Abbreviated duration of superheat-and-flush and disinfection of taps for *Legionella* disinfection: Lessons learned from failure

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One medical center in southern Taiwan faced an outbreak of nosocomial Legionnaires' disease; a total of 81 suspected cases were detected during an 8-month period. Baseline environmental surveillance showed that 80% of the distal sites in intensive care units (ICUs) were positive for *Legionella pneumophila*. Superheat-and-flush was selected for hospital water supply disinfection because it required no special equipment, and it can be initiated expeditiously. We conducted 2 episodes of superheat-and-flush based on the published recommendations from the Department of Health, Taiwan; US Centers for Disease Control and Prevention; and American Society of Heating, Refrigerating, and Air-Conditioning Engineers. Both flushes failed to control colonization of Legionella in the hospital water supply. The rate of distal sites positive for Legionella in wards and ICUs was 14% and 66%, respectively, 10 days after the second flush. The effect of replacement of faucets and showerheads in ICUs appeared to be insignificant in colonization of Legionella. The application of superheat-and-flush for flush duration of 5 minutes was ineffective. Superheat-and-flush may not be economic for a large medical center because it could be costly and labor intensive. (Am J Infect Control 2005;33:606-10.)

Sporadic cases of nosocomial Legionnaires' disease had been reported in Taiwan,[1,2] but no reports of outbreaks of nosocomial Legionnaires' disease have been documented. In the year 2000, a medical center in southern Taiwan faced the biggest nosocomial Legionnaires' disease outbreak ever reported. Thirty-three definite and probable cases of nosocomial Legionnaires' disease were diagnosed from January 2000 to April 2000. A total of 81 suspected cases were detected during an 8-month period. Baseline environmental surveillance showed that 80% of the distal sites in intensive care units (ICUs) were positive for *Legionella pneumophila*. The hospital management was under tremendous pressure. The director decided to take immediate action to halt the outbreak.

In searching for a disinfection control measure, superheat-and-flush was selected over hyperchlorination because it required no special equipment, and it can be initiated expeditiously, ideal for an outbreak situation.[3] However, no superheat-and-flush procedure had ever been implemented in Taiwan. The only reference available from the Taiwan health authority, a Department of Health report, recommended flushing the distal sites with 60°C hot water for 2 to 5 minutes once a day for 7 days if the hospital hot water system was contaminated with *Legionella pneumophila*.[4] The US Centers for Disease Control and Prevention (CDC) also recommended >5 minutes superheat-and-flush for disinfecting the hospital water distribution system.[5] In addition, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) suggested cleaning the taps (faucets and showerheads) with heat or replacing the taps with brand new ones.[6] We based our disinfection plan on these 3 authoritative bodies and initiated 2 superheat-and-flush episodes during March 2000 and July 2000.

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METHODS

Study hospital

The study hospital was a 1070-bed tertiary medical center in southern Taiwan. There were 4 wings in the main patient building (wings 1, 2, 3, and 5). Each wing had 10-story patient wards and basements (B1 and B2). The hot water was heated using steam heat exchangers. The hot water temperature at the storage tank was set at 75°C.

The distal sites decontaminated in this study included the following: (1) 533 restrooms in 27 patient wards; (2) 21 bathrooms in physician's apartment rooms; and (3) 62 basins in 9 ICUs. There were a total of 1241 showerheads and faucets to be disinfected in both superheat-and-flush episodes.

Hospital-acquired Legionnaires' disease definition

Case patients were identified from review of infection control and clinical microbiology laboratory records. A definite case was defined as a patient with pneumonia by radiologic confirmation and by at least one of the following: (1) positive culture from sputum; (2) positive urine antigen by ELISA for detection of *L pneumophila* serogroup 1; (3) positive staining of respiratory secretions with direct fluorescent antibody; (4) antibody titers with greater or equal to 4-fold rise for serum in acute and convalescent phase and with at least 1 titer $\geq$1:128; and presumptive cases, if at least 1 antibody titer (single or serial) was $\geq$1:1024 but without 4-fold rise and in association with pneumonia.

