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Infection Control of Bacteria in Hospital Drinking Water

Mohammed Ali Hadi Al-Hokash (1) *, Mohammed Huwaydir Ali Almansour (2), Alhassan Nasser Hamad Alqurayshah (2), Ali Hamad Saleh Almunajjim (3), Saleh Ali Hadi Al-Hokash(4), Hezam Saleh Mana Alzamanan (5), Mansour Abdullah Alsaab (6)

(1) X-Ray Specialist, Chest and Fever Hospital, King Khalid Hospital, Najran, Saudi Arabia.
(2) Health Administration Specialist, Prince Sultan Centre, King Khalid Hospital, Najran, Saudi Arabia.
(3) Health Administration Specialist, Algabil PHCC, King Khalid Hospital, Najran, Saudi Arabia.
(4) Nurse, Erada Complex for Mental Health in Najran, Saudi Arabia.
(5) Pharmacist, Alguilla PHCC, Kubash General Hospital, Najran, Saudi Arabia.
(6) Pharmacist, Erada Complex for Mental Health in Najran, Saudi Arabia.

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Corresponding author*

Abstract

Introduction: Cooling towers were originally believed to be the main source of Legionella bacteria, as the US Centers for Disease Control (CDC) found that a cooling tower near a hospital with cases of Legionnaires' disease was contaminated with the bacteria. However, since this discovery, there have been few reported cases of hospital-acquired Legionnaires' disease linked to cooling towers. This review aimed to explore the interventions to control infections transmitted through drinking water in hospitals.

Methods: The review searched for published peer-reviewed literature in English from 2000 to 2022 in the Medline Embase, Aqualine, and National Guidelines Clearing House databases. The review focused on critical care units, such as neonatal, pediatric, adult intensive care, burns, organ transplant, oncology, hematology, cystic fibrosis, and renal units. The review included experimental and epidemiological study designs such as non-clinical experiments, randomized controlled trials, non-randomized controlled trials, quasi-experimental studies, before-and-after studies, prospective and retrospective cohort studies, case-control studies, and analytical cross-sectional studies.

Results: Out of 196 potentially relevant studies identified in the search, 21 were assessed for this review. Of these, 11 provided plausible evidence, while the remaining 10 provided descriptive evidence of low plausibility. The majority of the studies focused on understanding the occurrence of Pseudomonas aeruginosa outbreaks in critical care units. Most of these studies were retrospective analyses of outbreaks or short-term prospective follow-up studies in intensive care or hematology-oncology units. Only two of the studies included comparison groups.

Conclusions: the research suggests that the water and plumbing systems in healthcare units can be a source of Pseudomonas aeruginosa and legionella, a bacteria that can cause colonization or infection in patients. This is especially likely if the bacteria is able to form biofilms, which may be facilitated by certain types of plumbing materials and locations.

Keywords: Infection, Prevention, Drinking water, Bacteria, Legionella.

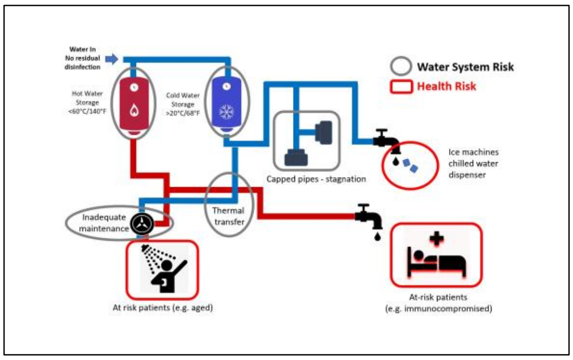
Introduction

Several investigations into outbreaks have found that environmental contamination in healthcare settings, such as ICUs and endoscopy suites, can be a significant source of antibiotic-resistant and antibiotic-susceptible P. aeruginosa infections. During these investigations, certain environmental surfaces were identified as sources of antibiotic-resistant P. aeruginosa, including tap water, sinks, plumbing systems, shower drains, faucets, wash basins, bronchoscopes, and automated endoscope preprocessors [1,2].

