Re-Engineering Today’s Hospitals to Prevent Infections Tomorrow

EA Bryce MD FRCPC
Division of Medical Microbiology and Infection Control
Department of Pathology, Faculty of Medicine, UBC
DISCLOSURE

Research: Biomerieux, Teck Resources Limited
OBJECTIVES

1. Discuss principles of engineering for infection reduction

2. Describe the Genome BMT Pilot Project

3. Review the results from the pilot project and the next steps and existing gaps in our knowledge on self-disinfecting surfaces
Microbes transfer between Patients, Healthcare Workers, and Environment
ADDRESSING THE ENVIRONMENT

Environmental factors contributing to increase risk of cross-contamination:

(1) Design (multi vs single bed)
(2) Thoroughness of cleaning
(3) Type of cleaning agent
(4) Types of surfaces that need to be cleaned
New Technologies in Surface Disinfection

- Ultraviolet C disinfection
- LED white light
- Vapor systems

Self-Disinfecting Surfaces

- Materials with inherent antimicrobial activity
- Photoactivated antimicrobicides
- Altered surface topography
UV SURFACE DISINFECTION

used in laboratories for years

new literature demonstrates value as an adjunct to cleaning

reduces CD spores, MRSA, VRE in hospital rooms

evaluation must include ability to integrate technology into workflow
IS IT SAFE?
Yes, sensors and barriers prevent accidental human exposure
UVC does not penetrate glass

DOES IT WORK?
Yes, both in laboratory and clinical setting
Types of UVC Technology Available

**CONTINUOUS UVC**
- Low pressure mercury 254 nm
- Cycle time: 5 to >60 min
- One study suggests more effective than pulsed xenon
- Purchase prices vary significantly

**PULSED XENON**
- Pulsed light from 200 to 320 nm
- Cycle time 5-7 min
- Purchase prices also vary
DOES UVC WORK CLINICALLY?

Many studies show decrease in bioburden
Limited studies on impact on HAI reduction

Vianna PG AJIC 2016:44:299-303
Napolitano NA AJIC 2015;43:1342-6
Anderson D Lancet 2017
Canadian facilities work at 100% capacity. No ability to extend “down time” for rooms.

Most UVC machines are microbiologically effective.

Functionality, integration into workflow, operator considerations become the primary determinants for purchase. Cycle time may become paramount.

Consider how your facilities operates when selecting UVC machines.
PERMANENT UVC INSTALLATION IN BATHROOMS

J Cooper, G Astrakianskis, K Bartlet, E Bryce

The Problem: Common shared hallway bathrooms with limited sink access

The background: Toilets generate aerosols of bacteria and viruses that follow air currents for long distances or land on surfaces.

The question: Is permanently installed UVC light effective in decreasing microorganisms in the air and on surfaces
THE STUDY DESIGN

J Cooper, G Astrakianskis, K Bartlet, E Bryce

Shared hallway washrooms of similar design and size with or without either UVC (with 5 minute run time)

150 litre air samples were collected 5 minutes and 30 seconds after patient use and cultured

Surface samples from toilet and counter cultured
Washroom Layout and Sampling Locations

- Location of air samples
- Location of surface samples

Dimensions:
- Width: 2.68 m
- Height: 1.96 m

Features:
- Sink
- Toilet
<table>
<thead>
<tr>
<th>Sample</th>
<th>Geometric Mean Concentration</th>
<th>Geometric Standard Deviation</th>
<th>% Reduction in Mean Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seat Bacteria¹ UV+ve</td>
<td>7.7</td>
<td>5.5</td>
<td>97*</td>
</tr>
<tr>
<td>Seat Bacteria¹ UV-ve</td>
<td>224</td>
<td>7.5</td>
<td></td>
</tr>
<tr>
<td>Counter Bacteria¹ UV+ve</td>
<td>1.6</td>
<td>2.2</td>
<td>95*</td>
</tr>
<tr>
<td>Counter Bacteria¹ UV-ve</td>
<td>31</td>
<td>3.1</td>
<td></td>
</tr>
<tr>
<td>Anaerobic Bioaerosol² UV+ve</td>
<td>45</td>
<td>2.4</td>
<td>47.7**</td>
</tr>
<tr>
<td>Anaerobic Bioaerosol² UV-ve</td>
<td>86</td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td>Aerobic Bioaerosol² UV+ve</td>
<td>153.2</td>
<td>1.7</td>
<td>35.2**</td>
</tr>
<tr>
<td>Aerobic Bioaerosol² UV-ve</td>
<td>236.5</td>
<td>1.4</td>
<td></td>
</tr>
</tbody>
</table>
Counter Contact Plate UV-ve

Counter Contact Plate UV+ve
Automated, permanent UVC lights can decrease exposure to potential pathogens

Again, careful consideration of where these devices are placed – AND WHY – is required.
Hand-held equipment can be fomites for microbe transmission

Aluvis machine is effective at disinfecting hand-held devices, but requires some human factors optimization

**UVC FOR MOBILE EQUIPMENT**

Li, Wong, Rose, Wickham, Bryce Am J Infect Control 2016
Ambient LED and White Light

