UVGI APPLIED DURING ORTHOPEDIC SURGERY AND THE RATE OF INFECTION
UVGI BASICS

Mercury Vapor lamps produce 253.7 nm radiation which breaks down the DNA and RNA of microorganisms, scrambling their genetic code so they cannot reproduce. Damage from ultraviolet exposure renders them effectively sterile and unable to grow or form new colonies.

Any microorganism, including bacteria, viruses, yeast, mold, and spores, that cannot reproduce are unable to cause infections.
OVERVIEW

- Mechanics of how UVGI is used in an OR
- Two major studies: UVGI vs. no UVGI in orthopedic surgery suites
- UVGI used during total knee and hip replacement surgeries
- Second, most recent, study tracks one surgeon’s results over 19 years
UVGI OPERATING ROOM EQUIPMENT “PACKAGE”

Example based on common OR layout.

- Direct SM Fixtures (ceiling mounted)
- Indirect Wall Mounted Upper Air UVGI Fixtures
- Door Barrier UV Fixtures
- Variable Transformer (dimmer)
- UVC Radiometer
- Safety Equipment
- Training
SAMPLE PLACEMENT OF SM FIXTURES

- Ceiling mounted, direct fixtures are evenly spaced for maximum coverage to eliminate “shadowing”
- Vastly superior to portable devices used for the same application
- Fixtures used at lower intensity during procedures, turned on between procedures to max intensity
- Variable transformer (Variac) is used to control lamp intensity in these fixtures
**Upper-Air UVGI Indirect Fixtures**

- Wall mounted 7.5’ - 8’ above floor
- Typically installed on opposite walls to cover room area appropriately
- Fixtures operate all full power at all times (even during procedures)
**DOOR BARRIER FIXTURES**

- Mounted over all access doors to operating suite
- Provide a protective “curtain” of UV energy
- Fixtures operate at full power during procedures
- Microorganisms are blocked from entering or exiting the operating theater when doors are opened
VARİABLE TＲＲＡＮＳＦＯＲＭＥＲ "VARIAC"

- Wired to Direct, Surface-Mounted fixtures
- Acts as a “dimmer” to dial down lamp intensity to desired level (23 μW/cm²) at the surgical site
- Adjustability allows maximum lamp life use
Radiometer & Safety Equipment

