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PHILIP W. BRICKNER, MD 1926-2014
Father of Healthcare for the Homeless and Leader in the Reapplication of UV in High Risk Settings
Why Upper-Room UVGI Systems Now?

Works well with natural and/or mechanical ventilation combined with diffusers and or fans for air-mixing

73-80% effective in reducing transmission of airborne pathogens (Escombe et al 2009, Mphaphlele et al 2015)

Works against a wide range of airborne pathogens (regardless of the drug-resistance of the strain) (virus, bacterium, spores, fungi)

Maintenance of systems is relatively simple

Human safety can be achieved with proper design, installation, commissioning, operation and maintenance.
Infection control:
Observed practices due to design constraints

Administrative pressures drive Triage procedures

No departmental waiting areas. Health and safety compromised

No physical separation among patients until sputum smear results available
How Effective is Upper Room UVGI?
Riley, Johns Hopkins 1976

- Inactivation of aerosolized surrogate TB bacilli from room air with and without upper-air UV irradiation using one 17-watt fixture

- AC/hr = air changes per hour

**Figure 2. Disappearance of aerosolized bacillus Calmette-Guérin (BCG) from room air with and without upper room ultraviolet (UVGI) irradiation using one suspended fixture with one 17 W lamp.**

- AC/hr = air changes/hour
- Y-axis = viable colonies remaining in air
- X-axis = duration of exposure to UVGI

**SOURCE:** adapted from Riley.34

Riley’s Bench-scale Studies Provide Guidance on TB Dosing

To develop practical application of UV-C$_{254nm}$ in high-risk settings, Riley conducted bench-scale studies where he exposed both virulent and non-virulent bacillus Calmette-Guerin (BCG), tubercle bacilli, and other organisms to UVC$_{254nm}$ of known intensity and duration under conditions of controlled temperature and humidity.

These studies demonstrated a 90% lethal dose (LD$_{90}$) for virulent TB and for BCG for a 12 seconds exposure at 50μW/cm$^2$ or 60 seconds at 10 μW/cm$^2$. [600μWs/cm$^2$]

Practically, these UV-C$_{254nm}$ intensity levels are achievable for the upper room with available upper room UVC$_{254nm}$ lamps and fixtures.

Walker and Ko’s Bench-scale Studies Provide Guidance on Dosing of Coronavirus

| TABLE 1. Ultraviolet Germicidal Irradiation Susceptibility (Z Value) of the MS2 Bacteriophage, Respiratory Adenovirus Serotype 2, and Murine Hepatitis Virus Coronavirus, at 50% Relative Humidity |
|-----------------------------------------------|-----------------|-----------------|
| UV dose (μW s/cm$^2$) | percent survival$^a$ | Z value ($\times 10^4$)$^b$ |
| MS2 ($N = 5$) | 2608 | 31.1 ± 2.9 | 3.8 ± 0.3 |
| adenovirus ($N = 4$) | 2608 | 32.9 ± 2.3 | 3.9 ± 0.3 |
| coronavirus ($N = 3$) | 599 | 12.2 ± 7.2 | 37.7 ± 11.9 |

$^a$ Percent survival = 100 x (number of plaques in the presence of UV exposure)/(number of plaques in the absence of UV exposure). $^b$ Z values ($\times 10^4$) were calculated as $-10^4 \times \log$(% survival)/UV dose (μW s/cm$^2$).


TUSS (1997-2004) was a double-blind, placebo controlled field trial in 6 USA cities, with 14 shelters

- Nearly 1200 UVGI luminaires were installed covering 200,000 sq. ft in a diverse set of buildings
- Upper air systems were monitored at set intervals, and measured before and after cleaning
- UVC lamps were replaced when output fell below a set criteria
Upper-Room Disinfection With UV-C
(Section View in Hospital Room)

Source: South Africa
Medical Research Council
UV-C LAMPS and Radiometers

- Upper air UVGI is generated by a low-pressure Hg vapor discharge lamp
  - 35% electrical input wattage is converted to UVC energy for which 253.7 nm is the strongest wavelength
- UV-C irradiance is measured in µW/cm²
- Electrical input to the UV-C lamp is regulated by a ballast (magnetic and electronic)
- LEDs and Krypton Chloride Lamps require different detectors for selected wavelengths

Low Pressure Hg lamps
253.7 nm

Future LED Germicidal Lamps
(265-280nm)