- Ultra Violet (UV)
- Visible Light Safety Zone
- Infrared (IR)

400nm to 700nm: Peak germicidal activity via photoexcitation of porphyrin molecules.
HYDROGEN PEROXIDE

Aerosolized HP: HP and silver combo

HP vapor: heat generated

Pros / Cons

Less easy to use compared to UV-C
Requires generator
Requires aeration unit
Door and vents need to be sealed

Multiple safety monitors to ensure no leakage occurs

Takes longer than UVC
**Stabilized Aqueous Ozone**

(1) Machine generates ozone and binds with H20

(2) Ozonated water comes in contact with pathogens

(3) Ozone molecule comes in contact with bacterial cell wall – oxidative burst creates holes, and pathogen dies

(4) Only normal water remains
Ozonated water has been evaluated in industrial settings and in vitro.

Little information on antimicrobial efficacy in clinical settings.

Has potential to be cost effective and safe for staff and patients.
Fig. 1 Algorithm for Overbed Tables Inoculation with MRSA or A. baumannii then Cleaning +/- Disinfecting with the test solution.

- **Inoculum of MRSA or A. baumannii in NS or TSB**

  - **-ve Control**
  - **+ve Control at 0**
  - **+ve Control at 20min**
  - **Test**

  **NO Inoculation**

  - **Inoculation**
  - **Inoculation**
  - **Inoculation**

  **Let dry**

  **Cleaning or cleaning & disinfecting with one of the tests:**
  - sterile distilled water, AHP, Quat or ozonated water.

  **Each area swabbed thoroughly with nylon Flock Swab twice**

  **Swabs placed into 1 mL of Neutralizing D/β brom**

  **Samples vortexed for 10 sec. and a 100 µL aliquot serially diluted 10 fold and plated onto BAP for Colony Count.**
<table>
<thead>
<tr>
<th>Sample</th>
<th>CFU/ml</th>
<th>% Reduction compared to dried inoculum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original Inoculum</td>
<td>5.5E+08</td>
<td></td>
</tr>
<tr>
<td>Neg Ctrl t Ctrl</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Neg Ctrl t AHP</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Neg Ctrl t Oz</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Neg Ctrl t CC</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>After Drying</td>
<td>8.20E+06</td>
<td></td>
</tr>
<tr>
<td>Distilled water and microfiber</td>
<td>36.7</td>
<td>99.99955</td>
</tr>
<tr>
<td>Distilled water and cloth rag</td>
<td>93.3</td>
<td>99.99886</td>
</tr>
<tr>
<td>AHP and microfiber</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>AHP and cloth</td>
<td>100</td>
<td>99.99988</td>
</tr>
<tr>
<td>Ozone 1 and microfiber</td>
<td>107</td>
<td>99.9987</td>
</tr>
<tr>
<td>Ozone 1 and cloth rag</td>
<td>233</td>
<td>99.9997</td>
</tr>
<tr>
<td>Ozone 2 and microfiber</td>
<td>86.7</td>
<td>99.9999</td>
</tr>
<tr>
<td>Ozone 2 and cloth rag</td>
<td>133</td>
<td>99.9998</td>
</tr>
</tbody>
</table>
**Antimicrobial Materials**

- Copper and other heavy metals (silver, nickel)
- Use dates back to Egyptians
  - Mechanism: Toxic oxygen radical formation
  - Alloy formulations
- Success in recent clinical trials

**Not Known**

- Durability
- Compatibility with cleaning agents
- Resistance development
- Activity over time
Copper/heavy metal Touch Surfaces

COPPER ON HIGH TOUCH SURFACES

Antimicrobial copper on high-touch surfaces may decrease transmission of microorganisms

photo courtesy of R. Dixon, CHAIR Canada
Suggests that compressed salt is an effective antimicrobial surface

Intriguing and hypothesis generating – requires further study

Whitlock et al. JHI 2016
PHOTOACTIVATED PAINTS

e.g. Titanium dioxide photoactivated, self-cleaning UV or fluorescent activation
UV Lamp

Organic contaminant or Bacteria

OH* Hydroxyl Radicals

H₂O, Air, H₂O, Air

DESTRUCTION

Bacteria with damaged hard shell

Photocatalyst Coating

Metallic Part
Altered Topography

Adaptations of that found in nature

Butterfly wings, shark skin, fish scales, lotus leaves...
GENBMT PILOT PROJECT:
HCW/Patient/Environmental Surveillance on the Bone Marrow Transplant Ward

T. WOZNOW 1, 2, T. WONG 1, 2, 3, A. STEFANOVIC 1, 2, 3, L. HOANG 3, 4, M. CROXEN 4, R. BROADY 2, 3, 5, R. DIXON 6, E.A. BRYCE 1, 2, 3

1. Division of Medical Microbiology and Infection Prevention and Control,
2. Vancouver Coastal Health, B.C., 3. University of British Columbia, 4. B.C. Public Health Microbiology and Reference Laboratory, Provincial Health Services Authority, 5. Leukemia/Bone Marrow Transplant Program, 6. Coalition for Health Acquired Infection Reduction (CHAIR) Canada
Acknowledgements

The patients, the Nursing staff of the BMT Unit, UBC & VGH Hospital Foundation, Mr. George Poling, CHAIR Canada, BCCDC Provincial Laboratory, VGH Medical Microbiology Laboratory, Genome BC
Bacteria and Other Microbes Live Everywhere in the Environment

Most bacteria are harmless to people.

