Application of Novel Local Exhaust Ventilation Devices to Control Bioaerosols in Chest Clinics and During Patient Transport

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Originated from 2003 SARS

- 1755 SARS infections in Hong Kong, 386 cases (22%) were healthcare workers
- Serious rethinking of collaboration between infection control and occupational hygiene
- Development of LEV prototypes based on well established IH and biosafety principles
Class I BSC

Source: Biosafety in Microbiological and Biomedical Laboratories, CDC-NIH, 1984 (1st ed), 2007 (5th ed)
“Enclosing Booth” in CDC TB Guidelines

FIGURE 2. An enclosing booth designed to sweep air past a patient with tuberculosis disease and collect the infectious droplet nuclei on a high efficiency particulate air (HEPA) filter.

FIGURE S3-1. An enclosing booth designed to sweep air past a patient who has active tuberculosis and entrap the infectious droplet nuclei in a high-efficiency particulate air (HEPA) filter.

Source: CDC Guidelines for Preventing the Transmission of *Mycobacterium tuberculosis* in Health-Care Settings (Facilities), 2005 (1994)
Patient Transport Outside of Healthcare Facility

Portable personal unit

Ambulance unit
Hospital Ward
Patient Transfer within Hospital
Bronchoscopy
Outpatient High-Risk Procedures

Sputum induction
Key Development Work in Collaboration with HCWs

- Field testing to verify effectiveness of LEV devices
  - Bioaerosol challenge test
- User survey to gauge acceptance of devices and collect feedback
- Refinement of design to better suit user
  - Booth surface disinfection study to reduce concern of contact infection risk, and to facilitate cleaning between patients
Field Testing Criteria and Results

<table>
<thead>
<tr>
<th>Test</th>
<th>Criterion</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Face Velocity</td>
<td>&gt;0.5 m/s</td>
<td>Passed</td>
</tr>
<tr>
<td>Airflow visualization</td>
<td>Smooth pattern</td>
<td>Passed</td>
</tr>
<tr>
<td>Aerosol Challenge of HEPA</td>
<td>&lt;0.03% penetration</td>
<td>Passed</td>
</tr>
<tr>
<td>Bioaerosol Challenge</td>
<td>&lt;10^-4 leakage</td>
<td>Details below</td>
</tr>
</tbody>
</table>
Bioaerosol Challenge

- *E. coli*T4 phage as surrogate
- Phage culture released by spray bottle to simulate respiratory release
- Petri dish with *E. coli* cells to sample by impactor
- Plaque formation quantifies phage numbers
**Setup of Bioaerosol Challenge**

- **A**: Access Hole A
- **B**: Access Hole B
- **C**: Access Hole C

- : Sampler inside booth
- : Sampler outside booth
- : Sprayer inside booth
Results of Bioaerosol Challenge (1)

Negative control

Plaques visible on bacterial lawn

Phage completely consumed bacterial lawn
Results of Bioaerosol Challenge (2)

<table>
<thead>
<tr>
<th>Access hole</th>
<th>Position</th>
<th>Ave plaques per m³ of air</th>
<th>Percent reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Inside</td>
<td>4873</td>
<td>99.27%</td>
</tr>
<tr>
<td></td>
<td>Outside</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Inside</td>
<td>92862</td>
<td>100.00%</td>
</tr>
<tr>
<td></td>
<td>Outside</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Inside</td>
<td>6489</td>
<td>100.00%</td>
</tr>
<tr>
<td></td>
<td>Outside</td>
<td>0</td>
<td></td>
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</tbody>
</table>
User Survey

- Patient and HCW questionnaires
- Three clinical settings selected for field trial of different LEV devices
  - Booths in chest and TB clinics
  - Hood for bronchoscopy in one hospital
  - Small tent for patient transfer in one hospital (volunteers)
- Largest data pool from 6 chest clinics where 100 HCWs & 350 patients responded
Chest Clinic HCW Survey Results (1)

- 90% willing to use booth again
- Increase to 100% when effectiveness is proven
- Reported 7-12% patients expressed discomfort or difficulty, leading to 3-7% stopping usage
- Main complaints: thermal comfort, communication difficulties
Majority considered booth
- Increased protection of HCWs
- Worthwhile to modify procedures
- Did not increase contact risk
- Increased workload
- Not easy to clean between patients
Chest Clinic Patient Survey
Results

- 95% willing to use booth again
- Increase to 97% when effectiveness is proven
- 6-7% reported feeling different or discomfort during usage
Surface Disinfection Study

- To ensure booth surface will not increase contact infection risk
- Use liquid disinfectant to wipe internal surface between patients
- Effect verified by bacterial culture introduced onto hood walls and subsequent sampling by RODAC plates
- Subsequent test on UVC disinfection
RODAC Plates Procedures

- Replicate Organism Detection and Counting
- Commonly used in microbiologic monitoring in food industry
- Less labor-intensive, recently demonstrated effective for assessing multidrug-resistant organisms in clinical setting
- *E. coli* culture used as surrogate
- Manually applied to surface followed by disinfection and RODAC sampling
RODAC Plates
### Surface Disinfection Results

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell untreated</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cell + 75% Ethanol wipe</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cell + 75% Ethanol without wipe</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cell + 1:99 bleach wipe</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cell + 1:99 bleach without wipe</td>
<td>0</td>
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<td>Cell + 1:49 bleach without wipe</td>
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Further Surface Disinfection Study with UVC

- Use literature data on UVC dosage necessary to kill TB bacterium
- Design UVC light source to fit booth dimensions
- Determine optimal irradiation time period to ensure disinfection
- Verification by same RODAC procedures
- Ensure protection of HCWs from UVC
Surface Disinfection by UVC

Sample Descriptions
1,2,3: Positive control (i.e. no UVC irradiation)
4,5,6: UVC irradiation for 20 seconds
7,8,9: UVC irradiation for 3 minutes
Applying Bacterial Culture and Collecting RODAC Sample
Surface Disinfection by UVC

Results

<table>
<thead>
<tr>
<th></th>
<th>Average no. of cells on the Isobooth surface under UV irradiation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>E</strong> control</td>
</tr>
<tr>
<td>control</td>
<td>25</td>
</tr>
<tr>
<td>20s</td>
<td>15</td>
</tr>
<tr>
<td>3 min</td>
<td>10</td>
</tr>
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</table>
Recap

- Field performance verification including bioaerosol challenge proved effectiveness of LEV in controlling airborne infectious agents
- User survey revealed acceptance of LEV device
- Contact infection risk of LEV device internal surface can be controlled by liquid disinfectant or UVC irradiation
Overall Lessons Learnt…

- LEV should and can be applied to clinical settings for control of airborne infectious agents
- Close collaboration among OH, IC and HCW critical to success:
  - education, demonstration, feedback, buy-in, field trial, survey, long-term support, continuous improvement
- OH and IC professionals should continue to collaborate closely
Acknowledgement

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- HKUST research team members:
  - Mr Stephen Tsu
  - Ms Winnie Fung

- Colleagues of Hospital Authority and Dept of Health Chest Clinics
Thank You!

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