Efficacy of new point-of-use water filter for preventing exposure to *Legionella* and waterborne bacteria

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Background: *Legionella* species cause health care-acquired infections in which immunocompromised patients are disproportionately affected. Epidemiologic studies have demonstrated that point-of-use water fixtures are the reservoirs for these infections. The current approach to prevention is system-wide chemical disinfection of the hospital water system. These methods affect both low-risk and high-risk areas. A more effective approach to prevention may be a targeted approach aimed at protecting high-risk patients. One option is the application of a physical barrier (filter) at the point-of-use water fixture.
Objectives: To evaluate the ability of point-of-use filters to eliminate *Legionella* and other pathogens from water.
Methods: One hundred twenty–milliliter hot water samples were collected from 7 faucets (4 with filters and 3 without) immediately and after a 1-minute flush. Samples were collected every 2 or 3 days for 1 week. This cycle was repeated for 12 weeks. Samples were cultured for *Legionella*, total heterotrophic plate count (HPC) bacteria, and *Mycobacterium* species.
Results: Five hundred ninety-four samples were collected over 12 cycles. No *Legionella* or *Mycobacterium* were isolated from the faucets with filters between T = 0 and T = 8 days. The mean concentration of *L pneumophila* and *Mycobacterium* from the control faucets was 104.5 CFU/mL and 0.44 CFU/mL, respectively. The filters achieved a greater than 99% reduction in HPC bacteria in the immediate and postflush samples.
Conclusions: Point-of-use filters completely eliminated *L pneumophila* and *Mycobacterium* from hot water samples. These filter units could prevent exposure of high-risk patients to waterborne pathogens. (Am J Infect Control 2005;33:S20-5.)

Hospital water distribution systems have been shown to be a major source of health care-acquired infections. More specifically, they serve as a reservoir for waterborne pathogens such as *Legionella* species, *Pseudomonas aeruginosa*, *Stenotrophomonas maltophilia*, *Acinetobacter* species, *Mycobacteria* species, and fungi.[1-5] Sensitive subpopulations of patients with immunosuppressive conditions such as advanced age, cancer, leukemia, HIV infection, diabetes, and transplantation are at the greatest risk of infection with these organisms.[3] The mortality for these health care-acquired infections is also higher among these patients. For example, the mortality for health care-acquired Legionnaires' disease is estimated to be approximately 40%, roughly double the mortality seen for community-acquired cases.[6] Patients that are housed in high-risk areas such as bone marrow transplant units, solid organ transplant units, and hematology/oncology units are at particularly high risk.[7] These individuals may require a higher standard of care, including purification of the water used in their care.[8,9]

Hospital water can be treated by various disinfection methods such as superheat and flush, copper silver ionization, hyperchlorination, chlorine dioxide, and ultraviolet light to reduce or eliminate *Legionella*.[10] Despite such disinfection efforts, the water may still contain low concentrations of harmful bacteria that can cause infections in severely immunocompromised patients.[9,11]

Point-of-use water filters could be used to eliminate *Legionella* and other pathogenic bacteria found in water. The filters can be attached to individual faucets and showers used by high-risk patients. A recommendation for their use cannot be made until a systematic and scientific evaluation of the efficacy of these point-of-use filters has been performed.[12] Therefore, the objective of this study was to determine the efficacy of point-of-use water filters in removing waterborne bacteria (*Legionella*, *Mycobacterium*, and gram-negative nonfermenting bacteria).

METHODS

Point-of-Use Water Filter

The water filter is a sterile disposable point-of-use water filter that contains Pall Nylon 6.6 Posidyne filter membrane rated and validated at 0.2 μm (Pall-Aquasafe

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Water Filter, Pall Corp. Pall Medical, Ann Arbor, MI) (Fig 1). According to the manufacturer's instructions, ''the filter is to be used for a maximum of 7 days following the initial installation and must be replaced after this time.'' The filter provides a barrier for particles greater than 0.2 micrometers in size and is attached to the faucet by using a quick connect adaptor. This adaptor allows for quick attachment or removal of the filter. If the filter is removed and not replaced, there is no water flow through the faucet. The filters were in place for a total of 12 weeks from September 2003 to January 2004.