- Used to measure UVC energy at surgical site (knee, hip, etc.)
- Variac is dialed down to achieve desired intensity level (23 µW/cm²) at the surgical site as indicated by radiometer
- UVC safety goggles and UV absorbing cream are provided with package to ensure safety of all personnel in suite
- On-site training of all personnel is the best safety precaution
<table>
<thead>
<tr>
<th>PATHOGEN</th>
<th>GROUP</th>
<th>ANNUAL CASES</th>
<th>PRIMARY INFECTION CAUSED</th>
<th>TYPE</th>
<th>MERV 13 REMOVAL %</th>
<th>UVGI D90 J/m²</th>
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</thead>
<tbody>
<tr>
<td>Influenza A virus</td>
<td>Virus</td>
<td>2,000,000</td>
<td>Flu, secondary pneumonia</td>
<td>Communicable</td>
<td>48</td>
<td>19.3</td>
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<td>Measles virus</td>
<td>Virus</td>
<td>500,000</td>
<td>Measles (rubeola)</td>
<td>Communicable</td>
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<tr>
<td>Streptococcus pneumoniae</td>
<td>Bacteria</td>
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<td>Lobar pneumonia, sinusitis, meningitis</td>
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<td>Streptococcus pyogenes</td>
<td>Bacteria</td>
<td>213,962</td>
<td>Scarlet fever, pharyngitis</td>
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<td>Respiratory Syncytial</td>
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<td>Pneumonia, bronchiolitis</td>
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<td>Varicella-zoster virus</td>
<td>Virus</td>
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<td>Chickenpox</td>
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<td>Flu, colds, croup, pneumonia</td>
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<td>Mycobacterium tuberculosis</td>
<td>Bacteria</td>
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<td>Bordetella pertussis</td>
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<td>Whooping cough</td>
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<td>Rubella virus</td>
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<td>Rubella (German measles)</td>
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<td>Staphylococcus aureus</td>
<td>Bacteria</td>
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<td>Pseudomonas aeruginosa</td>
<td>Bacteria</td>
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<td>Pneumonia</td>
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<td>9.7</td>
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<td>Klebsiella pneumoniae</td>
<td>Bacteria</td>
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<td>Opportunistic, pneumonia</td>
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<td>42.0</td>
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<td>Legionella pneumophila</td>
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<td>Legionnaire's Disease, opportunistic</td>
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<td>12.6</td>
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<td>Haemophilus influenzae</td>
<td>Bacteria</td>
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<td>Meningitis, pneumonia, endocarditis</td>
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<td>Histoplasma capsulatum</td>
<td>Fungal Spore</td>
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<td>Histoplasmosis, fever, malaise</td>
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<td>Aspergillus</td>
<td>Fungal Spore</td>
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<td>Aspergillosis, alveolitis, asthma</td>
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<td>1000</td>
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<td>Serratia marcescens</td>
<td>Bacteria</td>
<td>479</td>
<td>Bacteremia, endocarditis, pneumonia.</td>
<td>Endogenous</td>
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<td>Acinetobacter</td>
<td>Bacteria</td>
<td>147</td>
<td>Opportunistic/septic, meningitis</td>
<td>Endogenous</td>
<td>94 (10965)</td>
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<td>Corynebacterium diphtheriae</td>
<td>Bacteria</td>
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<td>Diphtheria, toxin produced.</td>
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<td>76</td>
<td>32.8</td>
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<td>SARS virus</td>
<td>Virus</td>
<td>10 (China)</td>
<td>Severe Acute Respiratory Syndrome</td>
<td>Communicable</td>
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<td>228.0</td>
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<td>Haemophilus parainfluenza</td>
<td>Bacteria</td>
<td>common</td>
<td>Pneumonia, bronchiolitis</td>
<td>Communicable</td>
<td>65</td>
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<tr>
<td>Burkholderia cenocepacia</td>
<td>Bacteria</td>
<td>common</td>
<td>Cryptococcosis, cryptococcal meningitis</td>
<td>Noncommunicable</td>
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<td>138</td>
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<tr>
<td>Cryptococcus neoformans</td>
<td>Fungal Spore</td>
<td>common</td>
<td>Pneumonia, bronchiolitis</td>
<td>Communicable</td>
<td>65</td>
<td>-</td>
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<tr>
<td>Chlamydia pneumoniae</td>
<td>Bacteria</td>
<td>rare</td>
<td>Coccidioidomycosis, valley fever</td>
<td>Noncommunicable</td>
<td>99</td>
<td>-</td>
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<td>Coccidioides immitis</td>
<td>Fungal Spore</td>
<td>rare</td>
<td>Nocardiosis</td>
<td>Noncommunicable</td>
<td>93</td>
<td>187</td>
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<td>Nocardia asteroides</td>
<td>Bacterial Spore</td>
<td>rare</td>
<td>Nocardiosis</td>
<td>Noncommunicable</td>
<td>97</td>
<td>-</td>
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<td>Nocardia brasiliensis</td>
<td>Bacterial Spore</td>
<td>rare</td>
<td>Nocardiosis</td>
<td>Noncommunicable</td>
<td>97</td>
<td>-</td>
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<tr>
<td>Alcaligenes</td>
<td>Bacteria</td>
<td>rare</td>
<td>opportunistic infections, endocarditis</td>
<td>Endogenous</td>
<td>81</td>
<td>-</td>
</tr>
<tr>
<td>Blastomyces dermatitidis</td>
<td>Fungal Spore</td>
<td>common</td>
<td>Sclerosing lobate, Glioblastoma Disease</td>
<td>Noncommunicable</td>
<td>98 (38)</td>
<td></td>
</tr>
<tr>
<td>Burkholderia pseudomallei</td>
<td>Bacteria</td>
<td>rare</td>
<td>Melioidosis, opportunistic</td>
<td>Noncommunicable</td>
<td>60 (58)</td>
<td></td>
</tr>
<tr>
<td>Cardiobacterium</td>
<td>Bacteria</td>
<td>rare</td>
<td>Opportunistic infections, endocarditis</td>
<td>Endogenous</td>
<td>70 (58)</td>
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<td>Moraxella</td>
<td>Bacteria</td>
<td>rare</td>
<td>Otitis media, opportunistic</td>
<td>Endogenous</td>
<td>94 (11513)</td>
<td></td>
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<tr>
<td>Mucor plumbeus</td>
<td>Fungal Spore</td>
<td>rare</td>
<td>Mucormycosis, rhinitis</td>
<td>Noncommunicable</td>
<td>99 (171)</td>
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<tr>
<td>Pneumocystis carinii</td>
<td>Fungal Spore</td>
<td>rare</td>
<td>Pneumocystosis</td>
<td>Noncommunicable</td>
<td>99</td>
<td>-</td>
</tr>
<tr>
<td>Rhizopus stolonifer</td>
<td>Fungal Spore</td>
<td>rare</td>
<td>Zygomycosis, allergic reactions</td>
<td>Noncommunicable</td>
<td>99 (267)</td>
<td></td>
</tr>
<tr>
<td>Burkholderia mallei</td>
<td>Bacteria</td>
<td>rare</td>
<td>Glanders, fever, opportunistic</td>
<td>Noncommunicable</td>
<td>74 (58)</td>
<td></td>
</tr>
</tbody>
</table>
Causes of Surgical Site Infections

