In with the Good Air & Out with the Bad:

Perspectives on air quality in healthcare facilities and impact on healthcare associated infections (HAIs)

Russ Olmsted, MPH, CIC
Director, Infection Prevention & Control Services (IPCS),
SJMHS, Ann Arbor, MI, U.S.  olmstedr@trinity-health.org

Note of thanks and appreciation for this opportunity are in order for Skip Gregory
Agenda for This Seminar

• Perspectives on Healthcare associated infections (HAIs)
• Overview of Transmission of Infectious Diseases
• Newer evidence involving influenza viruses
• Select airborne infections of importance to HVAC Systems
• Environmental controls for key areas in healthcare facilities
  • Protective environment, airborne infection isolation
  • Operating room / invasive procedures
• State of the evidence on relationship between air exchange and airborne disease transmission.
How Big of a Problem are Health Care-Associated Infections (HAIs) in U.S. Hospitals?

Total HAI’s / year = 1.7 million; 98,987 deaths

- 244,385 = SSI
- 133,368
- 263,810
- 424,060

SSI: 20%
UTI: 36%
PNEU: 11%
BSI: 11%
Other: 22%

HRN=High Risk Newborn, WBN=Well Baby Nursery, ICU=Intensive Care Unit,
SSI=Surgical Site Infection, BSI=Bloodstream Infection, UTI=Urinary Tract Infection, Pneu=Pneumonia

How About Cost of Care by Site of HAI?

• Total annual costs for 5 sites of HAI, U.S. = $9.8 billion
  • SSIs contributing the most to overall costs (33.7% of this total)

• Frequency:
  • SSIs are estimated as most frequent HAI (36%)
  • C. difficile infection (CDI); ranks second (30.3%)
  • Remaining ranking:
    • Cath.-associated UTI (17.4%)
    • Central Line-assoc. bloodstream infection (9.2)
    • Ventilator-associated pneumonia (7.1)

## Measuring Progress Toward Action Plan Goals

<table>
<thead>
<tr>
<th>Metric</th>
<th>National 5-year Prevention Target</th>
<th>On Track to Meet 2013 Targets?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bloodstream infections</td>
<td>50% reduction</td>
<td>✅</td>
</tr>
<tr>
<td>Adherence to central-line insertion practices</td>
<td>100% adherence</td>
<td>✅</td>
</tr>
<tr>
<td><em>Clostridium difficile</em> (hospitalizations)</td>
<td>30% reduction</td>
<td>✗</td>
</tr>
<tr>
<td><em>Clostridium difficile</em> infections</td>
<td>30% reduction</td>
<td>Data not yet available*</td>
</tr>
<tr>
<td>Urinary tract infections</td>
<td>25% reduction</td>
<td>✅</td>
</tr>
<tr>
<td>MRSA invasive infections (population)</td>
<td>50% reduction</td>
<td>✅</td>
</tr>
<tr>
<td>MRSA bacteremia (hospital)</td>
<td>25% reduction</td>
<td>Data not yet available*</td>
</tr>
<tr>
<td>Surgical site infections</td>
<td>25% reduction</td>
<td>✅</td>
</tr>
<tr>
<td>Surgical Care Improvement Project Measures</td>
<td>95% adherence</td>
<td>✅</td>
</tr>
</tbody>
</table>

*2009 or 2009-2010 is the baseline period.*

http://www.hhs.gov/ash/initiatives/hai/actionplan/index.html
 Reasons for Success in Prevention of HAIs: Bundling Prevention Strategies

- Collaboratives + Combining Prevention Strategies into Bundle
- Overall rate of central line-associated bloodstream infections in 103 ICUs reduced by 66%

Infection Prevention Bundle (Insertion):
- Hand hygiene
- **Maximal Sterile Barrier Precautions**
- **Skin antisepsis with chlorhexidine**
- Use of insertion checklist
- Avoiding femoral site
- Removing unnecessary catheters

Catheter-Associated UTI Bundle

- Adherence to general infection prevention principles (e.g., hand hygiene, surveillance and feedback, aseptic insertion, proper maintenance, education);
- Bladder ultrasound may avoid need for a catheter;
- Condom catheters or other alternatives to an indwelling catheter;
- Do not use the indwelling catheter unless you must!
- Early removal of the catheter using a reminder or nurse-initiated removal protocol appears warranted.