Location

A 3-story hospital administrative building was the site of this evaluation. We previously established that this building was colonized with *Legionella*, *Mycobacteria* species, and heterotropic plate count (HPC) bacteria. Hot water from the control faucets yielded a mean concentration of 108.2 CFU/mL *Legionella pneumophila*, serogroup 1; 13,144 CFU/mL total heterotrophic plate count (HPC) bacteria; and 0.4 CFU/mL *M gordonae* from September 2002 through January 2003, a year prior to the point-of-use filter evaluation. This data established the baseline colonization status for this building. During the filter evaluation, 7 sinks were available for study. Water samples were collected and cultured for bacteria every 2 days for 1 week × 12 weeks (12 cycles). The filters were also challenged to a 14-day test cycle twice during the evaluation period.

Sample Collection

One hundred twenty–milliliter hot water samples were collected from each faucet in sterile specimen bottles. The hot water temperature was 40°C to 45°C. One hot water sample was collected immediately after opening the valve (immediate sample), and a second sample was collected after a 1-minute flush (post-sample). After the initial sampling, the water filter was attached to 4 of the sink faucets, following the manufacturer's installation directions. Filters were changed weekly (1 test cycle). Two test cycles had a duration of 2 weeks. Sampling was repeated until 12 cycles had been completed. At the end of each cycle, immediate and postflush samples for the last sample day were obtained, and then the filter was changed. Because the water had already been running, we did not collect a postflush sample for the newly installed filters at T = 0. Four faucets were equipped with filters (Fig 1), and 3 faucets had no filters attached and represented the ''Control'' faucets. A total of 594 water samples was collected over the 12 test cycles.

Fig 1. Faucet with point-of-use water filter attached to the outlet.

Bacterial Monitoring

All cultures were performed in duplicate. Water samples were plated directly (0.1 mL per plate) and after concentration of 100 mL of the sample through a 0.2-μm, 47-mm polycarbonate filter. The filter was resuspended in 10 mL of the original sample, and 0.1 mL of the sample was plated. Total HPC bacteria were monitored using R2A media (Difco; Becton Dickinson Microbiology Systems, Sparks, MD). Plates were placed in a humidified 30°C incubator and were read after 5 days incubation. *Legionella pneumophila* was monitored using buffered charcoal yeast extract agar (BCYE) and DGVP selective agar media as previously described.[13] These plates were incubated at 35°C to 37°C in a humidified incubator and were held for 5 to 7 days. Colonies morphologically consistent with *Legionella* species were definitively identified by direct fluorescent antibody staining (Monoclonal Technologies, Alpharetta, GA).[14] 7H10 agar was used to enumerate *Mycobacterium* species (Difco; Becton Dickinson Microbiology Systems). Colonies that were acid-fast positive were definitively identified as *Mycobacterium* using the Gen-Probe AccuProbe Culture Identification Test (Gen-Probe, San Diego, CA). *Mycobacterium* cultures were performed only at the beginning and end of a cycle because of the requirement for 6-week incubation. Plates were incubated at 35°C to 37°C in a humidified incubator, with 5% CO_2 added for the *Mycobacterium* cultures.

Statistical Analysis

An ANOVA was used to compare bacterial counts between filtered and nonfiltered samples. The model was blocked by day of culture. Stat version 7.0 for

