Curr Treat Options Infect Dis (2020) 12:332–348
DOI 10.1007/s40506-020-00234-5

Bloodstream Infections Caused by Waterborne Bacteria

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Published online: 11 July 2020

This article is part of the Topical Collection on *Treatment and Prevention of Hospital Infections*

Keywords Waterborne · Outbreak · Bloodstream infection · Hospital-acquired

Abstract

Purpose of Review We describe the mechanisms and risk factors related to non-gastrointestinal waterborne hospital-acquired infections, including bloodstream infections. Included are some characteristics of the main bacteria described in the literature.
Recent Findings In the last two decades, the number of water living bacteria that had been identified as causing healthcare-associated waterborne infections has expanded. Among these, *Legionella*, *Enterobacteriaceae*, *Pseudomonas aeruginosa*, other non-fermenting bacteria, and nontuberculous mycobacteria are included. We describe some of the main characteristics of the bacteria associated with the infections in the hospital setting, mostly bloodstream infections.
Summary No single approach guarantees that hospital water will be safe for vulnerable patients, but a combination of engineering, chlorination surveillance, hygiene measures, and clinical care strategies can minimize the risk. Microbial contamination of the water supply in healthcare facilities is better prevented than remediated.

Introduction

In the last four decades, modern medicine has increased the life expectancy of patients with chronic life-threatening diseases, previously considered terminal, at the cost of increasing vulnerability of human beings, and frequently affecting both humoral and cellular immunity [1]. To this, we have to add the use of invasive devices, mainly vascular catheters that constitute a direct bridge between the external environment, including bath water, and the bloodstream; these intravascular devices put patients at risk of infection particularly bloodstream infection (BSI). Waterborne healthcare-associated infections (HAIs) have been increasingly recognized in the last decades as a source of pneumonia (*Legionella*) [2•]. More recently, water for human use has been related as a potential cause of HAI, in particular bacteremia in patients with invasive devices. Multiple microorganisms can grow in nonsterile water, and if preventive measures are not established to strictly avoid the contact between water and these devices, it can become a source of bacteremia. On the other hand, microorganisms that grow in hospital water incur significant morbidity and mortality [3••].

Environment

Hospital water and water-related devices, as well as moist environments and aqueous solutions, can serve as a reservoir of waterborne pathogens in healthcare settings where water temperatures can become suitable for bacterial growth. In addition, the complex structure of hospital water systems can lead to stagnation and corrosion and favor microorganisms' biofilm formation [4••]. A variety of water reservoirs have been linked to nosocomial outbreaks including the following: drinking water, tap water, ice machines, hospital water systems, sinks, showers, bathing and tub immersion, electronic faucets, flower vases, decorative water wall fountains, heater-cooler units, eyewash stations, and dental-unit water stations [4••].

Maintenance managers of healthcare facilities are responsible for the integrity and conservation of water systems for the distribution of drinking and non-potable water for various uses. Municipal drinking water and even hospital tap water are not expected to be free of pathogens. Municipal water undergoes routine microbiological surveillance to assure safe levels of important community pathogens such as coliform bacteria. Further processing may occur at the building for purposes such as supplementary disinfection, water softening, and water heating for hot water [2•].

Transmission of pathogens from a water reservoir may occur by direct or indirect contact, ingestion and aspiration of contaminated water, or inhalation of aerosols [4••].

Hosts

Most waterborne pathogens that cause infections in hospital do so in a small proportion of exposed patients. Certain pathogens are related with host characteristics that predispose to nosocomial infections (ex. transplantation, chronic comorbid conditions, immunosuppressive therapies, history of tobacco use, central venous catheters, other implanted devices or mechanical ventilation) [3••].

This article reviews the epidemiology of waterborne HAIs, describing the most frequent pathogens involved.

Bacteria related with waterborne BSI

Several bacteria are associated with waterborne non-gastrointestinal infections, mainly bacteremia; several of these have been described in different epidemic outbreaks (Table 1). The most important are described below.

