Waterborne Pathogens:

A source for Hospital Acquired Infections

Presented by:
Dustin Crumby, RN BSN MBA
Disclosures

- Employee of PALL Corporation, however this presentation does not express my personal interest or the interest of PALL Corporation.
Objectives

- Recognize that potable water systems are a source of gram negative hospital acquired infections
- Develop an understanding of the **IMPACT** of waterborne pathogens in the healthcare setting
Professional Background

- 10 years of nursing experience in various roles including ICU, Wound Care, Infection Prevention, and Healthcare Administration.
Water is essential to life...

- Approximately 71% of the earth's surface is water
- Approximately 60% of the human body is comprised of water
- Adult humans must consume between 2-3L of water per day
Hospital Acquired Infections and Infection Prevention

- Approximately 1 out of 20 hospitalized patients in the U.S. will contract an HAI.
- Infection prevention and control measures aim to reduce the risk of acquiring an infection while receiving care, with particular focus on those who are most vulnerable.
- Infection prevention promotes quality within the healthcare setting creating an environment that is safe for the patient and the staff in a cost efficient manner.
## Costs of HAIs

<table>
<thead>
<tr>
<th>Type of Infection</th>
<th>Low Cost</th>
<th>High Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgical Site Infection</td>
<td>$10,443</td>
<td>$25,546</td>
</tr>
<tr>
<td>Central Line Associated Blood Stream Infect.</td>
<td>$5,734</td>
<td>$22,939</td>
</tr>
<tr>
<td>Catheter Associated Urinary Tract Infection</td>
<td>$589</td>
<td>$758</td>
</tr>
<tr>
<td>Ventilator Associated Pneumonia</td>
<td>$11,897</td>
<td>$25,072</td>
</tr>
</tbody>
</table>

**Average of All HAIs:**

$13,973 with a standard deviation of $17,998

Direct costs of multidrug-resistant Acinetobacter baumannii in the burn unit of a public teaching hospital.


**Direct costs of multidrug-resistant Acinetobacter baumannii in the burn unit of a public teaching hospital.**


**Author information**

**Abstract**

We conducted a case-control study to determine the attributable direct costs of multidrug-resistant Acinetobacter baumannii (MDRAB) in the burn unit of a public teaching hospital. The mean total hospital cost of patients who acquired MDRAB was $98,575 dollars higher than that of control patients who had identical burn severity of illness indices (P < .01). These data should help infection control practitioners and others determine the cost-effectiveness of specific interventions designed to control this emerging nosocomial pathogen.
Waterborne Pathogens

- Microorganisms that are present in water supplies have been linked to infecting susceptible hosts.
- Infections commonly result during bathing/washing, drinking, preparation of food, manufacturing of ice, rinsing medical devices, and aerosolization of water particles from flowing water.
Common infectious agents found in potable water

A large variety of microorganisms can be detected within water systems:

- *Pseudomonas* spp.
- *Legionella* spp.
- Nontuberculous Mycobacteria
- *Acinetobacter* spp.
- *Cryptosporidium* spp.
- *Klebsiella* spp.
- *Escherichia coli*
- *Aspergillus* spp.

*Pseudomonas aeruginosa* and *Legionella pneumophila* are among those which are of particular concern for immunocompromised patients.
Water systems as a potential source of hospital associated infections

- Hot water recirculation loops
- Biofilms found in plumbing systems
- Bacterial colonization
- Modes of transmission
- Portal of exit
- Portal of entry
Legionella species

- Gram negative bacteria naturally found in the environment, usually in warm water.
- Legionella bacteria is not transmitted from person to person.
- Can cause Legionnaires’ disease or Pontiac fever.
- People get the disease when they breathe in the mist that is contaminated with bacteria.
Pseudomonas species

- Gram negative bacteria found naturally in the environment.
- Generally targets people with weakened immune systems.
- Most commonly spread by healthcare workers, hospital water systems and improperly cleaned equipment.
- Approximately 51,000 HAIs occur in the US annually.
Acinetobacter species

- Gram negative bacteria that generally targets immune compromised patients.
- Generally isolated from water and soil.
- High rate of antibiotic resistance.
- Known for its ability to form biofilms and survive on artificial surfaces.
How does bacteria enter the water system?