In the early 1980s, Tobin and Stout found a connection between the presence of Legionella pneumophila in hospital drinking water and hospital-acquired legionellosis. The first published study on disinfecting hospital drinking water using the "superheat-and-flush" method was conducted in 1983. In 1990, the first comprehensive review of disinfection methods was published, but it did not recommend a specific methodology as the best option. At that time, the drawbacks of hyperchlorination and ultraviolet light had become apparent, and copper-silver ionization was being tested as a new technology. Copper and silver have been shown to be bactericidal against Legionella and other waterborne pathogens, including Pseudomonas aeruginosa, Stenotrophomonas maltophilia, Acinetobacter baumannii, and mycobacteria [3]. Copper-silver ionization is the only disinfection method for which multiple field evaluations of effectiveness have been published in the peer-reviewed literature, and its effectiveness in eradicating Legionella has been documented in hospitals worldwide [4].

More than 300 hospitals worldwide have adopted ionization as the primary method for controlling Legionella in their water systems. The ions are typically only added to the hot water recirculation lines, so oral consumption is limited [4,5]. However, some hospitals have reported failures with ionization systems, such as in Germany and France, where a phosphate compound was added to the water system to control corrosion, which may have hindered mainly effectiveness of the ionization. There have also been a few documented cases of Legionella pneumophila developing resistance to copper-silver ions in hospitals several years after installing ionization systems, though the prevalence of this resistance is unknown. Many vendors now offer ionization systems. Chlorine dioxide has been used for water treatment in Europe since the 1940s and has also been installed in some hospitals in the United States for Legionella disinfection [6]. Chlorine dioxide is a gas in solution that is typically generated on site at the facility using chemical precursors or electrochemical generation.

A limited number of controlled studies have been conducted on the effectiveness of chlorine dioxide disinfection, such as a 30-month study in a New York hospital and the implementation of chlorine dioxide disinfection in a hospital in the UK where hospital-acquired Legionnaires' disease had occurred due to repeated failures with hyperchlorination. Additionally, cases of Legionnaires' disease caused by L. anisa are very rare [7]. Third, reactions with organic material and corrosion scale in pipes can cause the rapid conversion of chlorine dioxide to its byproducts, chlorite and chlorate, which may be harmful to consumers. Fourth, the corrosion of galvanized pipes can lead to the loss of chlorine dioxide due to its reaction with magnetite ($Fe3O4$), which may affect its effectiveness. One major challenge with using chlorine dioxide is maintaining an effective residual concentration (0.3-0.5 mg/L) throughout the drinking water system. Chlorite can cause congenital heart defects and hemolytic anemia, while chlorate is not currently regulated due to a lack of health data for setting a maximum contaminant level. The UK Drinking Water Inspectorate specifies a maximum value of 0.5 mg/L for all oxidants in drinking water, which includes the combined concentration of chlorine dioxide, chlorite, and chlorate [8]. In 2004, the US Environmental Protection Agency (EPA) mandated that any healthcare facility that adds a disinfectant to a water system serving at least 25 people is considered a public water system and must comply with the Safe Drinking Water Act and Stage in



Disinfection Byproducts Rule. This can be costly to implement, and this expense is often overlooked. Two case-control studies have suggested that hospitals in municipalities supplied with drinking water treated with monochloramine were less likely to report cases of hospital-acquired Legionnaires' disease [9]. However, the effectiveness of on-site monochloramine treatment in individual hospitals has not yet been studied over a prolonged period. Controlled evaluations of monochloramine treatment in hospitals over time have not been conducted. Cooling towers were originally believed to be the main source of Legionella bacteria, as the US Centers for Disease Control (CDC) found that a cooling tower near a hospital with cases of Legionnaires' disease was contaminated with the bacteria [10]. However, since this discovery, there have been few reported cases of hospital-acquired Legionnaires' disease linked to cooling towers. This review aimed to explore the interventions to control infections transmitted through drinking water in hospitals water system.