Table 1. Main organisms and characteristics related with waterborne infections

Organism	Characteristics	Origin	Risk factors	Other facts
Acinetobacter	Gram-negative coccobacilli, non-motile, strictly aerobic, catalase-positive, oxidase-negative, indole-negative, and do not ferment glucose or reduce nitrate.	Tap water, hospital-acquired infection, community-acquired infections in tropical environments, and infections that occur in the setting of wars and natural disasters.	Showering without protection, patients in ICU* units. Recent surgery, central vascular catheterization, tracheostomy, mechanical ventilation, enteral feedings, and treatment with third generation cephalosporin, fluoroquinolone, or carbapenem antibiotics.	More than 30 different species belonging to the genus *Acinetobacter* have been identified, most frequently *A. baumannii, A. calcoaceticus*, and *A. lwoffi*. Some strains can survive environmental desiccation for months, a characteristic that promotes transmission through fomite contamination in hospitals.
Aeromonas	Gram negative rod-shaped, facultative anaerobic, nonspore forming, catalase, and oxidase-positive, and chemoorganotrophic.	Ubiquitous, freshwater, estuarine (brackish) water, surface water, especially recreational, drinking water, including treated, well, and bottled, polluted waters, waste water effluent sludge.	Hepatic diseases, diabetes, hematologic malignancies, hepatobiliary, and renal diseases.	Two different types: Motile, mesophilic species, including eight that can cause disease in humans; and non-motile, psychrophilic species that generally cause disease only in fish.
Burkholderia cepacia	Non-fermenting Gram-negative bacilli.	Contamination of fluids and disinfectant solutions. Onions and soil.	Patients with cystic fibrosis and immunosuppressed.	Outbreaks in intensive care units and hemodialysis services.
Elizabethkingia	Gram-negative non-fermenting obligate aerobe.	Widely distributed in the environment, particularly soil and water.	Exposed to antibiotics in critical care units, and those with comorbidities.	Formerly *Flavobacterium meningosepticum* and during 1994–2005 *Chryseobacterium meningosepticum*. Three different species, *E. anopheles*, *E. meningoseptica*, and *E. miricola*.
Enterobacter	Facultative anaerobic Gram-negative bacilli, nonmotile, and may	Commonly found in soil and water. *E. cloacae* and *E. aerogenes* can inhabit	Prolonged hospital stays, especially ICU. The presence of a serious	*Enterobacter spp*. are in the family Enterobacteriaceae.

Table 1. (Continued)

Organism	Characteristics	Origin	Risk factors	Other facts
	decarboxylate ornithine slowly.	the intestines of humans and animals and can also be found in sewage. *E. aerogenes* has also been found in dairy products.	underlying illness, especially malignancy, burns, diabetes, immunosuppression from any cause, prematurity and low birth weight in neonates, and the presence of a foreign device.	There are 14 species or biogroups.
Halomonas	Gram-negative, catalase-positive bacteria.	Found in saline or hypersaline environments.	Hemodialysis, catheter related, ICU.	Seventy-six species had been taxonomically accepted. Most of the cases have been associated with hemodialysis.
Legionella pneumophila	Aerobic, Gram-negative, non-spore-forming gamma proteobacteria. Phenotypically distinct biphasic life cycle that alternates between a non--motile, replicative phase and a virulent, flagellated, transmissive phase.	Water, air conditioner.	Smokers, immunocompromised hosts, more than 60 years old, predominant pneumonia.	It was first reported at the American Legion Convention in Philadelphia in 1976.
Nontuberculous mycobacteria (NTM) (*M. abscessuss*, *M. avium*, *M. chelonae*, *M. genavense*, *M. chimaera*, *M. mucogenicum*, *M. fortuitum*, *M. neoaurum*, *M. phocaicum*, *M. porcinum*, *M. simiae*).	Mycobacteria.	Ubiquitous microorganisms in the environment. Most NTM is found in wet soil, natural waters, and even in tap water.	Diseases and therapies that reduce cell-mediated immunity increase the risk of NTM disease. AIDS, cancer, and hematologic and solid organ transplants, immunosuppressive drugs including anti-tumor necrosis factor biologics.	Rarely cause bloodstream infections.
Ochrobactrum	Aerobic, oxidase-positive, urease-positive, Gram-negative, motile,	Soil and water, biological products.	Critically ill or immunocompromised patients.	Belongs to the *Brucellaceae* and is known to be isolated from *Leguminosae*

Table 1. (Continued)