Krypton Chloride (excimer lamp 222nm)
#1 Start Volumetric Dosing
0.012 W/m³
Area Dosing
0.038/m²

#2 Refine Fluence and Safety in upper room using CAD Tool Target $6\mu W/cm²$ average in room volume

#3 Verify Safe levels in Occupied Space and Performance Output

Air-Mixing for Effectiveness
Adjusting Diffusers or adding fans

3 Criteria for Programming Upper Room UVGI into a Space + Air-Mixing
Computer Aided Design (CAD) Dosing Method

- Visual-3D Lighting Software – modified to calculate UVGI from multiple UVGI luminaires
- Using the volumetric dosing strategy #1 as a first approximation, the Visual™-UV can be used to verify the number, design, and optimal location of luminaires
- Model and calculate eye level readings.
- Calculate the average UV fluence rate for the entire room
- Rapidly interchange different models of upper-room UVGI luminaires that have a gonioradiometric data saved in .IES file
- Can calculate (NIOSH (2009) dose for the upper-room
Simulation

Fixtures Open for 10’ Ceiling Place in 32’ Ceiling Room

Total UV Watts Needed (E) = 1646.34 m³ x 0.012 UVC W/m³ = 19.76 UVC W

Total Open Fixtures Needed = 19.76 UVC W ÷ 3.7 UVC W/fixture = 5.34 or 5 Fixtures
SCHOOLS-THEN AND NOW
Karachi Hospital Corridor Natural Ventilation UVGI + Fan courtesy: IRD

Kings County Hospital Waiting Room: Mechanical Ventilation: UVGI + Diffusers courtesy: Aeromed
Where to apply?

- **Healthcare facilities**
  - Waiting Rooms
  - Emergency Departments
  - Special aerosol procedures
  - Operating rooms
  - Autopsy
  - X-Ray
  - Dental
  - Nursing Homes

- **Transportation Hubs**
  - Retail
  - Schools
  - Houses of worship
  - Pet Boarding/Care Centers
  - Refuge Centers
  - Homeless Shelters
  - Military Barracks

Source: Aeromed
GERMICIDAL UV AIR-MIXING SYSTEM
NATIONAL INSTITUTE OF TUBERCULOSIS RESPIRATORY DISEASES (NITRD),
ROHIT SARIN, MD, DIRECTOR, NEW DELHI, INDIA
ASHRAE GPC-37
Guidelines for the Application of Upper-Air (Upper Room) Ultraviolet Germicidal (UV-C) Devices to Control the Transmission of Airborne Pathogens

To provide minimum requirements for safe and effective implementation of upper room UVGI air-mixing systems for air disinfection in congregate settings, by

• **best practices** for assessing need in context of other airborne infection control measures

• **understanding what is necessary** for: design, installation, commissioning, maintenance & operation.
Acknowledgements

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Resources in following slides

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https://labs.icahn.mssm.edu/vincentlab/
Safety of Upper-Room Ultraviolet Germicidal Air Disinfection for Room Occupants: Results from the Tuberculosis Ultraviolet Shelter Study

SYNOPSIS

Objectives: We evaluated the safety of room occupants in the Tuberculosis Ultraviolet Shelter Study (TUS), a double-blind, placebo-controlled field trial of upper-room ultraviolet germicidal irradiation (UVGI) at 14 homeless shelters in six U.S. cities from 1997 to 2004.

Methods: Data collection involved administering questionnaires regarding eye and skin irritation to a total of 3,611 staff and homeless study subjects.

Results: Among those subjects, there were 223 reports of eye or skin symptoms. During the active UV period, 95 questionnaires (6%) noted such symptoms, and during the placebo period, 92 questionnaires (6%) did so. In the 36 remaining cases, either the UV period when symptoms took place was unknown or the symptoms spanned both periods. There was no statistically significant difference in the number of reports of symptoms between the active and placebo periods. One definite instance of UV-related keratoconjunctivitis occurred, resulting from a placement of a bunk bed in a dormitory where a single bed had been used when the UV fixtures were first installed.

Conclusions: These findings demonstrate that careful application of upper-room UVGI can be achieved without an apparent increase in the incidence of the most common side effects of accidental UV overexposure.

