Healthcare Plumbing Systems are **Sources and Vectors of Infection for HAIs**

> *Potable and utility water systems in healthcare settings are* ***reservoirs and vectors of HAIs,*** *resulting in pneumonias, bacteremias, skin infections, surgical site infections, eye infections, urinary tract infections and others.*

By John H. Hanlin, PhD, and Eric R. Myers, MS

Over the last 15 years, new genetic and investigational tools have strengthened the body of evidence linking water to healthcare-associated infections (HAIs). Potable and utility water systems in healthcare settings are reservoirs and vectors of HAIs, resulting in pneumonias, bacteremias, skin infections, surgical site infections, eye infections, urinary tract infections and others. Infections that are epidemiologically linked to potable water are now being referred to as waterborne healthcare-associated infections or wHAIs. Consequently, water has joined the well-recognized sources of HAIs such as surfaces, high-touch objects, hands and contaminated medical devices.

that comprehensively reviewed multiple outbreaks and infections caused by opportunistic, waterborne, bacterial and fungal pathogens.[2] These pathogens include the bacteria Legionella, Pseudomonas, Klebsiella, Acinetobacter, non-tuberculous mycobacteria (NTM) and fungal pathogens such as Fusarium and Aspergillus species.

Potable water is used extensively in the healthcare environment. It is used for drinking, patient bathing and showering, handwashing, rinsing medical devices, hydrotherapy pools and to make ice. Cooling towers, ornamental water features, misting systems and landscape irrigation use utility water.

Our review of the literature on healthcare premise plumbing systems and HAIs enabled the development of the Waterborne Pathogen Proliferation Model (WPPM) shown in figure 1.

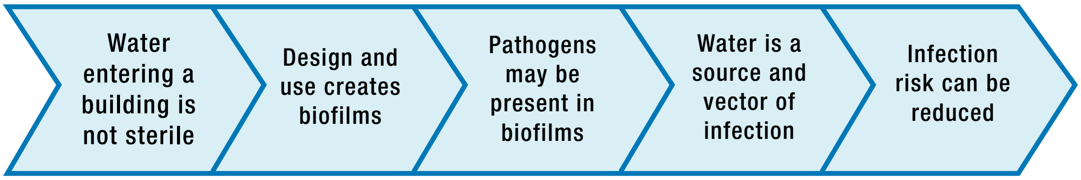

Figure 1. The WPPM illustrating the reservoir and vector of infectious disease in healthcare water systems.

This article reviews published literature on how hospital water systems support the growth of opportunist pathogens, pathogens of concern, epidemiological evidence linking these pathogens to HAIs, and how infection risk can be reduced by a water safety management program.

Introduction

Water brings life to all living organisms. Today we rely on fresh, safe water that meets national government standards. Water, however, is frequently overlooked as a source of HAIs, despite the infection prevention literature being replete with peer-reviewed studies linking healthcare premise plumbing systems with opportunist pathogens and patient infection.[1] Rutala and colleagues published a landmark article in 2016

The key elements of the model are:

1. Water entering a healthcare facility is not sterile.
2. The design of a healthcare's premise plumbing system and patterns of water use allow biofilms to form.
3. Bacterial and fungal pathogens establish themselves in premise plumbing biofilms.
4. Pathogens associated with premise plumbing biofilms have been epidemiologically linked to HAIs.
5. Infection risk can be reduced through development and implementation of a water management program.

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Water Entering a Building is Not Sterile

Healthcare facilities typically receive potable water from their local public water system or municipality. The U.S. Environmental Protection Agency (EPA) has established limits for coliforms, but has not promulgated or proposed a maximum contaminant level for heterotrophic plate count bacteria (HPC).[3]

Potable water is not sterile. For illustrative purposes, let us assume that water entering a healthcare facility has an average bacterial load of 10 HPC bacteria per mL. If a healthcare facility uses 100,000 gallons of water per day, the potential number of bacteria entering a healthcare facility in one day could approach 4 billion (10 X 3,7851 X 100,000). Although the majority of the HPC are innocuous, the potential exists for opportunistic pathogens including Legionella pneumophila, Pseudomonas aeruginosa, Acinetobacter baumannii to enter a premise's plumbing system.[4-5]

Design of and Water Use Patterns in Premise Plumbing Create Biofilms

A core principle for species survival, whether it be an animal, a plant or a microorganism is their need for food, water and shelter. Microorganisms can survive in potable water, but may not thrive therein because potable water is relatively nutrient poor. The microorganisms of concern in a healthcare environment such as those causing HAIs require carbon, nitrogen and other key nutrients, in addition to water. Biofilms in premise plumbing systems are complex ecosystems, and it is within these biofilms that bacteria, fungi and amoeba find the food, water and shelter they need.

