CONTROLLING LEGIONELLA IN HOSPITAL WATER SYSTEMS: EXPERIENCE WITH THE SUPERHEAT-AND-FLUSH METHOD AND COPPER-SILVER IONIZATION

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ABSTRACT

OBJECTIVE: To evaluate the effect of copper-silver ionization on Legionella colonization and nosocomial legionnaires' disease and to compare the efficacy of metal ions versus the superheat-and-flush method of disinfection.

RESULTS: The average number of cases of legionnaires' disease per year and the percentage of distal sites positive for Legionella pneumophila for the superheat-and-flush method versus the copper-silver ionization method was six cases with 15% positivity versus two cases with 4% positivity, respectively. The reduction in Legionella colonization after copper-silver ionization was significant (P<0.05) compared to the superheat and flush. Mean copper and silver ion concentrations (mg/L) from hot-water tanks, and 0.17 and 0.04 from distal outlets, respectively.

CONCLUSIONS: We conclude that a properly maintained and monitored copper-silver ionization system was more effective than the superheat-and-flush method for reducing the recovery of Legionella from the hospital water distribution system (Infect Control Hosp Epidemiol 1998;19:911-914).

METHODS

The Pittsburgh Veterans Affairs Health Care System, Oakland Division, is a 550-bed acute-care facility. Hot water is supplied to the basement through the 9th floor from two large-volume (2,000 gal) hot-water storage tanks. The 9th through 11th floors are supplied by two smaller-volume (1,000 gal) hot-water storage tanks. In 1987, the A wing was added to the hospital. This wing has a separate hot-water system that maintains water at 140°F by semi-instantaneous hot-water heaters. No cases of nosocomial legionnaires' disease have been associated with this wing of the hospital.

Legionella Eradication Methods

Intermittent superheat and flush. Beginning in July 1981, when cases of nosocomial legionnaires' disease were detected or when >30% of environmental surveillance sites were positive for Legionella, the temperature of the hot-water storage tanks was raised to 60° to 77°C, and outlets were flushed for 20 to 30 minutes.

Copper-silver ionization system. In November 1994, copper-silver ionization systems were installed on the hot-water distribution system.

Since 1981, the Pittsburgh Veterans Affairs Medical Center has used the superheat-and-flush method to control Legionella pneumophila in the hospital water distribution system. This practice halted an outbreak; however, sporadic cases of nosocomial legionnaires' disease have continued to occur (Figure 1). After 10 cases of nosocomial legionnaires' disease were diagnosed from November 1993 to November 1994, we instituted a new eradication method.

Copper-silver ionization systems were installed on the hot-water recirculating system. This system electrolytically generates copper and silver ions, which bind to the bacterial cell wall causing cell-wall disruption and lysis. We previously demonstrated the efficacy of this method in controlling Legionella both in vitro and in a non–acute-care hospital setting. This study was undertaken to evaluate the efficacy of the copper-silver ionization system in an acute-care hospital experiencing sporadic cases of nosocomial legionnaires' disease.

Our objectives were to (1) determine the effect of copper-silver ionization on Legionella colonization of the hospital water distribution system; (2) determine the effect of copper-silver ionization on the incidence of nosocomial legionnaires' disease; and (3) compare the efficacies of two Legionella eradication methods, copper-silver ionization versus superheat-and-flush, for controlling Legionella colonization and nosocomial legionnaires' disease.

METHOD AND COPPER-SILVER IONIZATION

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RESULTS: The average number of cases of legionnaires' disease per year and the percentage of distal sites positive for Legionella pneumophila for the superheat-and-flush method versus the copper-silver ionization method was six cases with 15% positivity versus two cases with 4% positivity, respectively. The reduction in Legionella colonization after copper-silver ionization was significant (P<0.05) compared to the superheat and flush. Mean copper and silver ion concentrations (mg/L) were 0.29 and 0.054 from hot-water tanks, and 0.17 and 0.04 from distal outlets, respectively.
Amperage was set at 3.0 A for the first 3 months of operation, before the water returned to the two smaller storage tanks. The copper-silver ionization system was installed in November 1994. and-flush procedures were instituted in July 1981. The copper-silver ionization system consists of a flow cell containing metal electrodes and a controller to direct current through the flow cell (Liqui-Tech, Inc, Willowbrook, IL). Each of two large-volume hot-water storage tanks had a dedicated controller and flow cell placed on a recirculating loop that moved water from the bottom of the tank, through the flow cell and back into the top of the tank. One controller and flow cell was placed on the return hot-water recirculating line before the water returned to the two smaller storage tanks. Amperage was set at 3.0 A for the first 3 months of operation, 2.0 A for the next 5 months, and 3.0 A thereafter.