- During initial construction, remodels, maintenance and water line breaks
- From patient or staff to water supply
- Incoming water supply
Drinking water supply chain

Water transport from source to communities
Drinking Water Supply Chain
Plumbing of hospital premises is a reservoir for opportunistically pathogenic microorganisms: a review

Williams, M.M., Armbruster, C.R., and Arduino, M.J.
Division of Healthcare Quality Promotion, Centers for Disease Control and Prevention, Atlanta, GA, USA: Department of Microbiology, University of Washington, Seattle, WA, USA

Conclusion:

• Several bacterial species are natural inhabitants of portable water distribution systems that are opportunistic pathogens to sensitive patients in healthcare facilities.
• Infection prevention is challenging since there is lack of understanding of the ecology, virulence and infectious does of these opportunistic infections.
• Water distribution systems and equipment or services can serve as reservoirs for waterborne pathogens.
Reservoirs in Healthcare Water System

- Corrosion of pipes and valves
- Dead ends
- Hydrotherapy tubs
- Mixing valves
- Ice Machines
- OR Hose Reals
Biofilms

- Group of microorganisms that stick together in a matrix allowing the organisms to adhere to a surface
- The matrix of extracellular polymeric substance provides protection to the group of microorganisms
- Microorganisms can multiply and/or remain viable in biofilms for long periods of time
Biofilm Develops in several stages
Biofilm Development

Phase 1: **Particles are adsorbed** to the inner surface of water pipes (conditioning)
Biofilm Development

Phase 2: **Bacteria attach** to the conditioned surface
Biofilm Development

Phase 3: Bacteria produce a **sticky extracellular matrix** & reproduce quickly
Biofilm Development

Phase 4: **Biofilm** increases in size and **protects microorganisms** within
Biofilm Development

Phase 4: Some cells are Viable But Non Culturable (VBNC)
Biofilm Development

Phase 5: **Biofilm particles shear off** under the force of water flow
Biofilm Development

Phase 5: Biofilm particles shear off under the force of water flow
Risk Factors for Biofilm Growth

- Stagnant water
- Rubber gaskets
- Flexible hosing
- Areas of low flow
- Pooling of water
Reconstruction measures may result in dead ends.
Eliminating Waterborne Pathogens in a Burn Unit
Crumby, D.R. and Lee, J.O.

Introduction
- Drinking water standards allow for the presence of bacteria at certain levels as long as they are not commonly pathogenic to healthy individuals.¹
- Pediatric patients who suffer a burn injury greater than a 20% Total Body Surface Area Burn are immune compromised making them more at risk for infection from environmental pathogens.²
- Between January 2010 through May 2011 53% of hospital acquired infections were related to waterborne pathogens.
- To prevent a hospital acquired infections the chain of infection must be broken at some point.

Methods
- An outbreak investigation began February 2010 after 27% of the ICU patients became infected with Pseudomonas (n=6) and Acinetobacter (n=2) species.
- Patient cultures were obtained on admission and weekly for surveillance purposes during the outbreak investigation.
- Staffing and patient transportation logs were reviewed to help identify potential cross contamination risks.
- Environmental cultures were obtained throughout the hospital.
- Water samples (n=24) were obtained from patient care areas.

Results
- The outbreak investigation data was reviewed by the Infection Control Committee.
- The water culture results tested positive for Pseudomonas (n=7) and Acinetobacter (n=2) species.
- Both the Pseudomonas and Acinetobacter species were multidrug resistant and linked to the positive patient culture results.
- Sterile water was utilized for all dressing changes, hydrotherapy, and operating room procedures.
- Water filters that provide sterilized grade filtered water were trialed and selected based on performance and staff reviews.
- During the trial 99.3% of the point of use filters that previously tested positive, tested negative for all gram negative bacteria.
- After implementing the 0.2 μm water filters on June 1, 2011, Acinetobacter (n=1) and Pseudomonas (n=3) accounted for 26% of the hospital acquired infections. These infections were linked to cross contamination.