Methods

The review searched for published peer-reviewed literature in English from 2000 to 2022 in the Medline Embase, Aqualine, and National Guidelines Clearing House databases. The review focused on critical care units, such as neonatal, pediatric, adult intensive care, burns, organ transplant, oncology, hematology, cystic fibrosis, and renal units. The review included experimental and epidemiological study designs such as non-clinical experiments, randomized controlled trials, non-randomized controlled trials, quasi-experimental studies, before-and-after studies, prospective and retrospective cohort studies, case-control studies, and analytical cross-sectional studies. If these designs were not available, the review also considered descriptive epidemiological studies including case series, individual case reports, and descriptive cross-sectional studies. A three-step search strategy was used to identify relevant studies, and two reviewers independently assessed the titles and abstracts of the search results for relevance and methodological quality. Data from the included studies was extracted using a standardized tool and synthesized in a narrative summary. The review found seven studies that provided evidence of a link between plumbing systems acting as reservoirs for Pseudomonas aeruginosa and colonization or infection in critical care units. These studies were all prospective observational or cohort studies that used molecular methods to investigate the contribution of endogenous and exogenous transmission of P. aeruginosa to colonization or infection during endemic periods. In two of the studies, samples were taken from taps with aerators, which were regularly decontaminated. The search for relevant studies included the use of the following MESH heading and search terms: pseudomonas aeruginosa, multidrug-resistant pseudomonas aeruginosa, outbreaks, infection, healthcare-associated infection, nosocomial infection, waterborne infection, infection control, biofilms, colonization, water, tap water, water quality, water temperature, water distribution, water network, plumbing, plumbing installations, water supply, water outlets, water systems, pipes, u-bends, water fittings, water sources, respirators, ventilators, incubators, humidifiers, faucets, taps, sensor taps, electronic taps, electronic faucets, showers, aerators, rosettes, thermostatic mixer valves, basins, sinks, sink traps, point-of-use water filters, end-line filters, filters, silver ions, copper ions, ionization, ozone, ultraviolet, chlorine dioxide, chemical disinfection, monochloramine, free chlorine, thermal disinfection, thermal shock. For studies specifically focused on plumbing systems, an additional search was conducted in Aqualine.

Results and discussion

Out of 196 potentially relevant studies identified in the search, 17 were assessed for this review. Of these, 11 provided plausible evidence, while the remaining 6 provided descriptive evidence of low plausibility. The majority of the studies focused on understanding the occurrence of Pseudomonas aeruginosa outbreaks in critical care units. Most of these studies were retrospective analyses of outbreaks or short-term prospective follow-up studies in intensive care or hematology-oncology units [4-8, 11]. Only two of the studies included comparison groups. There was limited evidence available to explain the specific mode of transmission of P. aeruginosa from plumbing to patients and vice versa. Some examples cited in the studies included the use of tap water for making enteral feeds and personal care activities such as oral hygiene and patient washing, as well as the disposal of wash water and ventilator traps potentially leading to the transfer of P. aeruginosa from patients to plumbing [12].

Eleven studies were retrieved that described interventions implemented to eliminate Pseudomonas aeruginosa from plumbing systems during outbreaks. However, the poor design and lack of long-term follow-up of these studies made it difficult to determine the effectiveness of the interventions or to distinguish the effects of multiple interventions. Some studies reported that chemical treatment and increasing water temperature were effective, while others did not [13]. Two clinical studies provided plausible evidence for the effect of intervention. The introduction of 7-day filters on showers and chlorine disinfection at 0.5 mg/L was associated with a reduction in Pseudomonas species recovered from the plumbing system, and increasing the chlorination to 2.7 mg/L eliminated P. aeruginosa from the plumbing system [14,15].

The use of point-of-use filters reduced P. aeruginosa colonization by 85% and invasive infections by 56%. In another study, an outbreak of P. aeruginosa in a hematology-oncology unit was linked to the use of a whirlpool bath, and replacing the bath eliminated further outbreaks. Other measures such as contact precautions and changes to antimicrobial prescribing policies were implemented during outbreak periods, but no studies provided plausible evidence for their effectiveness. There was limited evidence available on the role of plumbing fittings, such as non-touch taps and aerators, in the transmission of P. aeruginosa [16]. Some studies suggested that these fittings could be sources of contamination, but further research is needed to confirm this. The review did not identify any studies providing plausible evidence for the effectiveness of cleaning and disinfection methods in preventing P. aeruginosa colonization and infection in critical care units [14,15]. The studies included in the review used surveillance specimens collected from patients on admission and at least weekly until discharge to identify colonization with Pseudomonas aeruginosa and sampled multiple water system outlets, including tap water, sink siphons or overflows, and sink U-bends at various intervals [12-14]. The interventions implemented to address P. aeruginosa colonization and infection in the plumbing systems included avoiding the use of water, replacing fixtures and fittings, disinfecting outlets with chlorine or hydrogen peroxide, autoclaving, increasing the temperature of the water at the outlet, system-wide chlorination at higher than normal concentrations, and installing outlet filter devices or filtered water systems. Standard infection control measures such as hand hygiene, alcohol hand disinfection, contact isolation, and antimicrobial restriction were also implemented during outbreaks. The main interventions aimed at eliminating P. aeruginosa from the plumbing systems involved replacing components of the plumbing system, using filtration devices or disinfection methods, and decontaminating water and delivery systems [17]. This included treatment of the incoming water supply with chlorine, thermal disinfection of taps, autoclaving of tap aerators, and increasing the temperature of water in taps to above 50°C. The studies also described the dismantling and mechanical cleaning of taps and aerators.

