Prevention of Legionnaires' disease in hospitals

Summary

Background. Legionella infection was found in Norwegian hospitals for the first time in 2005. We describe the best known methods of controlling Legionella in hospitals.

Material and methods. The article is based on our own experience of measures to prevent Legionnaires' disease in hospitals and non-systematic searches in PubMed.

Results. There are several methods for combating Legionella in hospitals, such as chlorination, heat treatment and use of filters. However, removal of Legionella is rapidly followed by recontamination. Adding silver and copper ions to water is a well documented method for systemic and lasting removal of Legionella from water. The disadvantage of this measure is high costs, risk of water discolouration and the possible development of resistance by environmental bacterial. This resistance mechanism can theoretically be transmitted to pathogenic bacteria.

Interpretation. We recommend adding silver and copper ions to water as a method of preventing nosocomial Legionnaires' disease when standard methods fail and there is a high level of Legionella in water. The discolouration of surgical instruments caused by high silver concentrations can be avoided by having a separate water supply for surgical units.

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The most common infection route for Legionnaires' disease is via the air in the form of aerosols (1). The source of infection in the first outbreak of Legionnaires' disease in the USA in 1976 was probably the air-conditioning system at a conference hotel (2, 3). In recent years there has been a strong focus, *too* strong, some researchers would maintain, on cooling towers as a source of infection in epidemics (4).

In studies from the UK, the USA and Canada carried out in the period 1985–1994, Legionella was found in water at 12–70 % of hospitals (5, 6). In 2005, Legionella infection by way of aspiration was found at Telemark Hospital. There was systemic contamination of both the hot and the cold water system, despite the implementation of standard measures. In Trondheim, there was a single case of nosocomial Legionnaires' disease, where the infection source was found to be a hot water system (7). No outbreaks of nosocomial Legionnaires' disease have been described previously at Norwegian hospitals.

Large, complex hospital water systems are ideal reservoirs for Legionella (8). It is difficult to define an acceptable Legionella concentration in water at hospitals with immunocompromised patients. A concentration of 1 000 CFU/l is postulated as a theoretical threshold for developing the disease (8). The figure for CFUs (colony forming units) underestimates the real number of living Legionella bacteria in the water, since a CFU may represent more than one Legionella cell (9). Instead of the CFU count, the percentage of distal water sites colonised with Legionella can be used as a measure (10). If 30 % or more of the water samples show Legionella growth, the water is contaminated (10, 11).

Several studies have found the average temperature in hospital hot-water tanks to be 45–50°C, which is ideal for Legionella growth (5). Legionella bacteria will not establish themselves or proliferate at temperatures of over 60°C (1).

The purpose of this article is to describe methods of controlling Legionella in water and preventing outbreaks of nosocomial Legionnaires' disease in hospitals (box 1).

Material and method

The article is based on a non-systematic search in PubMed and on the authors' experiences of control of Legionella and the prevention of Legionnaires' disease in hospitals.

Sources of infection in hospitals

Aerosol formation, aspiration and direct installation of bacteria in the lungs in connection with manipulation of the respiratory tract are the most common means of Legionella infection in hospitals (12). Showering with aerosol formation is often maintained to be a frequent infection route for Legionella in hospitals. Surprisingly enough, some studies show that showering can prevent Legionnaires' disease (12). The explanation given is that patients who take showers are often less ill than bed-ridden patients and therefore less at risk through aspiration. Prospective studies show that showering is not associated with nosocomial Legionnaires' disease (13).

The most important risk factor for nosocomial pneumonia is aspiration (4). Foreign bodies that involve the oropharynx are the most important risk factors for microaspiration (4, 13). In patients with chronic ob-

Main points

- Legionella can cause outbreaks of infection in hospitals as a result of aspiration of contaminated water.
- Heat treatment and chlorination of water has a systemic, but short-term Legionella control effect.
- Installing silver and copper ionisation systems at hospitals is a well documented systemic method of controlling Legionella in water.