Conclusion
- The use of 0.2 μm water filters proved to be a cost effective method in eliminating the number of hospital acquired gram negative infections.
- The overall hospital acquired infection rate reduced from 8.0 per 1000 patient days to 5.1 per 1000 patient days after implementing 0.2 μm water filters.
- Sterilized grade filtered water is a cheaper alternative than sterile water.
- No patient deaths were related to sepsis from a hospital acquired infection in 2012 and 2013.

Research to Practice
- Burn centers should take a systematic approach to reduce and eliminate the risk of healthcare associated infections.

References
Chain of Infection

- Infectious Agent
- Reservoir
- Portal of Entry
- Portal of Exit
- Mode of Transmission
- Susceptible Host
Chain of Infection-Infectious Agent

- **Infectious Agent**
  - *Pseudomonas* spp.
  - *Legionella* spp.
  - Nontuberculous Mycobacteria
  - *Acinetobacter* spp.
  - *Cryptosporidium* spp.
  - *Klebsiella* spp.
  - *Escherichia coli*
  - *Aspergillus* spp.

- **Susceptible Host**
- **Portal of Entry**
- **Reservoir**
- **Portal of Exit**
- **Mode of Transmission**
Chain of Infection - Reservoir

- **Susceptible Host**
- **Portal of Entry**
- **Mode of Transmission**
- **Infectious Agent**
- **Reservoir**
- **Portal of Exit**
Chain of Infection-Portal of Exit

- Infectious Agent
- Reservoir
- Portal of Entry
- Susceptible Host
- Mode of Transmission
- Portal of Exit
Chain of Infection - Mode of Transmission

- **Susceptible Host**
- **Portal of Entry**
- **Infectious Agent**
- **Reservoir**
- **Portal of Exit**
- **Mode of Transmission**

The chain of infection involves the movement of an infectious agent through a susceptible host, entering through a portal of entry, passing through a reservoir, and exiting through a portal of exit, facilitating transmission.
Chain of Infection - Portal of Entry

- Infectious Agent
- Reservoir
- Portal of Entry
- Portal of Exit
- Mode of Transmission
- Susceptible Host
Chain of Infection: Susceptible Host

- Susceptible Host
- Infectious Agent
- Reservoir
- Portal of Entry
- Portal of Exit
- Mode of Transmission

- Solid Organ Transplant
- Burn
- Neonatal Intensive Care
- Pediatric Intensive Care
- Hematology/Oncology
- Medical Intensive Care
- Cardiac Intensive Care
- Respiratory Intensive Care
- Surgical Intensive Care
- Bone Marrow Transplant
At-Risk Patient Populations

- Solid Organ Transplant
- Bone Marrow Transplant
- Burn
- Neonatal Intensive Care
- Pediatric Intensive Care
- Surgical Intensive Care
- Hematology/Oncology
- Cardiac Intensive Care
- Medical Intensive Care
- Respiratory Intensive Care
Sources of Hospital Acquired Infections

- **Contaminated Hospital Environment**
  - Instruments
  - Food
  - Air
  - Water
  - Medications

- **Invasive Devices**
  - Urinary Catheters
  - Vascular Catheters
  - Endotracheal Tubes
  - Wounds

- **Medical Personnel**
  - Colonized
  - Infected
  - Transient
  - Carriers

- **Patient Flora**
  - Cutaneous
  - Gastrointestinal
  - Genitourinary
  - Respiratory
Tap from hospital colonized with *P. aeruginosa*
Drinking Water

Transmission pathways for waterborne pathogens

- **Consumption via drinking**
  - gastrointestinal
  - > liver, blood

- **Inhalation of aerosols**
  - lung
  - (also aspiration)

- **Application via contact**
  - Wounds, mucosa, catheters
Key Points:

- *Legionella pneumophilia* isolated from 9.6% of samples
- *Pseudomonas aeroginosa* from 11.4% of samples
- *Acinetobacter* isolated from 1.8% of samples

Conclusion:

Water proved to contain gram negative bacteria, the main cause of nosocomial pneumonia at this institution.
40% of healthcare associated pseudomonas infections/colonizations is potentially due to contaminated tap water.

