Environment of Care: Air and Water

William A. Rutala, Ph.D., M.P.H., C.I.C.
Director, Statewide Program for Infection Control and Epidemiology and Professor of Medicine, University of North Carolina at Chapel Hill, NC, USA
Former Director, Hospital Epidemiology, Occupational Health and Safety, UNC Health Care, Chapel Hill, NC
Consultations
- ASP (Advanced Sterilization Products), PDI

Honoraria
- PDI, ASP

Scientific Advisory Board
- Kinnos

Grants
- CDC, CMS
Environment of Care: Air, Water
Learning Objectives

- Identify the infection risks associated with construction and renovation
- Explain what infection prevention measures should be implemented to prevent patient exposure to fungal pathogens
- Discuss the HVAC system and how to control airborne contaminants
- Review the healthcare outbreaks associated with water reservoirs and discuss control strategies
Environment of Care: Air, Water

Learning Objectives

- Identify the infection risks associated with construction and renovation
- Explain what infection prevention measures should be implemented to prevent patient exposure to fungal pathogens
- Discuss the HVAC system and how to control airborne contaminants
- Review the healthcare outbreaks associated with water reservoirs and discuss control strategies
AIRBORNE FUNGAL OUTBREAKS

Requirements

- Susceptible host
- Reservoir
- Source
- Infecting dose inhaled (most dependent on concentration of fungi in the air)
MOST COMMON PATHOGENS ASSOCIATED WITH CONSTRUCTION OR RENOVATION OUTBREAKS

- *Aspergillus* spp. (by far most important)
- Zygomycetes
- Other fungi
- Miscellaneous
Review of Fungal Outbreaks and Infection Prevention in Healthcare Settings During Construction and Renovation

Hajime Kanamori,1,2 William A. Rutala,1,2 Emily E. Sickbert-Bennett,1,2 and David J. Weber1,2

1Hospital Epidemiology, University of North Carolina Health Care, and 2Division of Infectious Diseases, University of North Carolina School of Medicine, Chapel Hill

Hospital construction and renovation activities are an ever-constant phenomenon in healthcare facilities, causing dust contamination and possible dispersal of fungal spores. We reviewed fungal outbreaks that occurred during construction and renovation over the last 4 decades as well as current infection prevention strategies and control measures. Fungal outbreaks still occur in healthcare settings, especially among patients with hematological malignancies and those who are immunocompromised. The causative pathogens of these outbreaks were usually Aspergillus species, but Zygomycetes and other fungi were occasionally reported. Aspergillus most commonly caused pulmonary infection. The overall mortality of construction/renovation-associated fungal infection was approximately 50%. The minimal concentration of fungal spores by air sampling for acquisition of fungal infections remains to be determined. Performing infection control risk assessments and implementing the recommended control measures is essential to prevent healthcare-associated fungal outbreaks during construction and renovation.
### Table 2. Fungal Infections and Associated Mortality by Each Underlying Disease During Construction, Renovation, or Demolition

<table>
<thead>
<tr>
<th>Underlying Diseases</th>
<th>No. of Articles Published</th>
<th>No. of Patients Infected</th>
<th>No. of Patients Died</th>
<th>Mortality, No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hematologic malignancies or bone marrow transplant</td>
<td>26</td>
<td>414</td>
<td>148</td>
<td>131/288 (45.5)</td>
</tr>
<tr>
<td>Other malignancies, transplant, and/or immunosuppressed patients</td>
<td>13</td>
<td>105</td>
<td>38</td>
<td>38/60 (63.3)</td>
</tr>
<tr>
<td>Patients in intensive care unit</td>
<td>3</td>
<td>8</td>
<td>2</td>
<td>2/4 (50)</td>
</tr>
<tr>
<td>Rheumatology patients</td>
<td>2</td>
<td>6</td>
<td>4</td>
<td>4/6 (66.7)</td>
</tr>
<tr>
<td>After surgery</td>
<td>2</td>
<td>8</td>
<td>1</td>
<td>1/8 (12.5)</td>
</tr>
<tr>
<td>Premature infant</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2/3 (66.7)</td>
</tr>
<tr>
<td>Nephrology and dialysis patients</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>2/3 (66.7)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>49</strong></td>
<td><strong>547</strong></td>
<td><strong>197</strong></td>
<td><strong>180/372 (48.4)</strong></td>
</tr>
</tbody>
</table>

*Articles in which the number of patients infected or died was unknown were excluded for mortality calculation.*
Review of Fungal Outbreaks
Kanamori, Rutala, Sickbert-Bennett, Weber. CID. 2015;61:433
### Table 1. Characteristics of Fungal Outbreaks and Infections Associated With Construction, Renovation, and Demolition

