"Canyon Wall Effect": Why UVC Dosimetry Fails to Predict Germicidal Effectiveness of Vertical Lamps on Textured Horizontal Surfaces

Arthur Kreitenberg, MD FACS, University of California, Irvine School of Medicine
Maya Jaffe, (Bioengineering Student) Georgia Institute of Technology

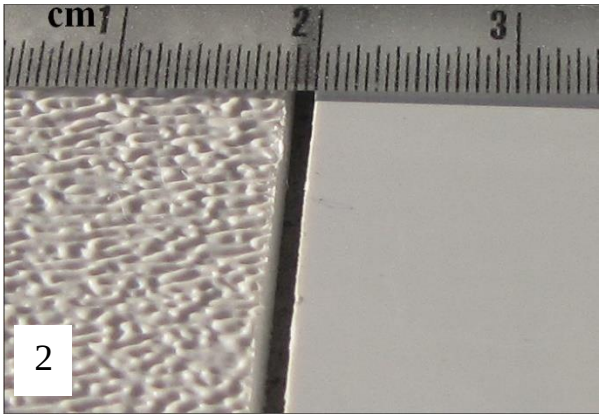
Germicidal UVC is acquiring an increasingly important role in healthcare room terminal disinfection. Published UVC dose requirements for log reductions are based on UVC sources parallel to the target surface. The vast majority of UVC emitters in use today have only vertical UVC sources which can effectively disinfect vertical surfaces. Airborne pathogens are more likely to land on a horizontal surface and most surfaces are textured. Recent studies of vertical UVC fluorescent lamps [1] and pulsed Xenon [2] showed dismal failures in reducing CFU's of target organisms on the majority of surfaces in hospital rooms. Boyce [3] described markedly decreased UVC delivery and germicidal effectiveness when vertical lamps are used on horizontal stainless-steel carriers. However, healthcare surfaces are frequently plastic, Formica, vinyl and wood that vary greatly in texture.

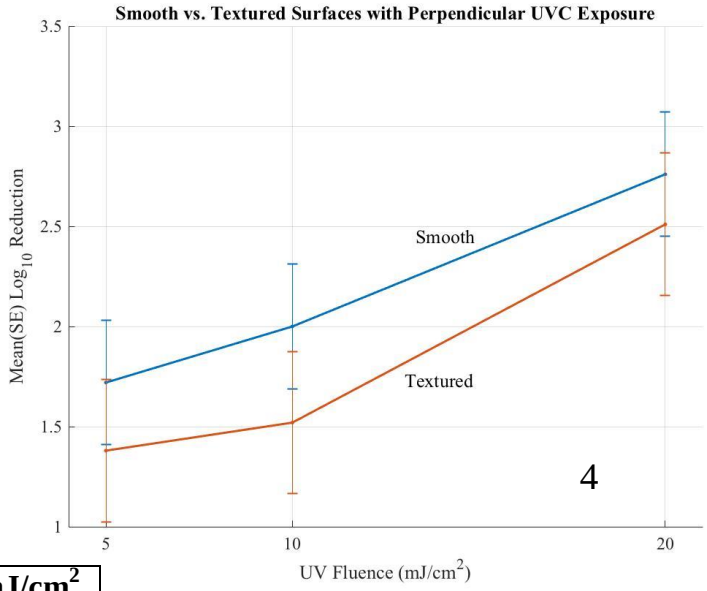
Figure 1 shows a 2m deep "canyon" at 9am and at noon, respectively. If the rocks on the canyon floor were bacteria and the morning sun were a vertical UVC emitter, those bacteria would remain unscathed, like a soldier shielded in a trench. A lightly textured surface with a peak/valley differential of only 0.1 mm (10^{-4}m), approximately that of human fingertip skin, has 100m tall canyon walls from the perspective of a 1-micron (10^{-6}m) MRSA bacterium. For an influenza virus, about 100 nanometers (10^{-7}) in diameter, the canyon walls are 1000m tall, about 27 times taller than Yankee Stadium.

Materials & Methods: Disinfected ABS 10cm x 10cm smooth and textured tiles (Figure 2) were inoculated with a Staph *aureus* solution, allowed to dry and arranged horizontally around a UVC meter (Intl Light Technologies). UVC lamps (Figure 3-UVHammer) were positioned horizontally (parallel) 1.1m directly above groups (n=9) of tiles and exposed to UVC 5, 10, or 20 mJ/cm^2. Quantitative Baird Parker contact plates (Hardy Diagnostics) were then used to culture the tiles. CFUs were counted 36 hours after incubation at 35 degC. The process was repeated with the lamps positioned vertically (perpendicular) to the side of groups of tiles. The UVC meter remained parallel to the lamps.

Results & Conclusions (Table 1):

1) Parallel UVC application on textured and smooth surfaces showed predicted, similar and excellent CFU reductions.
2) Perpendicular UVC application resulted in >150x CFU survival than parallel application on smooth surfaces and >500x CFU survival on textured surfaces.
3) UVC dosimetry fails to predict germicidal activity on surfaces perpendicular to the UVC source and is highly dependent on surface texture (Table 4)
4) Maintaining a parallel relationship (horizontal lamps for horizontal surfaces & vertical lamps for vertical surfaces) ensures UVC efficacy and predictability of UVC dosimetry.





Smooth	**5 mJ/cm^2**	**10 mJ/cm^2**	**20 mJ/cm^2**
Parallel	3.9*	4.5*	>5*
Perpendicular	1.7**	2.0**	2.8
Textured	**5 mJ/cm^2**	**10 mJ/cm^2**	**20 mJ/cm^2**
Parallel	4.1*	4.4*	>5*
Perpendicular	1.4	1.5	2.5

Table 1

All p<0.001 vs unexposed control

*p<0.001 parallel vs perpendicular

**p<0.01 smooth vs textured

References:

1. Rutala WA, Kanamori H, Gergen MF, et.al, Enhanced disinfection leads to reduction of microbial contamination and a decrease in patient colonization and infection, Infect Control Hosp Epidemiol, (2018) 39, 1118-1121.
2. Kitagawa H, Mori M, Kashiyama S, et.al. Effect of pulsed xenon ultraviolet disinfection on methicillin-resistant Staphylococcus aureus contamination of high-touch surfaces in a Japanese hospital, Am J Infect Control 00 (2019)1-4.
3. Boyce JM, Farrel PA, Towle D, Fekieta R, Aniskiewicz M, Impact of room location on UV-C irradiance and UV-C dosage and antimicrobial effect delivered by a mobile UV-C light device, Infect Control Hosp Epidemiol, 2016; 37:667-672.