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Box 1

Methods of Legionella control at hospitals

- Chlorination and shock chlorination
- Heat treatment
- Bacteriological barrier with filter
- Ozone
- Ultraviolet light
- Monochloramine
- Addition of silver and copper ions

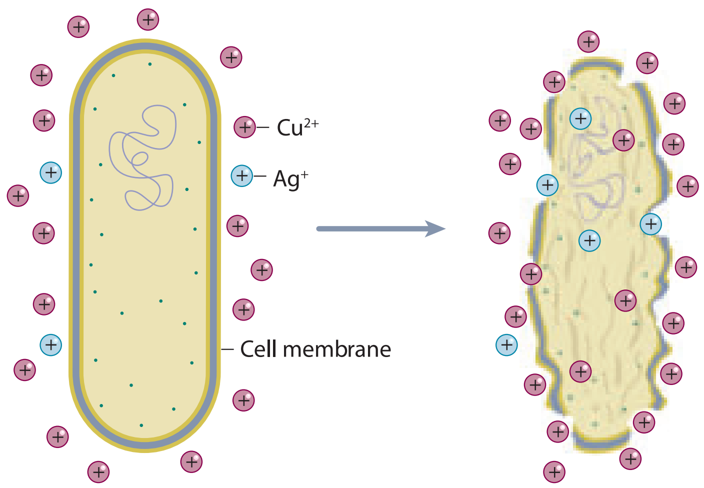

Figure 1 *Positively charged ions such as silver (Ag+) and copper (Cu2+) are attracted to the negatively charged cell walls of organisms. This electrostatic connection creates stress that causes the cell wall to break down. This, coupled with protein denaturation, causes cell lysis and prevents cell division.*

structive pulmonary disease (COPD), the protective function of the airways is impaired and the disease is associated with aspiration (4). Aspiration occurs more often among bed-ridden persons when they drink lying down than otherwise (1). Even a tap-water facility with a low Legionella level can cause the disease in immunocompromised patients (10). Water droplets on medical equipment that are passed down into the lungs may be infected with Legionella (1).

Since 1982, epidemiological studies have revealed that the primary source of infection for Legionnaires' disease in hospitals is via infected water (12). Since 1985, only one of several hundred international reports on nosocomial legionnnaires' disease has reported cooling towers as a source of infection (12).

Legionella can be introduced into the airways by means of contaminated Puritan nebulisers. It is recommended that sterile water be used for flushing nasogastric tubes in order to prevent nosocomial Legionnaires' disease (13). Sterile water should be used in all medical equipment by means of which Legionella infection may be transmitted (1).

Methods for combating infection

Chlorination

Adding chlorine to water systems is a known method of controlling Legionella in both hot and cold water systems (14). Shock chlorination is followed by continuous hyper-chlorination of the water. It is impossible to eradicate Legionella completely from the water system, and recontamination therefore takes place readily (14). The method requires precise monitoring of the chlorine level and personnel to perform the work (14). Chlorine can be used in the event of outbreaks or for long-term control of Legionella (1). Chlorine has no effect on Legionella in blind pipes, and over time it has a corrosive effect on pipes. Legionella forms a biofilm together with other microbes and amoebae in the pipe system. The bacteria in the biofilm are more resistant to biocides and heat treatment than freely circulating bacteria (5). Legionella is merely suppressed by hyper-chlorination. High chlorine concentrations can cause the formation of carcinogens such as trihalomethanes (5).

Heat treatment

Legionella flourishes at temperatures of between 20°C and 50°C (1). Shock heat treatment with flushing was one of the first methods established to control Legionella. The method is cheap, has a short-term systemic effect, and along with chlorination is the recommended method for preventing Legionella in water and for handling outbreaks in hospitals (1). The temperature in hot-water tanks is raised to 70°C for at least five minutes (1). There is a risk of scalding (1). The method is time-consuming and personnel-intensive, and there is a strong risk of recolonisation (14). Biofilm reforms and provides good growth conditions for bacteria. Shock heat treatment has little effect in a pipe system where blind ends have been colonised (1).

In 1995, shock heat treatment was applied at a hospital in Finland after an outbreak of Legionnaires' disease caused by Legionella pneumophila serogroup 5 (15). A shock heat treatment unit was installed after a single round of shock heat treatment had failed. The efficacy in terms both of eliminating Legionella from water and of preventing cases of nosocomial Legionnaires' disease was incomplete.

