Water is used in vast quantities in health-care premises. Many aquatic microorganisms can survive and flourish in water with minimal nutrients and can be transferred to vulnerable hospital patients in direct (e.g., inhalation, ingestion, surface absorption) and indirect ways (e.g., by instruments and utensils). Many outbreaks of infection or pseudoinfection occur through lack of prevention measures and ignorance of the source and transmission of opportunistic pathogens.

Public Water Companies

Public water companies have considerable expertise and resources to ensure that their supply systems are designed, operated, and monitored to comply with the minimum requirements of the law. U.K. legislation regards Escherichia coli as synonymous with fecal coliforms and does not give precise numerical values for colony counts. Baseline colony counts should be established for each supply system, and increases should be investigated. Most waterborne disease is related to fecal pollution of water sources; therefore, microbiologic testing of water needs to identify indicators of fecal pollution such as coliforms and Clostridium perfringens as surrogate markers is increasing. Coliforms must not be detected in 95% of samples when >50 samples are taken from the same sampling point during a 1-year period. Detecting E. coli in any one sample constitutes an infringement of the regulation. Recent U.K. legislation requires continuous monitoring of at-risk water treatment works for cryptosporidial oocysts (6). Supplying water containing >100 cryptosporidial oocysts per 100 L is a criminal offense; at least 1,000 L of water need to be filtered each 24 hours.

Private Water Supplies

Private water supplies may be used solely for domestic purposes (category 1) or on a larger scale to supply nursing homes, hospitals, and houses (category 2). Approximately 1% of the U.K. population obtains water from a well, borehole, or spring, which may not be treated. The quality of water from private supplies must comply with the requirements given in the Private Water Supplies Regulations 1991 (7). Category 1 supplies are further divided into classes A-F, depending on the amount of water and number of people supplied. Monitoring private supplies is problematic since water quality can change with the weather and smaller supplies are monitored infrequently (8). Outbreaks of cryptosporidiosis traced to tap water from the main supply are uncommon but may affect large numbers of people and cause public alarm. A recent report highlights a new problem of Cryptosporidium parvum contamination of filtered borehole water causing confirmed cases in 345 persons (9). Borehole supplies have been traditionally regarded as relatively pure sources of water, so this outbreak has implications for future monitoring and treatment of drinking water extracted from boreholes.

Water Storage and Distribution

Water should be stored safely in large, protected reservoirs and treated at the source, often by coarse filtration. Water should be distributed in a purpose-designed system, under pressure in a chlorinated form (e.g., 0.5 ppm free residual chlorine). Storage tanks should be protected from extraneous contamination, including by birds and vermin, and should be free from bacteria, particularly E. coli. Distribution systems should be controlled and free of “dead legs” (conduits that are capped off or rarely used) and spurs; joints and leaks should be repaired by qualified plumbers using defined materials. Uncontrolled water supplies are readily contaminated with coliform bacteria, environmental mycobacteria, Legionella spp., and filamentous fungi.

Water as a Reservoir of Hospital Pathogens

While >40 Legionella spp. are known, most outbreaks of Legionnaires’ disease are caused by Legionella pneumophila serotypes 1 and 6; 600 to 1,300 cases are reported each year in
the United States, although these figures may represent underreporting (10). Legionellae are naturally distributed in aquatic environments, growing best at temperatures of 25°C to 42°C. Colonization is enhanced by water stagnation and sediment buildup as a result of alterations in the plumbing of the complex distribution systems often found in hospital hot-water systems. Cooling towers are often implicated in hospital and community outbreaks. Wet cooling towers (if used) and cooling water systems should be regularly maintained, cleaned, and disinfected. Cooling towers readily generate fine water droplets, as they operate by spraying water onto a packing material through which there is a countercurrent flow of air. How systems become seeded with Legionella is unclear, but these organisms can colonize certain types of water fittings, pipework, and materials. In practice, Legionella is found in many recirculating and hot-water systems with no associated clinical infection; in fact, the number of organisms that cause infection has not been determined reliably and varies with host susceptibility and species of Legionella. For these reasons, routine water sampling for Legionella is not advocated, but sampling may sometimes be appropriate to check the efficiency of the water treatment regimen.

Water systems should be designed to minimize colonization and multiplication of bacteria. Water should not be allowed to stagnate and should be circulated at temperatures below 20°C or above 60°C. Storage tanks and calorifiers should be regularly inspected, cleaned, and disinfected. In reported cases of Legionnaires’ disease in which hot-water systems were implicated, contaminated water droplets were most commonly disseminated by showers and by taps with spray heads (faucet aerators). System design is all important in preventing buildup of Legionella; actions that lessen the risk for clinical cases include removing dead legs, avoiding washers and gaskets made of natural rubber (nutrient source), replacing heavily scaled faucets and showerheads, and avoiding shock absorbers and pipe materials not made of copper or plastic. Conditions that affect the proliferation of legionellae include sludge, scale, rust, algae, and organic particulates thought to provide nutrients for growth. Infection can be minimized by good engineering practices supplemented by heat, disinfectants, and biocides (11).