Biofilm formation, composition and function are well characterized.[6-7] Bacterial cells must attach and adhere to the inner wall of a water pipe. Bacteria including Pseudomonas aeruginosa are often considered architects of the biofilm, due to their ability to produce a sticky exopolysaccharide or glycocalyx.[8] Biofilm development generally follows the five steps outlined in figure 2.

The five steps are:

1. Initial attachment and adherence of microorganisms to a surface
2. Adherence further mediated by production of glycocalyx by one or more bacterial species
3. Early development of biofilm structure
4. Maturation of the biofilm
5. The release of microorganisms from biofilm
6. Bacterial and Fungal Pathogens May be Present in Biofilms

Opportunist pathogens are likely to be among the community of microorganisms comprising a biofilm. In addition to P. aeruginosa, non-tuberculous mycobacteria establish themselves in part, due to their waxy outer cell wall. Legionella pneumophila also finds a home in the biofilm, as do bacterial-grazing (predatory) amoeba. Other opportunist pathogens including Acinetobacter baumannii, Stenotrophomonas maltophila, Aspergillus flavus and Fusarium solani associate with biolfilms.[1-2, 9-10]

Water is a Source and Vector of Infection

The most granular example of a wHAI is Legionnaires' disease (LD). The causative bacterium, Legionella pneumophila, is a waterborne, opportunistic pathogen. It causes a severe form of pneumonia when Legionella-contaminated water droplets in mists or sprays are inhaled by susceptible individuals. More than 5,000 people are diagnosed with LD, and the Centers for Disease Control and Prevention (CDC) estimates more than 20 outbreaks of LD occur in the U.S. each year. Many of these occur in healthcare settings. According to the CDC, LD kills 25 percent of those who are infected in a healthcare facility.[11-12]

Outbreaks of LD are just the tip of the iceberg. Anaissie reviewed 43 documented outbreaks of HAIs

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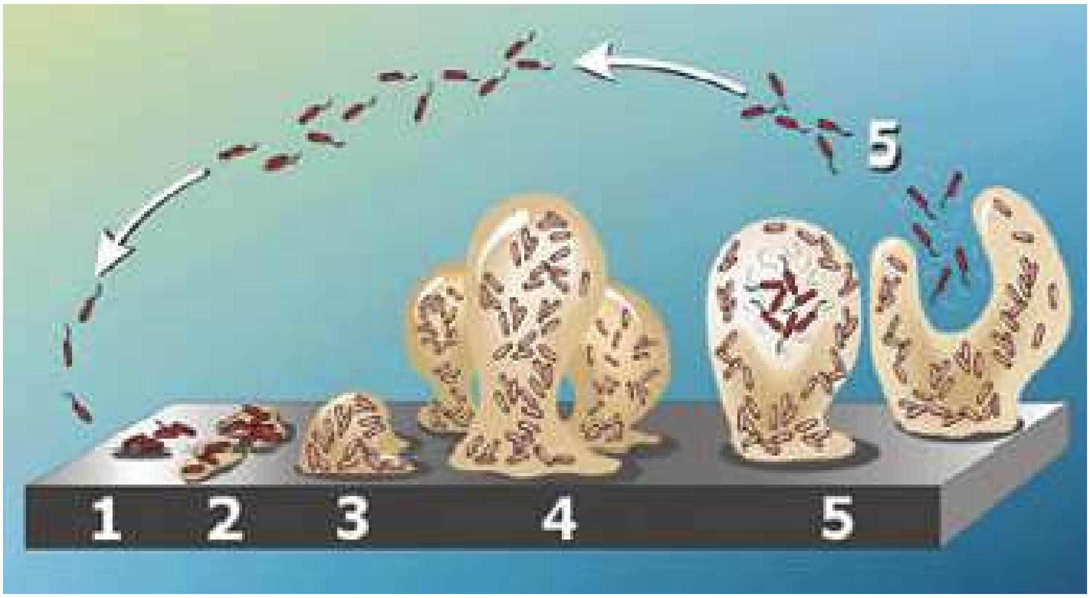
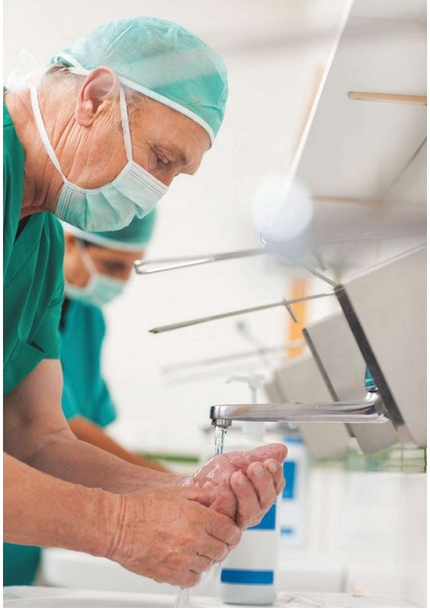