- Staphylococcus aureus: 20%
- Coag- staphylococci: 14%
- Enterococcus spp.: 12%
- Escherichia coli: 8%
- Pseudomonas aeruginosa: 8%
- Enterobacter spp.: 7%
- Candida albicans: 3%
- Klebsiella pneumoniae: 3%
- Other Streptococcus spp.: 3%
- Proteus mirabilis: 3%
- Bacteroides fragilis: 2%
- Group D streptococcus: 2%
- Other Gram positive aerobes: 2%
- Acinetobacter spp.: 1%
- Citrobacter spp.: 1%
- Gram positive anaerobes: 1%
- Group B streptococcus: 1%
- Other Candida: 1%
- Other enterobacteriaceae-aerobes: 1%
- Other Klebsiella spp.: 1%
- Other nonenterobacteriaceae-aerobes: 1%
- Serratia marcescens: 1%
- Other: 4%
Occurrence & Relative Size of Surgical Site Infections

- MRSA
- Coag-Staphylococcus
- Enterococcus
- Pseudomonas aeruginosa
- Enterobacter
- E. coli
- Klebsiella pneumoniae
- Proteus mirabilis
- Bacteroides fragilis
- Gram+ aerobes
- Gram+ anaerobes
- Group D Streptococcus
- Streptococcus spp.
- Serratia
- Candida albicans
- Candida spp.
- Non-enterobacteriaceae aerobes
- Enterobacteriaceae aerobes
- Group B Streptococcus
Transmission Routes of Surgical Site Infections

Nosocomial etiology can be complex, with multiple re-aerosolizations and equipment contamination affecting both patients and hospital workers.
Prior to patient entering room
- Using UVC radiometer and Variac, proper set point is found on Variac dial to achieve 23 μW/cm² at surgical site
- This setpoint is noted for use during the procedure
- Radiometer stored
- Lamps turned up to full power for 5 - 10 minutes to bathe OR
- Lamps dialed down to previously established set point, then shut off at that level

Patient brought in and prepped
- All exposed skin covered
- Eye protection for patient and staff
- Lamps re-ignited

During Procedure
- Lamps remain on
- Procedure completed
- Patient removed and lamps turned off