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Population</th>
<th>No. of Patient Infected</th>
<th>No. of Patient Deaths</th>
<th>Type of Infection (Site)</th>
<th>Type of Fungi</th>
<th>Reservoir or Source</th>
<th>Airborne Fungal Level(s)</th>
<th>Molecular Typing</th>
<th>Control Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arnow, 1978 [6]</td>
<td>Immunocompromised (renal transplant)</td>
<td>3</td>
<td>1</td>
<td>Aspergillus infection (lung)</td>
<td>A. fumigatus, Aspergillus sp.</td>
<td>Renovation, spores on dust from false ceiling tiles above transplant unit</td>
<td>Airborne spores &gt; 200 cfu below renovation</td>
<td>Unknown</td>
<td>Impermeable plastic barriers, immunosuppressed patients moved to other floors, horizontal surfaces, vacuumed, damp mopped, and dusted</td>
</tr>
<tr>
<td>Sarubbi, 1982 [8]</td>
<td>Hospitalized patients (acute nonlymphocytic leukemia for 1 infected)</td>
<td>1</td>
<td>1</td>
<td>Invasive Aspergillus infection (lung)</td>
<td>A. flavus</td>
<td>Construction, defective ventilation and air filtration</td>
<td>8 A. flavus-positive room, control 1 A. flavus-positive room, positive air sampling plates</td>
<td>Unknown</td>
<td>Pre-filters and filters in ventilation system replaced</td>
</tr>
<tr>
<td>Lentino, 1982 [7]</td>
<td>Immunocompromised patients with renal allograft recipients or hematologic malignancy</td>
<td>10</td>
<td>4</td>
<td>Invasive Aspergillus infection (lung)</td>
<td>Aspergillus sp.</td>
<td>Road construction for access to the new hospital, contaminated window air conditioners in renal transplant ward</td>
<td>400-200 Aspergillus spores/cm² from air conditioner filter</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
<tr>
<td>Kasinski, 1985 [9]</td>
<td>Premature infants</td>
<td>2</td>
<td>2</td>
<td>Fungal infection (lung)</td>
<td>Aspergillus sp., Zygomycetes, Rhizopus indicus</td>
<td>Renovation of adjacent special care unit and demolition of wall, mold in dust above a false ceiling</td>
<td>0.88 fungi per hour per settle plate in construction free area</td>
<td>Unknown</td>
<td>Patients moved from area of construction, additional dampers placed in air ducts, impervious dust barriers erected, area above false ceiling and ventilation ducts vacuumed, replaced HEPA filters, air ducts and environmental surfaces disinfected</td>
</tr>
<tr>
<td>Opal, 1986 [10]</td>
<td>Immunocompromised (lymphomatous malignancy, high-dose corticosteroid therapy or disseminated carcinoma)</td>
<td>11</td>
<td>11</td>
<td>Aspergillus infection (disseminated)</td>
<td>A. flavus, A. fumigatus, A. niger, Aspergillus sp.</td>
<td>Hospital renovation and construction</td>
<td>5.9 x 0.7 Aspergillus/m² inside construction site compared to 1.2 Aspergillus/m² outside construction site</td>
<td>Unknown</td>
<td>Copper II gluconolate, air tight plastic and dry wall barriers about the construction site, HEPA filters in patient room, negative pressure in construction area</td>
</tr>
<tr>
<td>Barnes, 1989 [14]</td>
<td>Children undergoing BMT</td>
<td>6</td>
<td>6</td>
<td>Invasive Aspergillus infection (lung)</td>
<td>Unknown</td>
<td>Building work installing a laminar air flow system to the unit</td>
<td>133 cfu/m² of A. fumigatus in the BMT unit during building work</td>
<td>Unknown</td>
<td>Improved hospital design</td>
</tr>
</tbody>
</table>
53 studies with 458 patients

356 patients (78%) were lower respiratory tract

Aspergillus fumigatus (154) and A. flavus (101)

Underlying disease-hemotologic malignancies 299 (65%)

Overall fatality rate in these 299 patients (57.6%)

Construction or demolition probable/possible source-49%; virtually all outbreaks attributable to airborne source, usually construction

Patients at risk should not be exposed to Aspergillus
Medically-Important Mycotic Agents

*Aspergillus fumigatus*
8 cases of invasive fungal sinusitis (6 *A. flavus*, 1 *A. fumigatus*, 1 *Rhizopus*) and 5 deaths; release of fungal spores from soil reservoirs during construction; cultures of air and dust during the construction period grew *Aspergillus*. Lueg et al. 1996
NOT AN EXIT
CONSTRUCTION SITE
DO NOT ENTER
Aspergillus

- *Aspergillus* spores are ubiquitous (soil, fruits, vegetables, dust, decaying organic matter) in the environment.
- Conidia may travel long distances as airborne particles and are inhaled by humans (several hundred spores each day).
- In most healthy persons, spores are removed by innate defense mechanisms (macrophages).
- Severely immunocompromised (IC) hosts (hematologic, solid organ transplant) a serious complication.
- Air is normally the route of fungal spore transmission.
## AIRBORNE FUNGAL OUTBREAKS

<table>
<thead>
<tr>
<th>Portal of Entry</th>
<th>Number of Outbreaks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory tract</td>
<td>27</td>
</tr>
<tr>
<td>Skin</td>
<td>7</td>
</tr>
<tr>
<td>Operative site</td>
<td>3</td>
</tr>
<tr>
<td>Peritoneal dialysis catheter</td>
<td>1</td>
</tr>
<tr>
<td>Mixed</td>
<td>1</td>
</tr>
<tr>
<td>Not stated</td>
<td>2</td>
</tr>
</tbody>
</table>
AIRBORNE FUNGAL OUTBREAKS

- Activities shown to increase the amount of airborne fungal spores dramatically (and in consequence increases the risk of *Aspergillus* infection in susceptible patients)
  - Internal/External renovation/construction/excavation/construction is a never-ending phenomenon
  - Ceiling access
  - Contaminated or defective air supply
- Minimal airborne concentration of *Aspergillus* necessary to cause infection in IC patients remains unknown
DANGER

NOT AN EXIT
CONSTRUCTION SITE
DO NOT ENTER
CONSTRUCTION AREA
DO NOT ENTER

CHECK WITH
SUPERINTENDENT
BEFORE ENTERING
Environment of Care: Air, Water

Learning Objectives

- Identify the infection risks associated with construction and renovation
- Explain what infection prevention measures should be implemented to prevent patient exposure to fungal pathogens
- Discuss the HVAC system and how to control airborne contaminants
- Review the healthcare outbreaks associated with water reservoirs and discuss control strategies
CONSTRUCTION OR RENOVATION

- When planning construction, demolition, and renovation activities in and around the facility, assess whether patients at high-risk for aspergillosis are likely to be exposed to high ambient-air spore counts of *Aspergillus* spp., and if so develop a plan to prevent such exposure (IA)

- During construction, demolition, or renovation activities construct impermeable barriers between patient-care and construction areas to prevent dust from entering the patient-care areas (IB)