<table>
<thead>
<tr>
<th>Author</th>
<th>Hospital</th>
<th>Unit</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferroni et al. 1998</td>
<td>Paris/France</td>
<td>Pediatric surgical unit</td>
<td>21.4 %</td>
</tr>
<tr>
<td>Berthelot et al. 2001</td>
<td>St. Etienne/France</td>
<td>2 mixed ICUs</td>
<td>14-25%</td>
</tr>
<tr>
<td>Trautmann et al. 2001</td>
<td>Ulm/Germany</td>
<td>Surgical unit</td>
<td>29.4%</td>
</tr>
<tr>
<td>Reuter et al. 2001</td>
<td>Ulm/Germany</td>
<td>Surgical unit</td>
<td>42%</td>
</tr>
<tr>
<td>Vallés et al. 2004</td>
<td>Barcelona/Spain</td>
<td>Mixed ICUs</td>
<td>37-42%</td>
</tr>
<tr>
<td>Blanc et al. 2004</td>
<td>Lausanne/Switzerland</td>
<td>5 ICUs</td>
<td>42%</td>
</tr>
<tr>
<td>Trautmann et al. 2005</td>
<td>Ulm/Germany</td>
<td>Medical ICU</td>
<td>50%</td>
</tr>
</tbody>
</table>

Trautmann M et al., Krh-Hyg+ Infverh 27:2005
Portal of entry
Portal of Entry
Portal of Entry
Portal of Entry
Pseudomonas aeruginosa and Pseudomonas putida outbreak associated with contaminated water outlets in an oncohaematology paediatric unit.


J Hosp Infect. 2007 Jan; 65(1);47-53, Epub 2006 Nov 30

Key Points:

- Eight children suffered blood stream infections with Pseudomonas species
- Repetitive intragenic consensus polymerase chain reaction indicated two discrete patterns for P. aerug. and P. putida in the water system and patients
Removal of waterborne pathogens from liver transplant unit water taps in prevention of healthcare-associated infections: a proposal for a cost-effective, proactive infection control strategy.

Zoy ZY, Hu BJ, Qin L, Lin YE, Watanabe H, Zou Q, Gao XD
Clinical Microbiol Infect. 2014 Apr; 20(4):310-4

Abstract
Hospital water supplies often contain waterborne pathogens, which can become a reservoir for healthcare-associated infections (HAIs). We surveyed the extent of waterborne pathogen contamination in the water supply of a Liver Transplant Unit. The efficacy of point-of-use (POU) water filters was evaluated by comparative analysis in routine clinical use. Our baseline environmental surveillance showed that Legionella spp. (28%, 38/136), Pseudomonas aeruginosa (8%, 11/136), Mycobacterium spp. (87%, 118/136) and filamentous fungi (50%, 68/136) were isolated from the tap water of the Liver Transplant Unit. 28.9% of Legionella spp.-positive water samples (n = 38) showed high-level Legionella contamination (≥10³ CFU/L). After installation of the POU water filter, none of these pathogens were found in the POU filtered water samples. Furthermore, colonizations/infections with Gram-negative bacteria determined from patient specimens were reduced by 47% during this period, even if only 27% (3/11) of the distal sites were installed with POU water filters. In conclusion, the presence of waterborne pathogens was common in the water supply of our Liver Transplant Unit. POU water filters effectively eradicated these pathogens from the water supply. Concomitantly, healthcare-associated colonization/infections declined after the POU filters were installed, indicating their potential benefit in reducing waterborne HAIs.