UV Safety Review

UV Germicidal irradiation can be safely and effectively used for upper air disinfection with out a significant risk for long term delayed effects such as skin cancer. (CIE 187:2010)
ETTi Guidance on Measurement and Maintenance of GUV Systems

www.StopTB.org/wg/ett

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### Disinfecting room air with upper-room (UR) germicidal UV (GUV) systems

**Count the Cost!**

STOPTB.ORG/wg/ett

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### UR GUV costs
(all costs presented in USD)

<table>
<thead>
<tr>
<th>Initial costs</th>
<th>Estimated</th>
<th>Unit cost</th>
<th>Lifecycle cost: 1 unit</th>
<th>Lifecycle cost: 10 units</th>
<th>Lifecycle cost: 50 units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UR GUV fixture(s):</strong> This price will vary depending on the volume of purchased units and taxes. Efforts are underway to develop negotiated prices through the GDF along with listing of pre-qualified fixtures (10% discount on 10 units; 20% discount on 50 units)</td>
<td>200 - 2,000 USD</td>
<td>1,000 USD</td>
<td>1,000 USD</td>
<td>9,000 USD</td>
<td>40,000 USD</td>
</tr>
<tr>
<td><strong>Shipping, customs, taxes:</strong> The price will vary by country depending on the volume purchased and local taxes.</td>
<td>0 - 100% of unit price</td>
<td>200 USD (20%)</td>
<td>200 USD</td>
<td>1,800 USD</td>
<td>8,000 USD</td>
</tr>
<tr>
<td><strong>Air Mixing system (fans, etc.):</strong> a method of air-mixing is required. In naturally ventilated space, either ceiling or wall fans can provide this function.</td>
<td>20 - 100 USD</td>
<td>30 USD</td>
<td>30 USD</td>
<td>300 USD</td>
<td>1,500 USD</td>
</tr>
<tr>
<td><strong>Layout design:</strong> Includes site visits, GUV fixture selection and specification, architectural, mechanical &amp; electrical drawings showing GUV fixture locations and model number.</td>
<td>0 - 50 USD</td>
<td>0 USD</td>
<td>0 USD</td>
<td>0 USD</td>
<td>0 USD</td>
</tr>
<tr>
<td><strong>Installation (fixture, fans, electrical, etc.):</strong> Electrical conduit to each fixture location. Individual electrical switch per location. Electric panel(s) &amp; circuit breakers as required. Added facility electric capacity as necessary. UV fixture mounting &amp; electric hookup at each location specified.</td>
<td>10 - 40% of unit price</td>
<td>200 USD (20%)</td>
<td>200 USD</td>
<td>1,800 USD</td>
<td>8,000 USD</td>
</tr>
<tr>
<td><strong>Acceptance testing (UR GUV performance):</strong> Each installed GUV unit is assessed for functionality, placement &amp; orientation. UV radiometric evaluation is performed to ensure each unit is both safe and effective. That adequate germicidal UV is present in the irradiated zone above room occupants and that only safe levels of UV are present in the occupied area near the unit. UV output adjustment as required. Prepare and document acceptance report.</td>
<td>5 - 10% of unit price</td>
<td>75 USD (7.5%)</td>
<td>75 USD</td>
<td>675 USD</td>
<td>3,000 USD</td>
</tr>
<tr>
<td><strong>GUV Meter:</strong> at least one UV radiometer with a 254 nm detector is required for operating and maintaining a GUV system. If a facility has over 100 units it may require an additional meter as a backup. (for lifecycle cost, the cost will be divided by the total number of fixtures purchased)</td>
<td>1,500 - 2,500 USD</td>
<td>2,000 USD</td>
<td>2,000 USD</td>
<td>2,000 USD</td>
<td>2,000 USD</td>
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</tbody>
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**Total initial costs**

<table>
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<tr>
<th></th>
<th>USD</th>
<th>USD</th>
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<tr>
<td><strong>3,505</strong></td>
<td><strong>15,575</strong></td>
<td><strong>62,500</strong></td>
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WHO guidelines on tuberculosis infection prevention and control

2019 update
TECHNICAL REPORT

CIE Guide for the Measurement of Upper Air Ultraviolet Germicidal Irradiation Luminaires Using Low Pressure Germicidal UV-C Lamps

ED/TR TC 6-52
UDC: 612.014.481-06  Descriptor: Optical radiation effects on humans
Guidance Documents
Groups working on UVGI Guidelines and Standards