- Direct pedestrian traffic that come from construction areas away from patient-care areas to limit the opening and closing of doors or other barriers that might cause dust dispersion (IB)

- Infection prevention staff must participate at all levels of a construction project

CONSTRUCTION OR RENOVATION

- Establish a multidisciplinary team that includes infection-control staff to coordinate demolition, construction and renovation (IB, IC)
- Educate construction and healthcare staff in immunocompromised patient-care areas regarding airborne infection risks associated with construction and preventive measures (IB)
- Incorporate mandatory adherence agreements for infection control into construction contracts (IC)
- Establish and maintain surveillance for airborne environmental disease (e.g., aspergillosis) as appropriate during construction (IB)

Guideline for environmental infection control in health-care facilities, 2003
CONSTRUCTION OR RENOVATION\textsuperscript{1}

- Implement infection-control measures during construction, renovation, maintenance, demolition, and repair (IB, IC)
  - Before the project gets underway, perform an ICRA to define the scope of the project and need for barrier measures (IB, IC)
    - Determine if immunocompromised patients may be at risk for exposure and develop a contingency plan to prevent exposures
  - Implement infection-control measures for external demolition and construction (IB)
    - Determine if facility can operate on recirculated air; if feasible, seal off adjacent air intakes
    - If not feasible, check and replace low-efficiency filters as needed
    - Seal windows and reduce outside air intrusion

\textsuperscript{1}Guideline for environmental infection control in health-care facilities, 2003
CONSTRUCTION OR RENOVATION

- Implement infection-control measures during construction, renovation, maintenance, demolition, and repair (IB, IC)
  - Implement infection-control measure for internal construction (IB, IC)
    - Construct barriers to prevent dust from entering patient-care areas
    - Block and seal off return air vents (if needed)
    - Implement dust control measures; divert pedestrian traffic
    - Relocate patients adjacent to work zone (depending on their immune status)

---

1 CDC Guideline for environmental infection control in health-care facilities, 2003
CONSTRUCTION OR RENOVATION$^1$

- Implement infection-control measures during construction, renovation, maintenance, demolition, and repair (IB, IC)
  - Perform engineering and work-site related infection control measures as needed for internal construction and renovations
    - Ensure proper operation of the air-handling system
    - Create and maintain negative pressure in work zones
    - Monitor negative air flow inside of rigid barriers
    - Monitor barriers; repair gaps and breaks in barriers
    - Direct pedestrian traffic away from work zones
    - Provide designated travel routes for construction crew
    - Clean work zones daily
    - Clean and replace air filters

$^1$Guideline for environmental infection control in health-care facilities, 2003
CONSTRUCTION OR RENOVATION

- No recommendation is offered on routine microbiologic air sampling, before, during, or after construction (unresolved)
- If a case of healthcare-acquired aspergillus airborne fungal infection occurs during construction, implement appropriate measures (IIB)
- If there is epidemiologic evidence of ongoing transmission of fungal disease, conduct an environmental assessment to determine and eliminate the source (IIB)
- If air-supply systems to high-risk areas are not optimal use portable, industrial-grade HEPA filters on temporary basis (II)
ICRA is a multidisciplinary, organizational, documented process that after considering the facility’s patient population and type of construction project (non-invasive to major demolition):

- Focuses on reduction of risk from infection
- Acts through phases of facility planning, design, construction, renovation, facility maintenance and
- Coordinates and weights knowledge about infection, infectious agents, type of construction project and care environment permitting the organization to anticipate potential impact
### Step 1: Identify Type of Construction Project

**TYPE A**

**Inspection and Non-Invasive Activities.**

Includes, but is not limited to:

- removal of ceiling tiles for visual inspection only, e.g., limited to 1 tile per 50 square feet
- painting (but not sanding)
- wallcovering, electrical trim work, minor plumbing, and activities which do not generate dust or require cutting of walls or access to ceilings other than for visual inspection.

**TYPE B**

**Small scale, short duration activities which create minimal dust**

Includes, but is not limited to:

- installation of telephone and computer cabling
- access to chase spaces
- cutting of walls or ceiling where dust migration can be controlled.

### STEP 1: IDENTIFY TYPE OF CONSTRUCTION PROJECT

<table>
<thead>
<tr>
<th>TYPE C</th>
<th>Work that generates a moderate to high level of dust or requires demolition or removal of any fixed building components or assemblies. Includes, but is not limited to:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>▪ sanding of walls for painting or wall covering</td>
</tr>
<tr>
<td></td>
<td>▪ removal of floorcoverings, ceiling tiles and casework</td>
</tr>
<tr>
<td></td>
<td>▪ new wall construction</td>
</tr>
<tr>
<td></td>
<td>▪ minor duct work or electrical work above ceilings</td>
</tr>
<tr>
<td></td>
<td>▪ major cabling activities</td>
</tr>
<tr>
<td></td>
<td>▪ any activity which cannot be completed within a single workshift.</td>
</tr>
<tr>
<td>TYPE D</td>
<td>Major demolition and construction projects</td>
</tr>
<tr>
<td></td>
<td>Includes, but is not limited to:</td>
</tr>
<tr>
<td></td>
<td>▪ activities which require consecutive work shifts</td>
</tr>
<tr>
<td></td>
<td>▪ requires heavy demolition or removal of a complete cabling system</td>
</tr>
<tr>
<td></td>
<td>▪ new construction.</td>
</tr>
</tbody>
</table>
## STEP 2: IDENTIFY PATIENT RISK