Ozone

Ozone is a powerful oxidant. A constant ozone concentration of 1–2 mg/l is required in water in order to bring about an adequate reduction in the Legionella concentration (1, 14). Ozone is only recommended internationally as a supplement to heat treatment or chlorine (1, 14).

Ultraviolet light

A swift local bactericidal effect is achieved with ultraviolet light (UV light) in the course of 20 minutes (14). This is not recommended as the only method for hospitals, because Legionella persists in biofilm, which is inaccessible to UV light (5). The system must be installed distally of the water site. Concomitant use of bacteriological filters is recommended, which also increases the costs. UV light is not recommended in water facilities that are already contaminated with Legionella (14).

Monochloramine

Monochloramine is formed when chlorine and ammonia are mixed in water in certain proportions. Experience of this method is limited (1).

Bacteriological barrier with filter

The installation of local physical barriers with filters is a relatively simple method for particularly susceptible departments. The filters are effective, and provide an absolute barrier against Legionella. They also constitute a barrier against other waterborne agents such as Mycobacterium species, Pseudomonas aeruginosa and Acinetobacter species. The water is not subjected to biocides or chemicals. The filters have a long-term effect, but this does not extend to the whole water facility because the filters are installed distally of water sites. The method requires extensive use of personnel resources to replace the filters weekly at all distal water sites. This may even be difficult to achieve in large buildings such as hospitals (16, 17).

Addition of silver and copper ions to water

The addition of silver and copper ions to water (Figs 1 and 2) is a systemic method for long-term control of Legionella (1, 5). In its guidelines, the World Health Organization (WHO) specifies maximum levels for silver (0.1 mg/l), and for copper (2.0 mg/l) in water (18). Copper levels higher than 1 mg/l may cause discolouration of laundry and sanitary

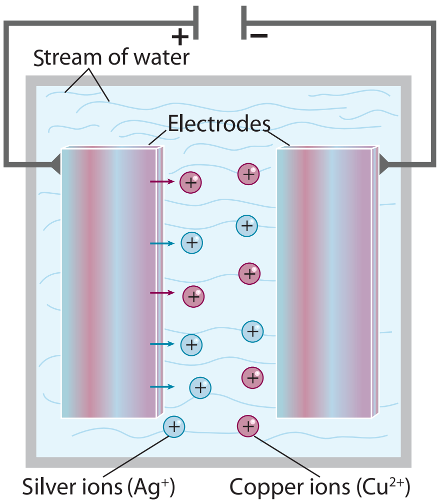

Figure 2 *Passing direct current through silver and copper electrodes that are immersed in water causes the release of positively charged ions into the water. When a stream of water is passed between the electrodes, the metallic ions will move into the water system before they reach the opposite electrode.*

equipment. At copper levels of over 2.5 mg/l, the water may acquire an undesirable bitter taste. At even higher concentrations, the water may become discoloured. There is a theoretical possibility of resistance to silver and copper developing, but so far this has not been found (5). A high water pH value may reduce the effect of copper ionisation (19).

The anti-bacterial effect of silver and copper ions on Legionella and Mycobacterium was studied in 2001 in Finland (20). Free Legionella in the water was found to be totally destroyed. For ionisation to be effective, it is important that water taps and showers be used regularly. Copper penetrates biofilm better than silver. The authors conclude that a well monitored ionisation system may be the solution to preventing nosocomial Legionnaires' disease (20).

Any new method for combating Legionella should be subjected to a step-by-step standardised evaluation before it is introduced into hospitals. The method must have an in vitro effect on Legionella, and its efficacy must be demonstrated in controlled studies (21). In a multi-centre trial on the efficacy of using silver and copper ions, no cases of Legionnaires' disease were reported during the study period for over five years apart from a single case at a hospital immediately after installation of the system (21). All the hospitals had cases of Legionnaires' disease before they installed the system. All had tried standard methods of controlling Legionella, such as shock chlorination and shock heat treatment, without success. The hospitals installed silver and copper ionisation systems in the period 1989–1995. Prior to the installation, 47 % of the hospitals reported Legionella contamination in more than 30 % of water samples. Legionella pneumophila serogroup 1 was reported in 75 % of cases. At the conclusion of the study in 2000, the hospitals had been using the method for seven years on average. At the start of the study in 1995, half of the hospitals reported that they had not experienced Legionella contamination of water after installation of the silver and copper ionisation system. When checked five years after the start of the study, 43 % of the hospitals had still had no Legionella contamination of their water. The remainder had Legionella occurrences in less than 30 % of their water samples. There were reports of water discolouration at high silver concentrations (21).

