spread by faeces and vomitus via hands. However, vomiting may be sudden and projectile, sometimes leading to widespread environmental contamination. The virus can survive in the environment for hours to weeks and environmental contamination may play a role in indirect spread. There is some evidence that the virus can be transmitted in air during vomiting and can infect other people in close proximity by the airborne route (Bonifait et al., 2015; Lopman et al., 2012). Nevertheless, air is a minor transmission route and does not require special control, except that isolation in side rooms rather than in bays or the open ward is recommended (Harris et al., 2013).

PREVENTION AND CONTROL MEASURES

The prevention and control of norovirus infection in hospitals depends largely on the following **four key actions** ("Norovirus | Guidelines Library | Infection Control | CDC", s. d.):

- **Keeping symptomatic patients and staff** out of the hospital where possible.
- **Enforcing strict contact precautions** of patients until 48 hours after symptoms have cleared.
- **Restricting patient movement**.
- **Reinforcing hand decontamination** and environmental cleaning.

1.7 Middle East Respiratory Syndrome (MERS) and other high-risk coronaviruses

Since April 2012, cases of severe and often fatal acute respiratory tract infection with a novel coronavirus (CoV), namely MERS-CoV, have been reported from the Middle East. This virus has some similarities to, but is distinct from, the coronavirus that caused the global outbreak of Severe Acute Respiratory Syndrome (SARS) in 2002-3. Many lessons learnt during the SARS outbreak can be applied to outbreaks of MERS-CoV. In particular, although inhalation protection was considered important, transmission was probably largely via droplets spread via hands and environmental contamination. Outbreaks were often brought under control by stringent application of infection prevention and control (IPC) procedures, including hand washing (Shaw, 2006).

MERS is less transmissible than SARS but has a higher case fatality rate. The prevention of airborne and other environmental transmission of these infections, as well as severe infections with avian influenza, follows the same principles as outlined here for MERS.

In December 2019, an outbreak of respiratory illness caused by a novel coronavirus, COVID-19, was first detected in China, and has since spread to all continents. On March 11, 2020, the WHO announced the COVID-19 outbreak to be a pandemic. As of the date of this booklet, the WHO continues to coordinate global response efforts and to closely monitor the evolving situation (WHO).

PREVENTION AND CONTROL MEASURES

As there are no effective anti-virals for MERS, the main protection is by **strict IPC practices** which should be in place at all times as soon a case is suspected. Detailed guidance and up-to-date advice on the changing epidemiology, diagnosis and management of MERS is given on the websites of the WHO (World Health organisation), CDC (Centers for Disease Prevention and Control, USA) and PHE (Public Health England). This guidance includes the updated list of countries at risk.

THE PRINCIPLES OF CONTROL ARE AS FOLLOWS:

- **Staff education** on the potential risk of a patient with MERS being admitted, especially from the Middle East.
- **Strict IPC practices** maintained by all staff at all times.
- **Prompt identification and reporting of possible cases.** Management according to local guidelines.
- **Enhanced protection** (negative pressure isolation and use of personal protective equipment [PPE, in this case appropriate FFP2/N95 ou FFP3 masks]) for suspected and confirmed cases.

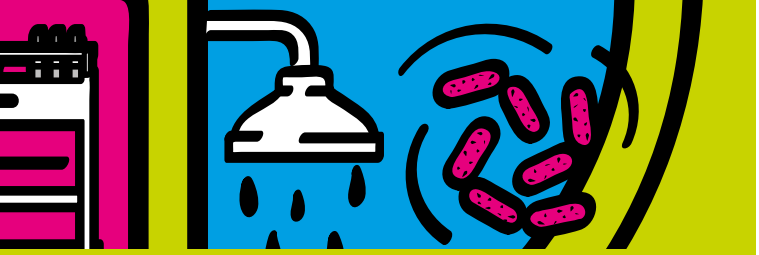
1.8 *Aspergillus*

Spores of the fungus *Aspergillus* spp. are widespread in the environment and can be released into the air in high concentrations during demolition and building work. These spores do not usually harm normal people, but may cause disseminated and fatal invasive disease in immunosuppressed patients, especially neutropenics and lung transplant patients. Hospital building works therefore pose a risk to patients, especially those in oncology/hematology and intensive care units, as patients can be exposed to environmental reservoirs.

There is no consistent relationship between airborne *Aspergillus* spore counts and invasive infection, even in neutropenic patients. However, evidence of similarities between environmental and patient strains during hospital works has been shown (Loeffert et al., 2019). Several hospital outbreaks have been associated with nearby building works and care must be taken to reduce dust exposure during construction by containment, vacuuming and damping (Kanamori et al., 2015).

PREVENTION AND CONTROL MEASURES DURING HOSPITAL BUILDING WORKS

- During a hospital stay, **bone marrow transplant patients** are normally protected from airborne infections, including those from *Aspergillus*, by being routinely nursed in **sealed, positive-pressure single rooms** with high-efficiency particulate air (HEPA)-filtered air. In addition, anti-fungal prophylaxis reduces the residual risk of aspergillosis for leukemia patients receiving induction chemotherapy.
- **Other types of immunocompromised patients** are normally nursed in less protected environments. If spore contamination is likely to be difficult to contain, vulnerable patients should be moved to safe areas during construction work.
- **General recommendations** to reduce the risk of *Aspergillus* exposure during on-site construction include the following ("Infection control in the built environment (HBN 00-09)", s. d.; Sehulster et al., 2003):
  - Involve the IPC team in the planning process from the beginning.
  - Implement a planned contamination-control program when building work is planned.
  - Seal windows in areas accommodating susceptible patients.
  - Use floor-to-ceiling barriers that completely enclose the work area.
  - Use dampening procedures to reduce dust formation.
  - Use vacuum cleaners with HEPA filters on exhausted air.



2 WATERBORNE TRANSMISSION

In hospitals, environmental water contamination has led to many hospital outbreaks. These include:

- ***Legionella* outbreaks** from contaminated general water supplies and air conditioning.
- **Outbreaks of Gram-negative opportunists** in high dependency units due to contamination of tap water, humidifiers, or other devices.
- ***Pseudomonas* outbreaks** associated with medical devices (see page 18), in particular fiber optic endoscopes (disinfection failure), or hydrotherapy pools.

2.1 *Legionella*

Legionnaires' disease is a potentially fatal pneumonia caused by *Legionella* bacteria, in particular *Legionella pneumophila* serogroup 1. It is the most well-known and serious form of a group of diseases known as legionellosis. Everyone is susceptible to infection but the risk is higher in those over 45 years, smokers, heavy drinkers, people suffering from chronic respiratory or kidney disease, diabetes, lung and heart disease, and those with impaired immunity.

Legionella commonly contaminate hospital water systems, including cooling units, evaporative condensers, hot and cold water supplies and spa pools, especially where water is stored or re-circulated and where there are high levels of scale, sludge and biofilms.

Legionella survive at low temperatures, multiply between 20-45°C and are killed by higher temperatures. At optimum temperatures, they multiply to high numbers in water systems and people are infected by inhaling highly contaminated aerosols. This often occurs when showers or taps that have been unused for a period - allowing organisms to multiply in the stagnant pipes - are turned on. Infection usually occurs as outbreaks in air conditioned buildings and patients in hospitals are particularly vulnerable because of their underlying medical conditions.

PREVENTION AND CONTROL MEASURES

The risk of *Legionella* outbreaks can be reduced by **installing safe water systems** and equipment and **implementing preventive maintenance programs**. There are extensive regulatory requirements for the control of *Legionella* and hospitals should be compliant with local/national guidance.

The principles of prevention and control are as follows ("WHO | *Legionella* and the prevention of legionellosis", s. d.):

- **Hospitals should produce a *Legionella* policy** (involving medical, nursing, laboratory professionals and infection prevention control teams) to:
  - Assess the risk of contamination.
  - Implement appropriate risk-reduction programs (including identifying and protecting high risk patients with terminal filtration).
  - Monitor compliance and contamination rates.
  - Rapidly identify cases and investigate and control outbreaks if they occur.
- **A named person should be managerially responsible** for the control systems and measures adopted and should report to appropriate authorities.
- **The water system installation and preventive maintenance program** should:
  - Avoid water stagnation.
  - Store and distribute cold water below 25 °C and ideally below 20 °C.
  - Maintain hot water temperatures at a high enough level to kill *Legionella* while avoiding scalding. This should be above 55°C, however, the recommended temperature should be aligned with local regulations on the risk of burns due to exposure to hot water.
  - Include a program of descaling and biocide treatment.
  - Include regular flushing of taps and showers regardless of routine use.
  - Monitor *Legionella* concentrations and implement additional treatment cycles to maintain safe levels if concentrations rise.