Organism	Characteristics	Origin	Risk factors	Other facts
	non-lactose-fermenting bacillus.			nodules currently comprises 9 species. To date, only 3 species, *O. anthropi*, *O. intermedium*, and *O. pseudintermedium*, have been reported to occur in clinical samples.
Pseudomonas aeruginosa	Gram-negative, rod-shaped, asporogenous, and monoflagellated bacterium. It has a pearlescent appearance and grape-like or tortilla-like odor. Grows well at 25 to 37 °C.	Ubiquitous found in a wide range of moist, nutrient-limited environments and can colonize hospital and domestic water, taps, sinks, drains, toilets, and showers.	Immunocompromised or critically ill patients, cystic fibrosis.	Forms biofilms that allow persistence of microorganisms in water systems for long periods, and this helps to explain the high colonization rates of hospital water systems. Nosocomial *P. aeruginosa* outbreaks have been associated with hospital water sources.
Sphingomonas	Gram-negative, non-spore forming, chemoheterotrophic, strictly aerobic bacterium	Aqueous (both fresh and seawater) and terrestrial habitats, plant root systems, clinical specimens. respiratory therapy items, humidifiers, water, air, bedside water bottles, sinks, and temperature probes.	Immunological deficiency in critically ill patients, rest ventilators.	The genus *Sphingomonas* contains at least 12 species, of which only one, *S. paucimobilis* is an occasional human pathogen. This organism, formerly known as *P. paucimobilis* and CDC group IIk-1.
Ralstonia pickettii	Aerobic Gram-negative, oxidase-positive, non-fermentative rods. Former members of *Burkholderia* spp. (*B. pickettii* and *B. solanacearum*)	Water for injection, saline solutions made with purified water, sterile drug solutions, and soil.	Immunocompromised hosts, cystic fibrosis patients, and Crohn's disease.	It is not considered to be a major pathogen and its virulence is thought to be low. Pseudo-outbreaks.
Serratia	Enterobacteriaceae family and is currently	Moist environments, intravenous solutions,		Outbreaks related with total parenteral nutrition.

Table 1. (Continued)

Organism	Characteristics	Origin	Risk factors	Other facts
	differentiated into ten species.	indwelling intravenous catheters, soaps, and disinfectants. Soil, water, and food.	Immunocompromised, long-lasting hospitalization.	
Vibrio cholerae Non-01, Non-0139	Family Vibrionaceae, Gram-negative bacteria, halophilic facultative anaerobes.	Ubiquitously distributed in marine, estuarine, and freshwater environments.	Immunocompromised hosts, diabetic, and cirrhosis.	Only twelve of more than 100 recognized species are pathogenic to humans. Survival is governed by the water's temperature and salinity; their incidence in water and aquatic animals increases during summer.

Acinetobacter spp.

Acinetobacter spp. has been identified in natural surface water samples in high proportions; it has been found in 1 to 5.5% of the heterotrophic plate count flora in drinking water, and in 5 to 92% of different water samples [5]. It has been also identified in the skin and respiratory tract in some healthy individuals. In a survey of untreated groundwater supplies in the USA, this microorganism was isolated in nearly 40% of the groundwater supplies [6]. The same study revealed that slime production of this microorganism, a recognized virulence factor for *A. calcoaceticus*, was not different between water isolates and clinical strains, suggesting the pathogenic potential for strains isolated from groundwater when it gets to a vulnerable subject [5, 6].

The identification of potential sources for HAI of these microorganisms is crucial to apply preventive interventions. Some published case reports found the microorganism in blood cultures and water supplies in patients with exposure of intravenous catheter insertion sites while bathing or showering, highlighting the importance of using an efficient physical barrier between the catheter insertion site and the environment with a plastic protection above semipermeable dressing that covers the insertion site of the catheter [7]. An outbreak reported in a newborn nursery was related to a breach in the aseptic technique during intravenous medication administration, along with environment factors through air conditioner condensate that predisposed to airborne dissemination via contaminated aerosols [8].

Aeromonas spp.

