Antimicrobial-Impregnated Surfaces in Preventing Healthcare-Associated Infections
Prof. Hilary Humphreys, The Royal College of Surgeons in Ireland
A Webber Training Teleclass

Antimicrobial-Impregnated Surfaces in Preventing Healthcare-Associated Infections. Differentiating the Hype from the Hope

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Hosted by Paul Webber
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Antimicrobial-Impregnated Surfaces in Preventing Healthcare-Associated Infections. Differentiating the Hype from the Hope

Declaration-1
The views expressed are in a personal but professional capacity & do not necessarily reflect those of the RCSI or Beaumont Hospital.

I have recent research collaborations with Pfizer. I have also recently received lecture & other fees from, Novartis, AstraZenca, Astellas & Pall Medical.

Learning Outcomes
By the end of this session you should ...

1. Understand the challenge of HCAI-causing microbes persisting in the environment
2. Appreciate the options for impregnating surfaces with antimicrobial activity
3. Have an overview of the in vitro results with different products
4. Be aware of the conclusions from the relatively few clinical studies
5. Know the requirements in to the future

Declaration-2
I am not an engineer
I am not a biochemist
I am not a molecular scientist

The Problem & Challenges - 1
The patient
High CFU (50/cm²) on skin of VRE patients
The pathogen
Clostridium difficile, VRE, MRSA & Acinetobacter spp. may survive on dry surfaces for 4-5 months
Practice
8-60% patients acquire VRE in a room previously occupied by a VRE +ve patient

Infect Control Hosp Epidemiol 2011;32: 689-699

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The Problem & Challenges - 2

- 92/939 (10%) patients +ve for MRSA in extensive screening study
- 65/1,252 (5%) environmental sites positive adjacent to MRSA patients
  - MRSA isolated from environment of MRSA -ve patients
- Sites +ve included
  - mattresses, 14%
  - air, 8%

Eur J Clin Microbiol Infect Dis 2012, 3151-3161

The Problem & Challenges - 3

Decontamination, cleaning inadequate even in ICUs
Improved cleaning enhances aesthetics & reduces bioburden, but some pathogens may persist

Crit Care Med 2010; 38: 1054-1059

The Problem & Challenges - 4

A wide variety of chemicals as disinfectants are used

Concern over efficacy, resistance & the environment

Am J Infect Control 2010; 38: S34-40

What to do?

- Alter the surface components
- Coat with or incorporate into the surface/fabric an antimicrobial compound
- Use a different material that has inherent anti-biofilm/microbial activity

Antifouling Coatings against Proteins, Bacteria & Marine Organisms

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Biofilm & Surface
Surfaces with pits enhance attachment of bacteria
Extracellular polymeric substances interact with surfaces

Coatings on Materials
Polyethylene glycol, a polymer imparts protein resistance to a surface but can auto-oxidise & lose its activity
Phosphorylcholine-based zwitterionic surfaces bind water, creating a hydration layer that does not allow proteins to adhere
Protease-based films in oil-based paints

Microbicidal Coatings
1. Silver ions/ nanoparticles embedded in polyamides, fibreglass, etc.
2. Octenidine dihydrochloride surfaces inhibit S. aureus & P. aeruginosa
3. Nanoparticle-impregnated textiles used in bandages, etc, with antimicrobial properties
4. Conjugates of perhydrolase generate peracetic acid

Enzyme-based Coatings
Starch Glucoamylase Hexose oxidase
Hydrogen peroxide biofilm

Photo-Activated Self-Cleaning Films
Lotus Leaf – water droplets roll down surfaces & pick up dirt, bacteria, etc
Photoactive films – UV leads to reactive oxygen species (ROS)
TiO2 – most commonly used photoactive material

Photocatalysis & Titanium Dioxide
- Activity related to H2O2 & other hydroxyl radicals
- Indoor use limited by need for UVA
- Membrane & cell wall damage; Gram + ve more resistant to killing

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### Light-Activated Antimicrobial Coating

<table>
<thead>
<tr>
<th>Type of bacteria</th>
<th>Visible bacterial count, median (range), 10^5 colony-forming units/cm^2/h</th>
<th>25-amino-L TBO and BB-containing coatings</th>
<th>Percentage of organisms killed, median (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerobes</td>
<td>9.2 (5.7-19.4)</td>
<td>15.3 (3.6-19.4)</td>
<td>7.2 (0.6-30.4)</td>
</tr>
<tr>
<td>Anaerobes</td>
<td>5.7 (1.9-8.7)</td>
<td>6.6 (0.9-10.2)</td>
<td>1.8 (0.8-14.0)</td>
</tr>
</tbody>
</table>

- Toluidine blue O & rose bengal coated surfaces under suspended lamp in clinic
- Settle plates & culture of coating
- 64-82% reductions (p<0.005)
- Surviving organisms were skin, e.g. *Micrococcus luteus*

