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PERSPECTIVES

Waterborne Outbreaks in Hemodialysis Patients and Infection Prevention

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Individuals treated with dialysis are at high risk for healthcare-associated infections. We conducted a literature review of outbreaks associated with water in hemodialysis during years 2011–2021 to understand the role of water as a source of infections for patients receiving hemodialysis with a focus on the risks associated with dialysis water and dialysate. For dialysis patients, water and dialysate have been a source of healthcare-associated pathogens, including nontuberculous mycobacteria and gram-negative bacilli as well as systemic reactions due to gram-negative bacilli–associated endotoxin. Lapses in infection prevention practices and dialysis water management were primarily involved in waterborne outbreaks. Dialysis clinics should adhere to recommendations regarding monitoring and levels of bacteria and endotoxin in hemodialysis water and dialysate. Since hemodialysis patients are at increased risk of healthcare-associated infections, it is important for healthcare personnel to adhere to infection prevention guidelines in hemodialysis patient care, especially hand hygiene, aseptic technique, cleaning/disinfection, and water management.

Keywords. healthcare-associated infections; hemodialysis; outbreaks; waterborne infections.

Water sources in healthcare facilities can serve as reservoirs of healthcare-associated pathogens [1, 2]. Water reservoirs including dialysis water have been associated with outbreaks in healthcare settings. Such outbreaks are a serious threat to critically ill or immunosuppressed persons, including patients undergoing hemodialysis. According to the United States Renal Data System, >490 000 people with kidney failure were treated with hemodialysis in 2018 [3]. Hemodialysis patients are at increased risk of healthcare-associated infections for the following reasons: (1) vascular access via central venous catheters (CVC), graft, or fistula with attendant risk of bloodstream infections; (2) frequent close contact with healthcare personnel and portable medical equipment increasing the risk of transmission of pathogens via direct or indirect routes; and (3) frequent exposure to dialysis systems that may be contaminated (eg, contamination of multidose medications from inappropriate use and administration; acquisition of pathogens from improperly disinfected equipment; and, less frequently, infection from contaminated water). Waterborne pathogens (ie, *Proteus mirabilis* [1.1%], *Stenotrophomonas maltophilia* [0.9%], *Burkholderia cepacia* [0.2%], *Candida parapsilosis* [0.2%], and *Ralstonia pickettii* [<0.1%]) accounted for 2.4% of 32 016 bloodstream infections in the 2014 National Healthcare Safety Network Dialysis Event Surveillance [4]. Unfortunately, waterborne outbreaks in the hemodialysis setting continue to occur [5]. In this perspective, we summarize waterborne outbreaks and infections in patients undergoing hemodialysis reported between 2011 and 2021, and highlight infection prevention strategies.

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DIALYSIS WATER AS A RESERVOIR

By its nature, hemodialysis leads to the patient's blood being separated from the dialysate by a semi-permeable membrane, which may lead to transfer of endotoxin, and less commonly bacteria, to the bloodstream. Microbial contamination in dialysis systems, including water treatment, water distribution, and machines, may occur due to lapses in appropriate disinfection, maintenance, and monitoring, thereby resulting in healthcare-associated infections due to rapid-growing nontuberculous mycobacteria and gram-negative bacteria [GNB] as a potential pathogen for hemodialysis patients [1]. Pipes and storage tanks in hemodialysis water distribution systems can serve as reservoirs of microbial contamination. GNB proliferate in water residues inside pipes and storage tanks, colonize the wet surfaces, form biofilm, and generate endotoxin.

WATERBORNE OUTBREAKS AND INFECTIONS IN HEMODIALYSIS

Examples of past outbreaks include the following. An *Acinetobacter calcoaceticus* outbreak (bacteremia and peritonitis) occurred from a water bath used to warm peritoneal fluid before dialysis [6]. An *Achromobacter xylosoxidans* epidemic of fatal infections (peritonitis and bacteremia) was associated with the deionized water from faucets of the hemodialysis system in an intensive care unit (ICU) [7]. Exposure to processed hemodialyzers in the setting of dialyzer reuse caused a *Mycobacterium chelonae* outbreak (bacteremia, soft tissue infections, and access graft infections) among dialysis patients in Louisiana, likely due to low concentration of formaldehyde in the hemodialyzers [8]. A *B cepacia* polyclonal outbreak (bacteremia) among hemodialysis patients was caused by contamination of postosmosis water and dialysates with bacterial colonization of the reverse osmosis membranes [9]. *Burkholderia cepacia* bacteremia occurred in hemodialysis patients because of inadequate cleaning and an osmosis tubing connection leak due to inadequate technical maintenance [10].

