The role of dry surface contamination in healthcare infection transmission

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Blog: www.ReflectionsIPC.com
You can download these slides from www.jonotter.net
The Role of Dry Surface Contamination in Healthcare Infection Transmission
Dr. Jon Otter, Imperial College London
A Webber Training Teleclass

Transfer of a surrogate marker in a NICU


Transfer over time: inoculated pod

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Transfer of a surrogate marker in a NICU

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Your hospital room can make you sick!


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An environmental ‘dose-response’?

**Setting & design:** 14-month prospective study on 2 ICUs, Boston, USA.

**Methods:** All patients were screened on admission and twice weekly, and the environment was screened weekly for VRE. The 50 patients who acquired VRE were compared with the 588 who did not.


Chased by an antibiotic-induced *C. difficile*-shaped shadow!

Significant risk factors for CDI.

Transmission routes


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Surface survival

<table>
<thead>
<tr>
<th>Organism</th>
<th>Survival time</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Clostridium difficile</em> (spores)</td>
<td>5 months</td>
</tr>
<tr>
<td><em>Acinetobacter</em> spp.</td>
<td>3 days to 5 months</td>
</tr>
<tr>
<td><em>Enterococcus</em> spp. including VRE</td>
<td>5 days – 4 years (?)</td>
</tr>
<tr>
<td><em>Pseudomonas aeruginosa</em></td>
<td>6 hours – 16 months</td>
</tr>
<tr>
<td><em>Klebsiella</em> spp.</td>
<td>2 hours to &gt; 30 months</td>
</tr>
<tr>
<td><em>Staphylococcus aureus</em>, inc. MRSA</td>
<td>7 days – 7 months</td>
</tr>
<tr>
<td>Norovirus (and feline calicivirus)</td>
<td>8 hours to &gt; 2 weeks</td>
</tr>
<tr>
<td>SARS Coronavirus</td>
<td>72 hours to &gt;28 days</td>
</tr>
<tr>
<td>Influenza</td>
<td>Hours to several days</td>
</tr>
</tbody>
</table>

Adapted from Kramer et al. BMC Infect Dis 2006;6:130.


Terminal cleaning


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Surface -> Hand -> Patient
Pathogens can be transferred from surfaces to HCW hands without direct patient contact

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Percentage of HCWs Acquired</th>
<th>Contact or Surface Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>VRE</td>
<td>52% of 23 hands</td>
<td>~10%</td>
</tr>
<tr>
<td>MRSA</td>
<td>45% of 50 hands</td>
<td>40%</td>
</tr>
<tr>
<td>C. difficile</td>
<td>50% of 30 hands</td>
<td>50%</td>
</tr>
</tbody>
</table>

Compliance with hand hygiene: 50% vs. 80%


Rethinking the ‘inanimate’ environment

- Scanning electron microscopy identified biofilm on 5/6 dry hospital surfaces from an Australian ICU (including MRSA on 3/5).
- Followup study identified biofilm on 41/44 (93%) of surfaces in an ICU; MRSA from 18%, ESBL from 11% and VRE from 8% of the samples.

Could explain why vegetative bacteria can survive on dry hospital surfaces for so long
Be part of the reason why they are so difficult to remove or inactivate using disinfectants
Explain (to some degree) the difficulty in recovering environmental pathogens by surface sampling

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“It’s airborne”
Detection of *C. difficile* in the air samples from the rooms of 50 patients.

![Bar chart showing % sites contaminated for symptomatic and asymptomatic patients.]


“It’s airborne”
Results of intensive air sampling surrounding 10 patients. *C. difficile* was detected in the air in 7/10 patients.

![Graph showing the number of *C. difficile* colonies isolated over time of day.]

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Improve existing procedures

Try something new!