2.2 Multidrug-Resistant (MDR) Gram-negative bacteria

(Kizny Gordon et al., 2017; Sehulster et al., 2003; Tacconelli et al., 2014)

Many Gram-negative opportunistic or even commensal pathogens can survive and proliferate in wet environmental sites such as hospital water systems and taps, ice machines, water baths, sink drains and hydrotherapy pools, and may sometimes spread from these reservoirs to cause infections in patients.

These water organisms include the non-fermenting bacteria *Pseudomonas*, *Serratia*, *Acinetobacter* and *Flavobacterium* species that are inherently antibiotic resistant and have the ability to acquire multiple resistance factors.

Multidrug-resistant Gram-negative bacteria may contaminate and survive in supposedly sterile solutions or clean water reservoirs associated with hospital equipment. Outbreaks of antibiotic-resistant infections may therefore occur when there are failures of sterilization of injectable solutions or breakdowns in the maintenance, decontamination and disinfection of hospital equipment, such as arterial pressure monitoring systems, endoscopes, suction apparatus, humidifiers, nebulizers, ventilators and breast pumps. Similarly, MDR *Klebsiella*, *Serratia* and *Enterobacter* species may contaminate and survive in cold hospital food or enteral feeds given to immunocompromised patients.

MDR Gram-negative organisms tend to be relatively resistant to disinfectants and bacteriostatic agents. Contamination of disinfectants and multiple-use medications may lead to outbreaks of antibiotic-resistant infection, such as post-operative endophthalmitis caused by *Pseudomonas aeruginosa* and *Burkholderia cepacia* associated with contaminated eye drops (Centers for Disease Control and Prevention (CDC), 1996; Lalitha et al., 2014) or post-biopsy prostatitis caused by *Achromobacter xylosoxidans* and *Ochrobactrum anthropi* associated with contaminated biopsy materials (Haviari et al., 2016).

PREVENTION AND CONTROL MEASURES

The prevention and control of infection with MDR Gram-negative bacteria in wet environmental sources depends on standard preventive measures:

- **Any water distribution point** not in use should be removed or at least kept away from the patient and from the zone of drug preparation.
- **Disinfectants** should be freshly prepared in newly sterilized bottles and ideally for single patient use only.
- **Standing water sources** (ice machines, water baths, humidifier water, ...) should be replaced regularly and the containers cleaned. Where appropriate, disinfectant can be added to suppress bacterial growth, and microbiological surveillance can be planned.
- **There are specific guidelines** on control of contamination of specific items and facilities such as:
  - Hydrotherapy pools
  - Expressed breast milk (Centre for Clinical Practice at NICE (UK), 2010);
  - Renal dialysis water
  - Fiber-optic endoscopes
- **In other cases**, appropriate cleaning and disinfection between each patient use is effective.
- **Disinfection of large equipment** such as ventilators and incubators in hydrogen peroxide rooms is a useful additional control.

3 MEDICAL DEVICE TRANSMISSION

In the hospital setting, infection outbreaks may frequently be associated with medical devices, in particular fiber optic endoscopes or heater-coolers during cardiac surgery.

Wherever possible, medical devices should be disposable and single use. If this is not possible, appropriate decontamination protocols should be in place for all re-useable items. All medical equipment should be decontaminated by specialized trained staff in certified and externally audited departments.

3.1 Fiber optic endoscopes

Fiber optic endoscopes are examples of medical devices that are introduced into both sterile and non-sterile body sites and which can cause infection if they are contaminated.

Because they are heat sensitive, fiber optic endoscopes have to be chemically disinfected. This is less reliable than autoclaving and failures of such disinfection have led to endoscope-associated infections, usually with water-borne MDR Gram-negative bacteria, especially *Pseudomonas* spp.

Some outbreaks have been with environmental *Mycobacteria* spp. that may contaminate mains water supplies and are relatively resistant to disinfectants (Culver, Gordon, & Mehta, 2003). Stringent systems must therefore be in place to ensure the safe decontamination of these endoscopes.

More recently, carbapenemase-producing Enterobacterales outbreaks related to contaminated duodenoscopes have been reported (Epstein et al., 2014; Kola et al., 2015; O'Horo et al., 2016). While no major failure in reprocessing lapses was identified, these outbreaks underline the need for stringent reprocessing of these complex fiber optic endoscopes.

3.2 Heater-cooler devices used in cardiac surgery

Since 2014, several outbreaks of invasive infections following cardiac surgery have been reported in various settings (Kasperbauer & Daley, 2019; van Ingen et al., 2017). The cause was the contamination of heater-cooler devices used in cardiac surgery with *Mycobacterium chimaera*, non-tuberculous *Mycobacteria* which are ubiquitous opportunistic organisms in the water environment. These cases highlight the vulnerability of complex technical systems, the need to proactively manage water and air safety in hospitals and to include non-tuberculous *Mycobacteria* in the list of environmental microorganisms to be managed carefully, in addition to *Legionella*, *Aspergillus* and *Clostridioides difficile*. New recommendations related to the control of "procedure-associated" invasive non-tuberculous *Mycobacteria* infections should emerge in the future and active reporting could be improved (Schreiber et al., 2018).

PREVENTION AND CONTROL MEASURES

ASGE Quality Assurance in Endoscopy Committee et al., 2018; "Management and decontamination of flexible endoscopes (HTM 01-06)", s.d.; "Guidance on Decontamination of Equipment for Gastrointestinal Endoscopy", s. d.

Decontamination of fiber optic endoscopes is a specialist procedure that should be performed only by trained personnel in accredited units. There are often local regulatory requirements and different instruments and automated washer-disinfectors (AWDs) may have different manufacturer's operational procedures. After cleaning, flexible endoscopes can be disinfected by special chemical solutions in AWDs, followed by rinsing and drying cycles. An enzymatic treatment is also commonly used to remove biofilms.

Successful disinfection depends on:

- **Correct operation of the automated washer-disinfector (AWD).**
- **Use of an appropriate disinfectant** at the correct concentration and exposure times.
- **Use of clean water** for the final rinse.

All medical equipment should be decontaminated by specialized trained staff in certified and externally audited departments. The following is a summary of common control measures but local policies should be consulted for more detail:

- **Control systems** should be in place to ensure effective cleaning, processing and tracking. Each step of decontamination and storage of fiber optic endoscope between consecutive patients should be recorded either on paper or computers.
- **If process failures** or possible instrument/device-associated outbreaks occur, potentially contaminated items should be recalled, potentially exposed patients identified, outbreak organisms typed, sources and transmission routes of infection investigated and system breakdowns rectified.
- **The most effective method of sterilization** is by high temperature/high pressure autoclaves (for heat-resistant items such as metal surgical instruments and rigid endoscopes).
- **Flexible fiber optic endoscopes** are heat labile and cannot be autoclaved; they are usually reprocessed by high level disinfection rather than sterilization. This process of high level chemical disinfection using peracetic acid is now performed in AWDs, which control the disinfection process and perform a final rinse of the endoscope with water.
- **Rinse water for gastro-intestinal endoscopes** (which make contact with mucous membranes, secretions and excretions but do not usually penetrate sterile areas of the body) needs to be only of potable quality.
- **Rinse water for endoscopes which enter sterile body cavities** (such as arthroscopes) needs to be of a higher standard.
- **Final rinse water from AWDs** should have a low microbial count. It should not present a potential hazard to the patient either through infection, or by an erroneous diagnosis due to contamination of aspirated samples for culture.

MICROBIOLOGICAL MONITORING OF AUTOMATED WASHER-DISINFECTORS (AWDS)

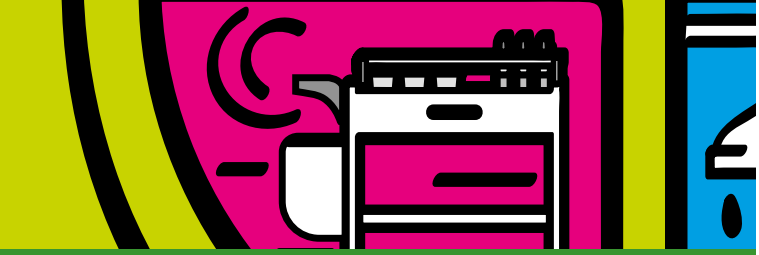
- **A weekly test** of the quality of the final rinse water. This involves measurement of total bacterial viable counts (TVCs) expressed as colony-forming units (CFUs) per 100 mL.

- **Quarterly and annual tests** that include the prolonged incubation needed to identify any contaminating mycobacteria:
  - **Safe bacterial TVCs** are usually considered to be **<10 CFU per 100 mL.**
  - **Safe mycobacterial counts** are usually considered to be **no mycobacteria per 200 mL.**

If higher TVCs are found up to 100 CFU per 100 mL, the AWD should go through a self-disinfection cycle.

If the TVCs remain high, or if the initial sample count is >100 CFU per 100 mL, the machine should be removed from service until remedial action has returned the TVCs to normal.

