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Brief Report

Impact of a novel mobile high-efficiency particulate air–ultraviolet air recirculation system on the bacterial air burden during routine care

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Aerosol transmission of pathogens can result in the rapid spread of disease. Introduction of a mobile air recirculation system based on high-efficiency particulate air filtration, photochemical oxidation, and germicidal ultraviolet light significantly decreased the bacterial load by over 40% under routine care in an emergency department. Application of this new technology promises to reduce the aerosol pathogen burden, thereby decreasing exposure risk and providing a safer environment for patient care.

The current understanding of aerosol transmission assumes that a number of human pathogens are spread by respiratory secretions or infect by way of the respiratory tract.[1] However, data on how to protect against the spread of these pathogens are sparse.[2-4] Masks, respirators, and eye protection are commonly used barriers to block transmission to the individual. Environmental controls employ air exchanges and air filtration and purification systems, diluting and removing aerosol pathogens within a physical space. This study assesses the efficacy of a mobile high-efficiency particulate air (HEPA) ultraviolet (UV) air recirculation system (HUAIRS) in eliminating the amount of bacterial contaminants in the air in a clinical setting.

METHODS

The Aerobiotix Illuvia 500uv system (Aerobiotix, West Carrollton, OH) is an innovative, high-volume air purification system combining HEPA filtration, zirconium-based photochemical oxidation, and germicidal UV irradiation, targeting particulates, aerosol pathogens, and volatile organic compounds. A small footprint and low noise of the mobile unit allow for placement in different care environments without the need for physical plant modification.

Sampling was performed in emergency rooms (convenience sample). Three 6-stage Andersen samplers (Thermo Scientific, Waltham, MA) were used for air sampling, placed at the head and foot of a patient's bed, along with 1 sampler at the doorway exit or entrance. All samples were collected on blood agar plates (BBL Trypticase soy agar II with sheep blood; BD, Franklin Lakes, NJ). The air was sampled with no restrictions on care activities. If the patient had to leave the room for any reason during sampling, the sample was excluded from analysis.

After completion of the 20-minute baseline air sampling, the HUAIRS system was placed inside the patient room and run for 8 air exchanges (washout phase, adjusted by room size). This was followed by air sampling for 20 minutes, as described earlier, while the HUAIRS was left on. The times of door openings were recorded during both measurement periods to assess possible impact on air burden. Once air sampling was completed, plates were placed in a 37°C incubator. After incubating for 48 hours, the number of colonies congruent with bacterial growth was counted on all plates and recorded as colony-forming units (CFU). No further identification of bacteria regarding speciation or pathogenicity was performed.

Baseline and HUAIRS run total colony count data were summarized and analyzed. Means and SDs were calculated. To assess change between baseline and HUAIRS run data, paired t tests were used to assess the magnitude of change, testing the observed versus expected mean of no change (mean of 0). Correlation between bacterial burden and door openings was assessed using the Pearson correlation coefficients. Significance was assumed if $P < .05$. No correction for multiple

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Table 1
Impact of HUAIRS on bacterial air burden by location and particle size

	Baseline Mean no. of Colonies (SD)	HUAIRS Run Mean no. of Colonies (SD)	Difference (SD)	p-value*
Head (Bed)				
<4.7 μm	6.4 (7.7)	3 (4.5)	−3.4 (5.4)	<0.001
>4.7 μm	8.7 (7.2)	7.1 (7.8)	−1.7 (7)	0.062
Total	7.2 (6.9)	4.4 (5.0)	−2.8 (5.1)	<0.001
Foot (Bed)				
<4.7 μm	7.2 (10.9)	3.2 (4.6)	−4.0 (8.8)	<0.001
>4.7 μm	13.4 (16.5)	9.7 (13.2)	−3.7 (13.1)	0.028
Total	9.3 (11.3)	5.3 (7.1)	−4.0 (8.6)	<0.001
Exit/Entrance				
<4.7 μm	7.4 (13.8)	3.3 (4.2)	−4.1 (11.6)	0.007
>4.7 μm	10.4 (13.2)	8 (12.2)	−2.4 (8.6)	0.030
Total	8.4 (12.0)	4.9 (6.0)	−3.5 (9.7)	0.005
All Locations				
<4.7 μm	7 (10.4)	3.2 (4.1)	−3.8 (7.7)	<0.001
>4.7 μm	10.9 (10.8)	8.3 (10.0)	−2.6 (8.1)	0.013
Total	8.3 (9.6)	4.9 (5.7)	−3.4 (6.9)	<0.001

HUAIRS, high-efficiency particulate air ultraviolet air recirculation system; *no.*, number.
*p-values based on paired t-tests

testing was applied to outcomes, as those selected for analysis were related and were used to evaluate consistency across findings. SAS software version 9.4 (SAS Institute, Cary, NC) was used for all analyses. The study was approved by the institutional review board of Wake Forest School of Medicine.