Aeromonas spp. has been cultured from more than 90% of natural water samples throughout the USA and Puerto Rico. Some studies have shown a higher burden in warmer environments with peaks during the summer, with 42 to 67% of clinical-associated infections in warmer months [9]. *A. hydrophila* is the most commonly identified species in humans, particularly in older population, followed by *A. caviae*, and A. *veronii* [10]. They have been found in chlorinated drinking water supplies in some countries, in low quantities (< 10 CFU/mL) in drinking water distribution systems, and it has been associated with biofilm production [10]. Extra-intestinal infections come from environmental origins, soil, or water contact [11].

The presentation of *Aeromonas*-related bacteremia includes fever (74 to 89%), hypotension (61%), jaundice (57%), and chills (46%), and it is more common in immunocompromised hosts. One-third of cases can be polymicrobial [10]. Bone infections in immunocompromised host are a result of blood bone spread, while in healthy individuals, it is most commonly a result of trauma of the tissue next to the bone, often after contamination with freshwater [12].

Burkholderia cepacia

Burkholderia cepacia bloodstream outbreaks have been described in ICUs and hemodialysis services due to contamination of fluids and disinfectant agents [13]. The severity is given by the virulence of the microorganism. It is more likely found in immunocompromised patients and epidemic outbreaks associated with the administration of contaminated parenteral solutions or antiseptic agents have been reported [14]. Outbreaks have been reported in hemodialysis units where *B. cepacia* has been concomitantly isolated from blood cultures obtained from catheter lumens and chlorhexidine bottles. Pulsed field gel electrophoresis (PFGE) and multilocus sequence typing (MLST) were used to study blood cultures [13].

Another outbreak in central venous catheters in Lebanon reported that contaminated tap water was used to dilute alcohol for skin antisepsis; when used for decontamination of heparin vial caps, the catheter and bloodstream were also contaminated with *B. cepacia*. The same clone was identified from blood cultures, tap water, and alcohol [15].

Elizabethkingia spp.

Elizabethkingia spp. are an uncommon but threatening infection among people with underlying medical conditions [16]. It is considered an emerging pathogen in the healthcare environment [16]. The first report of a primarily community-associated *Elizabethkingia* outbreak was in January 2016, when the Wisconsin Division of Public Health notified the Centers for Disease Control (CDC) of six *E. anophelis* BSI among residents of four counties during the previous 13 days. A thorough investigation revealed 63 cases in residents of 12 Wisconsin counties, two patients in Illinois, and one patient in Michigan. Twenty-five of the 48 affected patients (43%) were admitted to the intensive care unit (ICU); 10/61 (14%) required hemodialysis and 18/63 (29%) died. Only one sample of water containing material used by a patient while ill, grew the same microorganism, but the ultimate source of the outbreak was not identified [17, 18].

A study of an outbreak of *E. meningoseptica* in an ICU revealed that sinks used for hand hygiene and also used to dispose patient secretions were four times more contaminated than sinks that were only used for hand hygiene [19].

Enterobacter spp.

According to the National Nosocomial Infections Surveillance System (NNIS), *Enterobacter* spp. accounted for 5 to 7% of all nosocomial bacteremia in the USA from 1976 to 1989. However, in recent publications, these nosocomial pathogens were almost exclusively isolated from ICU patients; they represent in some reviews the fifth most common pathogens recovered from blood (5.3%) [20].

The isolation of *Enterobacter* spp. from blood is two- to threefold higher in specialized units, such as cancer centers, and two- to threefold lower in community hospitals. *E. cloacae* predominates in most series (46 to 91% of isolates) followed by *E. aerogenes* (9 to 43%), *E. agglomerans*, *E. sakazakii*, and others. Around 14 to 53% of bacteremia that involve *Enterobacter* spp. are polymicrobial [21].

A Malaysian study of 11 babies, 9 of them premature, who presented a nosocomial outbreak of bacteremia caused by *E. gergoviae* in the neonatal ICU of a general hospital, found the same microorganism isolated from the dextrose/saline used for the dilution of parenteral antibiotics and from the hands of a healthcare worker in the nursery [22, 23].

Halomonas spp.

Halomonas phocaeensis was identified in a nosocomial outbreak of BSI in neonatal ICU related to fresh frozen plasma warming. This first description of *H. phocaeensis* bacteremia illustrates the infection risks associated with poorly controlled water hygiene in healthcare settings [24].

Halomonas spp. was recognized as human pathogen causing BSI in dialyzed patients attributed to contamination of machines in a dialysis center with bicarbonate fluid products used to prepare dialysis solutions. It has been documented that they are biofilm producers [25, 26].