Clinical Disease

A confirmed case of Legionnaires’ disease is defined as clinical or radiologic evidence of pneumonia and a microbiologic diagnosis by culture of L. pneumophila from respiratory specimens, or a fourfold rise in serum antibody levels against L. pneumophila serogroups (often serogroups 1 and 6). Testing for L. pneumophila antigen in urine, which is rapid and convenient, is becoming the most common diagnostic method. Clinical cases have also occurred because of the inhalation of water droplets containing the blue-white fluorescent group of legionellae, e.g., L. gormanii and L. bozemanii. Care must be taken with the indirect immunofluorescent antibody test to absorb any cross-reactions from Campylobacter. Immunocompromised patients, e.g., transplant or dialysis patients or those on cytotoxic therapy, are at higher risk for infection with Legionella.

Legionellosis: Control by Disinfection

Ideally, hospital water systems should be free of legionellae, but it is exceptional for a water supply to be entirely free of aquatic organisms. Provided that water is derived from the public mains and its quality is preserved in the storage and distribution system by correct design, installation, and maintenance, it can be regarded as being microbiologically acceptable for use without further treatment. However, if the appropriate detection systems are in place to culture and detect nonculturable organisms, it is likely that legionellae will be found in distribution systems (12). Marrie et al. demonstrated that a water system may be contaminated without clinical consequence (13), although risk should be assessed. If regular prospective surveillance and environmental cultures are undertaken and low levels (<10² per L) of legionellae are found, no action is necessary; counts of 10² to 10⁸ on successive samples warrant a review of control procedures.

Heat

If storing water at 60°C is not practical or acceptable or the calorifier is not in use for 1 week or more, raising the temperature of the calorifier water to 70°C to 75°C for 1 hour will kill legionellae. However, this technique may not be effective if the temperature of water at the bottom of the calorifier does not reach 70°C.

Chlorination

Hot-water systems can be disinfected by chlorinating the water in the header tank (20 ppm to 50 ppm, superchlorination), allowing the water to flow to all parts of the system, and then allowing it to stand for at least 4 hours while not in use. The system should then be completely and thoroughly flushed before use. Cooling towers and cooling water systems can be chlorinated with 5 ppm for several hours before flushing. Water in a cleaned system can then be dosed to give a circulating level of free residual chlorine of approximately 1 ppm, although this may increase corrosion.

Biocides

Some biocides are effective against legionellae if used in sufficient concentrations for a sufficient time. Alternating high-level biocide treatment with chlorination and shock-dosing the water system are likely to be more effective than continuous low-level dosing with a single biocide. Strategies for preventing Legionnaires’ disease (14) and guides to minimizing the risk are available (15).

Other Disinfection Methods

Copper-silver ionization can be used to control legionellae in hospital hot-water recirculating systems (16). This method electrically generates copper and silver ions, which bind to the bacterial cell wall, causing cell-wall disruption and lysis. Other methods for disinfecting drinking water include ozonation, chlorine dioxide, and irradiation by UV light.

Legionella spp. and Free-Living Protozoa

Legionellae thrive in stagnant water at ambient temperatures and may survive chlorination by residing in sludge and scale or inside certain protozoa, e.g., Acanthamoeba, Hartmannella, and Tetrakymena spp. While legionellae and
m. xenopi, m. abscessus, m. fortuitum
become contaminated with environmental mycobacteria, e.g.,
of a bronchoscope (19). Hospital water supplies can readily
tuberculosis
has the transmission of highly drug-resistant
Pseudoepidemics of
which may recontaminate the endoscope during rinsing.
Environmental mycobacteria such as
M. chelonae can resist temperatures of 45°C and some disinfectants such as
aliphatic glutaraldehyde. Washer-disinfectors should be
installed and maintained according to manufacturer’s
recommendations. Management policies should emphasize
regular cleaning and maintenance (21). Use of contaminated
or hard water should be avoided to lessen formation of biofilm
and buildup of lime scale. Use of poor-quality water also
should be avoided, and the supply to the washer-disinfector
should be pretreated with heat and filtration and other
processes such as UV irradiation and reverse osmosis.
Additional chlorination of the water also should be considered, as should a final endoscope rinse with sterile water (22).