Over the last decade, waterborne outbreaks and infections in hemodialysis patients have continued to occur. We scrutinized the published articles using our literature search and selection criteria (Supplementary Materials), and clinical characteristics of waterborne outbreaks and infections in hemodialysis patients are shown in Table 1 by each category, including author, country, publication year, reservoir, organism, transmission, patient population, infection type, and prevention. We identified 11 articles reporting waterborne outbreaks and infections in hemodialysis from 9 countries from 2011 to 2021 (Table 1) [11–21]. Overall, infections impacted 154 patients, and 7 patients (4.5%) died from the infection. Bloodstream infections were reported in 9 articles (81.8%): GNB (N = 10 [90.9%]), including *Ralstonia* spp, *Elizabethkingia* spp, *S maltophilia*, *B cepacia*, *Serratia marcescens*, *Pseudomonas aeruginosa*, *Enterobacter cloacae*, and *Klebsiella pneumoniae* carbapenemase (KPC)–producing Enterobacterales.

Rapid growth of GNB can occur in supply water for hemodialysis (eg, distilled water, deionized water, reverse osmosis water, and softened water) and in dialysate, and endotoxin from those bacteria can trigger pyrogenic reactions [1]. A handwashing sink was contaminated with *Elizabethkingia meningoseptica*, presumably due to inconsistent infection prevention practices, which led to bacteremia, lower respiratory tract infection, and ventilator-associated pneumonia in patients dialyzed bedside in an ICU [16]. Several articles reported that contamination of dialysis water was involved in *Ralstonia* bacteremia [14, 18–21], demonstrating the importance of disinfection procedure and maintenance of dialysis water system. Incoming water supply (potable water) was associated with *Mycobacterium mucogenicum* bacteremia in a patient receiving home hemodialysis [12]. Contamination of dialysis water, including postosmosis points, reuse rooms, looping pipe, and dialysis machines, led to an outbreak of *S maltophilia* and *B cepacia* bacteremia in a hemodialysis clinic, possibly due to lack of proper disinfection of water system and maintenance [13].

Recently, contamination of recessed wall boxes connecting for dialysate components and effluent drain within dialysis treatment stations led to a large outbreak of GNB, including *S marcescens*, *P aeruginosa*, and *E cloacae*, in 3 hemodialysis clinics, and was associated with infection prevention deficiencies including inadequate aseptic technique during CVC care [15]. Contaminated dialysis drains and sinks were involved in KPC-producing Enterobacterales colonization, which was caused by inappropriate use of dialysis drains among continuous venovenous hemodialysis patients in an ICU [17]. Contamination of saline prime buckets and dialysis water also led to a multiclinic outbreak of *Candida tropicalis* bacteremia in hemodialysis patients, possibly due to inadequate disinfection of hemodialysis machine saline prime buckets [11]. Our review demonstrated that lapses in infection prevention practice and dialysis water management were primarily involved in these waterborne outbreaks.

INFECTION PREVENTION AGAINST WATERBORNE OUTBREAKS IN HEMODIALYSIS

Standard infection prevention methods should always be used in providing hemodialysis care. As many outbreaks are associated with transmission via the very close contact during hemodialysis (eg, contaminated hands touching contaminated sources, accessing lines, grafts, and fistulas), hand hygiene must be adhered to in order to prevent infection transmission to dialysis catheters. Reuse of dialyzers is still common in some resource-limited countries, but is rare in the United States [22]. The Centers for Disease Control and Prevention (CDC) published infection prevention recommendations specific to hemodialysis clinics and patients, as well as detailed recommendations for dialysis water quality and dialysate [1, 5], referring to the Association for the Advancement of Medical Instrumentation (AAMI) water standards (ie, preferred recommendation of allowable water total viable count <100 colony-forming units/mL per American National Standards Institute/AAMI/International Organization for Standardization 13959:2014). In the United States, the most common method of water treatment in hemodialysis is reverse osmosis along or in combination with deionization. While neither the water used to prepare dialysate nor the dialysate itself needs to be sterile, tap water cannot be used without additional treatment. Nontuberculous mycobacteria are pathogens associated with the failure to process dialysis water correctly. In addition, failure to process water for dialysis correctly may lead to pyrogenic reactions caused by lipopolysaccharide or endotoxin associated with GNB. The CDC also has recommendations for microbiological testing specific to water in dialysis

Table 1. Characteristics of Waterborne Outbreaks and Infections in Hemodialysis Patients, 2011 January–2021 July