<table>
<thead>
<tr>
<th>Low Risk</th>
<th>Medium Risk</th>
<th>High Risk</th>
<th>Highest Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office areas</td>
<td>Cardiology</td>
<td>CCU</td>
<td>Any area caring for immunocompromised patients</td>
</tr>
<tr>
<td></td>
<td>Echocardiography</td>
<td>Emergency Room</td>
<td>Burn Unit</td>
</tr>
<tr>
<td></td>
<td>Endoscopy</td>
<td>Labor &amp; Delivery</td>
<td>Cardiac Cath Lab</td>
</tr>
<tr>
<td></td>
<td>Nuclear Medicine</td>
<td>Laboratories (specimen)</td>
<td>Central Sterile Supply</td>
</tr>
<tr>
<td></td>
<td>Physical Therapy</td>
<td>Medical Units</td>
<td>Intensive Care Units</td>
</tr>
<tr>
<td></td>
<td>Radiology/MRI</td>
<td>Newborn Nursery</td>
<td>Negative pressure isolation rooms</td>
</tr>
<tr>
<td></td>
<td>Respiratory Therapy</td>
<td>Outpatient Surgery</td>
<td>Oncology</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pediatrics</td>
<td>Operating rooms including C-section rooms</td>
</tr>
</tbody>
</table>
**STEP 3:**
**MATCH RISK GROUP WITH CONSTRUCTION TYPE**

<table>
<thead>
<tr>
<th>Patient Risk Group</th>
<th>TYPE A</th>
<th>TYPE B</th>
<th>TYPE C</th>
<th>TYPE D</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOW Risk Group</td>
<td>I</td>
<td>II</td>
<td>II</td>
<td>III/IV</td>
</tr>
<tr>
<td>MEDIUM Risk Group</td>
<td>I</td>
<td>II</td>
<td>III</td>
<td>IV</td>
</tr>
<tr>
<td>HIGH Risk Group</td>
<td>I</td>
<td>II</td>
<td>III/IV</td>
<td>IV</td>
</tr>
<tr>
<td>HIGHEST Risk Group</td>
<td>II</td>
<td>III/IV</td>
<td>III/IV</td>
<td>IV</td>
</tr>
</tbody>
</table>

Note: Infection Control approval will be required when the Construction Activity and Risk Level indicate that **Class III** or **Class IV** control procedures are necessary.
## Infection Control by Class

<table>
<thead>
<tr>
<th>During Construction Project</th>
<th>Upon Completion of Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Execute work by methods to minimize raising dust from construction operations.</td>
<td>1. Clean work area upon completion of task.</td>
</tr>
<tr>
<td>2. Immediately replace a ceiling tile displaced for visual inspection</td>
<td></td>
</tr>
<tr>
<td>1. Provide active means to prevent airborne dust from dispersing into atmosphere.</td>
<td>1. Wipe work surfaces with cleaner/disinfectant.</td>
</tr>
<tr>
<td>2. Water mist work surfaces to control dust while cutting.</td>
<td>2. Contain construction waste before transport in tightly covered containers.</td>
</tr>
<tr>
<td>3. Seal unused doors with duct tape.</td>
<td>3. Wet mop and/or vacuum with HEPA filtered vacuum before leaving work area.</td>
</tr>
<tr>
<td>4. Block off and seal air vents.</td>
<td>4. Upon completion, restore HVAC system where work was performed.</td>
</tr>
<tr>
<td>5. Place dust mat at entrance and exit of work area</td>
<td></td>
</tr>
<tr>
<td>6. Remove or isolate HVAC system in areas where work is being performed.</td>
<td></td>
</tr>
</tbody>
</table>
## INFECTION CONTROL BY CLASS

<table>
<thead>
<tr>
<th>During construction</th>
<th>After construction</th>
</tr>
</thead>
</table>
| 1. Remove or Isolate HVAC system in area where work is being done to prevent contamination of duct system.  
2. Complete all critical barriers i.e. sheetrock, plywood, plastic, to seal area from non work area or implement control cube method (cart with plastic covering and sealed connection to work site with HEPA vacuum for vacuuming prior to exit) before construction begins.  
3. Maintain negative air pressure within work site utilizing HEPA equipped air filtration units.  
5. Cover transport receptacles or carts. Tape covering unless solid lid. | 1. Do not remove barriers from work area until completed project is inspected by the owner’s Safety Department and Infection Prevention & Control Department and thoroughly cleaned by the owner’s Environmental Services Department.  
2. Remove barrier materials carefully to minimize spreading of dirt and debris associated with construction.  
3. Vacuum work area with HEPA filtered vacuums.  
4. Wet mop area with cleaner/disinfectant.  
5. Upon completion, restore HVAC system where work was performed. |
## INFECTION CONTROL BY CLASS

### During construction

1. Isolate HVAC system in area where work is being done to prevent contamination of duct system.
2. Complete all critical barriers i.e. sheetrock, plywood, plastic, to seal area from non work area or implement control cube method (cart with plastic covering and sealed connection to work site with HEPA vacuum for vacuuming prior to exit) before construction begins.
3. Maintain negative air pressure within work site utilizing HEPA equipped air filtration units.
4. Seal holes, pipes, conduits, and punctures.
5. Construct anteroom and require all personnel to pass through this room so they can be vacuumed using a HEPA vacuum cleaner before leaving work site or they can wear cloth or paper coveralls that are removed each time they leave work site.
6. All personnel entering work site are required to wear shoe covers. Shoe covers must be changed each time the worker exits the work area.