Legionella pneumophila

Legionella pneumophila grows within free-living amoebae, which can tolerate a wide range of temperatures (between 20 and 50 °C), and other environmental conditions [3••]. It was first described as the cause of pneumonia among 182 delegates to the American Legion Convention in Philadelphia in 1976 [27].

Legionella spp. are ubiquitous in aquatic habitats, including rivers, ponds, hot springs, and lakes; all are recognized as potential human pathogens [28]. Although most Legionnaire's disease is community acquired, approximately 10% of cases are thought to result from hospital water exposure [3••]. The disease is typically transmitted to patients through aerosols that arise from showers, ice machines, decorative fountains, humidifiers, and other water sources in hospitals [29]. The most vulnerable and most affected patients in the hospital are those with advanced age and chronic lung disease. The mortality rate of nosocomial Legionnaire's disease is approximately 32%, fourfold higher than the community-acquired infection, likely because of the underlying co-morbidities of hospitalized patients [3••].

Prevention of healthcare-associated *Legionella* infection requires a multidisciplinary approach involving healthcare epidemiologists and hospital officers, hospital designers, architects, and maintenance engineers, as well as the clinicians and the microbiology laboratory [3••]. But when the water system of a hospital is already contaminated with *Legionella*, different options exist including super-heating and flushing the system with or without shock chlorination. These methods have been effective in terminating existing outbreaks [30]. Hospitals providing care for immunocompromised patients must conduct close clinical surveillance for Legionnaire's disease among hospitalized patients. The Centers for Disease Control (CDC) recommends that facilities with an already nosocomial outbreak of Legionnaire's disease conduct ongoing microbiologic surveillance to detect recontamination of their water supply. The use of environmental surveillance for primary prevention (when there has been no outbreak) remains controversial [31].

Nontuberculous mycobacteria

Nontuberculous mycobacteria (NTM) are ubiquitous microorganisms in the environment. Most are found in wet soil, aural water, and even tap water; survive in hot water systems; and resist chlorination. Plumbing features, such as stagnation, and warm water, also foster proliferation of NTM [32].

NTM, including both rapid-growing and slow-growing species, have caused waterborne healthcare-associated outbreaks and infections as follows: *M. abscessus* with tap water; *M. avium* with potable water; *M. canariasense* in the hospital water supply; *M. chelonae* with ice and ice machines; *M. chimaera* with heater-cooler units; *M. fortuitum* with hospital water system and showers; *M. genavense* with tap water; *M. mucogenicum* with bathing and tub immersion, electronic faucets, sinks, showers, and hospital water systems; *M. neoaurum* with hospital water systems; *M. phocaicum* with showers; *M. porcinum* with ice and ice machines and tap water; and *M. simiae* with tap water [4••, 33].

The invasive forms of disease are most common in immunocompromised hosts as in AIDS, cancer, and hematological and solid organ transplant patients and in those receiving immunosuppressive drugs including biologic therapies with anti-tumor necrosis factor molecules [34].

Many true outbreaks and several pseudo-outbreaks with NTM have been reported. HAI outbreaks and sporadic cases have included central line BSI, sternal wound infections, cosmetic surgery–associated soft tissue infections, and BSI related with dialysis. Most reported outbreaks involved exposure of invasive devices or non-intact skin to tap water [33].

Ochrobactrum spp.

Ochrobactrum infections are especially identified in immunocompromised patients. The outbreaks that have been reported affect patients receiving chemotherapy or organ transplant recipients. Poor hand hygiene was the primary source of the infection, responsible for catheter flushing solution contamination [35, 36].

Pseudomonas aeruginosa

Pseudomonas spp. is commonly associated with biofilms in hospital water sources. Therapy pools, tubs, and daily bathing in bed can be sources of transmission [30]. Being recognized as one of the most threatening microorganisms in hospitalized immunosuppressed patients, together with the increasing incidence of antimicrobial resistance in the last decades, has made *P. aeruginosa* an emerging infection control problem [37]. The source of many of *P. aeruginosa* infections remains unclear, but most are related with environmental contamination, including tap water [38].