To be included in the review, the studies needed to have robust molecular typing methods and clearly reported interventions that were introduced at a defined point in an epidemic or endemic period, and if more than one intervention was used, they needed to be implemented in a stepwise manner [18]. This review found that while there is evidence to suggest that plumbing reservoirs of Pseudomonas aeruginosa can be responsible for patient colonization and infection, there is also evidence of P. aeruginosa transmission between patients involving clones that were not found in the water or plumbing systems, potentially through staff or equipment [19]. The review also found that while there is limited evidence from prospective studies during endemic periods using molecular typing and frequent surveillance of both the plumbing systems and patients, this evidence suggests that strains of P. aeruginosa found in handwash basins, showers/taps, and tap water can be a source of P. aeruginosa colonization and infection in patients in acute care units [20]. However, it is not clear how handwash basins and sinks become contaminated. The contamination appears to be limited to the distal ends of plumbing installations (tap fittings, flow straighteners, shower heads, and sink drains), rather than the entire system. Multiple strains of P. aeruginosa may be present in the water system without being linked to patient colonization or infection, but the same strain of P. aeruginosa may remain in the water system for extended periods [21]. The review notes that there is limited evidence for interventions to minimize the transmission of P. aeruginosa from potable water to patients, and that the effectiveness of interventions such as hand hygiene, alcohol gel use, and contact precautions is uncertain due to a lack of data on compliance [22]. The review also notes that the effectiveness of methods for detecting P. aeruginosa and identifying contaminated water systems as the source of P. aeruginosa in patients varies.

Conclusions

In summary, the research suggests that the water and plumbing systems in healthcare units can be a source of Pseudomonas aeruginosa and legionella, a bacteria that can cause colonization or infection in patients. This is especially likely if the bacteria is able to form biofilms, which may be facilitated by certain types of plumbing materials and locations. While there is some evidence that certain interventions, such as point-of-use filters, can be effective in eliminating P. aeruginosa from water outlets and preventing colonization or infection, more research is needed to determine the best methods for preventing or eradicating contamination in water systems and for minimizing the risk of transmission from the water system to patients. Future research should be designed prospectively and include thorough surveillance and testing of both the plumbing system and patients, as well as molecular typing of multiple colonies to identify temporal relationships between the plumbing system and patient colonization or infection.

Conflict of interests

The authors declared no conflict of interests.

References

1. Curtis, L. Prevention of hospital-acquired infections: review of non-pharmacological interventions. (2008) Journal of Hospital Infection. 69(3); 204-219.
2. O'neill, E. and Humphreys, H. Surveillance of hospital water and primary prevention of nosocomial legionellosis: what is the evidence?. (2005) Journal of Hospital Infection. 59(4); 273-279.
3. Kim, B. R., Anderson, J. E., Mueller, S. A., Gaines, W. A., & Kendall, A. M. (2002). Literature review—efficacy of various disinfectants against Legionella in water systems. Water research, 36(18), 4433-4444.
4. Hocquet, D., Muller, A., Bertrand, X. and Muller, Hocquet. What happens in hospitals does not stay in hospitals: antibiotic-resistant bacteria in hospital wastewater systems. (2016) Journal of Hospital Infection. 93(4); 395-402.
5. Exner, M., Kramer, A., Lajoie, L., Gebel, J., Engelhart, S., Doz, Priv., Hartemann, P., Greifswald, . and Germany, Vandoeuvre. Prevention and control of health care–associated waterborne infections in health care facilities. (2005) American Journal of Infection Control. 33(5); S26-S40.
6. Khan, Nadeem., Ahmed, Sirajuddin., Farooqi, Haq., Ali, Imran., Vambol, V., Changani, Fazlollah., Yousefi, Mahmood., Vambol, Sergij., Khan, Saif. and Khan, Husain. Occurrence, sources and conventional treatment techniques for various antibiotics present in hospital wastewaters: A critical review. (2020) TrAC Trends in Analytical Chemistry. 129; 115921.
7. Lin, Yusen., Stout, Janet. and Yu, Victor. Prevention of hospital-acquired legionellosis. (2011) Current Opinion in Infectious Diseases. 24(4); 350-356.