### After construction

1. Do not remove barriers from work area until completed project is inspected by the owner’s Safety Department and Infection Prevention & Control Department and thoroughly cleaned by the owner’s Environmental Services Dept.
2. Remove barrier material carefully to minimize spreading of dirt and debris associated with construction.
3. Contain construction waste before transport in tightly covered containers.
4. Cover transport receptacles or carts. Tape covering unless solid lid.
5. Vacuum work area with HEPA filtered vacuums.
6. Wet mop area with cleaner/disinfectant.
7. Upon completion, restore HVAC system where work was performed.
PREVENTION

- Procedures during construction and renovations
  - Seal hospital construction areas behind impervious barriers
  - Clean construction area daily (i.e., remove dust)
  - Assure that ventilation system does not transport dust from inside construction area to other locations
  - Move immunocompromised patients from adjacent areas
  - Thoroughly clean construction area prior to patient use
  - Conduct surveillance for airborne fungal infections
  - Avoid transporting construction material through patient areas
SUMMARY

- Outbreaks of aspergillosis and other fungi continue to occur in US healthcare facilities
- Highly immunocompromised patients are at highest risk
- Most outbreaks are related to construction and renovation
- Appropriate implementation of CDC/HICPAC guidelines can prevent healthcare-associated infection
- Use of ICRA is a logical method to plan for construction and renovation projects
SUMMARY

- Airborne fungal infections cause significant morbidity and mortality for immunocompromised patients.
- Despite understanding of the usual sources and reservoirs of these pathogens outbreaks continue to occur.
- Well-designed and maintained ventilation systems and use of proper infection control techniques during construction will prevent most fungal outbreaks.
SUMMARY

- Surveillance is key to early detection of outbreaks
  - Maintain a high index of suspicion for healthcare-associated pulmonary aspergillosis in severely immunocompromised patients (ANC <500/mm³ for 2 weeks or <100/mm³ for 1 week)(IA)

- In the event of an outbreak careful evaluation of cases and an environmental evaluation will usually uncover a correctable cause

- New tools of molecular epidemiology may prove useful to link specific reservoirs with outbreaks
Environment of Care: Air, Water

Learning Objectives

- Identify the infection risks associated with construction and renovation
- Explain what infection prevention measures should be implemented to prevent patient exposure to fungal pathogens
- Discuss the HVAC system and how to control airborne contaminants
- Review the healthcare outbreaks associated with water reservoirs and discuss control strategies
Environmental Infection Control for Special Health Care Settings

Figure 3. Example of negative-pressure room control for airborne infection isolation (API)* + §

* Stacked black boxes represent patient’s bed. Long open box with cross-hatch represents supply air. Open boxes with single, diagonal slashes represent air exhaust registers. Arrows indicate direction of air flow.

+ Possible uses include treatment or procedure rooms, bronchoscopy rooms, and autopsy.
SPECIAL HEALTHCARE SETTINGS
(Airborne Infection Isolation—All, CDC Guideline 2003)

- Planning new or renovating All units
  - Directed airflow: exhaust air to the outside, away from air-intake and populated areas (IC)
  - Well-sealed room (IB)
  - Room-air pressure: Maintain continuous negative room with respect to corridor; monitor air pressure periodically (IB); install self-closing doors (IC)
  - Room-air changes: Maintain at >12 per hour (IB)
Figure 2. Example of positive-pressure room control for protection from airborne environmental microbes (PE) + §

* Stacked black boxes represent patient’s bed. Long open box with cross-hatch represents supply air. Open boxes with single, diagonal slashes represent air exhaust registers. Arrows indicate directions of air flow.

+ Possible uses include immunocompromised patient rooms (e.g., hematopoietic stem cell transplant or solid organ transplant procedure rooms) and orthopedic operating rooms.
Planning new units for high-risk patients

- **Air-filtration:** Install HEPA filters (99.97% efficient in filtering 0.3µ-sized particles) either centrally or point of use (IB)
- **Directed airflow:** Place air-intake and exhaust ports so that room air flows across patient’s bed and exits on opposite side of the room (IC)
- **Well-sealed room** (IB)
- **Room-air pressure:** Maintain room at positive pressure with respect to corridor (IB)
- **Room-air changes:** Maintain at >12 per hour (IC)
Infection control measures for operating rooms

- **Room-air pressure**: Maintain positive-pressure ventilation with respect to corridors and adjacent areas (IC)
- **Room-air changes**: Maintain at \( \geq 15 \) per hour (IC) with at least 3 ACH of fresh air (20 AC/hr per FGI)
- **Directed Airflow**: Introduce air at the ceiling and exhaust air near the floor (IC)
- **Doors**: Keep room doors closed except for essential personnel, patients, equipment; limit entry to essential personnel (IB)
AIR-HANDLING SYSTEMS IN HCF

- Ensure HVAC filters are properly installed and maintained (IB)
- Monitor areas with special ventilation (AII, PE) for ACH and pressure differentials (IB)
- Inspect filters periodically (IC)
- Ensure intakes (>6 ft above ground) and exhaust outlets (>25 ft from intake) are located properly (IC)
AIR-HANDLING SYSTEMS IN HCF

- Do not use through-the-wall ventilation units (air induction ventilation) for PE (IC)
- Seal windows with centralized HVAC, especially PE areas (IB, IC)
- Do not shut down HVAC for other than required maintenance, filter changes, and construction (IB, IC); coordinate to allow relocation of IC (IC)
- Keep emergency doors and exits in PE (protective environments) closed (II)
Windows Closed
Heating, Ventilation and Air Conditioning
Filter Bank of MERV 8
Environment of Care: Air, Water
Learning Objectives

- Identify the infection risks associated with construction and renovation
- Explain what infection prevention measures should be implemented to prevent patient exposure to fungal pathogens
- Discuss the HVAC system and how to control airborne contaminants
- Review the healthcare outbreaks associated with water reservoirs and discuss control strategies
Water As A Source of Nosocomial Outbreaks
WATER RESERVOIRS

- Potable water
- Sinks
- Faucet aerators
- Showers
- Tub immersion
- Toilets
- Decorative fountains
- Dialysis water
- Ice and ice machines
- Water baths
- Flowers
- Eye wash stations
- Water walls
Healthcare Outbreaks Associated With a Water Reservoir and Infection Prevention Strategies

Hajime Kanamori,1,2 David J. Weber,1,2 and William A. Rutala2

1Division of Infectious Disease, University of North Carolina School of Medicine, and 2Hospital Epidemiology, University of North Carolina Health Care, Chapel Hill