It is well recognized that immunocompromised patients are an important risk group for these infections; a study of an hematology ward where water samples were cultured and compared to clinical isolates from hematologic patients, using PFGE, found that *P. aeruginosa* isolated from blood cultures from three patients were indistinguishable from water strains [39]. The transmission was related to the infusion therapy procedure tray used to transport intravenous drugs to patients contaminated by water colonized by *P. aeruginosa* [39].

Ralstonia pickettii

Ralstonia spp. is a group of environmental low-virulent Gram-negative non-fermenting bacilli, slow-growing bacteria that can take almost 3 days to visualize colonies [1]. It can cause infection when contaminated solutions or intravenous medication is administered, causing nosocomial outbreaks of BSI, most commonly in immunocompromised hosts (organ transplant recipients, leukemia, or HIV patients) [40].

R. pickettii is the most clinically important pathogen from the *Ralstonia* genus. It causes bacteremia due to contaminated solutions, water for injection, saline solutions, hemodialysis water supplies, and sterile drug solutions [14, 41]. It has been described in a case of peritoneal dialysis-associated peritonitis, where different factors influenced bacterial proliferation and biofilms, being detected in high numbers in dialysis water treatment facilities equipped with chlorinated polyvinyl chloride piping [42, 43].

These organisms are prevalent in many different types of water supplies (including hospital water supplies), being well adapted to survive in low-nutrient conditions. It has also been reported in chlorinated polyvinyl tubbing [44, 45].

Serratia marcescens

Serratia marcescens is the primary species of the *Serratia* genus associated with disease. It can be isolated from different clinical specimens including blood, tracheal aspirates, and urine [46]. *S. marcescens* thrives in moist environments, including intravenous solutions, indwelling intravenous catheters, soap, and disinfectants, all of which have been described as the source of outbreaks [47].

Different outbreaks have been reported in situations which predispose to deficits in hygienic behavior, and a lack of standard infection control, for example the use of nonsterile used for intravenous administration [46, 48].

Sphingomonas

Sphingomonas paucimobilis bacteremia has been reported in patients who received hydromorphone analgesia syringes [49]. In another study, it was isolated from the blood of a patient with leukemia. The genotype of this microorganism was the same from tap water [50].

Stenotrophomonas maltophilia

Stenotrophomonas maltophilia has recently emerged as a significant pathogen of nosocomial infections in immunosuppressed or critically ill patients, with up to 53% mortality reported [51]. The intrinsic resistance to disinfectants and to commonly used antibiotics poses a threat to prevention and makes treatment difficult. The most frequent clinical manifestation is pneumonia in cancer and ICU patients. It has been associated with the use of broad-spectrum antimicrobials, mechanical ventilation, advanced age, and high APACHE II score [51]. A study conducted in a teaching hospital in China found that the incidence of *S maltophilia* bacteremia was from 3.4 to 15.4 episodes per 1000 admissions over a 9-year period. Malignancy was the most common comorbidity, and hemodialysis and septic shock were associated with death [52]. Another study from Beijing analyzed 76 BSI episodes secondary to *S. maltophilia* between 2010 and 2018 in a tertiary care hospital, and found that risk factors for infection were solid organ transplantation, hematological malignancy, and neutropenia. Altogether, risk factors associated with death were as follows: mechanical ventilation, hemodialysis, and septic shock [53, 54].

The second most frequent clinical manifestation was catheter-related BSI (CRBSI). A study reported that removal of central venous catheter was associated with a favorable outcome in patients with *S. maltophilia* bacteremia [51]. A 10-year case-control study from 2006 through 2016 performed at a tertiary-care hospital in patients with *S. maltophilia* bacteremia, and hematologic malignancies showed a higher overall 30-day mortality rate for patients with bacteremia compared to controls (61.0 and 32.2%; $P < 0.001$) [52].

Vibrio cholerae Non-01, Non-0139

Vibrio species are known to be ubiquitously found in marine environments, while their survival is mandated by the water's temperature and salinity; the incidence of the infections increases during summer [55]. The invasive form of non-O1, non-O139 *V. cholerae* infections is mainly seen in immunocompromised hosts. The main risk factors that have been reported are as follows: hepatic cirrhosis, liver diseases, alcoholism, diabetes mellitus, and hematologic malignancies [55].