RESULTS

A total of 70 participants were consented and enrolled in the study. Six participants were excluded because of leaving the room during sampling. Table 1 shows the mean bacterial counts at baseline and under HUAIRS use. A significant reduction of 41% in mean CFU was observed from baseline to HUAIRS use at all locations, with a maximum decrease seen at the foot of the bed (43%), followed by the exit (42%), and the head of the bed (39%). Combining sampler stages into less or greater than 4.7 μm particle sizes showed significant reduction of bacterial burden from baseline to HUAIRS run for the foot and exit locations but not the head location (>4.7 μm). Analysis of the 6 sampler stages confirmed a significant reduction owing to HUAIRS use for all particle sizes ($P < .05$) (Fig 1). The Pearson correlation coefficients indicating association between number of door openings and CFU were $r = 0.02$ (mean door openings, 4.6 [SD, 4.2], $P = .85$) for baseline and $r = 0.13$ (mean door openings, 4.0 [SD, 2.7], $P = .32$) for HUAIRS runs. The HUAIRS did not interfere with routine care and was well tolerated by patients and staff.

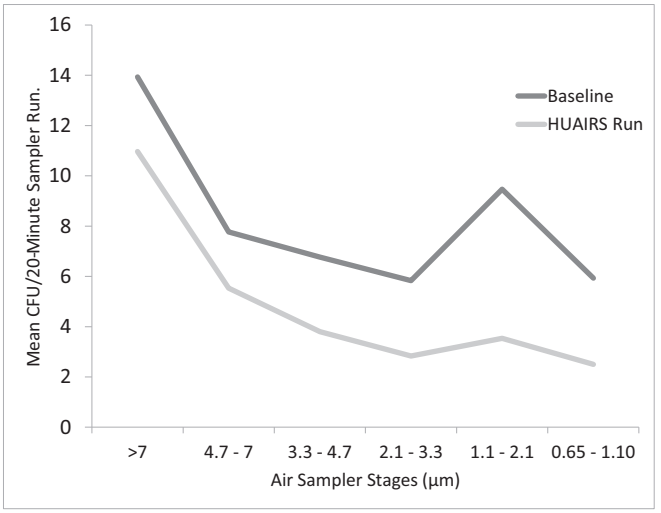

Fig 1. Reduction of bacterial air burden by air sampler stages (all locations). *CFU*, colony-forming units; *HUAIRS*, high-efficiency particulate air ultraviolet air recirculation system.

DISCUSSION

Human bioaerosols are generated by common activities, such as coughing, sneezing, and talking, creating a microbiome specific to the individual.[5,6] This microbiome cloud can contain communicable pathogens, such as *Neisseria meningitidis*, *Bordetella pertussis*, and *Mycobacterium tuberculosis*.[7]

Interventions to disrupt aerosol transmission target the individual caregiver or the environment. Surgical masks and respirators are the most common devices used for individual protection. However, evidence of their efficacy is still lacking.[8] Environmental controls include dilution through air exchange and air filtration and purification.[9] However, there is a limit to air exchange increases set by impaired comfort levels of inhabitants through draft and the diminishing return in aerosol pathogen reduction.[5] The process of air filtration and purification extracts and eliminates aerosol pathogens by filtration and other means, such as UV treatment or photochemical reactions. HEPA air filtration has set the gold standard for removing aerosol pathogens. Our study assessed the efficacy of a novel air purification system in reducing the overall bacterial burden during routine care. The HUAIRS significantly reduced the bacterial load throughout the patient room, indicating an evenly distributed cleansing pattern over collected particle sizes. Door openings did not change the bacterial burden during baseline and HUAIRS runs.

Our study is limited by the absence of comparison data for in-room air filtration and purification during routine care. Current standards assess filtration materials or use log reductions of aerosol particle or pathogen bursts to determine efficacy.[10] Our data were collected during routine care, with constant influx of bacterial contaminants from patients and caregivers. This may provide a more realistic assessment of the expected reductions in bacterial burden achievable by HUAIRS. Further studies are necessary to compare different air filtration and purification technologies and develop meaningful outcome measures regarding their impact on aerosol transmission.

CONCLUSIONS

Use of the HUAIRS in an emergency department setting led to a significant reduction in aerosol bacterial load. Applications of this new technology promise to reduce pathogen load and exposure and provide a safe environment for patient care.

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