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Research Brief

Correlation of the air–surface nexus of bacterial burden during routine patient care

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Bacterial pathogens have been detected in the air and can survive on surfaces for extended periods of time.[1–3] Our current understanding of pathogen transmission distinguishes between airborne, droplet, direct (hands) and indirect (surfaces) contact pathways.[4] The 4 transmission pathways appear not to be exclusive, but pathogens can transition between them.[5] Interventions such as air purification or surface cleaning may affect not only 1 pathway, but several.[5,6] This project determines the association between aerosol burden and surface contamination and the impact of a high-efficiency particulate air ultraviolet air recirculation system (HUAIRS) on transmission pathways.

Methods

Sampling was performed in a critical care decision unit (convenience sample) with no patient care activity restrictions. Three 6-stage Andersen samplers were used for air sampling and were placed at the head and foot of a patient's bed along with 1 sampler at the exit doorway.[7] A sedimentation plate (standard petri dish surface area, 56.7 cm^2) was placed next to each Andersen sampler. All samples were collected on blood agar plates (BBL: TSA II with Sheep Blood, Becton Dickinson, Franklin Lakes, NJ).

After completion of 20-minute baseline sampling, the HUAIRS (Aerobiotix Illuvia 500uv system [450 cfm], Aerobiotix, Dayton, OH) was placed within the vicinity of the patient bed and was run for at least 1 complete room air exchange. This procedure was followed by air sampling for 20 minutes with the HUAIRS running. Door openings were recorded. Once completed, plates were incubated for 48 hours at 37 °C. After incubation, the number of colonies congruent with bacterial growth was recorded as colony-forming units (CFU) per plate. No further speciation of bacteria was performed.

Baseline, HUAIRS run, and sedimentation CFU data were summarized and analyzed. Andersen sampler stages were combined into particles <4.7 μm or >4.7 μm. To assess the change between baseline and HUAIRS run data, paired *t* tests were used to determine the magnitude of change, testing the observed versus expected mean of no change (mean of 0). Correlations between aerosol burden and surface contamination were calculated using Spearman coefficients. The impact of door openings on environmental bacterial burden was assessed using Spearman coefficients. Significance was assumed if $P < .05$. We used SAS version 9.4 software (SAS Institute, Cary, NC) for all analyses. The study was approved by the Institutional Review Board of Wake Forest School of Medicine.

Results

In total, 65 participants were enrolled in the study (46% women and 54% men). Two participants were excluded due to unusual activities (eg, door remained open or food served). During HUAIRS use at all locations, a reduction of 58% in aerosol burden was observed: head, −7.1 (95% CI, −10.5 to −3.7; $P < .0001$); foot, −8.3 (95% CI, −12.0 to −4.7; $P < .0001$); and exit, −8.8 (95% CI, −12.0 to −5.5; $P < .0001$). A reduction of 51% in surface contamination was observed: head, −0.6 (95% CI, −1.1 to −0.1; $P = .024$); foot, −0.5 (95% CI, −1.5, 0.3; $P = .17$); and exit, −0.7 (95% CI − 1.3, to −0.1; $P = .016$) (Supplementary Data online). Except at baseline for air burden, door openings were correlated with air burden contamination (baseline Spearman ρ: 0.09, $P = .48$; HUAIRS run, Spearman ρ: 0.18, $P = .16$) and surface burden surface contamination (baseline Spearman ρ: 0.72, $P = .0001$, HUAIRS run: Spearman ρ: 0.35, $P = .0045$). Table 1 presents moderate to strong correlations between aerosol and surface burden for baseline/HUAIRS run samples.

Discussion

To interrupt the chain of transmission of pathogens, one must understand how these pathogens are spread. Our study focused on the redistribution of bacteria from airborne burden to surface contamination in a patient room during routine care. We found moderate to strong correlations of the air–surface nexus, indicating a direct link between bacteria released into the air and subsequent contamination of environmental surfaces. Using an air purification system led to significant reductions in the bacterial load.

Deposition of aerosolized bacteria on surfaces has been previously described.[8,9] Ijaz et al[5] studied the air-to-surface pathway in an aerobiological test chamber. One-time nebulization of a *Staphylococcus aureus* suspension let to measurable amounts of bacteria settling onto chamber surfaces. Our study confirms previous experimental findings and adds the element of continual bacteria release through patients and staff members and their

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Table 1. Correlation Between Aerosol Burden and Surface Contamination by Location and Particle Size

	Aerosol Burden Spearman Correlation, *P* Value								
Surface Contamination	Head Total	Head <4.7 μm	Head ≥4.7 μm	Foot Total	Foot <4.7 μm	Foot >4.7 μm	Exit Total	Exit <4.7 μm	Exit >4.7 um
Head	0.49, <.0001	0.50, <.0001	0.41, .0013	0.37, .0034	0.28, .034	0.47, .0002	0.33, .0099	0.30, .019	0.35, .0062
Foot	0.28, .029	0.28, .030	0.25, .054	0.29, .023	0.27, .041	0.27, .039	0.29, .025	0.27, .034	0.37, .0036
Exit	0.37, .0035	0.304, .019	0.40, .0019	0.33, .010	0.32, .015	0.26, .046	0.28, .035	0.26, .049	0.29, .027

interactions during routine care. Even under the chaotic air movement within a patient room, we found moderate to strong correlations at all sample locations. The head area displayed the strongest correlation, which may be related to calmer, less disruptive room activities compared to the foot or exit areas. These findings may help better define the air–surface nexus and its impact on pathogen distribution within a healthcare setting.

In a previous study we demonstrated the impact of an air purification system to reduce the aerosol bacteria burden during routine care.[7] In this trial, we found a reduction of >50% in air burden and notably in surface contamination. This finding points to a dual benefit of air purification reducing airborne and indirect contact transmission. Further studies should focus on the effect on pathogen transmissions through room decontamination devices.[10]

Our study has limitations. We studied the impact on the bacterial burden but not on direct pathogen-to-person transmission through air or contact. Using sedimentation plates may overestimate surface contamination due to favorable survival conditions. We also did not specify whether the bacteria collected included human pathogens.

We found moderate to strong correlations between aerosol bacterial burden and surface contamination throughout a patient care environment during routine care. Use of an air purifier led to significant reductions in both airborne and surface bacteria. Further studies are needed to define the impact of air purification on the transmission of bacteria and in view of severe acute respiratory coronavirus virus 2 (SARS-CoV-2).

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/ice.2020.436

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