Improve existing procedures

Education & training

<table>
<thead>
<tr>
<th>Question</th>
<th>“Answer”</th>
</tr>
</thead>
<tbody>
<tr>
<td>What to clean?</td>
<td>Focus of “high-touch” sites seems sensible</td>
</tr>
<tr>
<td>Who cleans what?</td>
<td>Checklists can help</td>
</tr>
<tr>
<td>What agent(s) to use?</td>
<td>Depends on the situation; sporicidal agent for C. difficile</td>
</tr>
<tr>
<td>What materials to use?</td>
<td>Microfibre may help</td>
</tr>
<tr>
<td></td>
<td>Wipes have pros and cons</td>
</tr>
<tr>
<td></td>
<td>“Bucket method” most effective</td>
</tr>
<tr>
<td>How to educate staff?</td>
<td>More than we currently do! Difficult task</td>
</tr>
<tr>
<td>Daily cleaning: how often?</td>
<td>Evidence for daily or twice daily</td>
</tr>
<tr>
<td>Terminal cleaning: optimal protocols?</td>
<td>More stringent protocol should be used for terminal disinfection</td>
</tr>
</tbody>
</table>
Improve existing procedures

Try something new!

Baseline cleaning rates of ‘high-risk objects’ in 36 acute US hospitals, as determined by removal of a fluorescent marker.


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Improve existing procedures Method comparison

<table>
<thead>
<tr>
<th></th>
<th>Visual</th>
<th>Micro</th>
<th>ATP</th>
<th>Fluorescent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of use</td>
<td>High</td>
<td>Low-Moderate</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Quantitative</td>
<td>No</td>
<td>Yes/No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Correlation with microbial contamination</td>
<td>Poor</td>
<td>Accurate</td>
<td>Indirect</td>
<td>Indirect</td>
</tr>
<tr>
<td>Identifies pathogens</td>
<td>No</td>
<td>Yes/No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Risk of “gaming” by staff</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Identifies ‘dirty’ surfaces*</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Published evidence of attributable clinical impact</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

* Non-microbial soiling

Improve existing procedures Try something new!

Published evidence of attributable clinical impact

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Contamination-sparing therapy?

\[ n = 66 \text{ patients (rooms) and 264 surfaces for vancomycin / metronidazole, and 68 patients (rooms) and 272 surfaces for fidaxomycin. } p<0.05 \text{ for both rooms and surfaces.} \]


Antimicrobial surfaces (e.g. copper)

614 pts in 3 hospitals randomised to ‘copper’ or ‘non-copper’ ICU rooms

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### Candidate Comparison

<table>
<thead>
<tr>
<th>Candidate</th>
<th>Application</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metals</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>Manufactured in /</td>
<td>Rapidly microbicidal; large evidence-base; evidence of reduced</td>
<td>Sporicidal activity equivocal; cost, acceptability and durability may be</td>
</tr>
<tr>
<td></td>
<td>liquid disinfectant</td>
<td>acquisition.</td>
<td>questionable.</td>
</tr>
<tr>
<td>Silver</td>
<td>Manufactured in /</td>
<td>Broadly microbicidal.</td>
<td>? sporicidal; tolerance development; relies on leaching so surface</td>
</tr>
<tr>
<td></td>
<td>liquid disinfectant</td>
<td></td>
<td>loses efficacy over time.</td>
</tr>
<tr>
<td><strong>Chemicals</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organosilane</td>
<td>Liquid disinfectant</td>
<td>Easy to apply.</td>
<td>Limited microbicidal activity; questionable “real-world” efficacy.</td>
</tr>
<tr>
<td>Light-activated</td>
<td>Manufactured in /</td>
<td>Broadly microbicidal; can be activated by natural light.</td>
<td>? sporicidal; requires light source for photoactivation (some require</td>
</tr>
<tr>
<td>(e.g. titanium dioxide or</td>
<td>liquid disinfectant</td>
<td></td>
<td>UV light); may lose activity over time.</td>
</tr>
<tr>
<td>photosensitisers)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Physical alteration of surface</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>“Liquid glass” (silicon dioxide)</td>
<td>Liquid application</td>
<td>Reduces deposition; improves ‘cleanability’.</td>
<td>Not microbicidal; some evidence of reduced contamination; unknown</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>required frequency of application.</td>
</tr>
<tr>
<td>Sharklet pattern</td>
<td>Manufactured-in</td>
<td>Reduces deposition; reduced. biofilms.</td>
<td>Not microbicidal; not feasible to retrofit.</td>
</tr>
<tr>
<td>Advanced polymer coatings (e.g. PEG)</td>
<td>Manufactured-in</td>
<td>Reduces deposition; some can be ‘doped’ with copper or silver.</td>
<td>Not microbicidal; may be expensive; scale up to large surfaces</td>
</tr>
<tr>
<td>Diamond-like carbon (DLC) films</td>
<td>Manufactured-in</td>
<td>Reduces deposition; can be ‘doped’ with copper or silver.</td>
<td>Not microbicidal; likely to be expensive; feasibility of scale up to</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>large surfaces questionable; not feasible to retrofit.</td>
</tr>
</tbody>
</table>

### Control contamination at the source

Pre-post study in a 16-bed ICU in Korea; CHG daily bathing implemented for 12 months after 14-month pre-intervention period. Significant reduction in rate of carbapenem-resistant *Acinetobacter baumannii* acquisition and environmental contamination.