Immersion in Water

Hydrotherapy Pools: Preventing Infection
The physical structure of hydrotherapy pools, their high
water and air temperatures, and intermittently intensive use
by diverse groups of patients and staff produce potentially
hazardous conditions (23). Hydrotherapy has become
popular, and many district hospitals have installed suitable
pools. Each pool should be a self-contained part of the hospital
physiotherapy facilities with a senior physiotherapist
responsible for overall daily management. The pool should be
designed to allow water to circulate through a filter and for
the addition of a suitable disinfectant (often hypochlorite) in
appropriate amounts with a mechanism for adjusting the pH
(appropriate range 7.2 to 7.8). Pools should be cleaned
regularly, have some water replaced weekly, and be emptied
annually. Additional measures should be implemented if
users release unformed stool into the pool, and strict
adherence to the rules of cleanliness and hygiene both in and
out of the pool should be enforced. Physiotherapists,
microbiologists, and engineers should have effective working
relationships. Management programs should be established,
and careful records should be kept. Despite careful control of
water quality, users will suffer from pool-related skin, ear,
chest, and gastrointestinal infections from time to time.
Numerous microorganisms have been implicated in these
infections, including Pseudomonas aeruginosa, Legionella
spp., adenoviruses, and enteroviruses. Legionnaires’ disease
has been associated with whirlpool spas, where agitation and
aeration of the water enable bacteria to be inhaled (24). (The
terms spa pool, spa bath, whirlpool, and hot tub are
sometimes used interchangeably [25].) More recently, a
cluster of gastrointestinal illnesses, including one case of
hemolytic uremic syndrome and one culture-confirmed E. coli
O157:H7 infection, was attributed to a poorly maintained
swimming pool (26). Frequently, immersion of hospitalized
patients contaminates the tub environment, including the tub
water, drains,agitators, floors, and walls.

Water Births: Minimizing Infection
Water births, pioneered in the 1960s, are increasingly
being used. The perceived infection problem is that the
birthing-pool water becomes contaminated with amniotic
fluid, blood, and fecal material, all of which contain large
quantities of maternal bacteria and viruses. Risks include
bloodborne viruses, e.g., hepatitis B and C, HIV-1, and HIV-2,
and fecal-orally transmitted viruses, e.g., the enteroviruses
and adenoviruses (27). Many of these concerns may be
unfounded, and calls for maternal testing for HIV have not
been supported. A more reasonable approach is to ensure that
infection control policies for water births include instructions
for pool maintenance and decontamination, use of universal
precautions, and use of personal protective equipment for
staff (28). Postnatal surveillance of mothers and babies
should be conducted to define infection rates.

Washing or Rinsing in Water

Burns Units: Part of Irrigation Therapy
Kolmos et al. reported five patients with extensive deep
burns in whom P. aeruginosa serogroup O-7 septicemia
developed shortly after hospital admission (29). Routine
microbiologic monitoring of such patients is not required,
provided the water quality is secured and the irrigation
tubing is decontaminated between uses.

Bathing Infants: Basic Hygiene and Appearance
At birth, infants are often diffusely covered in vernix,
amniotic fluid, and blood. Even though bathing them to
remove unsightly body fluids is very tempting, total body
immersion for preterm babies is not recommended. The skin
of a newborn is ideal for absorbing unwanted microorganisms.
In a report by Verweij et al., contaminated water was used to
wash preterm infants, leading to the colonization of four
infants and death of a fifth from Stenotrophomonas
maltophilia (30). The outbreak was controlled by reenforcing
hand disinfection, limiting use of tap water for handwashing,
and using sterile water to wash the preterm babies. For
cosmetic reasons, washing can be restricted initially to the
head and neck.

Miscellaneous Waterborne Outbreaks
Water baths used to warm up dialysis fluids (31), fresh-
frozen plasma, and albumin (32) have been implicated as the
source of infection by Acinetobacter calcoaceticus var anitratum and P. aeruginosa. Molecular methods such as pulsed-field gel electrophoresis or random amplification of polymorphic DNA can confirm the relatedness of some of these complex aerobic gram-negative bacilli. Removing the contaminated water baths ends the outbreaks.

Holy water is a potential source of cross-infection with various coliform bacteria, including A. baumannii and Aeromonas hydrophila (33). Patients with widespread burns and other debilitating skin lesions are at risk. Sterile holy water is one solution to this concern. A number of pseudoutbreaks have been reported that implicate contaminated ice machines. Coliforms and other debilitating skin lesions are at risk. Sterile holy water is one solution to this concern.

An outbreak of A hemolytic streptococcal purpural sepsis was traced to the communal use of bidets (35). Decontamination of the water spray nozzle and drain was necessary to control the outbreak. Routine cleaning might have prevented its occurrence.

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