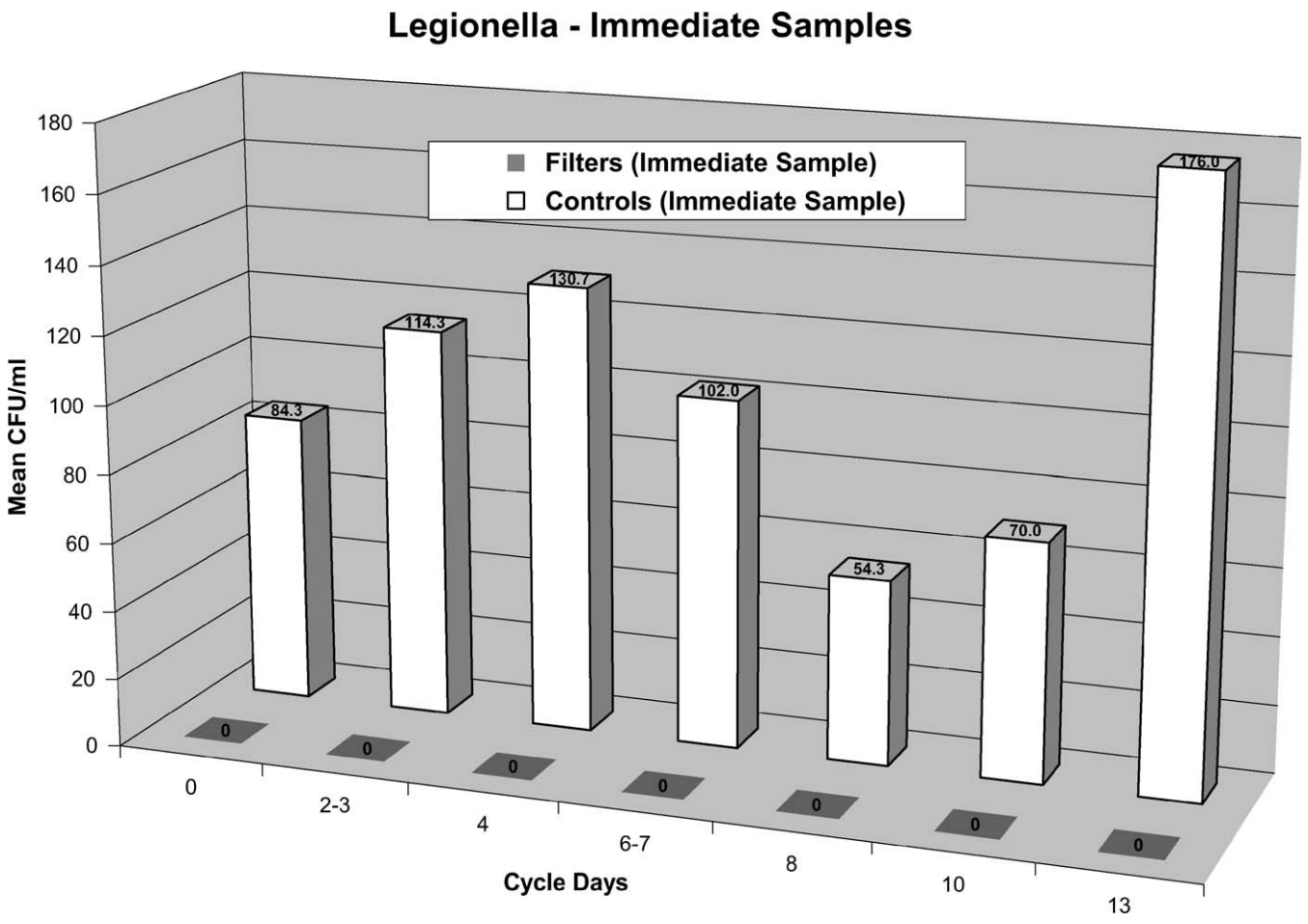

Fig 2. Recovery of *Legionella pneumophlia* (mean cfu/mL) from faucets with and without (controls) point-of-use filters through 13 days of use. Water samples were collected immediately after opening the faucet valve (immediate sample).

Windows was used for analysis (Stat Corp., College Station, TX).

RESULTS

A total of 594 water samples was tested from the 7 faucets. The number of times that water samples were collected from the faucets equipped with the filters were as follows: 13 times on day 0, 12 times on days 2 and 3, 6 times on day 4, 9 times on days 6 and 7, 3 times on day 8, 1 time on day 10, and 2 times on day 14. Control faucets were sampled on the same schedule. All 594 samples were tested for *Legionella* and HPC bacteria. The number of samples tested for *Mycobacterium* was 230.