First Author, Year, Country	Reservoir	Organism	Transmission	Patient Population	Type of Infection	No. of Cases Infected (Deceased)	Infection Prevention
Boyce [11], 2021, USA	Saline prime buckets, turbid fluid, RO product water, drains in wall boxes, RO reject water	*Candida tropicalis*	Inadequate disinfection of hemodialysis machine saline prime bucket.	Hemodialysis patients	BSI	8	Removal of saline prime bucket plates, daily disinfection of saline prime buckets by soaking in a 1:10 bleach solution and air drying before reuse, saline prime buckets with tap water after disinfection being not rinsed, educating healthcare personnel on disinfection policy and training documentation, replacement of tap water inlet hose, RO reject water hose, and dialysis hose on portable RO machines.
Dhruve [12], 2017, Canada	Incoming water supply (city water)	*Mycobacterium mucogenicum*	Cultures from dialysis sample port and RO sample port were negative, while culture from incoming water supply was positive.	Home hemodialysis patient	BSI	1	Environmental precautions with use of protective devices during bathing and showering as well as appropriate CVC care.
Diniz Rocha [13], 2020, Brazil	Dialysis water (postosmosis points, reuse rooms, looping pipe, dialysis machines)	*Stenotrophomonas maltophilia*, *Burkholderia cepacia*	Lack of proper disinfection of water system, an error in the dilution of peracetic acid, and maintenance of membrane filters beyond expiration date may have triggered biofilm formation in pipes.	Hemodialysis patients	BSI	43 (3)	Intensified disinfection of the water system with peracetic acid, replacement of dialyzers and membrane filters, halted practice of reusing dialyzers, installation of ionization purification system of dialysis water, and exchange of the entire plumbing system of the hemodialysis clinic.
Lim [14], 2017, Malaysia	Contamination crisis of municipal reservoir water	*Ralstonia mannitolilytica*	Contamination of river feeding reservoir plant supplying dialysis water to dialysis clinic and patient's house.	Dialysis patient	Infection	1	Not applicable
Novosad [15], 2019, USA	Wall boxes	GNB (eg, *Serratia marcescens*, *Pseudomonas aeruginosa*, *Enterobacter cloacae*)	Pooling and regurgitation of waste fluid at recessed wall boxes connecting dialysate components and effluent drain within dialysis treatment stations, infection control deficiencies (eg, inadequate aseptic technique during CVC care, poor hand and environmental hygiene).	Hemodialysis outpatients	BSI	58 (1)	Educating healthcare personnel on hand hygiene after touching wall boxes and improving infection prevention lapses (eg, aseptic technique during CVC care and maintenance; machine and station cleaning and disinfection) as well as utilizing wall box drain care protocol.
Ratnamani [16], 2013, India	Sink and water used for handwashing	*Elizabethkingia meningoseptica*	Contaminated handwashing sink and water as well as inconsistent infection control practices in dialysis technicians (eg, hand washing, aseptic technique).	Bedside hemodialysis patients on mechanical ventilation in ICU	Bacteremia, LRTI, VAP	8 (2)	Not applicable
Ross [17], 2019, Germany	Dialysis drains and sinks	KPC-producing Enterobacterales	Inappropriate use of dialysis drains installed near patients' head and directly besides infusion systems.	Continuous venovenous hemodialysis patients in ICU	Colonization	5	To avoid transfer of infection from dialysis drains to patients, drain use was discontinued. Single use ultrafiltrate bags were utilized and were disposed of directly into garbage. Dialysis and sink drains were disinfected using hypochlorite, and hand hygiene training of healthcare personnel was conducted. Patient rooms were cleaned with high concentrations of oxygen-producing disinfectant and were disinfected with hydrogen peroxide.

Table 1. Continued

First Author, Year, Country	Reservoir	Organism	Transmission	Patient Population	Type of Infection	No. of Cases Infected (Deceased)	Infection Prevention
Said [18], 2020, South Africa	Dialysis water	*Ralstonia mannitolilytica*	Dialysis water system was faulty. RO pump was visibly dysfunctional with leaks. Dialysis water was likely contaminated at this point. Maintenance of dialysis water system was lacking with inadequate service records and service contracts.	Hemodialysis patients	BSI	16 (1)	Piping in dialysis water system changed, RO pump repaired, maintenance of dialysis water system reinstituted.
Shankar [19], 2018, India	Sterile water	*Ralstonia mannitolilytica*	Contaminated sterile water.	Maintenance hemodialysis patients	BSI, infective endocarditis	5 (0)	Sterile water in use discarded, water treatment with shock chlorination and room disinfection implemented.
Tejera [20], 2016, Uruguay	Dialysis water	*Ralstonia pickettii*	Contaminated water used in hemodialysis was transmitted to patients during dialysis procedure.	Hemodialysis patients	BSI	2	Not applicable
Thet [21], 2019, Brunei Darussalam	Treated RO water	*Ralstonia pickettii*, *Stenotrophomonas maltophilia*	Possible contamination via polluted filters and usage of reprocessed dialyzers.	Hemodialysis patients	Vascular catheter infection	7	Sterilization procedures intensified, replacement of old, decrepit components of water treatment system, temporary cessation of dialyzer reuse practice.

Abbreviations: BSI, bloodstream infection; CVC, central venous catheter; GNB, gram-negative bacteria; ICU, intensive care unit; KPC, *Klebsiella pneumoniae* carbapenemase; LRTI, lower respiratory tract infection; RO, reverse osmosis; VAP, ventilator-associated pneumonia.

settings [5]. Adherence to current guidelines may substantially lower the risk of infections among dialysis patients. To ensure patient safety and avoid waterborne outbreaks, our review highlights the importance of adherence to infection prevention practices in hemodialysis patient care, especially hand hygiene, aseptic technique, cleaning, and disinfection of the dialysis environment, and management of water used in dialysis.

Supplementary Data

Supplementary materials are available at *Open Forum Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

Notes

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