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Legionella in transplant units
Patterson WJ et al, J Hosp Infect 37:1997

• Prospective, multicentre study in 69/81 (85%) British transplant units
• *Legionella* spp. has been isolated in 38/69 (55%) and *L. pneumophila* in 31/69 (45%) of transplant units. Free floating protozoa have been identified in 68%
• No significant differences between cold and warm water samples

<table>
<thead>
<tr>
<th>Warm water</th>
<th>Cold water</th>
</tr>
</thead>
<tbody>
<tr>
<td>56.2 °C (37 – 74.6 °C)</td>
<td>16.6 °C (8.3 – 28.9 °C)</td>
</tr>
<tr>
<td><em>Legionella</em> spp. 55 %</td>
<td><em>Legionella</em> spp. 47 %</td>
</tr>
<tr>
<td><em>L. pneumophila</em> 45 %</td>
<td><em>L. pneumophila</em> 35 %</td>
</tr>
<tr>
<td>Protozoa 70 %</td>
<td>Protozoa 42 %</td>
</tr>
</tbody>
</table>
CDC baffled by Legionnaire's disease cases way up in the US

August 19th 2011

- While older people and those living in the Northeast are most at risk Legionnaire's disease occurs in all age groups and regions
- Men account for 60% of cases
- Number of cases reported to the CDC rose from 1,110 in 2000 to 3,522 in 2009
- The incidence rate increased from 0.39 to 1.15 per 100,000 people during that time

http://www.medicalnewstoday.com/articles/233072.php
# Common Water Treatment/Filtration options

<table>
<thead>
<tr>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous Chlorination (Cl₂)</td>
</tr>
<tr>
<td>Chloramine/Monochloramine (Cl₂)</td>
</tr>
<tr>
<td>Copper Silver</td>
</tr>
<tr>
<td>Ozone</td>
</tr>
<tr>
<td>UV Lighting</td>
</tr>
<tr>
<td>Chlorine Dioxide (ClO₂)</td>
</tr>
<tr>
<td>Filtration/Point of Use Filtration</td>
</tr>
</tbody>
</table>
Continuous Chlorination

Typically applied to achieve 1 mg/L (ppm)

**PRO:**
- Relatively inexpensive
- Effective disinfectant
- Can provide a constant residual

**CON:**
- Efficacy depends on system pH
- Possible corrosion issues
- Possible THM issues (Tri-halomethanes)
- Rapid bacteria re-growth is common upon dosing disruption
- Safety issues with Cl₂ gas
Monochloramines

**PRO:**
- Low reactant disinfectant
- Can provide a constant residual
- On site generation

**CON:**
- Low reactant disinfectant
- Efficacy depends on system pH
- Possible corrosion issues
- Biofilm
- Nitrates
- Safety issues with ammonia
Copper-Silver Ionization

Target Doses: Copper 0.1 - 0.4 ppm  Silver 0.01 - 0.03 ppm
EPA Limits: Copper <1.3 ppm  Silver <0.1 ppm

PRO:
- Good residuals
- Good for low flow/stagnant conditions
- Easy to install
- Has been actively promoted
- Effective on bulk water bacteria

CON:
- EPA questions use in potable water
- Used in hot water systems only
- Difficult to control Cu-Ag ion doses
- Conflicting reports on biofilm reduction
- Issues in hard water
- Less effective at pH>7.6
- Galvanic corrosion issues reported
- Evidence of bacterial resistance to Cu-Ag over prolonged application
Ozone

**PRO:**
- An excellent point disinfectant
- Effective at low concentrations with short contact time

**CON:**
- Requires on-site generation
- Difficult to control, poor residual, which means poor biofilm control
- Expensive technology
- Works best at low pH
- Health and Safety issues
  - Poor solubility
  - Quickly off gases
Ultraviolet Radiation