Immediate Water Samples

There was a significant decrease in the mean concentration of *L pneumophila* recovered from the faucets with point-of-use filters compared with the control faucets through 7 days of use (0 CFU/mL vs 104.5 CFU/mL, respectively [$P < .001$]). In addition, samples collected from the point-of-use filter faucets after 10 and 13 days were also negative (Table 1 and Fig 2). There was also a significant decrease in the mean concentration of total HPC bacteria from the faucets with the point-of-use filters compared with the control faucets through 7 days of use (18.8 CFU/mL vs 60,100 CFU/mL, respectively [$P < .001$]).

Mycobacterium gordonae was isolated from 10.3% (4/39) of the immediate water samples from the control faucets on 4 occasions during the testing, with a mean concentration of 2.5 CFU/mL. No *M gordonae* was isolated from the faucets with point-of-use filters. The difference in isolation between filtered and nonfiltered water was significant at $P < .02$.

Postflush Samples

L pneumophila was recovered from water obtained from a faucet with a point-of-use filter only once. The

Table 1. Mean concentration of *Legionella pneumophila* and total heterotrophic plate count (HPC) bacteria in water samples collected from faucets with and without point-of-use filters

Faucet location (room number)		Mean *Legionella* concentration (CFU/mL) by sample day							Mean HPC bacteria × 10^3 (CFU/mL) by sample day						
Controls (immediate sample)	Day	0	2-3	4	6-7	8	10	13	0	2-3	4	6-7	8	10	13
BA 103		72.0	149.0	197.0	124.0	73.0	60.0	120.0	25.6	42.4	30.5	44.5	57.6	73.6	144.0
1A 104		94.0	128.0	92.0	133.0	70.0	100.0	365.0	36.9	50.3	27.7	39.8	76.5	83.2	131.2
2A 102A		87.0	66.0	103.0	49.0	20.0	50.0	43.0	24.7	33.1	35.3	39.7	52.2	97.6	115.2
	Mean	84.3	114	131	102	54	70	176	29.1	41.9	31.2	41.3	62.1	84.8	130.1
Filters (immediate sample)	Day	0	2-3	4	6-7	8	10	13	0	2-3	4	6-7	8	10	13
BA 105		0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5
1A 102		0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	2.6	8.4
2A 102		0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.6	1.8
2A 104		0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.1	26.4
	Mean	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.8	9.5
Controls (postsample)	Day	0	2-3	4	6-7	8	10	13	0	2-3	4	6-7	8	10	13
BA 103		74.0	98.0	63.0	63.0	60.0	100.0	90.0	1.0	1.0	1.5	1.7	1.1	2.1	1.0
1A 104		46.0	97.0	42.0	78.0	57.0	50.0	60.0	0.8	1.4	2.0	1.4	1.0	6.7	1.0
2A 105A		100.0	91.0	53.0	85.0	70.0	70.0	65.0	1.2	1.2	2.0	2.4	1.3	2.4	1.9
	Mean	73.3	95.3	52.7	75.3	62.3	73.3	71.7	1.0	1.2	1.8	1.8	1.1	3.7	1.3
Filters (postSample)	Day	0	2-3	4	6-7	8	10	13	0	2-3	4	6-7	8	10	13
BA 105		Not	0	0	0	0	0	0	Not	0.0	0.0	0.0	0.0	0.0	0.1
1A 102		Done	0	0	0	0	0	0	Done	0.0	0.0	0.0	0.0	0.0	0.8
2A 102			0	0	0	0	5	0		0.0	0.0	0.0	0.0	0.0	0.2
2A 104			0	0	0	0	0	0		0.0	0.0	0.0	0.1	0.0	3.3
	Mean		0	0	0	0	1	0		0	0	0	0.025	0	1.1

HPC, heterotrophic plate count.

concentration was 5 CFU/mL in a postflush sample collected on day 10 from 1 faucet (Table 1). Otherwise, no *Legionella* was detected in water samples from the point-of-use filters, compared with a mean concentration of 72.0 CFU/mL for the control faucets ($P < .001$).

