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Evaluation and control of microbial and chemical contamination in dialysis water plants of Italian nephrology wards

M. Totaro[a], B. Casini[a], P. Valentini[a], M. Miccoli[b], S. Giorgi[a], A. Porretta[a], G. Privitera[a], P.L. Lopalco[a], A. Baggiani[a,*]

[a] Department of Translational Research and New Technologies in Medicine and Surgery, University of Pisa, Pisa, Italy
[b] Department of Clinical and Experimental Medicine, University of Pisa, Pisa, Italy

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S U M M A R Y

Background: Patients receiving haemodialysis are exposed to a large volume of dialysis fluid. The Italian Society of Nephrology (ISN) has published guidelines and microbial quality standards on dialysis water (DW) and solutions to ensure patient safety.

Aim: To identify microbial and chemical hazards, and evaluate the quality of disinfection treatment in DW plants.

Methods: In 2015 and 2016, water networks and DW plants (closed loop and online monitors) of nine dialysis wards of Italian hospitals, hosting 162 dialysis beds overall, were sampled on a monthly basis to determine the parameters provided by ISN guidelines. Chlorinated drinking water was desalinated by reverse osmosis and distributed to the closed loop which feeds all online monitors. Disinfection with peracetic acid was performed in all DW plants on a monthly basis.

Findings: Over the 24-month study period, seven out of nine DW plants (78%) recorded negative results for all investigated parameters. Closed loop contamination with *Burkholderia cepacia* was detected in a DW plant from January 2015 to March 2015. *Pseudomonas aeruginosa* was isolated from March 2016 to May 2016 in the closed loop of another DW plant. These microbial contaminations were eradicated by shock disinfection with sodium hypochlorite and peracetic acid, followed by water flushing.

Conclusion: These results highlight the importance of chemical and physical methods of DW disinfection. The maintenance of control measures in water plants hosted in dialysis wards ensures a microbial risk reduction for all dialysis patients.

Introduction

Over the last few years, the number of patients receiving haemodialysis has increased worldwide, especially in the USA, Japan, China and some European countries, including Italy [1,2]. All patients undergoing chronic renal dialysis are exposed, across a dialysis membrane, to 400–600 L of water for

* Corresponding author. Address: Department of Translational Research and New Technologies in Medicine and Surgery, University of Pisa, Pisa, Italy. Tel.: +39 050 2213583; fax: +39 050 2213588.
E-mail address: angelo.baggiani@med.unipi.it (A. Baggiani).

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blood depuration every week [3,4]. Haemodialysis patients often have additional comorbidities such as cardiovascular disease, hypertension and diabetes, that make them more vulnerable to adverse outcomes [5,6]; therefore, high-quality dialysis water (DW) is needed to ensure their health. Nevertheless, the risk of chemical and bacterial contamination of DW is often underestimated. Renal services in hospitals, as well as home dialysis treatments, frequently derive their water supply from the municipal water distribution network [7,8]. European regulations state that drinking water must not contain pathogens or high concentrations of chemical products that would threaten public health [9]. In hospital settings, opportunistic pathogens may grow in water systems and in medical devices that use water, such as DW plants and dialysis units [10].

A number of Gram-negative waterborne pathogens, such as *Escherichia coli*, *Pseudomonas aeruginosa*, *Acinetobacter baumanni* and *Burkholderia cepacia*, and some fungi and free-living protozoa may colonize dialysis devices in nephrology dialysis wards (NDWs). These micro-organisms may persist in biofilm, and may be resistant to chemical disinfectants [11–14].

Furthermore, Gram-negative bacterial endotoxins are heat-stable lipopolysaccharides which can induce the production of pro-inflammatory cytokines, causing acute symptoms and various dialysis-related complications [8,15].

Moreover, chemical contaminants such as nitrate, calcium, sulphate and chloramines cause well-defined acute or chronic syndromes (e.g. cardiac problems, anaemia, bone diseases) in haemodialysis patients [16,17].

To minimize the microbial risk, a range of preventive strategies are needed to control bacteria and biofilm growth in DW plants, including the use of chemical products, such as chlorine dioxide [8], ozone [18] and peracetic acid with and without hydrogen peroxide [19], or physical disinfection methods such as ultraviolet radiation [20].

