REVIEW

# Water-associated nosocomial infections

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**It is estimated that 5–10% of hospitalised patients in developed countries contract hospital acquired infections (HAI). Increasing levels of antimicrobial resistance manifested by many HAI-causing pathogens such as *Acinetobacter* spp in the intensive care unit (ICU) setting present a significant challenge to those managing these infections. Consequently, much attention has been focused on the prevention of HAIs. Particular emphasis has been placed on interventions intended to interrupt patient-to-patient transmission of pathogens, such as enhanced hand hygiene and identification of patients colonised with methicillin-resistant *Staphylococcus aureus* (MRSA) using rapid DNA-based screening techniques. However, comparatively little attention has been given to the hospital environment, including water supplies, as a source of nosocomial pathogens of importance for patients on the critical care unit. This article reviews the role of hospital water sources in the epidemiology of HAI and new technologies which can be employed in the prevention and control of such infections.**

The scale of the problem of patients contracting infections whilst being treated is of major concern. The US Centers for Disease Control and Prevention in the USA estimated that there were 1.7 million nosocomial infections in 2002 in US hospitals alone, resulting in 99,000 deaths.[1] The most common fatal HAIs are pneumonia and bacteraemia respectively, followed by urinary tract infections and surgical site infections,[1,2] with patients requiring intensive care being at particular risk.

The sources of nosocomial pathogens can be broadly classified as either endogenous (arising from the patients' own microflora), or exogenous i.e. those from external sources such as the hands of healthcare workers, contaminated medical equipment or from the immediate inanimate environment. The role of the latter has often been underestimated although recently hospital cleanliness has become a focus of concern for patients, the wider public and the media. This is resulting in increased efforts to improve environmental cleanliness, but hospital water as a source of exogenous infection has been largely ignored. Gram-negative bacteria, including those genera associated with HAI in ICU patients can be readily isolated from water in the hospital setting, including water outlets within the ICU itself.[3,4] For example, Arvantidou *et al*.[5] isolated a wide range of antibiotic-resistant Gram-negative bacteria from haemodialysis water, tap and treated water in 71 Greek haemodialysis centres. Such findings have raised questions about the microbiological quality of water being used within wards and the risk that micro-organisms from water sources pose to patients.[6]

Firmly establishing an association between sporadic or epidemic cases of infection and water sources was not possible in many earlier studies because phenotypic methods were used to compare patient and water isolates. More recently, robust genotyping techniques have been employed to characterise isolates and identify epidemiological associations.[4] A selection of reports that have employed this approach are summarised in Table 1.

The range of aquatic reservoirs which have been implicated in HAI is very wide and includes hydrotherapy pools,[16] shower heads,[17] ice machines[18] and disinfectant solutions.[13] The routes of transmission of water-associated bacteria are also very varied e.g. inhalation of aerosols, exposure to equipment washed with contaminated tap water and irrigation of wounds with contaminated water.

**Table 1. Key examples of water-associated nosocomial infections**

| Pathogen | No. of patients affected | Site of infection | Source of infection | Reference |
|---|---|---|---|---|
| *Acinetobacter baumannii* | 38 patients (colonised or infected) , 2-year period | Skin wound | Wide contamination of the patient's rooms including water tap | Pina *et al.*[7] |
| *Acinetobacter junii* | 3 children, June–September, 1994 | Blood | Tap water aerators | Kappstein *et al.*[8] |
| *Burkholderia cepacia* | 411 infections in 361 patients over 7 years | Blood | Hospital water used for diluting alcohol skin antiseptic | Nasser *et al.*[9] |
| | 2 neonatal infections, March–April 1998 | Blood | Commercially supplied vial of water for injection | Moreira *et al.*[10] |
| *Pseudomonas aeruginosa* | 27 infected + 9 colonised, 16 month period | Urinary tract (17 cases), pneumonia (10), sinusitis (4) | Wash basins & nutrition solutions contaminated with tap water | Bert *et al.*[11] |
| | 14 cases, Sept–Nov 1994 | Urinary tract | Tap water | Ferroni *et al.*[12] |
| *Pseudomonas aeruginosa & Pseudomonas putida* | 8 children, Jan-April 2005 | Central-venous-catheter (CVC) related infections | Contaminated water outlets (showers) and detergent – disinfectant solution on an oncohaematology paediatric unit | Aumeran *et al.*[13] |
| *Stenotrophomonas maltophilia* | 12 infected & 2 colonised 1-year period | Respiratory, blood, central line | Patient ventilators | Alfieri *et al.*[14] |
| | 4 colonised, 1 death, March–May 1996 | Endotracheal aspirate | Tap water | Verweij *et al.*[15] |