**Case Detection and Definition**

A case of nosocomial legionnaires' disease was defined as pneumonia with onset of symptoms more than 48 hours after admission and a positive result for one or more of the following tests: culture of respiratory secretions on Legionella-selective buffered charcoal yeast extract agar, direct fluorescent antibody staining of secretions, urinary antigen testing by radioimmunoassay (Binax, South Portland, ME), and Legionella serology by the enzyme-linked immunosorbent assay method (a single elevated titer to $\geq 1:256$ or a fourfold rise in titer to $\geq 1:128$). Subtyping of patient and environmental isolates of L pneumophila serogroup 1 was performed by monoclonal antibody analysis (courtesy of Jean R Joly, MD). Subtyping demonstrated that patient strains of L pneumophila serogroup 1 were identical to isolates recovered from the hospital water system. From 1980 to 1997, there were 71 culture-confirmed cases of legionnaires' disease due to L pneumophila serogroup 1. Monoclonal antibody subtyping of these isolates showed that 56 were subtype Allentown, 10 were Philadelphia, 4 were Bellingham, 1 was Oxford, and 1 was subtype OLDA. Isolates of both Allentown and Philadelphia subtypes were recovered from one patient. Throughout this same period, isolates of L pneumophila serogroup 1 recovered from the hospital water system were identified as monoclonal subtypes Allentown, Philadelphia, and Bellingham. Epidemiologically linked patient and environmental strains also were matched genotypically using restriction endonuclease analysis with pulsed-field gel electrophoresis. Pulsed-field gel electrophoresis was performed on the isolates recovered from the patients in 1995 and 1996 and also confirmed nosocomial acquisition.

**Environmental Surveillance**

The change in recovery of Legionella from distal sites and hot-water storage tanks is depicted in the Table and Figure 2. The hot-water storage tanks became negative for Legionella only after treatment with the copper-silver ionization system. Distal-site positivity also was reduced from 14% to 4% after copper-silver ionization ($P<0.05$).

**Monitoring the Copper-Silver Ionization System**

Atomic absorption testing for copper and silver ions was performed on 110 hot-water samples from the hot-water tanks and 60 samples from ward faucets. Mean copper and silver concentrations (mg/L) were 0.29 and 0.054 and 0.17 and 0.04, respectively.

**DISCUSSION**

L pneumophila in the water distribution system of hospitals is the source for the majority of cases of nosocomial legionnaires' disease. Control of nosocomial outbreaks has been accomplished by disinfecting the hospital water distribution system. Superheat and flush and hyper-chlorination have been successful at halting outbreaks;
TABLE

Efficacy of Two Different Eradication Methods on Legionella Colonization and Cases of Nosocomial Legionnaires’ Disease

<table>
<thead>
<tr>
<th>Eradication Method</th>
<th>Time Period</th>
<th>Legionella Cases (Avg/yr)</th>
<th>% of Environmental Surveillance Sites Positive (N)*</th>
<th>Distal Sites</th>
<th>Hot-Water Tanks</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>1979-1981</td>
<td>25</td>
<td>50% (90)</td>
<td>100% (30)</td>
<td></td>
</tr>
<tr>
<td>Heat and flush</td>
<td>1981-1994</td>
<td>6</td>
<td>14% (1,345)</td>
<td>46% (383)</td>
<td></td>
</tr>
<tr>
<td>Copper-silver ionization</td>
<td>1995-1998</td>
<td>2</td>
<td>4% (270)</td>
<td>0% (72)</td>
<td></td>
</tr>
</tbody>
</table>

* N = Number of samples tested.  
† Statistically significant decrease, P<.05, chi-square test.

however, neither method is ideal. Long-term use of hyperchlorination leads to severe corrosion of the distribution pipes. Elevated levels of carcinogenic by-products of chlorine have been linked to cancer and associated with higher rates of miscarriages in pregnant females.11,12 Intermittent use of the superheat-and-flush method is logistically difficult, labor-intensive, and time-consuming. Scalding is a potential hazard, although such incidents have not occurred in our 13-year experience. We examined the efficacy of copper-silver ionization as an alternative disinfection method for controlling nosocomial legionnaires’ disease.