The European Pharmacopoeia and Italian Society of Nephrology (ISN) [21] have recommended a wide range of control measures to ensure the high quality of haemodialysis fluids. Drinking water may be pretreated with chlorination in addition to pre-filtration following by softening, dechlorination and reverse osmosis treatment. Reverse osmosis systems use pressure to force a solution through a membrane, retaining the solute on one side and allowing the pure solvent to pass to the other side. Desalinated water may be transported through a loop distribution system within a dialysis centre where it is used in the preparation of the final dialysate concentrates [5,8].

The purpose of this study was to evaluate the quality of DW plants in NDWs in Tuscan hospitals in Italy, and to assess the chemical and microbiological contamination of DW according to the requirements of the ISN guidelines.

Methods

Setting, DW plants and disinfection

Environmental surveillance was performed over a two-year period from January 2015 to December 2016 in nine NDWs of Tuscan hospitals. NDWs had between eight and 30 dialysis units, giving a total of 162 stations.

In all hospitals, municipal drinking water was pretreated with a continuous chlorination system (chlorine dioxide 0.2 mg/L), followed by pre-filtration with 20–25-μm cartridge filters to remove organic and inorganic materials from the water. Calcium and magnesium ions were removed by two softeners with 'food-grade' resins. Two carbon filters were installed to dechlorinate water before it was micro-filtered with 5-μm cartridge filters. Pretreated water was then desalinated with a double reverse osmosis system before being distributed to the closed loop plants that feed all online monitors. A schematic diagram of a typical DW plant is shown in Figure 1.

Six out of nine (67%) distribution systems were made of American Iron and Steel Institute (AISI) type 316 stainless steel, two (22%) were made with polyvinylidene fluoride, and one (11%) was made of cross-linked polyethylene. All DW plants had a single loop distribution system (Table I).

Routine monthly disinfection with peracetic acid (0.5%) was used in all DW plants, and shock disinfection was only applied in response to microbial contamination of DW. Shock treatment programmes consisted of three fortnightly disinfection rounds

Table I
Number of dialysis stations and materials used in each dialysis water (DW) plant in nine Italian nephrology dialysis wards (NDWs)

NDWs ($N = 9$)	Number of dialysis stations ($N = 162$)	DW plant material
NDW 1	30	AISI type 316 stainless steel
NDW 2	30	AISI type 316 stainless steel
NDW 3	20	AISI type 316 stainless steel
NDW 4	8	Polyvinylidene fluoride
NDW 5	8	AISI type 316 stainless steel
NDW 6	6	Polyvinylidene fluoride
NDW 7	30	AISI type 316 stainless steel
NDW 8	15	Cross-linked polyethylene
NDW 9	15	AISI type 316 stainless steel

AISI, American Iron and Steel Institute.

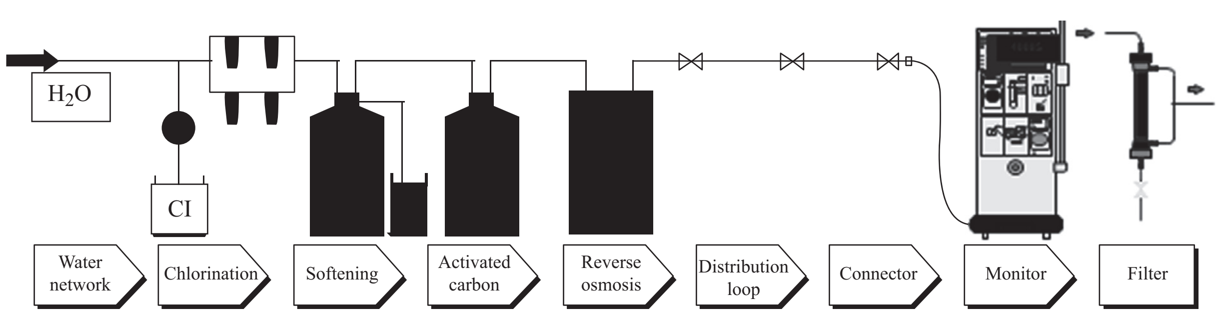

Figure 1. Schematic diagram of a typical dialysis water plant.