Hospital water may serve as a reservoir of healthcare-associated pathogens, and contaminated water can lead to outbreaks and severe infections. The clinical features of waterborne outbreaks and infections as well as prevention strategies and control measures are reviewed. The common waterborne pathogens were bacteria, including Legionella and other gram-negative bacteria, and nontuberculous mycobacteria, although fungi and viruses were occasionally described. These pathogens caused a variety of infections, including bacteremia and invasive and disseminated diseases, particularly among immunocompromised hosts and critically ill adults as well as neonates. Waterborne outbreaks occurred in healthcare settings with emergence of new reported reservoirs, including electronic faucets (Pseudomonas aeruginosa and Legionella), decorative water wall fountains (Legionella), and heater-cooler devices used in cardiac surgery (Mycobacterium chimaera). Advanced molecular techniques are useful for achieving a better understanding of reservoirs and transmission pathways of waterborne pathogens. Developing prevention strategies based on water reservoirs provides a practical approach for healthcare personnel.

Keywords: waterborne outbreaks; healthcare-associated infections; water; outbreaks.
CLASSIFICATION OF HEALTHCARE-ASSOCIATED INFECTIONS LINKED TO WATER

- Key pathogens
  - Other: Fungi (*Aspergillus, Fusarium, Rhizomucor*), norovirus, *Cryptosporidium*

- Key water sources
  - Potable water (contamination may occur anywhere along the distribution track): Sinks, showers, faucets, tubs, ice, eyewash stations, flower vases
  - Other: Fish tanks, water walls, dialysis water, internal fluid channels of medical equipment

- Transmission mechanisms
  - Inhalation of aerosols, direct or indirect contact with contamination source, ingestion, aspiration of contaminated water

Water supply + Use + Patient susceptibility

Reddy S. CDC, 2018
### Table 2. Summary of Key Issues and Infection Prevention Strategies Against Waterborne Outbreaks by Major Water Reservoir in Healthcare Settings

<table>
<thead>
<tr>
<th>Reservoir</th>
<th>Key Issues</th>
<th>Infection Prevention Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potable water, tap water, and hospital water systems</td>
<td>Potable water is not sterile, and pathogenic waterborne organisms may exist in potable water at acceptable levels of coliform bacteria (&lt;1 coliform bacterium/100 mL). Healthcare-associated outbreaks have been linked to contaminated potable water. Semicritical devices are often rinsed with potable water, which may lead to contamination of the equipment and subsequent healthcare-associated infections. Common pathogens include nonmotile gram-negative bacilli (e.g., <em>Pseudomonas aeruginosa</em>, <em>Legionella</em>, NTM).</td>
<td>Follow public health guidelines. Hot water temperature at the outlet at the highest temperature all bealve, preferably &gt;51°C. Water disruptions: post signs and do not drink tap water. Maintain standards for potable water (&lt;1 coliform bacterium/100 mL). Rinse semicritical equipment with sterile water, filtered water, or tap water followed by alcohol rinse. Some experts have recommended periodic monitoring of water samples for growth of <em>Legionella</em>. <em>Legionella</em> eradication can be technically difficult, temporary, and expensive. Potential methods of eradication include filtration, ultraviolet, ozonization, heat inactivation (&gt;60°C), hyperchlorination, and copper-silver ionization (&gt;0.4 ppm and &gt;0.04 ppm, respectively).</td>
</tr>
<tr>
<td>Sinks</td>
<td>Colonization of sinks with gram-negative bacilli has been reported. Some studies demonstrate a transmission link between a colonized sink and infected patients. Some studies describe that multidrug-resistant gram-negative bacilli are associated with contaminated sinks. Gram-negative bacilli can survive wet environments, including sinks, for a long time (&gt;280 d). Transmission can be caused by splashing of water droplet from contaminated sinks to hands of healthcare personnel, followed by transient colonization of hands. Common pathogens include gram-negative bacilli (e.g., <em>Pseudomonas</em>, <em>Acinetobacter</em>, <em>Serratia</em>).</td>
<td>Use separate sinks for handwashing and disposal of contaminated fluids. Decontaminate or eliminate sinks as a reservoir if epidemic spread of gram-negative bacteria via sinks is suspected.</td>
</tr>
<tr>
<td>Faucet aerators</td>
<td>Faucet aerators may serve as a platform for accumulation of waterborne pathogens. Potential pathogens include <em>Pseudomonas</em>, <em>Stenotrophomonas</em>, and <em>Legionella</em>.</td>
<td>Routine screening and disinfection or permanent removal of all aerators are not warranted at present. No precautions necessary at present. For <em>Legionella</em> outbreaks, clean and disinfect faucet aerators in high-risk patient areas periodically, or consider removing them in the case of additional infections.</td>
</tr>
<tr>
<td>Showers</td>
<td>Some outbreaks are linked to contaminated shower heads or inhalation of aerosols. Potential pathogens include <em>Legionella</em>, <em>Pseudomonas</em>, NTM, group A <em>Streptococcus</em>, and <em>Aspergillus</em>.</td>
<td>Prohibit use of showers in neutropenic patients. Control <em>Legionella</em> colonization of potable water.</td>
</tr>
<tr>
<td>Ice and ice machines</td>
<td>Patients may acquire pathogen by sucking on ice, ingesting iced drinks, or use of contaminated ice for cooling medical procedure and patients’ skin. Large outbreaks occurred when ice machines have become contaminated and ice used for cooling drinking water. Common pathogens include <em>Pseudomonas</em>, <em>Enterobacter</em>,</td>
<td>Do not handle ice by hand. Do not store pharmaceuticals or medical solutions on ice for consumption. Use automatic disperser rather than open chest storage compartments in patient areas. Clean and disinfect ice-storage chests regularly.</td>
</tr>
</tbody>
</table>
Healthcare Outbreaks Associated with Water Reservoir


Eyewash stations
- Stationary and portable eyewash stations may not be used for months or years.
- The water source may stand in the incoming pipes at room temperature for a long period.
- Pathogens, including *Pseudomonas*, *Legionella*, amoebae, and fungi, could be transmitted.