Microbiological results should be monitored sequentially to identify normal variation and take early action if abnormal trends occur. During investigations of poor results, collection of water samples prior to the final treatment process (supply water and break tank water) should be considered. In addition, filters, pipework and pumps should be checked and replaced if necessary.



4 DRY SURFACE TRANSMISSION

Until recently, infection control has tended to focus on patients' endogenous flora as the main source of healthcare-associated infection, with the main route of transmission from infected and colonized patients being staff hands. Contaminated hospital equipment, medicines, and water supplies have also been recognized as other common sources of hospital outbreaks.

In contrast, the dry hospital surface environment has only recently been considered as a potentially important source of healthcare-associated infection and as playing a role in the transmission of multi-drug resistant organisms (Clarivet et al., 2016; Tan et al., 2013; Weber et al., 2010) but also of common viruses such as norovirus (Wu et al., 2005) or influenza virus (Greatorex et al., 2011).

There is increasing evidence of the important role the environment plays in hospital infections (Carling & Huang, 2013). This chapter will cover recent evidence and general strategies to reduce and control surface contamination.

4.1 Current evidence of the role of dry surface transmission

4.1.1 Important hospital pathogens can survive on dry surfaces for prolonged periods

The major hospital pathogens, methicillin-resistant and -sensitive *Staphylococcus aureus* (MRSA, MSSA), vancomycin-resistant and sensitive *Enterococcus* spp. (VRE, VSE), *Clostridioides difficile*, *Acinetobacter* spp., and norovirus may survive for months on dry surfaces (**Table 1**).

Gram-negative organisms other than *Acinetobacter* tend to be less resistant to drying but *Pseudomonas aeruginosa* and *Klebsiella* spp. can also survive for long periods and this may contribute to cross-infection.

Table 1. Survival of hospital pathogens on dry hospital surfaces.

Adapted from Kramer A, et al. *BMC Infect Dis*. 2006;6:130

MICROORGANISM	LENGTH OF SURVIVAL
Acinetobacter spp.	3 days to 5 months
Clostridioides difficile (spores)	5 months
Enterococcus spp. including VRE	5 days to 4 months
Pseudomonas aeruginosa	6 hours to 16 months
Klebsiella spp.	2 hours to >30 months
Staphylococcus aureus, including MRSA	7 days to 7 months
Norovirus	8 hours to >2 weeks

Candida auris has been identified as an emerging yeast species which now represents a serious global health threat and a high challenge for clinicians. *Candida auris* is a virulent yeast, often multi-resistant, that affects debilitated patients. It is associated with high mortality and has recently been responsible for several hospital-acquired outbreaks (Eyre et al., 2018; Lockhart et al., 2017). *Candida auris* can spread through contact between affected patients and contaminated surfaces or equipment as it can live on surfaces for several weeks. Good hand hygiene and cleaning in healthcare facilities are important to control infections by *Candida auris*, which are nationally notifiable in the US and closely monitored by the CDC ("*Candida auris* | 2019 Case Definition", s. d.).

During the major 2014-2016 Ebola outbreak in West Africa, specific measures for environmental cleaning were recommended despite the limited evidence of the role of the environment in disease transmission. Due to the disease severity and because the virus can remain viable in the environment (Fischer et al., 2015), reinforced measures to avoid the risk of contaminated surfaces need to be applied ("Interim Guidance for Environmental Infection Control in Hospitals for Ebola Virus | Cleaning and Disinfecting | Clinicians | Ebola (Ebola Virus Disease) | CDC", 2018).

4.1.2 The surface environment around colonized or infected patients is frequently contaminated with hospital pathogens

(Weber et al., 2013)

The proportion of surface samples from rooms occupied by infected or colonized patients contaminated with the infecting pathogen has been reported as 1 to 64% for MRSA, 7 - 70% for VRE, 3 - 74% for *C. difficile* and 3 - 50% for *Acinetobacter* spp. Some studies have isolated multiple strains of some pathogens, such as MRSA, from the room environment that differ from the organism affecting the most recent occupant, indicating that pathogens from previous patients can survive in rooms for prolonged periods, despite room cleaning.

The contamination rate depends on the local epidemiology and cleaning practices of each hospital, but also on the speciality, with a possible relationship between cleaning practices and environment contamination with multidrug-resistant microorganisms (Mora et al., 2016).

4.1.3 Contact with room surfaces or medical equipment by staff frequently leads to contamination of hands and/or gloves

Studies showed that staff hand contamination after being in rooms with patients with contact precautions occurs at similar rates for both direct patient contact and surface environmental contact (**Table 2**).

The risk of staff hand contamination appears to depend on the level of environmental contamination. 'High touch surfaces' are those that are frequently touched and are the most heavily contaminated, in particular technical devices (i.e. infusion line, ventilator...) or patient beds.

Table 2. Transfer of microorganisms from surface to the hands of healthcare workers after contact.

Adapted from Otter JA, et al. *Am J Infect Control* 2013;41:S6-11

CHARACTERISTIC	DIRECT PATIENT CONTACT	CONTACT WITH ENVIRONMENTAL SURFACES ONLY
VRE		52% of 44 HCP* acquired VRE on their hands or gloves
MRSA	45% of 50 HCP* acquired MRSA on their gloved hands	40% of 50 HCP* acquired MRSA on their gloved hands
Clostridioides difficile	50% of 30 HCP* acquired *C. difficile* on their gloved hands	50% of 30 HCP* acquired *C. difficile* on their gloved hands
Compliance with hand hygiene according to the type of contact	80%	50%
Klebsiella spp.	2 hours to >30 months	2 hours to >30 months
Staphylococcus aureus, including MRSA	7 days to 7 months	7 days to 7 months
Norovirus	8 hours to >2 weeks	8 hours to >2 weeks

* HCP: Health care personnel

The same observation was reported in different contexts: after contact with colonized patients, MDR *Acinetobacter baumannii* contaminated gloves or gowns of staff in one out of three interactions (Morgan et al., 2012) and in 26% of staff in another unit (Ye et al., 2015). Environmental contamination with an MDR bacterium was strongly associated with healthcare worker contamination. A high association was also seen between *A. baumannii* environmental contamination of patient rooms and positive patients (Munoz-Price et al., 2013).

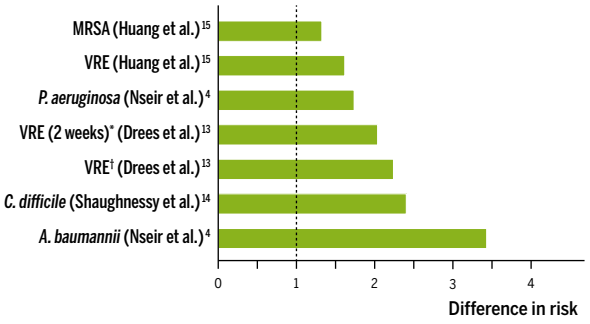
Therefore, although pathogen transfer between patients most commonly occurs via the hands of staff, contaminated hospital surfaces can be directly or indirectly involved in the transmission pathways (**Figure 1**, page 5).

4.1.4 A patient admitted to a room previously occupied by a patient colonized or infected with a hospital-acquired pathogen has an increased risk of acquiring that pathogen through colonization or infection

This has been shown for MRSA, VRE, *C. difficile*, *P. aeruginosa* and *Acinetobacter* spp. (**Figure 2**) and is important evidence that contaminated environmental surfaces are sources of hospital cross-infection.

Figure 2. Relative risk of acquiring certain pathogens in patients admitted to rooms where the prior occupant was known to be infected/colonized with the pathogen.

Adapted from Otter JA, et al. *Am J Infect Control* 2013;41:S6-11



4.1.5 Improved environmental cleaning of wards and terminal cleaning of isolation rooms leads to decreased infection rates

This has been shown in several studies where environmental ward cleaning with hypochlorite was associated with a reduction in *C. difficile* infection, and in other studies where improvements in the frequency or quality of environmental cleaning was associated with reductions in MRSA and VRE infection rates (Donskey, 2013).

Similarly, improved terminal cleaning of rooms after a patient with contact precautions is discharged and before the next, non-colonized, patient is admitted has been shown to reduce infection rates. In a quasi-experimental study (Passaretti et al., 2013), using hydrogen peroxide vapor (HPV) for the terminal disinfection of rooms previously occupied by patients known to be infected/colonized with multidrug-resistant organisms (MDROs) showed the following benefits:

- HPV decontamination reduced the proportion of rooms contaminated with MDROs by 35%.
- Patients admitted to rooms decontaminated with HPV were significantly less likely to acquire any MDRO (64% reduction) than patients admitted to rooms disinfected with standard methods.
- There was a significant 80% reduction in the risk of acquiring VRE from the prior occupant and non-significant reductions in the risk of acquiring MRSA, *C. difficile* and MDR Gram-negative bacilli.