![Graph showing control period vs. intervention period](image)


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Wiping away infection

Impact of changing from QAC to bleach wipes for daily disinfection of all rooms. Cleaning thoroughness was 97-98% throughout the study using ATP benchmarking (<250 RLUs).

2.4 cases / 1000 patient days

0.4 cases / 1000 patient days

‘Given the choice of improving technology or improving human behavior, technology is the better choice’.

Dr Bob Weinstein

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Automated room decontamination (ARD)

- Hydrogen peroxide vapour 30% H₂O₂ (HPV)
- Aerosolised hydrogen peroxide 5-6% H₂O₂ (AHP)
- Ultraviolet radiation (UVC)
- Pulsed-xenon UV (PX-UV)


ARD systems - overview

<table>
<thead>
<tr>
<th></th>
<th>HPV 30-35% H₂O₂ vapour</th>
<th>AHP 5-6% H₂O₂ + Ag aerosol</th>
<th>UVC UVC (280 nm)</th>
<th>PX-UV Pulsed-xenon UV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficacy</td>
<td>1 &gt;6-log reduction</td>
<td>2 ~4-log reduction</td>
<td>3 ~2.4 log reduction</td>
<td>4 ~1-3 log reduction</td>
</tr>
<tr>
<td>Distribution</td>
<td>1 Homogeneous</td>
<td>2 Non-homogenous</td>
<td>3 Line of sight issues</td>
<td>3 Line of sight issues</td>
</tr>
<tr>
<td>Ease of use</td>
<td>4 Multiple units; sealing / monitoring</td>
<td>3 Sealing &amp; monitoring</td>
<td>2 Multiple positions; no sealing / monitoring</td>
<td>2 Multiple positions; no sealing / monitoring</td>
</tr>
<tr>
<td>Cycle time</td>
<td>3 ~1.5 hrs single room</td>
<td>4 &gt;2 hrs single room</td>
<td>1 ~10-30 mins</td>
<td>1 ~10-30 mins</td>
</tr>
<tr>
<td>Purchase cost</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Running cost</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

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Persistent contamination – sorted!

- % sites contaminated with A. baumannii
- % sites contaminated with MRSA

- 140 samples from 9 rooms after 2x bleach
- 5705 samples from 312 rooms after 4x bleach
- 2680 sites from 134 rooms after HPV


HPV: clinical impact

30-month prospective cohort intervention study performed on 6 high-risk units (5 ICUs) including 8813 patients at Johns Hopkins Hospital.

- 64% reduction in the rate of MDRO acquisition


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HPV: clinical impact

2 years before HPV, 2 years during HPV. Breakpoint model indicated significant reduction in rate of CDI when HPV implemented (1.0 to 0.4 per 1000 patient days, 60% reduction).


UVC: clinical impact

Cluster randomised study over >2 years across 9 hospitals including >25,000 exposed patients (admitted into a room where the previous occupant was known to have an MDRO). * = statistically significant reduction in the per-protocol analysis. ** = statistically significant when rooms occupied by patients with C. difficile removed from the analysis.

Anderson et al. Lancet in press.
UVC vs. HPV

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>HPV</th>
<th>UV systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycle time (for single room)</td>
<td>90 mins</td>
<td>15 mins to &gt;1hr</td>
</tr>
<tr>
<td>Practicalities</td>
<td>Door and air vent sealing and leak detection required</td>
<td>No door and air vent sealing or leak detection required</td>
</tr>
<tr>
<td>Distribution</td>
<td>Homogeneous</td>
<td>Affected by line of sight</td>
</tr>
<tr>
<td>Microbiological efficacy</td>
<td>Elimination of pathogens from surfaces; 6-log sporicidal reduction</td>
<td>Does not eliminate pathogens from surfaces; 1-3 log sporicidal reduction</td>
</tr>
<tr>
<td>Evidence of clinical impact</td>
<td>Published evidence</td>
<td>Emerging evidence</td>
</tr>
<tr>
<td>Cost</td>
<td>Lower purchase cost; higher running costs</td>
<td>Higher purchase cost; lower running costs</td>
</tr>
</tbody>
</table>


Spread contamination to stop contamination?