Picture is Worth A Lot:
“Honest Russ, all I did was an abdominal exam”

Level of contamination with MRSA after abdominal exam

Same hand after application of alcohol-based hand rub (ABHR)

Your 5 moments for HAND HYGIENE

1. BEFORE PATIENT CONTACT
2. BEFORE ASEPTIC TASK
3. AFTER BODY FLUID EXPOSURE RISK
4. AFTER PATIENT CONTACT
5. AFTER CONTACT WITH PATIENT SURROUNDINGS
Principles of Disease Transmission

Pathogen (germ, e.g. bacteria, virus, fungus):

- Leaves person or place in environment where its present
- Germ survives in environment
- Is transmitted to a susceptible person
- Germ gets to target cell /area of susceptible person
- Germ avoids or escapes host defenses
- Multiply and cause tissue damage
Chain of Infection

- Entry
- Transmission
- Exit
- Reservoir
- Infectious Agent
- Patient
Modes of Transmission

• **Contact:**
  - **Direct** = microbe transferred directly from patient to caregiver; example: scabies
  - **Indirect** = transfer of germs via intermediate object or person; caregiver picks up germs from contaminated surface and transfers to the patient, example: methicillin-resistant S. aureus (MRSA)

• **Droplet:** microbe in respiratory droplets produced by cough or sneeze; droplets travel 3-6 feet; examples: influenza, SARS-CoV

• **Airborne:** germ in respirable droplet nuclei becomes airborne and can travel long distance and be inhaled deep into lung; examples: *Mycobacterium tuberculosis, Aspergillus spp.*
Re-Examination of the “5 microns” Rule & New Concepts

- **Obligate** airborne transmission - droplet nuclei that are inhaled; prototype = *Mycobacterium tuberculosis*

- **Preferential** transmission from aerosols of infectious particles that reach distal respiratory tract; examples: measles, chickenpox

- However, we know that:
  - Much larger particles can float and are inhaled.
  - Most respiratory pathogens do not require terminal alveolar deposition, but infect the upper respiratory mucosa, e.g. influenza.
  - “**Opportunistic**” transmission through air but over short range of 1-2 m [e.g. SARS-CoV, norovirus, pertussis, influenza virus]

Source: Michael Bell, MD – CDC & Roy CJ, Milton NEJM 2004
Respiratory Tract and Infectious Agent Particle Size

Roy CJ, Milton DK NEJM 2004
Coughing and Aerosols

- cough plume may project infectious aerosols into the surrounding air
- maximum airspeed of 8 m per second (18 mph) was observed, averaged during the half-second cough

Tang, Julian. “Coughing and Aerosols” NEJM, 2008 Vol. 359:e19, No.15
The “Calculus” of Transmission by Air

Figure 3  Droplet suspension. Illustration of the mechanics of suspension of droplet nuclei produced by an infected patient due to the effects of air friction and gravity.

Airborne Diseases & Risk of Secondary Transmission

- List of Select Infectious Microbes/Diseases; & Associated $R_0$:
  - Obligate inhalational transmission:
    - *M. tuberculosis*; variable
    - Chickenpox; 15-17
    - Measles (rubeola); 10-15
    - Aspergillus spp; variable
    - *Bacillus anthracis*;
  - Opportunistic transmission:
    - SARS-CoV; 2 - 3
    - Influenza;
      - seasonal = 1.5-3.1; H1N1 '09=1.7 – 1.8
    - Smallpox; 4 - 7

$R_0$ = the number of secondary cases from a single index case of infection in a totally susceptible population

White LF, et al 2009

Green font = diseases more likely encountered in healthcare facilities
Deeper Dive into Influenza

**Influenza:** viral infection of the respiratory tract

Transmission:

- **Droplets:** when a person with influenza coughs or sneezes... or
- **Contact:** direct (shaking hands) or indirect contact (a surface), where the virus is present.
- **Airborne?** – perhaps opportunistic
Real World Experiences with pandemic H1N1 2009

- Tour Group in China; N=31
- Index case:
  - 40 yo female traveler from US to Jiuzhaigou, China; 3 different flights, 179 fellow passengers
- 9/30 (30%) on bus = secondary cases but all 9 had face-to-face contact in direct conversation
- 1/87 passengers on one flight had influenza-like illness (ILI); 2 rows away from index
- Conclusion: transmission only droplet, 1-2 meters

Environmental Investigations of Influenza

• Air sampling investigations: stationary & personal sampling devices used
    • Hospital Emergency Dept, 6 days in February 2008
    • 53% of influenza viral particles detected by RT-PCR were of respirable size, i.e. 1-4 microns
    • Urgent care clinic, 11 days, Feb. 2009
    • Influenza A RNA (17-19%) and RSV RNA (32-38%) recovered from stationary and personal samplers

• Does viral RNA = viable, infectious virus?
• No data on ILI or HA-influenza in HCWs or others in these study sites
More Recent Study on Influenza Particle Size & Distance

26/61 patients with influenza released virus into the air

High influenza virus [ ] within 0.914 m of the head, dropping significantly by 1.829 m.