Certain bacteria can even protect us from disease.

Only a tiny fraction of microbes cause disease in people.

There are 10 times more bacteria on our bodies than our own cells!
Bone Marrow Transplant Patients are Especially Vulnerable to Healthcare-Associated Infections

- Aspergillosis
- Clostridium difficile

Weakened Immune System
Treatment Requires Lengthy Hospital Stay
Multiple Antibiotics
Understand HOW and WHEN Microbes are Transmitted in BMT Patients
Pilot Study: Impact of Re-engineered rooms in Bone Marrow Transplant Patients

Regular Room versus Re-engineered Room
Objectives

• Assess the impact of re-engineered BMT rooms on microbial bioburden
• Assess the impact of re-engineered BMT rooms on HCW bacterial flora
• Assess the feasibility of collecting specimens and maintaining re-engineered rooms over a one-year period

Methods

• One year pilot: nine AML patients undergoing Bone Marrow Transplant (BMT) randomized to standard or re-engineered room for ENTIRE duration of stay
• Weekly sampling of a) seven high touch surfaces b) Air (SAS Dual Head Air Sampler) and c) Water (membrane filtration method)
• Weekly sampling of the Healthcare worker and consented patients
  • HCWs = nares, hands, perineum
  • Patients = Baylor wash, stool sample, axillae

USE CONVENTIONAL MICROBIOLOGY TO IDENTIFY TARGET ORGANISMS AND GENOMICS TO LOOK AT THE MICROBIOME (STILL IN PROGRESS)
Study Design

-7 0 +7 +14 +21 +28 +35

vs.

Regular room vs. Re-engineered room

Patient, environment and healthcare worker sampling

stem cell infusion
Re-engineered Patient Room
<table>
<thead>
<tr>
<th>Environment</th>
<th>Units</th>
<th>Standard Room</th>
<th>Engineered Room</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surfaces</td>
<td>Average CFU/Plate</td>
<td>62.6 (n=147)</td>
<td>6.32 (n=175)</td>
<td>0.0083</td>
</tr>
<tr>
<td></td>
<td>Average RLU</td>
<td>434.4 (n=147)</td>
<td>62.9 (n=182)</td>
<td>0.0001</td>
</tr>
<tr>
<td>Water</td>
<td>Average CFU/plate</td>
<td>26.5 (n=20)</td>
<td>0.08 (n=25)</td>
<td>0.0007</td>
</tr>
<tr>
<td>Air</td>
<td>Average CFU/plate</td>
<td>14.2 (n=21)</td>
<td>15.6 (n=25)</td>
<td>0.8145</td>
</tr>
</tbody>
</table>
Average ATPB (RLU): Standard vs Re-engineered Room

(P = 0.066)

Standard Room - Average ATPB (RLU) (n=21)
Re-Engineered Room - Average ATPB (RLU) (n=26)

Surface Numbers

• Statistically significant reduction of microbial bioburden on copper vs standard surfaces
• Statistically significant reduction of microbial bioburden on filtered shower water vs standard
• No statistical difference in air microbial bioburden between re-engineered vs standard rooms
HCWs
311/352 (88%) opportunities

Patients
129/144 (90%) opportunities

SAMPLING COMPLIANCE
Staphylococcus aureus carriage

Healthcare Workers
• 9/32 (28%) positive for sensitive S. aureus
  – 5/9 persistently colonized & 2/9 transiently colonized (2/9 HCWs only tested once so colonization persistence is unknown)
  – 1/32 (3%) positive for MRSA (transiently only)

Patients
• 2/9 (22%) positive
• No patients positive for MRSA
Vancomycin Resistant enterococcus

Healthcare Workers
• None were positive at any point in the pilot

Patients
• 4/9 patients (44%) positive BUT
• All were acquired prior to admission to the BMT unit
• One patient developed a VRE blood infection
**Clostridium difficile**

Healthcare workers

- None were positive at any time in the pilot

Patients

- 6/9 (72%) positive
- 1 was acquired at VGH and developed clinical symptoms requiring treatment
  - The rest had C. difficile **prior** to admission
PILOT KEY FINDINGS

1. Low ARO colonization in healthcare workers
2. High ARO colonization in patients
3. High compliance for ARO surveillance
4. Lower microbial counts on re-engineered rooms
LIMITATIONS

Next Steps

1. Small pilot study
2. Surveillance compliance was not 100%

1. BCCDC PHL analysis of genomics data (LH, MC, AK)
2. Take lessons learned to inform larger, multi-center study
1. Durability in a healthcare environment
2. Potential development of resistance to the self-disinfecting “material”
3. Interaction with hospital cleaners/disinfectants
4. Maintenance and operational costs in addition to capital costs
5. Incremental benefit in reducing infections
Innovation is the only way to win

Steve Jobs