A similar cluster-randomized crossover trial tested the impact of different products for terminal disinfection of rooms previously occupied by patients with MDRO or *C. difficile*. Disinfection with UV resulted in a slight but significant decrease of some of the target organisms, as compared to other methods (Anderson et al., 2017, 2018).

4.2 Strategies to reduce and control environmental surface contamination

4.2.1 Improvements in cleaning quality

Numerous studies have shown that environmental cleaning in hospitals often falls below acceptable standards and conventional cleaning processes produce only a 50% reduction in surface contamination rates (Otter et al., 2011; Weber et al., 2013).

However, improved cleaning practices on patient wards can reduce infection rates as reported in evaluation studies:

- 66% reduction in VRE acquisition rates following a 75% improvement in thoroughness of environmental cleaning (Hayden et al., 2006).
- 50% and 28% reduction in MRSA and VRE acquisition respectively, as a result of an 80% improvement in cleaning practices (Datta, Platt, Yokoe, & Huang, 2011).
- A bundled intervention resulted in a 37% reduction of VRE infection, but not that of MRSA and *C. difficile* infections (Mitchell et al., 2019).

Educational or training programs, together with feedback on cleaning effectiveness, can improve the quality of cleaning, leading to a reduction in contamination and, in some cases, to a reduction in infection rates (Donskey, 2013).

In recognition of the importance of environmental contamination as a reservoir for hospital-acquired infection, the Centers for Disease Control and Prevention (CDC) have produced a tool kit to help hospitals comply with the guidance and improve environmental cleaning (see page 28).

PRACTICAL TOOL KIT BY CDC

A tool kit has been developed by the Centers for Disease Control and Prevention (CDC) ("Options for Evaluating Environmental Cleaning | HAI | CDC", s. d.) to help hospitals comply with the 2003 CDC recommendation to *"implement procedures that ensure consistent cleaning and disinfection of surfaces closely approximated to the patient and likely to be touched by the patient and health care workers."* (Sehulster et al., 2003).

This tool kit describes two levels of single room terminal decontamination:

- **Level I** - comprises basic interventions to optimized disinfection cleaning practices, procedures and staff education and practice.
- **Level II** - all elements of Level I plus objective monitoring of practice, by measuring 'cleanliness' (a measurement of surface bioburden) or 'cleaning' (a measure of how well cleaning is done).
  - Bioburden can be measured by swab and other cultures and adenosine triphosphate (ATP) bioluminescence. However, no standards of cleaning and cleanliness have yet been universally accepted (Rutala & Weber, 2016).
  - Cleaning can be assessed by direct practice observation and the use of fluorescent markers.

4.2.2 Testing for environmental contamination

Bacteriological sampling: Routine bacteriological sampling of environmental surfaces is **not currently indicated**. However, sampling may be used:

- For surface sampling in **high-risk zones**, such as haematology units with rooms with HEPA filters, or operating rooms.
- **To identify** an environmental source or reservoir of an outbreak.

The microbiological methods used are:

- **Swab cultures** to identify pathogens and provide quantitative measurement of contaminating pathogens. More time is required to take swabs and then plate them out than to use direct agar contact plates (see below). This technique is therefore mainly employed in research studies of cleaning effectiveness or to identify specific pathogens and help clarify the epidemiology during outbreaks.
- **Direct agar contact cultures** using agar-coated plastic slides or contact plates to directly sample environmental surfaces. The number of colonies growing on the agar surface can be used to quantitate the bacterial burden.

Other rapid and flexible methods for assessment of environmental contamination and effectiveness of cleaning:

- **Fluorescent gel** can be used to assess the thoroughness of cleaning practice. The gel is applied covertly to mark surface areas to be cleaned but theoretically cannot be seen by the cleaners. After cleaning, ultraviolet light can show how much of the gel has been removed and therefore how thoroughly cleaning has been performed. This method has been used successfully in educational programs to improve cleaning practices but is not a direct indicator of bacterial contamination.
- **Adenosine triphosphate (ATP) bioluminescence technology** detects the presence of organic debris, including viable and nonviable bacteria, on surfaces. Semi-automated ATP systems have been used widely to monitor surface contamination in the food industry and have recently been applied in healthcare settings. However, because of the generally low level of contamination on healthcare surfaces and the detection by ATP of non-viable material, ATP is not a reliable indicator of microbiological contamination (Cooper et al., 2007; "Options for Evaluating Environmental Cleaning | HAI | CDC", s. d.). The method is therefore of limited use for critical monitoring of the hospital environment, but may have a role in monitoring the effectiveness of cleaning practice.

Bacteriological sampling of environmental surfaces may possibly be used to evaluate the efficacy of disinfection or cleaning procedures or to monitor adherence to cleaning practices **in case of lapses in cleaning procedures**.

4.2.3 Use of surface disinfectants

For disinfection and sterilization purposes, medical devices and equipment can be divided into critical, semi-critical and non-critical according to the degree of risk for infection (Rutala, 2008; "Updates | Disinfection & Sterilization Guidelines | Guidelines Library | Infection Control | CDC", s. d.):

- **Critical devices** enter sterile tissue or body cavities, and include surgical instruments, vascular or urinary catheters and implants. Critical devices have a high risk for infection if contaminated. These devices should be sterile single-use items or multi-use items sterilized by autoclaving between use.

  Heat sensitive items such as fiber optic endoscopes should be disinfected by high level chemical disinfection; because of the potential risks associated with this method, processing should be carefully regulated and monitored.

- **Semi-critical devices** come into contact with mucous membranes or non-intact skin, and include anaesthesia equipment and devices used in respiratory therapy, some endoscopes, laryngoscope blades and cystoscopes. These can have high-level chemical disinfection (removal of bacteria and viruses but not spores) after cleaning.
- **Non-critical devices** come into contact with intact skin but not mucous membranes and include bedpans, blood pressure cuffs, stethoscopes, crutches and computers used in healthcare settings. These can be cleaned with standard cleaning materials or disinfectant wipes. The potential for patient to patient transmission of MDR hospital pathogens has led to the increasing use of disposable blood pressure cuffs and tourniquets.
- **Hospital surfaces** such as floors or bedside tables are classified as non-critical items. Many therefore consider that cleaning with detergent is sufficient (Rüden & Daschner, 2002), while others routinely use a disinfectant (Rutala, 2008). The potential for transmission of MDR pathogens has led to the implementation of special disinfection procedures for beds after use by known colonized or infected patients, including steam cleaning or hydrogen peroxide decontamination. C. difficile is a particular task as spores are resistant to several disinfectant detergents. Use of hypochlorite solution for room cleaning (compared with the use of disinfectant detergent) is effective in decreasing the risk of C. difficile infection (Mayfield et al., 2000).

There is increasing evidence for terminal disinfection of single rooms previously occupied by patients colonized with an MDR pathogen (Anderson et al., 2017) or the cleaning of a ward or bed area during or after an outbreak of *C. difficile* or norovirus infections (Weber et al., 2010).

Furthermore, with the increasing recognition of the importance of environmental contamination, routine disinfection of floors and other surfaces is becoming more widely practiced, although the evidence that this reduces infection rates is limited.

Disinfection should be an integrated part of infection prevention and control with appropriate standards and controls (Gebel et al., 2013). There is a need to:

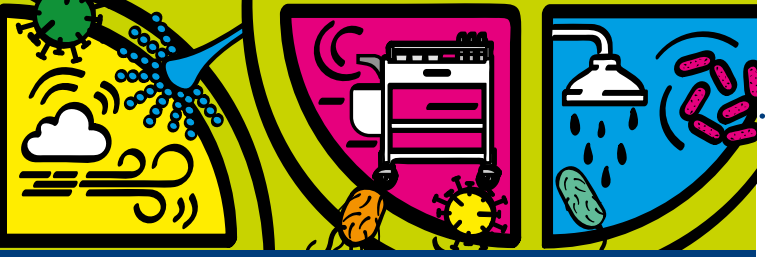
- **Define standard principles** for cleaning and disinfection.
- **Ensure compliance** with these principles by measures such as written standard operating procedures, adequate training and suitable audit systems.
- **Develop test procedures** to assess the efficacy of surface disinfectants in different situations.

4.2.4 Improvements in surface materials and design

The effectiveness of surface cleaning can be improved by designing hospital surfaces, furniture, fittings and equipment that resist contamination and are easy to clean. Many surface materials now incorporate anti-bacterials to reduce surface contamination, but there is limited evidence so far that they have a significant impact on infection rates (Muller et al., 2016). However, in a randomized controlled trial, the use of copper coated surfaces in hospital rooms in intensive care units was associated with a reduced risk of healthcare-associated infections (Salgado et al., 2013).