This is our second report in which copper-silver ionization has proven effective in controlling L pneumophila in a hospital water distribution system.3 Copper-silver ionization appeared to be more effective than the superheat-and-flush method for reducing Legionella colonization of the hospital water distribution system (Table).

One weakness of this study is that conditions during the two periods may not have been comparable. Thus, studies from other hospitals using copper-silver ionization as the primary disinfection modality are needed to verify our conclusion. A study by Mietzner et al has been performed, and they similarly concluded that copper-silver ionization was superior to thermal treatment for controlling Legionella in the plumbing system of their hospital.13 Mean copper and silver levels in our hot-water system did not exceed Environmental Protection Agency-recommended levels for drinking water, and no problems with water quality were reported. Maintenance of the ionization system is important, as demonstrated by the fact that mechanical failure of a recirculating pump was temporally related to the occurrence of two cases of legionnaires’ disease in the fall of 1995.

Despite the use of copper-silver ionization, some cases of legionnaires’ disease occurred. It appears that it may be unrealistic to expect that any disinfection method can prevent every case of hospital-acquired legionnaires’ disease. This is probably due to the following: (1) every method is subject to mechanical or human failure; (2) the complexities of large water distribution systems make it difficult to assure effective treatment of the entire system; and (3) exposure of high-risk patients to even low concentrations of L pneumophila may result in disease. Recognizing the limitations of a retrospective comparison and the changes in patient population over the course of this study, there appeared to be a trend toward a reduction in nosocomial legionellosis following the installation of the copper-silver ionization system. Not only was there a reduction in the number of cases in 1995 and 1996, there were no cases of nosocomial legionnaires’ disease detected in all of 1997. This was the first time that no cases were diagnosed in a 1-year period since we began looking for cases in 1979 (Figure 1). This reduction in the number of cases was not due to reduced surveillance for the disease; the average number of Legionella urinary antigen tests performed in the 3-year period from 1992 to December 1994 was 316, compared to 378 from January 1995 to December 1997.

The approximate cost for installation of three copper-silver ionization systems at this hospital was $70,000. Maintenance costs were minimal. Electrode replacement is expected after 2 to 3 years at an estimated cost of $2,000 per flow cell. For comparison, the cost of a single heat-and-flush procedure for one community hospital was estimated at $20,000,14 due primarily to overtime costs. Installation of continuous hyperchlorination equipment at one facility was estimated to cost approximately $75,000, with annual costs of $7,000.14

For hospitals with documented nosocomial legionellosis, particularly those with transplant patients, the copper-silver ionization system appears to be a cost-effective...
alternative to hyperchlorination and thermal disinfection for the control of nosocomial legionnaires' disease in healthcare facilities. Vigilance for cases of legionnaires' disease, routine environmental cultures for Legionella, and monitoring of ion levels should continue as part of the Infection Control Program to document efficacy or detect problems with the system. We perform Legionella environmental monitoring and copper-silver analysis every other month. If Legionella culture is performed in-house, the costs for supplies and media would be less than $1,000 per year. Ion analysis should be performed by atomic absorption spectrophotometry. The copper test kit provided with the ionization system offers only a crude estimate of copper concentration and no information on silver levels. Monitoring for silver is important, because elevated silver ion concentrations can cause discoloration of the hot water due to precipitation of silver chloride. For our hospital, the cost for copper and silver analysis for 1 year was approximately $2,000.

In summary, copper-silver ionization was more effective than superheat and flush in reducing Legionella colonization. If properly monitored, it does not affect water quality adversely and is comparable in cost to hyperchlorination. However, regular monitoring and maintenance of the system is required for optimal efficacy. Our data supports the opinions expressed by Goetz and Yu15; the apparent technical advance and efficacy of copper-silver ionization should be viewed with optimism, albeit restrained.

REFERENCES