8. Lin, Yusen., Stout, Janet. and Yu, Victor. Controlling<i>Legionella</i>in Hospital Drinking Water: An Evidence-Based Review of Disinfection Methods. (2011) Infect. Control Hosp. Epidemiol. 32(2); 166-173.

9. Lin, Yusen., Stout, Janet. and Yu, Victor. Controlling<i>Legionella</i>in Hospital Drinking Water: An Evidence-Based Review of Disinfection Methods. (2011) Infect. Control Hosp. Epidemiol. 32(2); 166-173.

10. Loveday, H., Wilson, J., Kerr, K., Pitchers, R., Walker, J. and Browne, J. Association between healthcare water systems and Pseudomonas aeruginosa infections: a rapid systematic review. (2014) Journal of Hospital Infection. 86(1); 7-15.

11. and Muscarella, Lawrence. Contribution of Tap Water and Environmental Surfaces to Nosocomial Transmission of Antibiotic-Resistant <i>Pseudomonas aeruginosa</i>. (2004) Infect. Control Hosp. Epidemiol. 25(4); 342-345.

12. Decker, Brooke. and Palmore, Tara. The role of water in healthcare-associated infections. (2013) Current Opinion in Infectious Diseases. 26(4); 345-351.

13. Kizny Gordon, Alice., Mathers, Amy., Cheong, Elaine., Gottlieb, Thomas., Kotay, Shireen., Walker, A., Peto, Timothy., Crook, Derrick., Stoesser, Nicole. and Gordon, A. The Hospital Water Environment as a Reservoir for Carbapenem-Resistant Organisms Causing Hospital-Acquired Infections—A Systematic Review of the Literature. (2017) 64(10); 1435-1444.

14. Atif Nisar, Muhammad., Ross, Kirstin., Brown, Melissa., Bentham, Richard. and Whiley, Harriet. Legionella pneumophila and Protozoan Hosts: Implications for the Control of Hospital and Potable Water Systems. (2020) Pathogens. 9(4); 286.

15. Suleyman, Geehan., Alangaden, George. and Bardossy, Ana. The Role of Environmental Contamination in the Transmission of Nosocomial Pathogens and Healthcare-Associated Infections. (2018) Curr Infect Dis Rep. 20(6);

16. Rutala, William. and Weber, David. Water as a Reservoir of Nosocomial Pathogens. (1997) Infection Control and Hospital Epidemiology. 18(9); 609-616.

17. Williams, Margaret., Armbruster, Catherine., Arduino, Matthew. and Matthew, . Plumbing of hospital premises is a reservoir for opportunistically pathogenic microorganisms: a review. (2013) Biofouling. 29(2); 147-162.

18. Muraca, P. W., Victor, L. Y., & Goetz, A. (1990). Disinfection of water distribution systems for Legionella: a review of application procedures and methodologies. Infection Control & Hospital Epidemiology, 11(2), 79-88.

19. Casini, B., Buzzigoli, A., Cristina, M. L., Spagnolo, A. M., Del Giudice, P., Brusaferro, S., ... & Privitera, G. (2014). Long-term effects of hospital water network disinfection on Legionella and other waterborne bacteria in an Italian university hospital. Infection Control & Hospital Epidemiology, 35(3), 293-299.

20. Liu, Z., Stout, J. E., Tedesco, L., Boldin, M., Hwang, C., & Victor, L. Y. (1995). Efficacy of ultraviolet light in preventing Legionella colonization of a hospital water distribution system. Water Research, 29(10), 2275-2280.

21. Muchesa, P., Leifels, M., Jurzik, L., Hoorzook, K. B., Barnard, T. G., & Bartie, C. (2017). Coexistence of free-living amoebae and bacteria in selected South African hospital water distribution systems. Parasitology research, 116(1), 155-165.

22. Mouchtouri, V., Velonakis, E., & Hadjichristodoulou, C. (2007). Thermal disinfection of hotels, hospitals, and athletic venues hot water distribution systems contaminated by Legionella species. American journal of infection control, 35(9), 623-627.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