*Infect Control Hosp Epidemiol* 2008, 1181-1184

### Visible Light & Influenza

- 71% of virus activity eradicated in 15 min
- Inactivation of haemagglutinin & neuraminidase

### Sharket AF™ – Skin of Fast-Moving Shark

- Microbial retention depends on cell surface pits
- Diamond-like array
- *S. aureus* biofilm assay
- Delays biofilm formation on surface

*Biomaterials 2007; 20: 4182-4190*

### Poly (ethylene glycol), PEG on Surfaces

- Long chain PEG more effective for *P. aeruginosa*
- Reduced adherence & biofilm for *S. epidermidis* & *P. aeruginosa*  

### Quaternary Ammonium Salt

*Am J Infect Control 2011; 38: 663-7*

### Silver Nanoparticle Coatings

*Biomaterials 2014; 38: 4801-4809*

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Copper & HCAI

1. Clarity on copper content required for efficacy & other factors, e.g. durability
2. Trials of surface microbes & HAI rates
3. Impact on aesthetics, cleaning & durability

Copper & Cladobium difficile

Stainless steel had no activity against C. difficile
2-3 log reduction in spores at 3 h with no impact from soil load

<table>
<thead>
<tr>
<th>Surface/exposure time</th>
<th>Mean C. difficile cfu/mL remaining (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stainless steel</td>
<td></td>
</tr>
<tr>
<td>0 min</td>
<td>7.6 x 10^6 (6.8-8.3)</td>
</tr>
<tr>
<td>30 min</td>
<td>7.3 x 10^6 (6.8-7.8)</td>
</tr>
<tr>
<td>Copper</td>
<td></td>
</tr>
<tr>
<td>0 min</td>
<td>1.2 x 10^6 (1.0-1.4)</td>
</tr>
<tr>
<td>30 min</td>
<td>0.000</td>
</tr>
</tbody>
</table>


Copper & E. coli 0157

- Brasses (78-95%), bronze (74-97%), copper nickel (70-96%) & copper-nickel-zinc alloys (55-72%) reduced numbers

* E. coli 0157 could survive in a desiccated state for 28 days & some alloys less effective at 4°C


Copper Alloy Furnishing – Cross Over Study

- Open-plan, with no partition between beds
- Domestic staff, 7.30 – 12.30 h & 17.00- 20.00 h
- Detergent & Na dichlorasocyanurate for high touch surfaces
- Door handles, rails, toilet seats, light switches, etc.
- Sampled 14-17.00 h & cfu/cm²

Infect Control Hosp Epidemiol 2012; 33: 3-9
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Copper, Bed Rails & ICU

Copper Objects in 16 Rooms x 43 Months

Copper Surface & HAI Rates
• Three medical centres, ICUs, coffee-alloy surfaces, weekly sampling of objects

<table>
<thead>
<tr>
<th>Copper</th>
<th>Control</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>No HA/colonization</td>
<td>94%</td>
<td>67%</td>
</tr>
<tr>
<td>HA/colonization</td>
<td>7%</td>
<td>1.9%</td>
</tr>
<tr>
<td>HA only</td>
<td>4.9%</td>
<td>1.9%</td>
</tr>
<tr>
<td>Colonization only</td>
<td>5.7%</td>
<td>3.8%</td>
</tr>
<tr>
<td>ICU LOS &gt;7 days</td>
<td>23.9%</td>
<td>25.9%</td>
</tr>
<tr>
<td>RIF in ICU</td>
<td>14%</td>
<td>18%</td>
</tr>
</tbody>
</table>

Copper Surfaces & HAI Rates

How to Evaluate?
• Surfaces
  – Semi-quantitative culture
  – Target organisms
  – Mixed flora
  – Biofilm

• Fabrics – American Association of Textile Chemists & Colorists protocol

Tests on self-disinfecting surfaces
By D. KINGSTON and W. C. NOBLK*
Cross-Infeciton Reference Laboratory, Central Public Health Laboratory,
Colindale Avenue, London, N.W. 9
(Received 26 June 1964)
Blankets, wood & painted surfaces have some self-disinfecting processes
Used fine cotton dust impregnated with organisms in broth suspension

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Which Method on What Surfaces?
Infect Control Hosp Epidemiol 2014;35(7):669-871

Conclusions
1. Impregnated surfaces reduce bacterial counts but do not eradicate
2. Methodologies of assessment vary
3. Impact on use of item over period of time not evaluated
4. Longevity of anti-microbial effect
5. Commercially-driven innovative approaches with potential but remain to be proven

The Future
A. More trials that include optimal cleaning
B. Some standardisation of methods for impregnated surfaces
C. Patient & staff response to antimicrobial & or disinfection – impregnated surfaces, fabrics
D. Intervention studies, multi-site involvement & stepwise models

High Throughput Sequencing & Hygiene
J Clin Micro 2013; 51: 2617-2624

147 samples before & after cleaning
Less bacteria & fungi after cleaning

Thank You