First superheat-and-flush episode

The first superheat-and-flush was performed from March 14 to May 12, 2000. All distal sites to be disinfected in the first episode were divided into 8 sections. The duration of the first episode of superheat-and-flush was 8 weeks (1 section/wk). Disinfection procedure was administrated at each site of the section once a day for 5 days (Monday-Friday). The disinfection procedure was as follows: (1) removal of the faucet aerators and showerheads at the distal sites; (2) flushing of the distal sites with cold water for 2 minutes; (3) flushing of the distal sites with hot water at 60°C or higher for 5 minutes. The water temperature before and after flush and the flushing duration were documented. Water samples were taken at the sites before the flush and 10 days after the flush.

Disinfecting faucets and showerheads

During the first superheat-and-flush, all faucets and showerheads were unscrewed and soaked in a chlorine solution at concentration of 10 ppm for 10 minutes. After chlorination, these taps were rinsed, air-dried, and restored back to the distal site that was just flushed. In addition, all faucets and showerheads with connection tubing in ICUs were replaced with brand new ones.

Second superheat-and-flush episode

The second superheat-and-flush was performed June 30 and July 1, 2000. All distal sites in patient wards and ICUs were flushed consecutively within a 48-hour period. The hot water tank temperature was set at 89°C. To simplify the documentation process, we revised the procedure, and each site was flushed as follows: (1) turned on the hot tap and measured the running water temperature; (2) started the timer for 5 minutes as soon as the hot water temperature exceeded 60°C; (3) continued to monitor the hot water temperature using thermometer; (4) check the water temperature at the end of 5 minutes if the temperature still exceeded 60°C. If the criteria in the above steps (2) to (4) were fulfilled, the technicians put a check mark on the record sheet of that particular site.

Sample collection, process, and analysis

Sampling sites were selected randomly. Potable water samples were obtained as follows: (1) a sterile swab was inserted into faucet outlets and rotated against the interior surface 2 times to dislodge the sediment, (2) a 50-mL flushed water sample was collected, and (3) 0.5 mL distilled water was added to the swab samples. Water samples were centrifuged at 4000*g* for 30 minutes. One milliliter of the centrifuged water specimen and the swab sample were treated with 2 mL of 0.2 mol/L HCL-KCL buffer (pH 2.0) for 3 to 4 minutes; 0.1 mL of the acid-treated sample was directly inoculated onto buffered charcoal yeast extract (BCYE) culture media and selective media containing dyes, glycine, vancomycin, and polymxin B (DGVP). Culture media were incubated at 37°C in a humidified incubator for 3 to 7 days.[7] Suspected colonies were subcultured in parallel onto BCYE and blood agar plate (BAP) media. Colonies that grew after subculture on BCYE medium but not on BAP were tested with a latex test (Oxoid, Basingstoke, United Kingdom) and confirmed using a DFA monoclonal antibody (Monoclonal Technologies, Inc., Alpharetta, GA). Isolates categorized as *L pneumophila* serogroup 1 on the latex test were confirmed using a polyvalent *L pneumophila* serogroup 1 antibody; *L pneumophila* serogroup 2-14 was confirmed with a monovalent *L pneumophila* serogroup 1-6 antibody; and Legionella-like organisms were tested with monovalent *L micdadei* antibody.