Figure 2. Steps in the development and maturation of a biofilm. Courtesy of the Center for Biofilm Engineering. Montana State University, Bozeman, Mont.



and concluded that 29 of the 43 outbreaks were linked to water.[1] Rutala's group provided outbreak summaries for 73 outbreaks and infections associated with water in healthcare settings.[2] Other studies have shown the following:

- 74 percent of taps without temperature selection were contaminated with P. aeruginosa.[13]
- More than 50 percent of water samples were positive for P. aeruginosa. About one-third of P. aeruginosa infections were genetically identical to P. aeruginosa found in tap water in their ICU.[14]
- The hospital water system was suspected as being the source of patient infection in a neonatal unit. Taps were dismantled and 14 percent of the components tested positive for P. aeruginosa. The range of plate counts were from 20 to 2.2x107 CFU per component.[15]
- The source of a pseudo outbreak of Elizabethkingia meningoseptica infecting 30 patients over a 22-month period was most likely the water in a critical care unit. The authors suggested that the organism's ability to be associated with biofilms played a role in the reservoir and vector of infection.[16]

Infection Risk Can be Reduced

A multi-faceted approach is recommended to reduce the risk of wHAIs. This is best accomplished through education and under the umbrella of a water management program. Refer to the CDC toolkit and American National Standards Institute/American Society of Heating, Refrigerating and Air-Conditioning Engineers (ANSI/ASHRAE) Standard 188 for model programs.[17-18]

For Legionella, a comprehensive program can be developed, implemented and monitored using these seven steps:

1. Establish a cross-functional water safety management team.
2. Describe water systems and flow diagrams.
3. Identify areas where Legionella could grow.
4. Determine where control measures should be applied and how to monitor them.
5. Determine corrective actions when control limits are not met.
6. Verify the program is in control and effective.
7. Document and communicate all activities associated with program.

Several approaches used individually or in combination have been used to reduce risk. Examples include the use of sterile water in high-risk patient areas, engineering controls, supplemental disinfection and point-of-use water filters. In regards to the use of supplemental disinfection, two common approaches are available as a long-term control strategy: EPA-approved drinking water disinfectants such as on-site generation of chlorine and chlorine dioxide. Other approaches including monochloramine, copper/silver and systems that generate UV light and ozone are available. The team must consider the benefits and limitations of each technology given water quality and the water systems type (cold or hot water) to be treated.[4,7,9] Multiple studies have shown the benefit of point-of-use water filters in high-risk patient areas. These filters have a porosity of 0.2 um or less and can be attached to showers or faucets in high-risk patient-care areas.[9,14,19]

In summary, the body of scientific evidence linking water to HAIs is strong. Infection risk can be reduced and is best accomplished through education and implementation of a site-specific program. Engineering controls, supplemental disinfection and point-of-use water filters are a few of the important tools available to the infection prevention community. ICT

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