PRO:
- Good point disinfectant
- Effective at low concentrations with short contact time
- Easy to install, and no adverse effects on water chemistry or on plumbing integrity
- Good for High Velocity Recirculating loops

CON:
- Provides no residual in the system
- Localized disinfection only
- Flow rate and contact time in the UV exposure cell have a direct impact on efficacy
- UV lamps have a limited life, and are susceptible to scale and mineral deposits
Chlorine Dioxide ($\text{ClO}_2$)

**PRO:**
- Very effective disinfectant at low concentrations (0.2 - 0.5 ppm)
- Penetrates biofilms
- Does not react with water, nor does its chemical composition or activity change with shifts in water pH
- EPA approved for potable water below 0.8 ppm

**CON:**
- Must be generated on-site.
- Low conversion efficiencies could lead to chlorite formation, which is regulated by EPA at <0.8 ppm
Point of Use Filtration

**PRO:**
- Very effective barrier that reduces the risk of patient exposures to waterborne pathogens
- Product validation
- Can be used with hot water flushes and secondary disinfection
- Compatible with all sinks, showers, and ice machines
- Does not modify chemical composition of water
- Meets healthy drinking water standards

**CON:**
- Cost
- Increases workload
Point-of-use water filtration reduces endemic Pseudomonas aeruginosa infections on a surgical intensive care unit

Trautmann M, Halder S, Hoegel J, Royer H, Haller M

Abstract
BACKGROUND: Endemic infections because of Pseudomonas aeruginosa were observed on a surgical intensive care unit (ICU) for a period of >24 months. Tap water probing revealed persistent colonization of all ICU water taps with a single P aeruginosa clonotype.

METHODS: Water outlets of the ICU were equipped with disposable point-of-use water filters, changed in weekly and, later, 2-week intervals. To delineate the effect of the filters, 4 study approaches were followed: (1) a descriptive analysis of the incidence of P aeruginosa colonizations and infections, (2) microbiologic examinations of tap water before and after installation of the filters, (3) a comparative cohort analysis of representative patient samples from the prefilter and postfilter time periods, and (4) an analysis of general ward variables for the 2 periods.

RESULTS: (1) The mean monthly rate (+/- SD) of P aeruginosa infection/colonization episodes was 3.9 +/- 2.4 in the prefilter and 0.8 +/- 0.8 in the postfilter period. P aeruginosa colonizations were reduced by 85% (P < .0001) and invasive infections by 56% (P < .0003) in the postfilter period. (2) Microbiologic examinations of tap water revealed growth of P aeruginosa in 113 of 117 (97%) samples collected during the prefilter period, compared with 0 of 52 samples taken from filter-equipped taps. (3) In the comparative cohort analysis, a number of patient-related variables were significantly associated with P aeruginosa colonization/infection. Considering these variables in a multivariate analysis, belonging to the postfilter cohort was the factor most strongly associated with a reduced risk of P aeruginosa positivity (relative risk, 0.04; P = .0002). (4) General ward variables such as bed occupancy, personnel-to-patient ratio, or microbiologic culturing density did not differ significantly between the 2 periods.

CONCLUSION: Taking into account various patient-related and general ward variables, point-of-use water filtration was associated with a significant reduction of chronically endemic P aeruginosa colonizations/infections on a surgical ICU.
When is surveillance recommended?

- Signs that the water system is not under control
- After periods of stagnation
- After work on the distribution system
- Notice a cluster of cases of a gram negative pathogens
Sampling (culturing) Water

Bacterial counts in water samples can differ significantly within a short time period due to the irregular shedding of biofilm particles into the water distribution system.
Sampling Water

- If water samples are obtained when the water is first turned on, this sample represents the water quality between the faucet and the circulating system.
- If water samples are obtained after allowing the water flow for a period of time, this sample represents the water quality in the circulating system.
Control Measures

- Facility Specific
  - Establish base line data
  - May use antibiograms
  - May perform active surveillance
  - Monitor content of water
  - Use your NHSN/State Reportable Data
  - Establish thresholds
Questions