4.2.5 Use of new technologies for surface decontamination

Due to the problems with conventional cleaning and terminal disinfection, several new decontamination methods have been introduced. These include automated systems using ultraviolet light or hydrogen peroxide vapour (H_2O_2) (Otter et al., 2013). Automation can eliminate some of the failures of practice often seen with manual cleaning methods and the systems have been referred to as 'No Touch Disinfection' (NTD). H2O2 systems have been shown to be effective in reducing the risk of patient acquisition of MDR pathogens as well as environmental contamination (Mitchell et al., 2014; Passaretti et al., 2013) The limitations of these H2O2 systems are that they require rooms to be vacated and sealed before disinfection, and they are expensive.



5 BACTERIOLOGICAL SAMPLING OF THE ENVIRONMENT

When sampling the hospital environment, careful thought must be given to the nature and purpose of the sampling, and whether quantitative or qualitative results are needed. Before sampling, it is also important to decide what actions will be taken in response to the results. This may be difficult because in many cases there are no defined standards for microbial contamination.

5.1 Air Sampling

Air sampling is usually undertaken to assess air quality in areas such as operating rooms, positive-pressure single rooms, pharmacy sterile units and sterile supply units.

Before sampling, it should be decided:

- What organisms are to be targeted.
- What culture media are to be used.
- The volume of air or time to be sampled.
- The need for quantitative or qualitative results.
- What actions might be taken with different results.

Air sampling may be passive or active:

- **For passive sampling**, several agar plates are simply exposed in the area for a defined period of time (usually 30 minutes or up to 4 hours). After exposure, plates should be stored at 1 - 8°C and processed the same day or at least within 24 hours of collection. Culture should be at 30°C (+/- 1°C) for 3 days for bacteria detection and 22.5°C (+/- 2.5°C) for 5 days for yeasts and molds. The results are calculated as the number of colonies that appear over a unit of time. Results may be affected sampling factors such as air movements and activity, which need to be controlled.
- **Active sampling** uses mechanical air samplers, which draw in known volumes of air onto culture media or filters. Numbers of microorganisms present per unit volume of air can then be calculated accurately.

The use of mechanical air samplers ensures measurement standardization and result traceability. Total microbial counts may be assessed and/or yeast and molds can be enumerated separately, using appropriate selective agars.

AIR SAMPLE TESTING TARGET RESULTS

There are no standard accepted targets for active air sampling. The CDC recommends assaying only molds for control of aspergillosis. The CDC also recommends particle counting for assessment of the effectiveness of air filtration. The figures below are consensus figures but variations of the recommended thresholds can be related to national/local policies, or surgical or patient infectious risk. The targets are given for unsatisfactory results that require remedial action.

Operating room air quality (active air sampling)
(Dharan & Pittet, 2002; Hoffman et al., 2002; Sehulster et al., 2003)

Tested on commissioning or following any refurbishment work	
Aerobic Colony Count	**< 10 CFU per m^3**
Test in empty rooms	
Aerobic Colony Count	**< 35 CFU per m^3**
Tested during surgery	
Aerobic Colony Count	**< 180 CFU per m^3**

CFU = colony forming unit

5.2 Water sampling

In most countries, the only statutory requirements for water quality testing are for drinking water. However, guidance on water testing according to the type of medical context is given in several documents addressing best practice:

- General guidance (Sehulster et al., 2003; Tacconelli et al., 2014).
- Control of *Legionella* ("Legionnaires' disease. The control of legionella bacteria in water systems", s. d.; "WHO | Legionella and the prevention of legionellosis", s. d.).
- Endoscopy rinse water (ASGE Quality Assurance in Endoscopy Committee et al., 2018; "Guidance on Decontamination of Equipment for Gastrointestinal Endoscopy", s. d.; "Management and decontamination of flexible endoscopes (HTM 01-06)", s. d.).
- Swimming and hydrotherapy pools ("HSE - Legionnaires' disease", "Risk systems", Spa-pool systems", s. d.; "Legionnaires' disease. The control of legionella bacteria in water systems", s. d.; "WHO | Legionella and the prevention of legionellosis", s. d.).
- Renal dialysis water ("Guideline on water treatment systems, dialysis water and dialysis fluid quality for haemodialysis and related therapies", 2016).

A general guideline by Public Health England is also available ("Examining food, water and environmental samples", s. d.).

Samples must be collected aseptically into sterile bottles. In general, neutralizing agents are added during water testing to neutralise the effect of any disinfectant (including chlorine) that may be in the sample and may prevent the growth of any contaminating organisms. The appropriate neutralizer should be chosen for each specimen and detailed recommendations can be obtained from guidance documents.

5.2.1 Water sample collection (refer to the guidelines listed previously)

Tap water

- **Quality of water delivered from the tap:** the tap should not be sanitized and the sample taken from the first portion of water delivered.
- **Quality of water before reaching the tap:** clean and disinfect the tap with sodium hypochlorite solution (1% available chlorine) and run for 2 – 3 minutes before sampling. Collect the sample aseptically into a sterile 1L or 500 mL bottle containing neutralizer (40 mg/L sodium thiosulfate).

Hydrotherapy pool water

Normally, a single sample of pool water (or several samples in larger pools) is taken from an area where the water velocity is lowest and away from fresh water inlets or outlets. Samples should also be taken from the balance tank and skimmers, and swabs from inside/behind any jets and from the lid or pool cover if used:

- Wipe the outside of a sterile 500 mL bottle containing neutralizer (120 mg/L sodium thiosulfate) with an alcohol wipe.
- Aseptically open the bottle and immerse it in the pool and fill with water.
- Recap and shake to disperse the neutralizing agent.

If *Legionella* testing is required, collect a separate 1 liter sample in the same way.

Sampling water for Legionella testing

Note: When investigating water for Legionella, it is essential that an assessment is made of the risks involved and the protection needed before samples are collected.

Sampling should be done as part of a risk assessment and review of the whole water system. Water should be sampled from areas where *Legionella* are likely to multiply, such as the warmest parts of a cold system, the coolest parts of a hot system, or areas where there is low usage/stagnation.

For pools and taps (pre-flush samples), see above.

For showers, collect a 1 liter sample as follows:

- Before turning on, adjust the temperature setting to the midpoint for non-thermostatic taps and the normal use temperature (35°C to 43°C) for thermostatic taps.
- Detach the shower head and gently fill a sterile sample bottle containing neutralizer.
- Recap and shake to distribute the neutralizing agent.

For routine testing of water systems to ensure the continuing effectiveness of preventative maintenance programs, 'dip slides' coated with an appropriate *Legionella* agar can be used.

Renal unit dialysis water and fluids

Samples should be taken from points expected to have the highest bacterial load, such as the end of the distribution loop or the last machine in a dead-end system. If the sample is to be collected from a tap used solely for sampling, disinfect the outlet as described above. The samples should be collected aseptically into sterile, pyrogen-free bottles.

Automated washer-disinfector (AWD) rinse water

For bacterial and mycobacterial testing, 100 mL final rinse water is taken in duplicate from the appropriate port with aseptic technique during the final cycle.

5.2.2 Water Sample Processing

Water samples (except for *Legionella*) should be stored between 1 - 8°C and submitted to the laboratory for testing, ideally the same day, but at the latest within 24 hours of collection.

Water samples for *Legionella* testing should be stored at an ambient temperature (approximately 20°C), in the dark, and returned to the laboratory for processing as soon as possible, preferably the same day but at the latest within 24 hours.

Quantitative analysis of water specimens is usually done by passing the samples through sterile filter membranes of <0.45 µm pore size and culturing on an appropriate selective or non-selective agar plate at 28 - 32°C. Colony counts are performed after 48 hours and 5 days. The test should be performed in duplicate.

For quarterly mycobacterial testing of AWD rinse water, the filtering method is the same but a mycobacterial agar should be used for culture and the incubation prolonged for 28 days.

WATER SAMPLE TESTING TARGET RESULTS

The targets below are given for satisfactory results that require no further action ("Examining food, water and environmental samples", s. d. Public Health England, 2013).

Hydrotherapy water samples

Tested weekly

Escherichia coli	0 CFU per 100 mL
Total coliforms at 37°C	0 CFU per 100 mL
Pseudomonas aeruginosa	0 CFU per 100 mL
Aerobic Colony Count	0-10 per mL

General water systems for *Legionella*

Tested according to a preventative maintenance program and during suspected outbreaks

Legionella	0 - 100 CFU per L

Tap water in units caring for compromized patients

Tested according to a preventative maintenance program and during suspected outbreaks

Pseudomonas aeruginosa and other *Pseudomonas*	0 - 100 CFU per L

Renal dialysis fluid and water used for the preparation of dialysis fluid

Tested monthly

Aerobic Colony Count	0 - 50 per mL
Endotoxin /mL	<0.125 EU per mL

Renal dialysis ultrapure fluid and water used for the preparation of ultrapure fluid

Tested monthly

Aerobic Colony Count	<10 per 100 mL
Endotoxin /mL	<0.03 IU per mL

Endoscopy washer disinfector final rinse water

Tested weekly

Aerobic Colony Count	<1 per 100 mL

Tested quarterly

Environmental mycobacteria	0 per 200 mL

CFU = colony forming unit EU = Endotoxin unit
For details of alert levels and action levels see local guidelines.