Bacterial load of coliforms (black circles) and S. aureus (white circles). Black arrow = beginning of the “live” cleaning agent; black dotted arrow = conventional cleaning agent.

More here if you’re interested.
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Improve existing procedures
Try something new!

Try something new! Microbe unfriendly design

The surface finish of 6 hospital bedrails; ease of cleaning was inversely proportional to the transfer of *S. aureus* from the surfaces


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Try something new!

“Design bugs out!”


Try something new!

Single room shortage

ECDC Point Prevalence Survey of healthcare-associated infections and antimicrobial use in acute care hospitals (HAiNet PPS) in the period 2011-2012 as reported to TESSy as of 2013-02-06 14:06:48
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Try something new!

Single rooms vs. bays

<table>
<thead>
<tr>
<th>Single Rooms</th>
<th>Bays</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced HCAI¹-⁶</td>
<td>Reduced risk of adverse events¹¹-¹²</td>
</tr>
<tr>
<td>• Better hand hygiene compliance</td>
<td>• Fall risk, tracheostomy, confused</td>
</tr>
<tr>
<td>• Improved air containment</td>
<td>• Better observation by staff</td>
</tr>
<tr>
<td>Some patients more satisfied⁵-⁹</td>
<td>Patients report:¹¹-¹⁴</td>
</tr>
<tr>
<td>• Improved privacy</td>
<td>• Reduced feelings of isolation</td>
</tr>
<tr>
<td>• Less disturbance from others</td>
<td>• More social and HCW contact</td>
</tr>
<tr>
<td>Fewer &quot;mix up&quot; errors through uninterrupted patient contact</td>
<td>Reduced staffing levels and patient: HCW ratios¹⁴,¹⁵</td>
</tr>
</tbody>
</table>


Try something new!

‘Privatization’ of an ICU

Intervention
24 bed ICU
2x10 bed and 4x single rooms
Converted to 100% single rooms in 2002

Comparison
25 bed ICU
2, 5, 6 or 8 bed rooms
No change in unit configuration


Change in the acquisition rate ratio before and after privatisation; * = not statistically significant.
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<table>
<thead>
<tr>
<th>Date</th>
<th>Topic</th>
<th>Speaker</th>
<th>Venue</th>
</tr>
</thead>
<tbody>
<tr>
<td>March 9, 2017</td>
<td><strong>EVALUATION OF INFECTION CONTROL TRAINING</strong></td>
<td>Dr. Martin Kiernan, University of West London</td>
<td></td>
</tr>
</tbody>
</table>
| March 18, 2017| **FREE Teleclass**  
**HOW TO BECOME CIC CERTIFIED WITHOUT BECOMING CERTIFIABLE** | Sue Cooper, Public Health Ontario, Canada                                                          |                              |
| March 29, 2017| **FREE European Teleclass**  
**TREATMENT OF SEVERE MRSA INFECTIONS: CURRENT PRACTICE AND FURTHER DEVELOPMENT** | Dr. Philippe Eggimann, Centre Hospitalier Universitaire Vaudois, Switzerland                      |                              |
| March 30, 2017| **SCREENING FOR STAPHYLOCOCCUS AUREUS BEFORE SURGERY ... WHY BOTHER** | Dr. Hilary Humphreys, The Royal College of Surgeons in Ireland                                  |                              |
| April 6, 2017 | **TECHNOLOGIC INNOVATIONS TO PREVENT CATHETER-RELATED BLOODSTREAM INFECTIONS** | Prof. Mark Rupp, University of Nebraska Medical Center                                            |                              |
| April 25, 2017| **FREE European Teleclass ... Denver Russell Memorial Teleclass Lecture**  
**DO’S AND DON'T’S FOR HOSPITAL CLEANING** | Dr. Stephanie Dancer, Health Protection Scotland                                                |                              |

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