The addition of silver and copper to water is not generally permitted in Norway because of the effect it would have on waste water treatment and the possibility of depositing sewage sludge. However, the Norwegian National Institute of Public Health (FHI) and the Norwegian Food Safety Authority (NFSA) have concluded that the addition of limited amounts of silver and copper ions to water should be permitted to prevent susceptible groups of patients from contracting Legionnaires' disease. Telemark Central Hospital applied for and was granted dispensation by the NFSA in 2008. Since 23 June 2009, the NFSA approves the use of copper and silver ions in internal water distribution facilities when the public health service believes that the quantity of Legionella in the water is so high that the health hazard can only be handled by means of such methods (22).

Silver is absorbed via the gastrointestinal tract, mucous membranes and skin lesions. Most of the absorbed silver is excreted with gall in the faeces (1, 18). FHI assessed that the planned silver concentration of 40 mg/l does not constitute a health risk for hospital staff and patients (1, 18).

Copper is an important trace metal, but also contaminates drinking water. Copper is primarily absorbed in the small intestine, and most of it is transported to the liver, where it is incorporated in proteins. Copper is excreted in faeces. There are documented cases of acute and chronic copper poisoning. For adults, long-term intake in concentrations of 1–10 mg/day is not harmful (18). The EU has specified a maximum concentration of 2 mg/l copper in drinking water, which is consistent with the WHO's drinking water guidelines of 2002 (18).

Silver and copper are heavy metals, and it is therefore desirable to reduce the quantity of these metals in nature. Silver accumulates in the soil to a greater extent than copper. Extensive use of silver, which goes into waste water, may contribute to environmental bacteria developing resistance to antibiotics (5). This resistance mechanism can theoretically be transmitted to pathogenic bacteria.

Experience from Telemark Central Hospital

A number of unsuccessful attempts to eradicate Legionella from hot and cold water pipes by means of heat treatment and chlorination triggered a desire to find a permanent method of eradicating Legionella at Telemark Central Hospital. We wanted to treat all tap water (both hot and cold) systemically because Legionella was found throughout the water facility. Using filters at all distal water sites would have involved too much work. A silver and copper ionisation system was installed in March 2008. The system cost NOK 750 000 (90000 Euro) and annual operating expenses amount to around NOK 75 000 (9000 Euro). The pipeline system consists of copper pipes and therefore has a high copper content. Monthly CFU counts are taken together with readings of the silver and copper ion concentrations in the water from different sites. Sampling has revealed no pathogenic Legionella strains. During the months immediately following installation the water was reported to have a bitter taste and sanitary equipment to be discoloured. There were problems associated with discolouration of surgical instruments. The hospital still has problems with discolouration of surgical instruments, but to a lesser extent. The water is still not free of Legionella, but no pathogenic Legionella strains have been found since the installation of the treatment system.

Conclusion

Hospitals in Norway must expect occurrences of Legionella in water and cases of nosocomial Legionnaires' disease. Water as a source of pathogenic bacteria is a continuous threat that hospitals must be well prepared for. Adding silver and copper ions to water is a well documented method for systemic and long-term removal of Legionella from water. The system is expensive, there is a possibility of environmental bacteria developing resistance, and there may be discolouration of instruments at hospitals if there are high levels of copper.