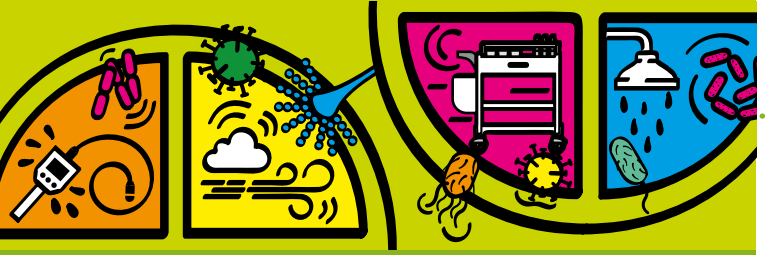
5.3 Surface sampling

Surface sampling usually requires moisture, and a sterile diluent such as saline or buffered peptone water is used. Appropriate neutralizers must be used if disinfectant residues are likely on the surface to be sampled.

- **Quantitative sampling** involves swabbing a known area (using a sterile template) in a standardized way in order to compare results from different sites, or from the same site at different times or using an agar contact plate.
- **Qualitative sampling** is appropriate when investigating the source of an outbreak. In this case, the larger the area sampled, the better the chance of detecting the pathogen of interest.
- **Swabbing** can be done with cotton-tipped swabs but wipes or sterile sponges are more convenient for larger areas and generally achieve a more efficient recovery of micro-organisms.
- **Organisms** are extracted from the swab or wipe or sponge in saline or other suitable fluid and transferred to appropriate agar plates (e.g. Trypcase Soy agar and Sabouraud Chloramphenicol agar).
- **After incubation** (usually at 30°C +/-1°C for 3 days for bacteria and 22.5°C +/-2.5°C for 5 days for yeasts and molds), the colonies are counted and the surface bioburden calculated using the number of colony forming units per unit area. Colonies on contact plates or slides are counted directly and a similar calculation made, based on the area of the slide.

There are **no standard target values** for surface contamination in healthcare facilities. Qualitative bacteriology is usually done if an outbreak is suspected or to assess the effectiveness of cleaning or for research purposes.

In an outbreak context, it can be useful to detect specific microorganisms from surfaces using chromogenic media: multidrug-resistant organisms (MRSA, VRE, ESBL, carbapenemases), *P. aeruginosa* or *C. difficile*.



6 MANAGEMENT AND ORGANIZATION

Healthcare environments are liable to become contaminated with potential pathogens, many of which are now increasingly multi-drug resistant (MDR). This situation must be managed by the hospital Infection Control Committee (ICC) that reports to the main Hospital Board, either directly or via Risk Management and Clinical Governance. The ICC should have multidisciplinary representation, including from Infection Control team, Microbiology, Nursing, Medicine, Surgery, Housekeeping, Estates, Endoscopy and Sterile Supply (Figure 3). In larger hospitals, consideration should be given to having a separate decontamination subcommittee of the ICC.

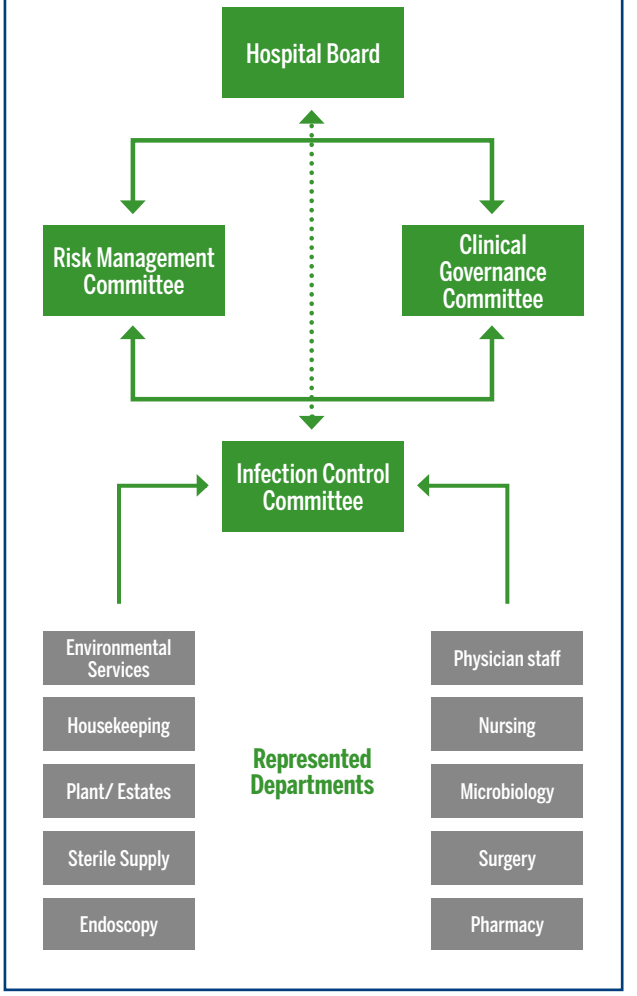
Education and training programs should be set up to ensure that staff are aware of and understand the problems of hospital infection and the importance of environmental hygiene in its prevention and control. Audits should be conducted to ensure the education is effective.

Written policies based on published guidelines and regulatory requirements should be produced and regularly updated for all major issues of concern. Compliance with these policies should be audited.

Surveillance systems should be in place to ensure the early detection of healthcare-associated infection and the possible occurrence of outbreaks. If a transmission or outbreak is suspected, the sources and routes of transmission should be investigated, with organism identification and typing where necessary. An incident group may need to investigate the possible outbreak and implement appropriate interventions to bring it under control.

Initial investigations may indicate environmental sources. If so, appropriate investigations, including environmental sampling, should be implemented. Once an environmental incident has been identified and controlled, appropriate changes to policies and practices should be made to ensure prevention of a recurrence.

Figure 3. Example of Environmental Control Pathway and Organization within the Hospital Setting



REFERENCES

- Allegranzi, B., Zayed, B., Bischoff, P., et al. **WHO Guidelines Development Group. New WHO recommendations on intraoperative and postoperative measures for surgical site infection prevention : An evidence-based global perspective.** *The Lancet. Infectious Diseases* 2016;16(12):e288-e303.
- Anderson, D. J., Chen, L. F., Weber, D. J., et al. **Enhanced terminal room disinfection and acquisition and infection caused by multidrug-resistant organisms and *Clostridium difficile* (the Benefits of Enhanced Terminal Room Disinfection study) : A cluster-randomised, multicentre, crossover study.** *The Lancet* 2016;389(10071):805-814.
- Anderson, D. J., Moehring, R. W., Weber, D. J., et al. CDC Prevention Epicenters Program. **Effectiveness of targeted enhanced terminal room disinfection on hospital-wide acquisition and infection with multidrug-resistant organisms and *Clostridium difficile* : A secondary analysis of a multicentre cluster randomised controlled trial with crossover design (BETR Disinfection).** *The Lancet. Infectious Diseases* 2018;18(8):845-853.
- ASGE Quality Assurance in Endoscopy Committee, Calderwood, A. H., Day, L. W., Muthusamy, V. R., et al. **ASGE guideline for infection control during GI endoscopy.** *Gastrointestinal Endoscopy* 2018;87(5):1167-1179.
- Bischoff, P., Kubilay, N. Z., Allegranzi, B., Egger, M., & Gastmeier, P. **Effect of laminar airflow ventilation on surgical site infections : A systematic review and meta-analysis.** *The Lancet. Infectious Diseases* 2017;*17*(5), 553-561.
- Bonifait, L., Charlebois, R., Vimont, A., et al.**Detection and Quantification of Airborne Norovirus During Outbreaks in Healthcare Facilities.** *Clinical Infectious Diseases* 2015;61(3), 299-304.
- Candida Auris | 2019 Case Definition. (s. d.). https://wwwn.cdc.gov/nndss/conditions/candida-auris/case-definition/2018/ Accessed March 26, 2019.
- Carling, P. C., & Huang, S. S. **Improving healthcare environmental cleaning and disinfection : Current and evolving issues.** *Infection Control and Hospital Epidemiology* 2013;34(5):507-513.
- Centers for Disease Control and Prevention (CDC). (1996). **Outbreaks of postoperative bacterial endophthalmitis caused by intrinsically contaminated ophthalmic solutions**. Thailand, 1992, and Canada, 1993. *MMWR. Morbidity and Mortality Weekly Report* 45(23), 491-494.
- Centers for Disease Control and Prevention (CDC). **Prevention Strategies for Seasonal Influenza in Healthcare Settings Guidelines and Recommendations.** https://www.cdc.gov/flu/professionals/infectioncontrol/healthcaresettings Accessed June 17, 2020.
- Centre for Clinical Practice at NICE (UK). (2010). **Donor Breast Milk Banks : The Operation of Donor Milk Bank Services.** http://www.ncbi.nlm.nih.gov/books/NBK66142/ Accessed March 25, 2019.
- Clarivet, B., Grau, D., Jumas-Bilak, E., et al. **Persisting transmission of carbapenemase-producing *Klebsiella pneumoniae* due to an environmental reservoir in a university hospital, France, 2012 to 2014.** *Eurosurveillance* 2016;21(17), 30213.
- Cooper, R. A., Griffith, C. J., Malik, R. E., Obee, P., & Looker, N. **Monitoring the effectiveness of cleaning in four British hospitals.** *American Journal of Infection Control* 2007;35(5), 338-341.
- Culver, D. A., Gordon, S. M., & Mehta, A. C. **Infection Control in the Bronchoscopy Suite.** *American Journal of Respiratory and Critical Care Medicine* 2003;167(8), 1050-1056.
- Datta, R., Platt, R., Yokoe, D. S., & Huang, S. S. **Environmental cleaning intervention and risk of acquiring multidrug-resistant organisms from prior room occupants.** *Archives of Internal Medicine* 2011; 171(6), 491-494.
- Dharan, S., & Pittet, D. **Environmental controls in operating theatres.** *The Journal of Hospital Infection* 2002;51(2), 79-84.
- Donskey, C. J. **Does improving surface cleaning and disinfection reduce health care-associated infections?** *American Journal of Infection Control* 2013;41(5 Suppl), S12-19.
- Epstein, L., Hunter, J. C., Arwady, M. A., et al. **New Delhi Metallo-β-Lactamase–Producing Carbapenem-Resistant Escherichia coli Associated With Exposure to Duodenoscopes.** *JAMA*, *312*(14), 1447-1455.

