SYNOPSIS

KEY POINT SUMMARY

OBJECTIVES

1. To evaluate the efficacy of an upper-room air ultraviolet germicidal irradiation (UVGI) system for inactivating airborne bacteria.
2. To evaluate the following factors influencing the performance of upper-room air UVGI: room ventilation rates, UV fluence rates and distribution, airflow patterns, relative humidity, and photoreactivation

Impact of Environmental Factors on Efficacy of Upper-Room Air Ultraviolet Germicidal Irradiation for Inactivating Airborne Mycobacteria

Xu, P., Kujundzic, E., Peccia, J., Schafer, M., Moss, G., Hernandez, M., Miller, S.
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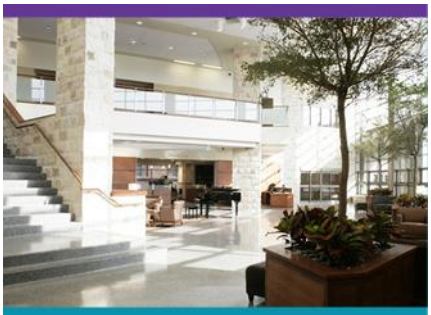
Key Concepts/Context

Hospitals are high exposure environments where transmission of infectious diseases is a large concern. To prevent this Ultraviolet Germicidal Irradiation (UVGI) systems are used as an engineering control. A common application is upper-room irradiation for which germicidal lamps are suspended from ceilings/ attached to walls, while the bottom of the lamps are shielded to direct radiation. The principle is to maximize UV radiation exposure to airborne microorganisms in the upper part of the room while minimizing radiation exposure to patients in the lower part. The performance of UVGI systems can be affected by infrastructure and environmental factors such as air flow patterns, room relative humidity, UV fluence rates etc. Due to the fundamental assumption of the system it is important that air from the lower part of the room move to the upper part to be irradiated, which could be impacted by supply/exhaust locations, ventilation, and air temperature. While it is obvious that efficacy of the UVGI system depends on numerous other external factors, research on this subject has been sparse. This paper looks at some of these issues within an experimental framework.

Methods

A full-scale test room (87 m3) was fitted with a UVGI system consisting of 9 louvered wall and ceiling fixtures (504Wall lamps operating) and operated at 24 and 34 °C, between 25 and 90% relative humidity, and at three ventilation rates. Mycobacterium parafortuitum cells were aerosolized into the room such that their numbers and physiologic state were comparable both with and without the UVGI system operating. Airborne bacteria were collected in duplicate using liquid



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impinges and quantified with direct epifluorescent microscopy and standard culturing assay.

Findings

Performance of the UVGI system degraded significantly when

1. The relative humidity was increased from 50% to 75-90% RH,
2. The horizontal UV fluence rate distribution was skewed to one side compared to being evenly dispersed, and
3. The room air temperature was stratified from hot at the ceiling to cold at the floor.

The inactivation rate increased linearly with effective UV fluence rate up to 5 íW cm-2; however an increase in the fluence rate above this level did not yield a proportional increase in inactivation rate. This implies that a higher fluence rate from a UVGI system provides better inactivation of airborne bacteria up to a threshold, beyond which adding more UVGI does not substantially increase the rate of inactivation.

Authors concluded that to obtain maximum benefit from an upper room air UVGI system inactivating airborne Mycobacteria, an adequate level of UV radiation should be provided within a symmetric volume (at least 6 W of UV-C per cu.m in the upper zone); the UV radiation should be evenly distributed; room air mixing should be ensured; and operational room relative humidity should be kept around 50%. Authors also concluded that photo reactivation is probably not an issue at full-scale operation under common room lighting conditions.

Limitations

While the test conditions in this study simulated real life settings better (arguably) than previous lab-based studies, there is still a need to test these findings in an operational healthcare setting.

Design Implications

Room air flow patterns should be carefully designed such that a symmetric volume of air can be achieved (providing hot supply air without a mixing fan can reduce the efficacy of the UVGI system).

While providing UVGI systems, UV radiation should be evenly distributed and room air mixing should be ensured.

Operational room relative humidity should be kept at around 50% Fluence rates should be routinely monitored in occupied zones to ensure exposure limits are met.