Dental-unit water systems
- Potable water usually supplies dental units.
- Water delivered to dental devices (eg, dental handpieces and air/water syringes) as well as dental unit water lines may be contaminated.
- Immunocompromised patients may be at risk for infection.
- Pathogens, including *Sphingomonas*, *Pseudomonas*, *Acinetobacter*, *Legionella*, and NTM, have been recovered from water supplies in dental units.

Dialysis water
- Excessive levels of gram-negative bacilli in the dialysate were responsible for pyrogenic reactions in patients or bacteremia, which was caused by bacteria or endotoxin entry into the blood from the contaminated dialysate.

Water and ice baths
- Contaminated water baths were used to thaw or warm blood products (fresh plasma, cryoprecipitate) or peritoneal dialysate bottles, followed by contamination of the infusates occurred during preparation.
- Contaminated ice baths were used to cool syringes or bottles of saline in measuring cardiac output.
- Potential pathogens include *Pseudomonas*, *Acinetobacter*, *Burkholderia*, *Staphylococcus*, and *Ewingella*.

Use sterile water for eye flush or regularly (eg, monthly) flush eyewash stations.

Clean dental water systems.

Flush with water and disinfectant solution, or use of clean-water systems that put sterile water into the dental unit.

Flush dental instruments with water and air for 20–30 sec from any dental device connected to the dental water system that enters the patient’s mouth (eg, handpieces).

Ensure that water in dental unit meets standards (<500 CFU/mL).

Follow AAMI standards for quality assurance performance of dialysis devices.

Disinfect water distribution system on a regular basis.

Perform microbiological testing and endotoxin testing for water in dialysis settings regularly.

Maintain dialysis water (input) <200 CFU/mL and dialysate (output) <200 CFU/mL per CMS.

Consider routine cleaning, disinfection, and changing of water in water baths.

Add germicide to water bath or use plastic overwrap of blood products and keep the surfaces dry.

Use sterile water in ice baths (or at room temperature) used for thermodilution catheters.
# Healthcare Outbreaks Associated with Water Reservoir


<table>
<thead>
<tr>
<th>Reservoir</th>
<th>Key Issues</th>
<th>Infection Prevention Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bathing, tub immersion, and hydrotherapy</td>
<td>Tub immersion used in hospitals for physical hydrotherapy and for cleaning of burn wounds can cause cross-transmission, transmission from environmental reservoirs, or auto-transmission. Skin infections such as folliculitis and cellulitis occurred related to water immersion. Water contamination of central venous catheters during bathing was related to bloodstream infection. Potential pathogens include <em>Pseudomonas</em>, <em>Enterobacter</em>, <em>Citrobacter</em>, <em>Acinetobacter</em>, <em>Legionella</em>, <em>Alcaligenes</em>, and NTM.</td>
<td>Adhere strictly to proper disinfection of tub between patients. Drain and clean tanks and tubs after use of each patient, and disinfect surfaces and components according to the manufacturer’s instructions. Add disinfectant to the water: 15 ppm in small hydrotherapy tanks and 2–5 ppm in whirlpools per CDC. Disinfect after using tub liners. Cover catheter sites with transparent occlusive dressing.</td>
</tr>
<tr>
<td>Toilets</td>
<td>Transmission can be caused by aerosolization of fecal bacteria via flushing or surface contamination by fecal bacteria. Transmission could happen in healthcare facilities caring for mentally or neurologically impaired patients, or children. Potential pathogens include enteric bacteria, <em>Pseudomonas</em>, <em>Clostridium difficile</em>, and norovirus.</td>
<td>Facilitate good handwashing practices. Maintain clean surfaces with disinfectants. Clean bowl with a scouring powder and a brush. No reason to pour disinfectant into bowl. Separate toilet bowl from clean hospital surfaces.</td>
</tr>
<tr>
<td>Flowers and vases</td>
<td>Flower vases and potted plants are heavily colonized with potential pathogens, including <em>Acinetobacter</em>, <em>Klebsiella</em>, <em>Enterobacter</em>, <em>Pseudomonas</em>, <em>Serratia</em>, <em>Burkholderia cepacia</em>, <em>Aeromonas hydrophila</em>, and <em>Flavobacterium</em>. No healthcare-associated outbreaks directly linked to flower vases or potted plants have been reported.</td>
<td>Prohibit fresh flowers and potted plants in the rooms of immunocompromised and ICU patients. Or add antimicrobial agent to vase water and disinfect vases after use.</td>
</tr>
<tr>
<td>Electronic faucets</td>
<td>Electronic faucets were likely to be contaminated by several waterborne pathogens than handle-operated faucets. Issues associated with electronic faucets include a longer distance between the valve and the tap, resulting in a longer column of stagnant, warm water, which favors production of biofilms; reduced water flow; reduced flushing effect (growth favored); valves and pipes made of plastic (enhances adhesion of <em>P. aeruginosa</em>).</td>
<td>Electronic faucets need to be designed so that they do not promote the growth of microorganisms. No guideline (but some authors have recommended) to remove electronic faucets from high-risk patient care areas (e.g., BMTU). Some have recommended periodic monitoring of water samples for growth of <em>Legionella</em>.</td>
</tr>
<tr>
<td>Decorative water wall fountains</td>
<td><em>Legionella</em> pneumonia cases associated with decorative water fountain were reported. There is an unacceptable risk in hospitals serving immunocompromised patients (even with standard maintenance and sanitizing methods).</td>
<td>Avoid installation, especially in healthcare facilities serving immunocompromised patients or in areas caring for high-risk patients. Perform maintenance regularly and monitor water safety strictly unless removed.</td>
</tr>
<tr>
<td>Heater-cooler units</td>
<td>Healthcare-associated <em>Mycobacterium chimaera</em> outbreak due to contamination of heater cooler units during cardiac surgeries as a water source has been recently reported. Airborne transmission from contaminated heater cooler unit water tanks.</td>
<td>Ensure that heater-cooler units are safe and properly maintained according to the manufacturer’s instructions. Enhance vigilance for NTM infections in patients after cardiac surgeries using heater-cooler devices. If NTM infections are suspected, review microbiology database (NTM-positive cultures) and medical records of surgical procedures within several years after cardiac surgeries.</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>Potential reservoirs include distilled water or containers (outbreaks with <em>Enterobacter cloacae</em> and <em>B. cepacia</em>), wash basins (Salmonella, <em>Legionella</em>, <em>Trichosporon</em> infection), <em>Legionella</em> pneumonia, <em>intraoral</em> balloon pump (B. cepacia bacterial), humidifier water in ventilator systems (<em>Acremonium</em> kiliense postoperative endophthalmitis), water cooler (gastrointestinal illness), hot water (<em>Acinetobacter baumannii</em> infection), deionized water (<em>Escherichia</em> bacteria, fungal), water-damaged plaster (mucormycosis), water birth (<em>Legionella pneumophila</em>, water-saving device, <em>S. aureus</em> infection), rinse water during endoscope reprocessing (gram-negative bacteria).</td>
<td>Consider control measures based on risk assessment by each reservoir when available.</td>
</tr>
</tbody>
</table>
Water Wall Fountains
Water Walls Linked to Legionnaires’