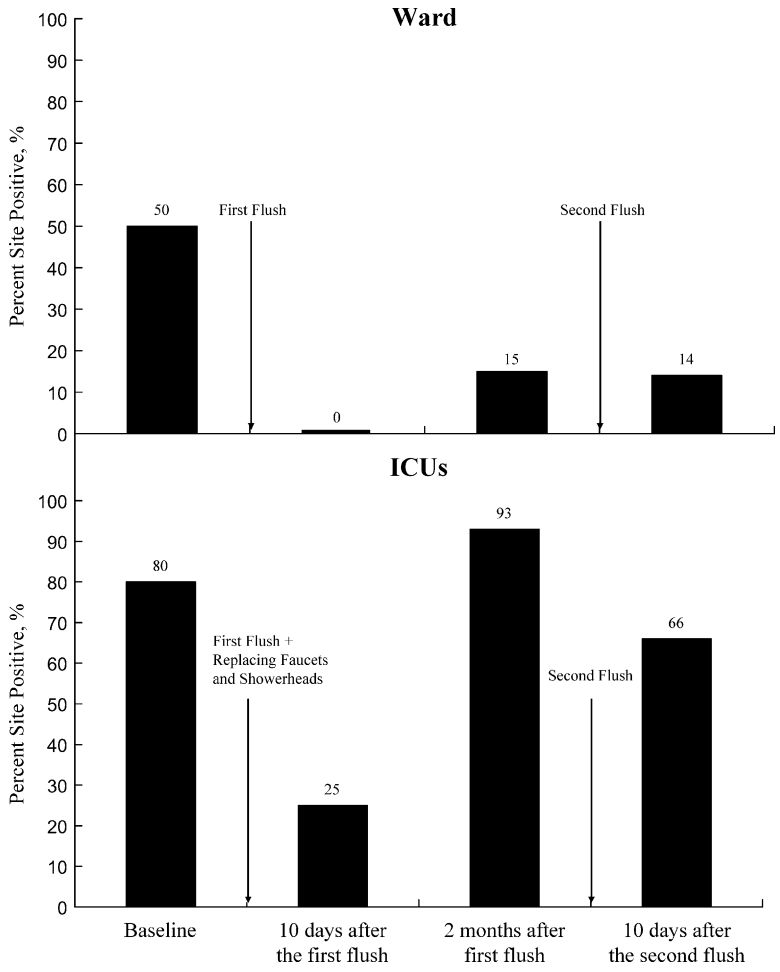

Fig 1. Short duration of superheat and flush failed to eliminate the site positivity for Legionella in patient ward and intensive care units (ICUs).

RESULTS

Baseline results

The first environmental surveillance for Legionella was performed on March 9, 2000. Eighty percent (4/5) of distal sites in ICUs and 50% (3/6) of distal sites in patient wards were positive for Legionella. *L pneumophila* serogroup 2-14 was the predominant species present in the water system. Fifty-five percent (6/11) of cooling tower water samples were positive for Legionella. Among the positive samples in cooling towers, isolates were identified as *L pneumophila* serogroup 2-14 (83%; 5/6) and *L pneumophila* serogroup 1 (17%; 1/6). In case patients, 40% (14/35) were diagnosed by a 4-fold rise of serum, 34% (12/35) by serum titer >1024, 23% (8/35) by positive sputum using DFA, and 3% (1/35) by positive sputum culture, during the January to March period in 2000. It is noteworthy that the isolate from the sputum-culture-positive patient matched the isolate from the hospital water system by pulse-field gel electrophoresis (Chen YS, unpublished data).

First superheat-and-flush

The first superheat-and-flush reduced the distal site colonization rate for *L pneumophila* from 50% (3/6) to 0% (0/41) in the patient wards (Fig 1). Water temperature flushing at the distal sites was greater than 60°C; 19% (236/1241), 69% (856/1241), and 12% (149/1241) of taps were flushed at water temperatures of 60°C to 69°C, 70°C to 79°C, and >80°C, respectively. However, the first superheat-and-flush did not achieve complete reduction of *L pneumophila* in the ICUs; the distal site colonization rate in ICUs was reduced from 80% (4/5) to 25% (23/94) (Fig 1). Unfortunately, 2 months later, the distal site colonization for *L pneumophila* increased after the first flush to 15% (3/20) of distal sites in patient wards and 93% (14/15) of distal sites in the ICUs (Fig 1).