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Bibliography

1. Folkehelseinstituttet. Forebygging av legionella-smitte – en veiledning. www.fhi.no/eway/default.aspx?pid=233&trg=MainLeft_5631&MainArea_5661=5631:0:15,4729:1:0:0:::0:0&MainLeft_5631=5544:80826::1:5590:2:::0:0 (26.5.2011).
2. Fraser DW, Tsai TR, Orenstein W et al. Legionnaires' disease: description of an epidemic of pneumonia. N Engl J Med 1977; 297: 1189–97.
3. McDade JE, Shepard CC, Fraser DW et al. Legionnaires' disease: isolation of a bacterium and demonstration of its role in other respiratory disease. N Engl J Med 1977; 297: 1197–203.
4. Yu VL. Cooling towers and legionellosis: a conundrum with proposed solutions. Int J Hyg Environ Health 2008; 211: 229–34.
5. Lin YS, Stout JE, Yu VL et al. Disinfection of water distribution systems for Legionella. Semin Respir Infect 1998; 13: 147–59.
6. Nazarian EJ, Bopp DJ, Saylors A et al. Design and implementation of a protocol for the detection of Legionella in clinical and environmental samples. Diagn Microbiol Infect Dis 2008; 62: 125–32.
7. Garåsen H, Sagvik E, Kvendbø JF et al. Legionella i Trondheim -smitteoppsporing og miljøkartlegging. Tidsskr Nor Legeforen 2005; 125: 1791–3.
8. Kusnetsov J, Torvinen E, Perola O et al. Colonization of hospital water systems by legionellae, mycobacteria and other heterotrophic bacteria potentially hazardous to risk group patients. APMIS 2003; 111: 546–56.
9. Perola O, Kauppinen J, Kusnetsov J et al. Persistent Legionella pneumophila colonization of a hospital water supply: efficacy of control methods and a molecular epidemiological analysis. APMIS 2005; 113: 45–53.
10. Exner M, Kramer A, Lajoie L et al. Prevention and control of health care-associated waterborne infections in health care facilities. Am J Infect Control 2005; 33(suppl 1): S26–40.
11. Best M, Yu VL, Stout J et al. Legionellaceae in the hospital water-supply. Epidemiological link with disease and evaluation of a method for control of nosocomial legionnaires' disease and Pittsburgh pneumonia. Lancet 1983; 322: 307–10.
12. Sabria M, Yu VL. Hospital-acquired legionellosis: solutions for a preventable infection. Lancet Infect Dis 2002; 2: 368–73.
13. Stout JE, Yu VL. Nosocomial Legionella infection. I: Mayhall CG, red. Hospital epidemiology and infection control. 2nd edition. Philadelphia, PA: Lippincott Williams & Wilkins, 1999: 456–7.
14. Muraca P, Stout JE, Yu VL. Comparative assessment of chlorine, heat, ozone, and UV light for killing Legionella pneumophila within a model plumbing system. Appl Environ Microbiol 1987; 53: 447–53.
15. Perola O, Kauppinen J, Kusnetsov J et al. Nosocomial Legionella pneumophila serogroup 5 outbreak associated with persistent colonization of a hospital water system. APMIS 2002; 110: 863–8.
16. Sheffer PJ, Stout JE, Wagener MM et al. Efficacy of new point-of -use water filter for preventing exposure to Legionella and waterborne bacteria. Am J Infect Control 2005; 33 (suppl): S20–5.
17. Ortolano GA, McAlister MB, Angelbeck JA et al. Hospital water point-of-use filtration: a complementary strategy to reduce the risk of nosocomial infection. Am J Infect Control 2005; 33: 1–18.
18. WHO Guidelines for Drinking-water quality. Genève: WHO, 2004.
19. Lin YS, Vidic RD, Stout JE et al. Negative effect of high pH on biocidal efficacy of copper and silver ions in controlling Legionella pneumophila. Appl Environ Microbiol 2002; 68: 2711–5.
20. Kusnetsov J, Iivanainen E, Elomaa N et al. Copper and silver ions more effective against legionellae than against mycobacteria in a hospital warm water system. Water Res 2001; 35: 4217–25.
21. Stout JE, Yu VL. Experiences of the first 16 hospitals using copper-silver ionization for Legionella control: implications for the evaluation of other disinfection modalities. Infect Control Hosp Epidemiol 2003; 24: 563–8.
22. Hofshagen T. Sølv og kobber til Legionella-bekjemping. Norsk Vann 23.6.2009. http://norskvann.no/ (26.5.2011).

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