89% < 4.7 micron size

Bischoff WE, et al JID 2013
Role of “Supershedders” of Influenza Virus?

- Five of the 26 emitters (19%) released, on average, 32 times more influenza virus into room

- Bischoff WE, et al. et al JID 2013
Influenza Virus & Airborne Transmission? A perspective

• “…did not show that influenza virus in the particles detected was viable and infectious or that transmission to others actually occurred…”

• clinical studies of respiratory viruses, including influenza virus and rhinovirus, the preferential means of spread appear to be those requiring close contact over airborne transmission…”

• Still need combination of consistent use of PPE + protection from influenza vaccine.

• Hall CB. InfluenzaVirus: Here, There, Especially Air? JID 2013
Infection Prevention Strategies
Hierarchy of Controls

Administrative Controls: Respiratory Hygiene + cough etiquette

Environmental Controls: HVAC, AIIR#

Personal Protective Equipment

# Heating, Ventilation and Air Conditioning; Airborne Infection Isolation Room
Prevention Of Infection works at home, school, and the hospital
* Cover your cough
* Wash your hands or use waterless alcohol handrub
* Stay home if you are sick
Environmental Controls: HVAC System

“Airborne contamination can result when HVAC systems are improperly designed, built, or maintained. In addition to providing comfort and minimizing exposure to chemical pollution, ventilation systems are an important means for preventing infection.”

Protecting Susceptible Patients in Healthcare Settings

Examples of populations at risk of infection -

• Transplant recipient
  • solid organ
  • Hematopoietic (stem) cells
• Hematological malignancies
• Advanced AIDS
• Splenectomy
• Genetic disorders
• Solid tumors
• Long term steroid use – e.g. rheumatoid arthritis
• Diabetes
Aspergillus spp

- Spore forming fungus
- Ubiquitous in the environment – suspended in air
- Can cause invasive pulmonary aspergillosis (IPA)
  - High mortality among certain hospitalized patient populations
Healthcare Associated Aspergillosis

- 53 clusters or outbreaks:
  - 458 patients
  - Overall case fatality rate = 57.6%
- In one half of these the probable / possible source =
  - Construction &/or demolition work in healthcare facilities
- Infections observed even with concentration of Aspergillus spp in air was ≤ 1 colony-forming unit /m³

Contain & Confine Contaminants

Especially during construction, Renovation, or remediation.

See also: Bartley JM, et al. Am J Infect Control 2010;38:S1-12
Additional Investigation of Construction & Aspergillus spp.

- Setting: Childrens Hospital, Palo Alto, California
- High concentration of Aspergillus spores [400 conidia equivalents/m³] coincided with demolition activity, Oct. 06
- Concentrations of Aspergillus spores remained low in patient care areas
- Reason for success = Containment strategies for construction zone:
  - Temporary walls
  - Negative pressure anteroom between entry to construction – patient care areas
  - HEPA filter units
  - PM₅ = particulate matter < 5 micron size

Protection of Severely Immunocompromised Patients

Indications for PE: severely immunocompromised patients:
e.g., i) solid organ transplant patients or
ii) allogeneic neutropenic patients

- Parameters of Protective environment (PE):
  - Positive pressure (greater supply than exhaust air volume) – HEPA filters;
  - Pressure differential range of 2.5–8 Pa (0.01–0.03-in. water gauge), ideal at 8 Pa;
  - Sealed room; Clean to dirty air flow;
  - Monitoring;
  - >12 air changes per hour (ACH); and
  - Return air if refiltered.
Does PE protect against infection for stem cell and other high risk populations?

All cause mortality, PE + antimicrobial Prophylaxis @ 3 yr = significant reduction with:
- Air quality control
- Barrier precautions
- Antimicrobials

risk ratio 0.86 (0.81-0.91)

Significant reduction in HAI also associated with care in PE

What About Outside the PE room?

- 991 patients; 19,365 patient-days; 1999-2005
  - stem cell & solid organ transplant recipients.
- Cooperative care center: 44-suite unit on 2 floors
  - 6 ACH; MERV 12 filter media on supply

- Most significant HAIs:
  - Central line associated bloodstream infections
  - Clostridium difficile infection
- No invasive fungal infections observed but air sampling did find water intrusion + Aspergillus contamination
Diversity of Potential Sources of Microorganisms In the Operating Room (OR)

Exposure to microbes during interval between incision and closure; primarily
1) Pt endogenous flora;
2) Personnel;
3) Environment

Figure 1 Source and routes of infection in the operating room (Lewis 1993).