Disinfecting faucets and showerheads

Chlorinating all faucets and showerheads in the patient wards, in the combined effect of the first superheat-and flush, reduced the distal site colonization rate for Legionella from 50% (3/6) to 0% (0/41). However, the colonization rate for Legionella was only reduced from 80% (4/5) to 25% (23/94) in the ICUs. The hospital distal site colonization rate increased to 15% (3/20) and 93% (14/15) in patient wards and ICUs, respectively.

Second superheat-and-flush

Instead of flushing 1 ward each week, the second superheat-and-flush was initiated in patient wards consecutively, and each site was flushed 5 minutes based on US CDC recommendation. All distal sites were documented to ensure flushing at 60°C or higher for at least 5 minutes. However, the result from the second superheat-and-flush was unsatisfactory. The distal site colonization rate for *L pneumophila* patient wards remained unchanged (from 15% [3/20] to 14% [6/44]), whereas the colonization rate in the ICUs was only decreased from 93% (14/15) to 66% (23/35) (Fig 1).

DISCUSSION

In this report, we document the disinfection of a colonized hospital water system. The recommendations of 2 authoritative bodies, the CDC[5] and the ASHRAE[6] were followed but were shown to be ineffective in eradicating Legionella from this hospital's water system.

Superheat-and-flush was the first disinfection method used for eradication of Legionella in hospital water distribution systems.[8] The superheat-and-flush method requires no special equipment, so it can be initiated as an emergency decontamination procedure in an outbreak situation. However, the disinfection may be only temporary, and recolonization of Legionella has been reported after superheat-and-flush procedures, followed by new cases of hospital-acquired Legionnaires' disease.[9-12]

The temperature of the hot water flushing at distal sites and the duration of the flush are critical. If the water temperature at the distal outlet does not exceed a critical point or the duration of flushing is too short, the procedure is likely to fail. Authorities and professional organization guidelines suggest that the temperature of the hot water flushing the distal sites should be >60°C. However, there is no consensus for the duration of the flush that is required. The 1997 CDC Guidelines for Prevention of Hospital-acquired Pneumonia recommended flushing outlets for greater than 5 minutes without specifying the rationale for hospitals to select the exact duration.[5] On the other hand, authorities from the Pittsburgh Veterans Administration Medical Center who first devised the superheat-and-flush method recommended a flush duration of 30 minutes in the first reported use of this method[8]; this duration was based on the experience of the Pittsburgh VA Medical Center in their empiric use of superheat-and-flush.[13] They also documented that replacement or disinfection of distal sites was ineffective, given the fact that the biofilm containing Legionella extended beyond that of the distal site. Two US hospitals experienced failure when flush time was only 5 minutes, whereas 30-minute flush times were subsequently successful (Yu VL, personal communication).

We followed the published recommendations by the Department of Health, Taiwan, and the CDC for the superheat-and-flush disinfection procedure.[4,5] However, both attempts failed to decrease Legionella colonization despite the fact that the hot water temperature at the distal sites was maintained at above 60°C. The reason for the failure of the first flush may be because that the Department of Health, Taiwan, did not explicitly indicate that flushing of the distal sites has to be systematic and simultaneously performed over a short period so that the Legionella present in the unflushed sites cannot recolonize the water system. We applied our superheat-and-flush measure over an 8-week period to minimize the infection control personnel and overtime cost. Although the environmental culture results 10 days after the flush showed reduction of Legionella colonization, the recolonization occurred in 2 months. We followed the CDC guideline and performed the second superheat-and-flush because of the first failure. However, after the second superheat-and-flush, the distal site colonization rate for Legionella in ICUs was only reduced from 93% (14/15) to 66% (23/35), and the colonization rate in patient wards remained unchanged (from 15% [3/20] to 14% [6/44]).

It is necessary to evaluate scientifically the effectiveness of disinfecting faucets and showerheads to prevent Legionella colonization. In our study, the replacement of the faucets and showerheads in the ICUs did not have any effect on minimizing the Legionella colonization, which contradicted the ASHRAE guideline.[6] Furthermore, the idea of disinfecting taps may be conceptually flawed. These cleaning methods, including chemical or thermal disinfection of taps, only eradicate the Legionella at the outlets, a small proportion of the total inocula in an existing plumbing system. However, Legionella can be isolated from water flowing through within days to weeks because Legionella is still present in biofilms throughout the plumbing system. Legionella colonization can be

established when distal outlets were placed back on-line in a contaminated water distribution system. We suggest that the authorities should validate their recommendations based on scientific evidence.