- Examining food, water and environmental samples : Healthcare settings. (s. d.). Accessed 28 March 2019, at GOV.UK website: https://www.gov.uk/government/publications/examining-food-water-and-environmental-samples-healthcare-settings
- Eyre, D. W., Sheppard, A. E., Madder, H., et al.**A *Candida auris* Outbreak and Its Control in an Intensive Care Setting.** *New England Journal of Medicine* 2018;379(14), 1322-1331.
- Fischer, R., Judson, S., Miazgowicz, K., et al. **Ebola Virus Stability on Surfaces and in Fluids in Simulated Outbreak Environments.** *Emerging Infectious Diseases* 2015;21(7), 1243-1246.
- Gebel, J., Exner, M., French, G., et al.**The role of surface disinfection in infection prevention.** *GMS hygiene and infection control* 2013;8(1).
- Greatorex, J. S., Digard, P., Curran, M. D., et al.**Survival of Influenza A(H1N1) on Materials Found in Households : Implications for Infection Control.** *PLOS ONE* 2011; 6(11), e27932.
- Groothuis J, Bauman J, Malinoski F & Eggleston M. **Strategies for prevention of RSV nosocomial infection**. *Journal of Perinatology* 2008;28:319–323.
- Guidance on Decontamination of Equipment for Gastrointestinal Endoscopy : 2017 Edition. (s. d.). https://www.bsg.org.uk/resource/guidance-on-decontamination-of-equipment-for-gastrointestinal-endoscopy-2017-edition.html Accessed March 26, 2019.
- Guideline on water treatment systems, dialysis water and dialysis fluid quality for haemodialysis and related therapies. (2016, January 1). Accessed at https://renal.org/wp-content/uploads/2017/06/raandartguidelineversion-12647da131181561659443ff000014d4d8-2.pdf
- Harris, J. P., Lopman, B. A., Cooper, B. S., & O'Brien, S. J. **Does spatial proximity drive norovirus transmission during outbreaks in hospitals?** *BMJ Open* 2013;3(7).
- Haviari, S., Cassier, P., Dananché, C., et al. **Outbreak of *Achromobacter xylosoxidans* and *Ochrobactrum anthropi* Infections after Prostate Biopsies, France, 2014.** *Emerging Infectious Diseases* 2016;22(8), 1412-1419.
- Hayden, M. K., Bonten, M. J. M., Blom, D. W., et al. **Reduction in acquisition of vancomycin-resistant enterococcus after enforcement of routine environmental cleaning measures.** *Clinical Infectious Diseases: An Official Publication of the Infectious Diseases Society of America* 2006;42(11), 1552-1560.
- Hoffman, P. N., Williams, J., Stacey, A., **Microbiological commissioning and monitoring of operating theatre suites.** *The Journal of Hospital Infection* 2002;52(1), 1-28.
- HSE - Legionnaires' disease / Risk systems / Spa-pool systems. (s. d.). Accessed 28 March 2019, at http://www.hse.gov.uk/legionnaires/spa-pools.htm
- Infection control in the built environment (HBN 00-09). (s. d.). GOV.UK website: https://www.gov.uk/government/publications/guidance-for-infection-control-in-the-built-environment Accessed March 25, 2019.
- Interim Guidance for Environmental Infection Control in Hospitals for Ebola Virus | Cleaning and Disinfecting | Clinicians | Ebola (Ebola Virus Disease) | CDC. (2018, May 31). https://www.cdc.gov/vhf/ebola/clinicians/cleaning/hospitals.html Accessed March 26, 2019.
- Jensen, P. A., Lambert, L. A., Iademarco, M. F., Ridzon, R., & CDC. **Guidelines for preventing the transmission of Mycobacterium tuberculosis in health-care settings, 2005.** *MMWR. Recommendations and Reports: Morbidity and Mortality Weekly Report. Recommendations and Reports* 2005;54(RR-17):1-141.
- Kanamori, H., Rutala, W. A., Sickbert-Bennett, E. E., & Weber, D. J. **Review of fungal outbreaks and infection prevention in healthcare settings during construction and renovation.** *Clinical Infectious Diseases: An Official Publication of the Infectious Diseases Society of America* 2015;61(3): 433-444.
- Kasperbauer, S. H., & Daley, C. L. **Mycobacterium chimaera Infections Related to the Heater-Cooler Unit Outbreak : A Guide to Diagnosis and Management.** *Clinical Infectious Diseases: An Official Publication of the Infectious Diseases Society of America* 2019;68(7):1244-1250.
- Kizny Gordon, A. E., Mathers, A. J., Cheong, et al. **The Hospital Water Environment as a Reservoir for Carbapenem-Resistant Organisms Causing Hospital-Acquired Infections - A Systematic Review of the Literature.** *Clinical Infectious Diseases: An Official Publication of the Infectious Diseases Society of America* 2017;64(10):1435-1444.
- Kola, A., Piening, B., Pape, U.-F., et al. **An outbreak of carbapenem-resistant OXA-48 – producing *Klebsiella* pneumonia associated to duodenoscopy.** *Antimicrobial Resistance and Infection Control* 2015;4(1):8.