Lewis JR. ASHRAE Transactions, 1993
Addendum “d” to ANSI/ASHRAE 170-2008: *Ventilation of Health Care Facilities & FGI Guidelines*: lower limit for relative humidity = **20%; upper limit = 60** ; 2010

---

**Memorandum Summary**

- **RH of ≥20 Percent Permitted in Anesthetizing Locations**: The Centers for Medicare & Medicaid Services (CMS) is issuing a categorical LSC waiver permitting new and existing ventilation systems supplying hospital and critical access hospital (CAH) anesthetizing locations to operate with a RH of ≥20 percent, instead of ≥35 percent. We are also recommending that RH not exceed 60 percent in these locations.

- **This Waiver Does Not Apply**:  
  - When more stringent RH control levels are required by State or local laws and regulations; or  
  - Where reduction in RH would negatively affect ventilation system performance.

- **Hospitals & CAHs Must Elect to Use the Categorical Waiver**:  
  - Individual waiver applications are not required, but facilities are expected to have written documentation that they have elected to use the waiver.  
  - At the entrance conference for any survey assessing LSC compliance, a facility that has elected to use this waiver must notify the survey team.
Important Reality: Perfectly Functioning HVAC for OR is at mercy of perioperative team activity

- Orthopedic surgery cases observed
- Strongly positive correlation between the total CFU/m3 per operation and total traffic flow per operation.
- OR door opened 17.4x/case on average. 31% of traffic in and out of OR deemed unnecessary
- Andersson AE, et al. AJIC 2012
Airborne Infection Isolation Room (AIIR)

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

CDC, Environmental IC Guideline, 2003
HVAC Parameters for AIIR

- Pressure Differential ≥0.01 inch (2.5 Pa)
- Air changes per hour (ACH) ≥ 12
- Airflow volume: exhaust > supply
  - by 10% or 50 cfm (1.42 cmm)
  - aim for 125 cfm (3.55 cmm)
- Sealed room, approx. 0.5sq. Ft. leakage
- Discharge exhaust outside or filter through HEPA (99.97% effective @ 0.3 μm) before recirculation
Mass Isolation – Airborne

- Physical barrier separation
- Negative pressure separation
- Extended space for gurneys, etc.
- Easily Expanded
Just a Word About Water…Features that is is

- Outbreak of Legionnaires disease associated with decorative water wall. 8 cases; 3 needed ICU care
- Exposure: walked by or in a lobby at hospital A where water feature was installed.
- Prev. maint. per manuf. L. pneu.gp 1 in foam (B) > 1.2 M cfu.
- Take home: do not plan, design or install in HCFs!

State of The Science on Relationship Between Air Changes/Hour & Airborne Disease Transmission

“there are insufficient data to specify or quantify the minimum ventilation requirements in public spaces, including hospitals, office buildings, aircraft, and schools in relation to the spread of airborne infection..”

Literature Review: Room Ventilation and Airborne Disease Transmission. Memarzadeh F. 2013
Questions from Skip: Inquiring mechanical engineers and Others want to know… 1. Do microbes obey Surgery Suite Zones; unrestricted (UR), semi-restricted (SR), restricted (R)?

NO!
Question 2. Seamless Floors? What about “Walker Duct” and need to create a seam in the OR or Cath Lab Floor?

Answer: No evidence that a seam elevates post procedure infection risk.
Q3. What is the impact of external climate conditions, e.g. wind forces on indoor air quality in a “leaky” healthcare facility?

A. Good question… no precise data that points to impact on occupants risk of infection but study by Nausair A, 2008, did not find unexpected risks of infection in very susceptible patient population.

☑ Facility Guidelines Institute (FGI)
   http://www.fgiguidelines.org/index.html

New content for 2010:
• Updated requirements for the design of hand-washing stations

• Design information for technology and medical communication rooms

• A new appendix on performing patient safety risk assessments

• New material on selecting surfaces and furnishings
Summary Points

• It’s more than just about the germ; transmission + infection takes multiple steps.
• The line between droplet and airborne transmitted diseases is not black & white – more shades of grey
  • Newer evidence on detection of influenza RNA indicates particle sizes that can remain suspended in air – question is relationship to clinical infections in those exposed
• Properly designed & maintained HVAC continues to be critical to comfort and safety of occupants of HCFs
• Preventing disease transmission and protecting patients requires a combination of strategies; administrative, environmental and personal protective equipment.
  • Thank you….any questions?