In summary, superheat-and-flush can still be the first choice of disinfection method for Legionella when a hospital faces an outbreak because it requires no special equipment and can be implemented immediately. However, we suggest that a longer flush time (eg, 30 minutes) as recommended by the originators of this method[8,13] may be required to make the flush effective because superheat-and-flush is time consuming and labor intensive. Moreover, replacement or cleaning of distal sites was ineffective. Our institution did not repeat superheat-and-flush for the third time because it was costly and labor intensive for a large medical center with more than 1000 distal sites to be flushed. It was estimated that the labor $\times$ time for a complete superheat-and-flush was greater than 2000 person-hours in personnel overtime (1.87 person-hours/hospital bed). The hospital has subsequently installed a copper-silver ionization (LiquiTech, Boling brook, IL) for long-term protection of the hospital water system.

References

1. Liu YC, Cheng DL, Shi FW, Huang WK, Wong JH. Legionnaires' disease: a case report. J Formos Med Assoc 1980;84:1180-5.
2. Wang RS, Liu CY, Liu YC, Cheng KK. Legionnaires' disease following cardiac transplantation. Zhonghua Yi Xue Za Zhi 1989;44:336-40.
3. Lin YE, Stout JE, Yu VL, Vidic RD. Disinfection of water distribution systems for Legionella. Semin Resp Infect 1998;13:147-59.
4. Pan TM, Yeh SL, Hung CP. Preliminary surveillance of Legionnaires' disease in Taiwan. Epidemiol Bull 1996;12:237-49.
5. Centers for Disease Control and Prevention. Guidelines for prevention of nosocomial pneumonia. Centers for Disease Control and Prevention. MMWR Recomm Rep 1997;346(RR-1):1-79.
6. American Society of Heating, Refrigerating and Air Conditioning Engineers. Legionellosis: position document GPC-12. Atlanta, GA: American Society of Heating, Refrigerating and Air Conditioning Engineers; 2000.
7. Ta AC, Stout JE, Yu VL, Wagener MM. Comparison of culture methods for monitoring *Legionella* species in hospital potable water systems and recommendations for standardization of such methods. J Clin Microbiol 1995;33:2118-23.
8. Best M, Yu VL, Stout J, Goetz A, Muder RR, Taylor F. *Legionellaceae* in the hospital water supply: epidemiological link with disease and evaluation of a method of control of nosocomial Legionnaires' disease and Pittsburgh pneumonia. Lancet 1983;2:307-10.
9. Colville A, Crowley J, Dearden D, Slack RC, Lee JPV. Outbreak of Legionnaires' disease at a university hospital, Nottingham: epidemiology, microbiology, and control. Epidemiol Infect 1993;10:105-16.
10. Darelid J, Bengtsson L, Gastrin B, Hallander H, Lofgren S, Malmvall BE, et al. An outbreak of Legionnaires' disease in a Swedish hospital. Scand J Infect Dis 1994;26:417-25.
11. Snyder MB, Siwicki M, Wireman J, Pohlod D, Grimes M, Bowman-Riney S, et al. Reduction in *Legionella pneumophila* through heat flushing followed by continuous supplemental chlorination of hospital hot water. J Infect Dis 1990;162:127-32.
12. Heimberger T, Birkhead G, Bornstein D, Same K, Morse D. Control of nosocomial Legionnaires' disease through hot water flushing and supplemental chlorination of potable water. J Infect Dis 1991;163:413.
13. Best MG, Goetz A, Yu VL. Heat eradication measures for control of hospital-acquired Legionnaires' disease: implementation, education, and cost analysis. Am J Infect Control 1984;12:26-30.