Editorial

Legionella Disinfection of Water Distribution Systems: Principles, Problems, and Practice

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As laboratory diagnostic techniques for *Legionella* become more widespread (especially culture on selective dye-containing media and urinary antigen), more and more hospitals are discovering nosocomial legionellosis. As a result, disinfection directed at hospital water systems has assumed major priority.

Many techniques are being applied, but an adequate assessment requires a minimum of three to five years so as to evaluate the long-term success or failure of any disinfection measure in an actual hospital water distribution system; hence, progress in this field has been necessarily slow. Nevertheless, cases of nosocomial legionellosis continue to appear, increasing pressures for hospitals to find solutions.

Previous approaches were performed by trial and error in heterogenous hospitals characterized not only by differing patient populations, but also by differing building sizes and water distribution systems. Baseline microbiologic surveillance often was inadequate or absent, and subsequent evaluation was erratic and uncontrolled.[1-3]

However, controlled studies were initiated several years ago in a number of hospitals, and their experiences soon will be reported. Multiple sequential approaches are becoming commonplace as disinfection techniques are tried and discarded. In this issue, Matulonis et al describe a multifaceted approach to *Legionella* disinfection using combinations of superheat and flush, ultraviolet light irradiation, and chlorination.[4] In reviewing this report and others to follow, some basic principles must be understood and kept in mind.

FOCAL VERSUS SYSTEMIC DISINFECTION

"Focal" disinfection refers to disinfection directed only at a portion of the water distribution system, usually the incoming water, but not at the biomass of *Legionella* residing at distal sites or in stagnant areas within the water distribution system. "Systemic" disinfection refers to disinfection directed at the entire water distribution system. Focal disinfection modalities are modular and easy to install, but are notably less effective if the water distribution system is extensive or the system is heavily colonized with *Legionella*.

Focal modalities include ultraviolet light, instantaneous heating systems, and ozone.[5] Ultraviolet light can be effective as the sole disinfection modality if the area to be disinfected is small,[6] (eg, a transplant unit as reported by Matulonis or an intensive care unit). Matulonis et al maximized the exposure of *Legionella* to ultraviolet light by recirculating the water of the transplant unit in a closed loop. Focal modalities are not effective if the water distribution system has preexisting *Legionella* colonization because the biomass of *Legionella* in the water distribution system remains unperturbed. Focal modalities work best in a virgin water distribu-

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tion (eg, a new hospital); for maximal effectiveness, a superheat-and-flush sterilization prior to activation and intermittently thereafter is advisable.

Systemic modalities provide a disinfectant residual that is bacteriostatic or bactericidal throughout the water distribution system; these modalities include hyperchlorination and a new high-technology method, copper/silver ionization.[2,7,8] Superheat and flush is a systemic modality that cannot be applied continuously; however, maintaining hot water temperatures at 140°F (60°C) will minimize recolonization.[5,9]

SURVEILLANCE OF THE ENVIRONMENT WITH QUANTIFIABLE ENDPOINTS

Continual surveillance with environmental cultures on a routine basis are critical because mechanical failures and human error occur in any system. Performing cultures at one-month or two-month intervals generally is sufficient. For hospitals using hyperchlorination, environmental cultures at two-week intervals may be necessary because *Legionella* are relatively chlorine-resistant. Organisms can emerge in dangerously high levels within days of chlorine withdrawal if the chlorinator malfunctions. For the superheat and flush method, recolonization will occur with *Legionella* regrowth from existing biofilms as well as entry of new organisms.

Commercially available media containing dyes and glycine can be purchased at low cost.[10] Acid pretreatment of the specimen is used if overgrowth by commensal flora is shown. Swab cultures of selected sites are obtained (faucets, showerheads, ice machines), especially in intensive care units or transplantation wards. If any cultures are positive, then greater scrutiny should be paid to nosocomial pneumonias in that hospital for the distinct possibility that unrecognized Legonnaires' disease is occurring.[11-13] Positive environmental cultures certainly would mandate the introduction of specialized diagnostic tests, especially culture on multiple selective media containing dyes and antibiotics.

The endpoints for environmental surveillance should be realistic and clinically relevant. Total sterility is extremely difficult to achieve with any disinfection modality. The efficacy of some modalities may vary, depending on water use. For example, if superheated water or water containing metallic ions or chlorine cannot reach a site because the faucet is unused, disinfection cannot occur. While the disinfection modality may remove the larger portion of the biomass of *Legionella,* small pockets of *Legionella* may still be present, but in insufficient amounts to cause infection.