- Palmore et al. ICHE 2009;30:764
  2 immunocompromised patients exposed to decorative fountain in radiation oncology; isolates from patients and fountain identical; disinfection with ozone, filter and weekly cleaning

- Houpt et al. ICHE 2012;33:185
  Lab-confirmed Legionnaires disease was dx in 8 patients; 6 had exposure to decorative fountain (near main entrance to hospital); high counts of *Legionella pneumophila* 1 despite disinfection and maintenance
Water Walls and Decorative Water Fountains

Present unacceptable risk in hospitals serving immunocompromised patients (even with standard maintenance and sanitizing methods).
WORLDWIDE OUTBREAK OF *M. chimaera* DUE TO CONTAMINATED HCUs

- Since 2003, >200 cases of *M. chimaera* prosthetic valve endocarditis and disseminated disease reported
- Outbreak linked to intrinsically contaminated heater-cooler unit (HCU) – Stockert 3T HCU (Sorin)
- Internal water channels/tanks intrinsically contaminated; transmission from device to patients via aerosols
- Error = Failure to use disposable channels/tanks and/or inability to disinfect/sterilize internal water tanks
- Problem = Presence of biofilm
- Risk = 0.4-16 per 10,000 Pt-years

Sommerstein R, et al.  ICHE 2017;38:103;
Schreiber PW, Sax H.  Curr Opin ID 2017;30:388
LEGIONELLA INCIDENCE OVER TIME, US, CDC

Potential reasons (per CDC) for 4.5-fold increase in Legionnaires’ disease since 2000

- Artifact (increased awareness and testing)
- Increased susceptibility of population
- Increased Legionella in environment
- Combination of factors

400 cases of legionellosis in Australia each year

https://www.cdc.gov/legionella/surv-reporting.html
LEGIONELLA: EPIDEMIOLOGY

- 10,000 - 40,000 cases/yr (1-5% of adult pneumonia)
- Reservoir: Ubiquitous in aquatic environments
- Associated with devices that produce potable or non-potable water aerosols (e.g., cooling towers, evaporative condensers, showers, faucets, decorative water fountains, whirlpool baths, ice machines, medication nebulizers, nasogastric feedings diluted in tap water)
- Transmission: Inhalation of aerosols (no person-to-person transmission)
CONTROLLING WATERBORNE MICROORGANISMS

● Water Systems in HCF
  ■ Hot water temp at the outlet at the highest temp allowable, preferable >124°F (IC)
  ■ When state regulations do not allow hot water temp >120°F, chlorinate the water or periodically increase >150°F (II)
  ■ Water disruptions: post signs and do not drink tap water (IB, IC)
LEGIONELLA: CONTROL MEASURES

- Establish surveillance system to detect Legionnaires disease (IB); provide clinicians with lab tests (e.g., urine antigen, DFA, culture)

- No recommendation on culturing water in HCF that do not have patients at high-risk for Legionella (transplant)(unresolved issue)

- One laboratory-confirmed case of Legionella, or two cases suspected in 6 mo in facility that does not treat IC patients, conduct epidemiological investigation (IB).
LEGIONELLA: CONTROL MEASURES

- One case in IC patient, conduct a combined epidemiological and environmental investigation (IB)
- If evidence of HA transmission, conduct environmental investigation to determine source: collect water samples from potential source of aerosolized water and subtype isolates of *Legionella* from patients and environment (IB)
- If source identified, institute water system decontamination (IB) and assess the efficacy of implementing control measures (IB)
- Culturing for *Legionella* in water from transplant units can be performed as part of comprehensive strategy (II)
LEGIONELLA: CONTROL MEASURES

If *Legionella* spp are detected in water of a transplant unit, do the following:

- Decontaminate the water supply (IB)
- Restrict immunocompromised patients from showers (IB)
- Use non-contaminated water for sponge baths (IB)
- Provide sterile water for drinking, tooth brushing (IB)
- Do not use water from faucets in patient rooms (IB)
Environment of Care: Air, Water
Learning Objectives

- Identify the infection risks associated with construction and renovation
- Explain what infection prevention measures should be implemented to prevent patient exposure to fungal pathogens
- Discuss the HVAC system and how to control airborne contaminants
- Review the healthcare outbreaks associated with water reservoirs and discuss control strategies
THANK YOU!
www.disinfectionandsterilization.org