Ready for next procedure
THE STUDIES

DUKE UNIVERSITY & 2 MASSACHUSETTS HOSPITALS
- Duke had 10% post-op infection rate for “clean surgical wounds”
- UV lights installed
- 0.24% post-op infection rate in 5 years following UVGI installation
- 0.34% total post-op infection rate in the 26 years since UV installation
- 2 Mass. Hospitals dropped rate from 3.5% to 0.89% after installing UVGI in OR suites

ST. FRANCIS HOSPITAL
- Center for Hip & Knee Surgery
- Followed a single surgeon for 19 years and 5,980 total joint replacements
- 5 years without UV/14 with UV
- Infection rate dropped from 1.77% prior to UVGI installation to 0.57% after installation.
- 310% greater risk of post-operative infection without UVGI in the OR suite.
### UVGI Effectiveness in Hospitals

<table>
<thead>
<tr>
<th>Type</th>
<th>System</th>
<th>Location</th>
<th>Infection</th>
<th>Infection Before</th>
<th>Infection After</th>
<th>Decrease Net %</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgical Site Infections</td>
<td>Overhead Surgical Site UVGI</td>
<td>Duke University Hospital</td>
<td>SSI</td>
<td>5%</td>
<td>1%</td>
<td>4%</td>
<td>80% Kraissl et al 1940</td>
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<tr>
<td></td>
<td></td>
<td>Duke University Hospital</td>
<td>Hip arthroplasty infection</td>
<td>5%</td>
<td>0.5%</td>
<td>5%</td>
<td>90% Lowell et al 1980</td>
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<tr>
<td></td>
<td></td>
<td>NE Deaconess Hospital</td>
<td>SSI</td>
<td>15%</td>
<td>6.53%</td>
<td>8.5%</td>
<td>56% Overholt and Betts 1940</td>
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<tr>
<td></td>
<td></td>
<td>Infant &amp; Children's Hospital, Boston</td>
<td>SSI</td>
<td>12.5%</td>
<td>2.7%</td>
<td>9.8%</td>
<td>78% Del Mundo &amp; McKhann 1941</td>
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<tr>
<td></td>
<td></td>
<td>Watson Clinic, FL</td>
<td>Mediastinitis</td>
<td>1.4%</td>
<td>0.23%</td>
<td>1.2%</td>
<td>84% Brown et al 1996</td>
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<td>St. Francis Hospital</td>
<td>SSI</td>
<td>1.77%</td>
<td>0.57%</td>
<td>1.2%</td>
<td>68% Ritter et al 2007</td>
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<tr>
<td><strong>Average Reduction</strong></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td><strong>76%</strong></td>
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<td>Airborne Infections</td>
<td>Upper Room UVGI</td>
<td>The Cradle, Evanston</td>
<td>Respiratory infection</td>
<td>14.5%</td>
<td>4.6%</td>
<td>9.9%</td>
<td>68% Sauer et al 1942</td>
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<td></td>
<td>St. Luke's Hospital, NY</td>
<td>Respiratory infection</td>
<td>10.0%</td>
<td>6.6%</td>
<td>3.4%</td>
<td>33% Higgon &amp; Hyde 1947</td>
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<td></td>
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<td>Livermore, CA Veteran's Hospital</td>
<td>Influenza epidemic</td>
<td>19.0%</td>
<td>2.0%</td>
<td>17.0%</td>
<td>89% McLean 1961</td>
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<td></td>
<td></td>
<td>North Central Bronx Hospital</td>
<td>TB conversions among staff</td>
<td>2.5%</td>
<td>1%</td>
<td>2%</td>
<td>60% EPRI 1997</td>
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<td>Home for Hebrew Infants, NY</td>
<td>Varicella epidemic</td>
<td>97%</td>
<td>0%</td>
<td>97%</td>
<td>100% Wells 1955</td>
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<tr>
<td><strong>Average Reduction</strong></td>
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<td></td>
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<td><strong>70%</strong></td>
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</tbody>
</table>

Reduced infection rates mean:

- Fewer post-op complications
- Fewer deaths
- Fewer repeated procedures
- Lower costs to insurance companies and hospitals
- Better PR for hospitals

Overhead UVGI at St. Francis Hospital
QUESTIONS & COMMENTS

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