There was a significant reduction in total HPC bacteria isolated from point-of-use filter faucets versus the control faucets through 7 days of use (0 CFU/mL vs 1700 CFU/mL, respectively [$P < .001$]). No *Mycobacterium* species were isolated from the postflush water samples from either the control faucets or point-of-use filter faucets.

DISCUSSION

Certain patient populations may benefit from the exclusive use of water that meets a higher standard for microbiologic quality than normal tap water. This is due to their increased risk of infection if exposed to even small concentrations of opportunistic waterborne pathogens.[9] These patients may be housed in burn units, hematology-oncology units, transplant units, and neonatal intensive care units. Infections from exposure to water contaminated with *Pseudomonas aeruginosa*, *Acinetobacter* species, *Stenotrophomonas maltophilia*, *Mycobacterium* species, *Chryseomonas*, and *Legionella* species have been reported in such immunocompromised patients.[1-5]

Given the established predilection for Legionnaires' disease in transplant recipients, it would be prudent for all hospitals specializing in transplantation to culture their water distribution system for *Legionella*. The Centers for Disease Control and Prevention (CDC) recommends that hospitals with solid organ and hematopoietic stem cell transplantation programs perform periodic culturing for *Legionella* in the potable water supply of the transplantation unit as part of a comprehensive strategy to prevent hospital-acquired Legionnaires' disease.[15,16] We recommend a standardized approach, as directed by the Allegheny County (Pittsburgh) Health Department Guidelines and by the State of Maryland Department of Health (guidelines are available on www.legionella.org).[17] These guidelines recommend that hospitals routinely perform environmental surveillance for *Legionella* and consider disinfection of the water supply if the water system is heavily colonized with *Legionella*.[1,3,11,18,19] Minimizing the risk of health care-acquired Legionnaires' disease has been accomplished by reducing the level of *Legionella* throughout the hospital water system.[12]

Systemic disinfection methods significantly reduce the risk of health care-acquired Legionnaires' disease.[10] These methods include continuous or intermittent elevated hot water temperatures, continuous or intermittent hyperchlorination, installation of copper-silver ionization or chlorine dioxide generating systems. These disinfection methods inject biocides into the hospital water system. Some of the chemicals are regulated by the Environmental Protection Agency (EPA) because of potential health risks.[20] Rather than treat the entire water system, perhaps a more targeted approach to prevention may be successful in some health care institutions. One limitation of systemic disinfection methods is that they cannot render a complex water distribution system sterile.[4,18] The end result may be that severely immunocompromised patients are still at risk of infection because of exposure to low concentrations of *Legionella* and other waterborne pathogens.[21]

Point-of-use filters have the potential to be an absolute barrier between the high-risk patient and *Legionella* or other waterborne pathogens. Bacterial filters have been used in intensive care units (ICU) in Germany and are currently being used in hospitals in Utah and Chicago to prevent exposure of immunocompromised patients to *Legionella* (Stout, personal communication, 2004).[22] We found that point-of-use water filters completely eliminated *Legionella pneumophila* and *Mycobacterium* species from water samples through 8 days of use and yielded a >99% reduction in total HPC bacteria through 7 days of use. The microbiologic quality of tap water was significantly improved with the use of point-of-use filters.

We have proposed that any new disinfection methods undergo a standardized evaluation with the following steps: (1) demonstrated efficacy in vitro, (2) anecdotal experience of efficacy in individual hospitals, (3) controlled studies of prolonged duration of efficacy in preventing cases of health care-acquired infections, and (4) confirmatory reports from multiple hospitals with prolonged duration of follow-up (validation step).[12] The in vitro efficacy of the point-of-use filters was validated by the manufacturer according to industry standard laboratory microbial challenge tests for 0.2-μm sterilizing grade filters. These tests were performed using *Brevundimonas diminuta* at $>10^7$ cfu/cm^2.[23] Our study validates the efficacy of the filters in eliminating *L pneumophila* and other waterborne bacteria in an individual hospital. Given these successful results, controlled studies of prolonged duration are now warranted.

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