At our institution, *Legionella* infections in the hospital setting do not occur until the percentage of colonized sites exceed 30%[14]; this empiric cutoff of 30% has been surprisingly accurate for the last ten years. While the figure certainly will vary among different hospitals, there may be a critical level of *Legionella* colonization above which cases are more likely to appear. The figure will depend not only on the extent of *Legionella* colonization, but also on the susceptibility of the patient population to *Legionella* infection. For example, patients on a transplant ward may become infected with *Legionella* with a much smaller inoculum of *Legionella* in the water than would ambulatory patients on a psychiatric ward.

MAINTENANCE

Maintenance is a major, but often underestimated factor in any mechanical disinfection modality. For example, scale deposition on quartz sleeves of the ultraviolet lights decreases the emission of ultraviolet light. Similarly, the electrodes of the copper/silver system must be cleaned.

REDUNDANCY

One lesson from the report by Matulonis et al is that in some hospitals with endemic legionellosis and a high-risk population (especially transplantation patients), multiple disinfection techniques may be needed so that if one fails because of human error or mechanical failure, the other can serve as a safety net. Futhermore, a focal modality (ultraviolet light) can be combined with two systemic modalities (superheat and flush, hyperchlorination) to ensure maximal kill of *Legionella*.[4,6,9]

SYNERGISM

Hyperchlorination generally has proven to be unsatisfactory due to corrosion after years of use,[15] recognition of carcinogenicity,[16] and the static (rather than cidal) nature of the disinfection. However, in vitro studies show synergy between chlorine and ozone, ultraviolet light, or copper/silver ions such that chlorination could be combined with any one of the other three techniques. Lower chlorine concentrations could be used with better efficacy, as shown by Matulonis et al.

COST-EFFICIENCY

Given current economic constraints, disinfection techniques should be selected with the long-term goals of sustained efficacy at reasonable costs. Choosing a disinfection modality requires careful planning and analysis, taking into account maintenance and ease of installation.[5] We advise hospitals not to make a mad dash for the nearest disinfection

modality. Often, the approach is akin to panic, such that the most economical and the most effective disinfection modality may be overlooked. Because research in this area is in its infancy, each hospital should approach this issue in a reasoned and thoughtful manner.

One tentative solution is to use superheat and flush as the initial disinfection method. This may result in complete sterilization of the entire system in the short term, so that virtually all surveillance cultures will become negative. Other modalities will require longer contact times and exposure before killing *Legionella* this effectively. Because superheat and flush can be implemented almost immediately without special equipment, it is ideal for terminating outbreaks. Following a superheat and flush, the *Legionella* biomass in the water distribution system usually will drop sufficiently low that nosocomial cases are not a problem in the short term. During this time, the hospital administration and engineering department can explore other commercially available disinfection modalities for cost efficacy. Important factors for consideration include the area requiring disinfection (one building or multiple buildings; number of floors), the number of heating systems in place (one versus several), the extent of colonization, and the age of the facility. Older hospitals generally pose a more formidable task in disinfection than newer hospitals because of accumulation of scale and *Legionella* within biofilms.[17,18]

Finally, given the public health implications, any commercial vendor's history of experience and service commitment in *Legionella* disinfection should be reviewed. It would be prudent to obtain assessments from other hospitals that have used the vendor's product.

SURVEILLANCE OF PATIENTS

Occurrence of cases of nosocomial legionellosis is the ultimate test for efficacy. Ideally, isolates from patients with pneumonia should be subtyped by molecular methods[19,20] to verify the putative nosocomial origin. If *Legionella pneumophila* serogroup 1 is present in the water distribution system, a commercially available test for *Legionella* urinary antigen, which detects only serogroup 1, is recommended for in-house testing for patients with nosocomial pneumonia.[21,22]

ACTIVE INFECTION CONTROL PROGRAM

Finally, a strong infection control program is critical if a cost-effective and scientifically valid approach is to be used. We advise that each hospital evaluate the utility of its approach in a scientific manner. Obtaining baseline cultures over a period of time before disinfection is critical, so that the efficacy of a new disinfection modality can be adequately evaluated. Using concurrent controls would be ideal and might consist of an adjoining building without patients. Since every hospital has its unique setting,[23] insights would be gained from published reports by individual hospitals of their experience with a particular disinfection modality.

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