- Kramer, A., Schwebke, I., & Kampf, G. **How long do nosocomial pathogens persist on inanimate surfaces? A systematic review.** *BMC Infectious Diseases* 2006;6:130.
- Lalitha, P., Das, M., Purva, P. S., et al. **Postoperative endophthalmitis due to *Burkholderia cepacia* complex from contaminated anaesthetic eye drops.** *The British Journal of Ophthalmology* 2014;98(11):1498-1502.
- Legionnaires' disease. The control of legionella bacteria in water systems. (s. d.). http://www.hse.gov.uk/pubns/books/l8.htm Accessed March 28, 2019.
- Lockhart, S. R., Etienne, K. A., Vallabhaneni, S., et al. **Simultaneous Emergence of Multidrug-Resistant *Candida auris* on 3 Continents Confirmed by Whole-Genome Sequencing and Epidemiological Analyses.** *Clinical Infectious Diseases: An Official Publication of the Infectious Diseases Society of America* 2017;64(2):134-140.
- Loeffert, S. T., Melloul, E., Gustin, M.-P., et al. **Investigation of the Relationships Between Clinical and Environmental Isolates of *Aspergillus fumigatus* by Multiple-locus Variable Number Tandem Repeat Analysis During Major Demolition Work in a French Hospital.** *Clinical Infectious Diseases: An Official Publication of the Infectious Diseases Society of America* 2019;68(2):321-329.
- Lopman, B., Gastañaduy, P., Park, G. W., et al. **Environmental transmission of norovirus gastroenteritis**. *Current Opinion in Virology* 2012;2(1):96-102.
- Management and decontamination of flexible endoscopes (HTM 01-06). (s. d.). GOV.UK website: https://www.gov.uk/government/publications/management-and-decontamination-of-flexible-endoscopes Accessed March 26, 2019.
- Mayfield, J. L., Leet, T., Miller, J., & Mundy, L. M. **Environmental Control to Reduce Transmission of *Clostridium difficile.*** *Clinical Infectious Diseases* 2000;31(4):995-1000.
- Mitchell, B. G., Digney, W., Locket, P., & Dancer, S. J. **Controlling methicillin-resistant *Staphylococcus aureus* (MRSA) in a hospital and the role of hydrogen peroxide decontamination : An interrupted time series analysis.** *BMJ Open* 2014;4(4):e004522.
- Mitchell, B. G., Hall, L., White, N., et al. **An environmental cleaning bundle and health-care-associated infections in hospitals (REACH) : A multicentre, randomised trial.** *The Lancet. Infectious Diseases* 2019;19(4):410-418.
- Mora, M., Mahnert, A., Koskinen, K., et al. **Microorganisms in Confined Habitats : Microbial Monitoring and Control of Intensive Care Units, Operating Rooms, Cleanrooms and the International Space Station.** *Frontiers in Microbiology* 2016;7:1573.
- Morgan, D. J., Rogawski, E., Thom, K. A., et al. **Transfer of multidrug-resistant bacteria to healthcare workers' gloves and gowns after patient contact increases with environmental contamination.** *Critical care medicine* 2012:40(4):1045-1051.
- Muller, M. P., MacDougall, C., Lim, M., et al. **Antimicrobial surfaces to prevent healthcare-associated infections : A systematic review.** *Journal of Hospital Infection* 2016;92(1):7-13.
- Munoz-Price, L. S., Namias, N., Cleary, T., ***Acinetobacter baumannii* : Association between environmental contamination of patient rooms and occupant status**. *Infection Control and Hospital Epidemiology* 2013;34(5):517-520.
- National Collaborating Centre for Chronic Conditions (UK), & Centre for Clinical Practice at NICE (UK). **Tuberculosis : Clinical Diagnosis and Management of Tuberculosis, and Measures for Its Prevention and Control.** http://www.ncbi.nlm.nih.gov/books/NBK97852/ Accessed March 25, 2019.
- Norovirus | Guidelines Library | Infection Control | CDC. (s. d.). https://www.cdc.gov/infection-control/guidelines/norovirus/index.html Accessed March 25, 2019.
- O'Horo, J. C., Farrell, A., Sohail, M. R., & Safdar, N. **Carbapenem-resistant Enterobacteriaceae and endoscopy : An evolving threat.** *American Journal of Infection Control* 2016;44(9):1032-1036.
- Options for Evaluating Environmental Cleaning | HAI | CDC. (s. d.). https://www.cdc.gov/hai/toolkits/evaluating-environmental-cleaning.html Accessed March 28, 2019.
- Otter, J. A., Yezli, S., & French, G. L. **The role played by contaminated surfaces in the transmission of nosocomial pathogens.** *Infection Control and Hospital Epidemiology* 2011;32(7):687-699.
- Otter, J. A., Yezli, S., Salkeld, J. A. G., & French, G. L. **Evidence that contaminated surfaces contribute to the transmission of hospital pathogens and an overview of strategies to address contaminated surfaces in hospital settings.** *American Journal of Infection Control* 2013;41(5 Suppl):S6-11.
- Passaretti, C. L., Otter, J. A., Reich, N. G., **An evaluation of environmental decontamination with hydrogen peroxide vapor for reducing the risk of patient acquisition of multidrug-resistant organisms.** *Clinical Infectious Diseases: An Official Publication of the Infectious Diseases Society of America* 2013;56(1):27-35.
- Rüden, H., & Daschner, F. **Should we routinely disinfect floors?** *The Journal of Hospital Infection* 2002;51(4):309; author reply 309-311.
- Rutala, W. A. **Guideline for Disinfection and Sterilization in Healthcare Facilities.** 2008;161.
- Rutala, W. A., & Weber, D. J. **Monitoring and improving the effectiveness of surface cleaning and disinfection.** *American Journal of Infection Control* 2016;44(5, Supplement):e69-e76.
- Salgado, C. D., Sepkowitz, K. A., John, J. F., et al. **Copper surfaces reduce the rate of healthcare-acquired infections in the intensive care unit.** *Infection Control and Hospital Epidemiology* 2013;34(5):479-486.
- Schreiber, P. W., Hasse, B., & Sax, H. ***Mycobacterium chimaera* infections after cardiac surgery - lessons learned.** *Clinical Microbiology and Infection: The Official Publication of the European Society of Clinical Microbiology and Infectious Diseases* 2018;24(11):1117-1118.
- Sehulster, L., Chinn, R. Y. W., CDC, & HICPAC. **Guidelines for environmental infection control in health-care facilities. Recommendations of CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC).** *MMWR. Recommendations and Reports: Morbidity and Mortality Weekly Report. Recommendations and Reports* 2003;52(RR-10):1-42.
- Shaw, K. **The 2003 SARS outbreak and its impact on infection control practices.** *Public Health* 2006;120(1):8-14.
- Tacconelli, E., Cataldo, M. A., Dancer, S. J., et al. European Society of Clinical Microbiology. **ESCMID guidelines for the management of the infection control measures to reduce transmission of multidrug-resistant Gram-negative bacteria in hospitalized patients.** *Clinical Microbiology and Infection: The Official Publication of the European Society of Clinical Microbiology and Infectious Diseases* 2014;20(Suppl 1):1-55.
- Tan, T. Y., Tan, J. S. M., Tay, H., et al. **Multidrug-resistant organisms in a routine ward environment : Differential propensity for environmental dissemination and implications for infection control.** *Journal of Medical Microbiology* 2013;62(5):766-772.
- Updates | Disinfection & Sterilization Guidelines | Guidelines Library | Infection Control | CDC. (s. d.). https://www.cdc.gov/infectioncontrol/guidelines/disinfection/updates.html Accessed March 28, 2019.
- van Ingen, J., Kohl, T. A., Kranzer, K., et al. **Global outbreak of severe *Mycobacterium chimaera* disease after cardiac surgery : A molecular epidemiological study**. *The Lancet. Infectious Diseases* 2017;17(10):1033-1041.
- Weber, D. J., Anderson, D., & Rutala, W. A. **The role of the surface environment in healthcare-associated infections.** *Current Opinion in Infectious Diseases* 2013;26(4):338-344.
- Weber, D. J., Rutala, W. A., Miller, M. B., Huslage, K., & Sickbert-Bennett, E. **Role of hospital surfaces in the transmission of emerging health care-associated pathogens : Norovirus, *Clostridium difficile,* and Acinetobacter species.** *American Journal of Infection Control* 2010;38(5, Supplement):S25-S33.
- WHO | *Legionella* and the prevention of legionellosis. (s. d.). WHO website: http://www.who.int/water_sanitation_health/publications/legionella/en/ Accessed March 25, 2019.
- WHO-Europe: https://www.euro.who.int/en/health-topics/health-emergencies/coronavirus-covid-19 Accessed June 17, 2020.
- Wu, H. M., Fornek, M., Schwab, K. J., et al. **A Norovirus Outbreak at a Long-Term-Care Facility : The Role of Environmental Surface Contamination.** *Infection Control & Hospital Epidemiology* 2005;26(10):802-810.
- Ye, D., Shan, J., Huang, Y., et al. **A gloves-associated outbreak of imipenem-resistant *Acinetobacter baumannii* in an intensive care unit in Guangdong, China.** *BMC Infectious Diseases* 2015;15(1):179.

NOTES

bioMérieux

We help make the world a healthier place

A major player in *in vitro* diagnostics for more than 60 years, bioMérieux has always been driven by a pioneering spirit and unrelenting commitment to improve public health worldwide.

Our diagnostic solutions bring high medical value to healthcare professionals, providing them with the most relevant and reliable information, as quickly as possible, to support treatment decisions and better patient care.

bioMérieux's mission entails a commitment to support medical education, by promoting access to diagnostic knowledge for as many people as possible. Focusing on the medical value of diagnostics, our collection of educational booklets aims to raise awareness of the essential role that diagnostic test results play in healthcare decisions.

Other educational booklets are available.
Consult your local bioMérieux representative, or visit
www.biomerieux.com/en/education/educational-booklets

The information in this booklet is for educational purposes only and is not intended to be exhaustive. It is not intended to be a substitute for professional medical advice. Always consult a medical director, physician, or other qualified health provider regarding processes and/or protocols for diagnosis and treatment of a medical condition. bioMérieux assumes no responsibility or liability for any diagnosis established or treatment prescribed by the physician.

bioMérieux S.A. • 69280 Marcy l'Étoile • France
Tel.: + 33 (0)4 78 87 20 00 • Fax: +33 (0)4 78 87 20 90
www.biomerieux.com