In a review of 48 patients with non-O1, non-O139 *V. cholerae* bacteremia with skin and soft tissue infections (most commonly are cellulitis and necrotizing fasciitis), these were associated with aquatic environments exposure, and at least one comorbidity such as liver disease and/or alcohol abuse [56].

Yersinia enterocolitica

The principal route of *Y. enterocolitica* infection is through contaminated food or water [57]. Although bacteremia and sepsis are rare, there are some cases associated with blood cell transfusion [58, 59].

Prevention

Hand hygiene of healthcare personnel is the most important preventive measure to avoid HAI [60]. It is ironical that transmission in the setting of appropriate hand hygiene may occur when hands become contaminated during handwashing in a sink with a contaminated aerator, faucet, or drain. This method of transmission has been reported in several outbreaks [60].

No single approach guarantees that hospital water will be safe for vulnerable patients, but a combination of engineering and hygiene measures along with clinical strategies can minimize the risk [1]. Engineering measures in the built environment include avoidance of features in plumbing systems that predispose to stagnation, and maintenance of separate cold and hot water systems until near the point of use [61]. Decorative fountains should not be placed inside healthcare facilities [30]. Clinical strategies include aggressive surveillance for nosocomial waterborne infection [1]. Infection control specialists should be quick to respond to increases in rates of known and emerging waterborne pathogens [60].

Direct aerosol transmission from water to patients (from a shower, room humidifier, cooling tower); indirect transmission from fomites that had contact with contaminated water; inappropriate use of nonsterile water for tasks that require higher measures of caution, such as care of ventilated patients and rinsing of respiratory therapy or endoscopic equipment in tap water or exposure of implanted devices to water; or transmission on the hands of healthcare personnel [3••]. All of the above represent opportunities for prevention through hospital policies, education and monitoring of healthcare personnel practices, and proper cleaning and maintenance of equipment [3••].

In patients with catheters, the optimal care for cleaning and taking care of it is essential for preventing waterborne CRBSI. Some strategies are shown in Table 2.

The delivery of drinking water to ever-increasing populations for which there are finite sources of freshwater is a common problem in middle- and low-income countries [62].

When water chlorination is not guaranteed because of diverse reasons (lack of supplies, shortage of electricity), chlorine surveillance of hospital water at different areas should be mandatory as it is an important

Table 2. Measures to prevent hospital-acquired waterborne bloodstream infection

Measures to prevent hospital-acquired waterborne bloodstream infection
* Use of occlusive dressing in any intravascular site insertion.
* Patient should not be bathed or shower himself if the occlusive dressing of a venous catheter insertion site is detached; it should be changed before bathing or showering.
* Plastic protection of the occlusive dressing intravascular site insertion while bathing.
* Surveillance of the chlorine levels of the water entering the hospital 0.5 ppm and chlorinate in case of suboptimal levels (in countries where the water is not chlorinated).
* Surveillance of the chlorine levels of the water random at different faucets within the hospital, particularly in critical care services, such as the intensive care unit or surgical theaters.
* Establish cleaning procedures for warming baths for blood components to maintain their sterility and use of sterile water to be changed in each term.
* Sterile procedures for preparation of dialysis fluid.

preventive policy of waterborne HAI [62, 63]. A number of alternatives to chlorination have been developed that are in active use in many parts of the world, but the risks associated with their by-products are even less well established than for chlorination [63]. A useful guideline for chlorine testing is water chlorination locally to maintain it at a concentration ≥ 0.5 mg/L in every point of use [62].

Conclusions

In the last two decades, the number of water-living bacteria that have been identified as causing healthcare-associated waterborne infections has expanded. No single approach guarantees that hospital water will be safe for vulnerable patients, but a combination of engineering, chlorination surveillance, hygiene measures, and clinical care strategies can minimize the risk. Microbial contamination of healthcare facility water supply is better prevented than remediated.

Compliance With Ethical Standards

Conflict of Interest
Gómez-Gómez B declares that she has no conflict of interest. Volkow-Fernández P declares that she has no conflict of interest. Cornejo-Juárez P declares that she has no conflict of interest.

Human and Animal Rights and Informed Consent
This article does not contain any studies with human or animal subjects performed by any of the authors.

Reference and Recommended Reading

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- • Of importance
- •• Of major importance

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