## PREVENTION

One of the problems faced by those designing strategies to prevent the acquisition of environmental bacteria from aquatic sources is that of biofilms – complex microbial communities formed predominantly by environmental Gram-negative bacteria such as *Pseudomonas* spp. Biofilms, once mature, are refractory to many cleaning modalities and bacteria within them may survive thermal or chemical disinfection. Furthermore, some species of bacteria are able to survive and replicate inside protozoa. *Acanthamoeba*, a common protozoan found in water, can act as a reservoir for various species of bacteria. Amoeba are relatively resistant to some disinfectants and bacteria within them may be protected from the effects of these agents. Importantly, intra-amoebal bacteria may manifest increased virulence. For example, *Legionella pneumophila* become 100-fold more invasive of epithelial cells in comparison with agar-grown bacteria.[19] Of particular concern is the finding that epidemic clones of MRSA can replicate inside amoebae, which may enhance the ability of this bacterium to persist within moist niches on the ward.[20]

Despite these problems, and the near ubiquity of pathogenic micro-organisms in some water sources, waterborne bacteria are certainly amenable to control.[6]

As an immediate measure, intensive care and haematology units have considered using bottled water (carbonated or still), boiled water or sterile water provided by the hospital pharmacy.[21] However, there are safety and cost considerations with each of these options. Bottled water in particular may actually contain bacteria capable of causing nosocomial infections.[22] In a recent report, Eckmanns *et al.*[23] described an outbreak of *Pseudomonas aeruginosa* infections, affecting patients in six ICUs of a hospital in Berlin. Genetic analysis showed that isolates from 19 patients (15 infected and four classed as colonised) were a match to a strain isolated from unopened bottles of still water. The bottles were being used on the units for the preparation of oral medications and oral fluid replacement. It has thus been recommended that units ban the use of bottled still water.[22,23] Similarily, some hospitals have banned ice machines from wards.[18]

Other examples of infection control strategies employed to prevent transmission from hospital water sources include non-touch tap fittings. However, concerns have been expressed over these devices because of development of biofilms and difficulty of decontamination by chemical means.[24] Alternative technologies are copper and silver ionisation within the pipe network,[25] chlorination of the water supplies and thermal disinfection using heat-shock units inbuilt into the water circulatory system, elevating temperatures to 80°C.[26] Some of these technologies may, however, be expensive to retro-fit into existing hospital supplies and may be ineffective in eradicating outbreaks of infection. Indeed one outbreak of *Pseudomonas aeruginosa* infection on a neurosurgery ICU proved refractory to control measures and was only terminated when the ward was closed and sinks and taps replaced.[11]

'Point of use' (POU) filtration, achieved by attaching disposable filters to taps and shower heads, provides an immediate way of creating a barrier before the individual at the distal end of the water supply. POU filtration has been recommended as a relatively low cost intervention which is comparatively simple to implement and maintain.[21,27] These devices have been used on a number of occasions to control outbreaks, particularly those caused by *P. aeruginosa* (Table 2) and studies are underway to evaluate the effectiveness of these devices in preventing sporadic infection.

## CONCLUSIONS

Reports describing outbreaks in which investigators have employed molecular typing techniques to characterise bacterial isolates have highlighted the infection risk posed by water-associated bacteria in critical care settings. More recently the importance of hospital water in the epidemiology of sporadic colonisation or infection of patients on ITUs has been identified.[32–34]

It is thus evident that robust measures to prevent acquisition of infection in this way are needed. Consensus guidelines on optimum control measures are not yet available. In the interim, prospective clinical studies to evaluate and refine interventions are needed.

**Table 2. Studies using point-of-use (POU) filtration as a control measure in an outbreak situation**

| Reference | Title | Conclusion |
|---|---|---|
| Engelhart *et al.*[28] | *Pseudomonas aeruginosa* outbreak in a haematology-oncology unit associated with contaminated surface cleaning equipment | Outbreak terminated using POU filtration alongside surface disinfection and chemical disinfection of washbasin drains. |
| Sheffer *et al.*[29] | Efficacy of new point-of-use water filter for preventing exposure to *Legionella* and waterborne bacteria | Complete elimination of *L. pneumophila* and *Mycobacterium* from hot water supplies |
| Vianelli *et al.*[30] | Resolution of a *Ps. aeruginosa* outbreak in a haematology unit with the use of disposable sterile water filters | A significant reduction in the number of Pseudomonas bacteraemias and control of the outbreak |
| Aumeran *et al.*[13] | *Pseudomonas aeruginosa* and *Pseudomonas putida* outbreak associated with contaminated water outlets in an oncoheamatology paediatric unit | Filtration only one method used to control the outbreak. Following all methods, no further *Pseudomonas* spp isolated clinically or environmentally |
| Shingles[31] | Implementation of point-of-use filtration | POU filtration adopted following a *Pseudomonas* outbreak in central lines. |

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