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Short Report

Effectiveness of a plasma treatment device on microbial air quality in a hospital ward, monitored by culture

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SUMMARY

This study analysed the effectiveness of plasma treatment on airborne bacteria and surface counts during a 14-day intervention within a four-bedded bay in an adult respiratory ward at Cork University Hospital, Ireland. One-hundred-litre air samples were collected twice daily every weekday for 4 weeks, with settle plates and surface swabs. The plasma treatment did not have an effect on airborne bacteria and fungi that was detectable by culture. However, the possibility that culture-based sampling may be insufficiently sensitive to detect an effect, or that the duration of the study was insufficient for plasma treatment to affect a complex environment, cannot be excluded.

Introduction

The World Health Organization has reported that 7.6% of patients in high-income countries acquire a healthcare-associated infection (HAI) [1]. Although there are many routes to infection spread, airborne transport may be responsible for up to 10% of all HAIs [2]. The current coronavirus disease 2019 (COVID-19) pandemic has highlighted the need for

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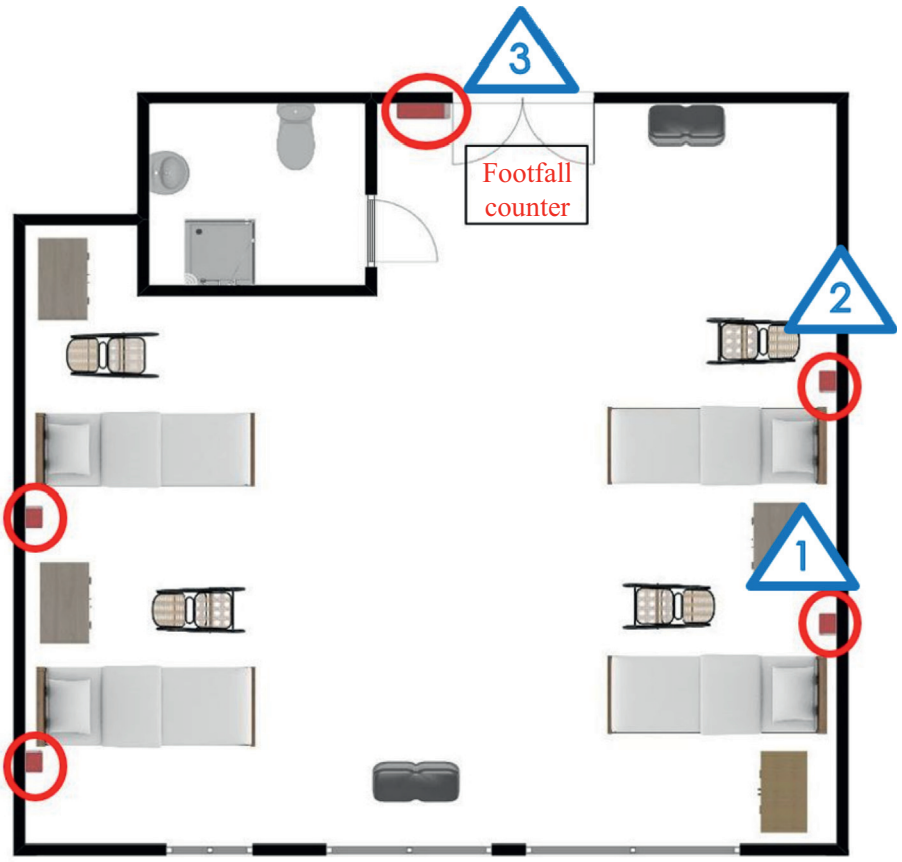

Figure 1. Schematic of ward with plasma disinfection units marked with red circles and swab sites marked with blue triangles.

effective and efficient removal of airborne pathogens from the air by ventilation, including in the healthcare environment [3]. Airborne micro-organism culture is applied to parts of the hospital environment where patient contamination by airborne organisms is recognized to be particularly harmful, such as operating theatres. However, although air culture data have been reported for other areas, only empirical airborne micro-organism standards exist for operating theatres [4].

Filtration — the removal of particulates from air — is the usual method for improving the quality of indoor air in modern buildings. An existing heating, ventilating and air-conditioning system may be augmented by a 'portable air cleaner'. The US Centers for Disease Control and Prevention recognizes portable high-efficiency particulate air (HEPA) filtration devices as a means to increase the effective number of air changes per hour in controlled environments [5].

This study relates to an adult respiratory ward at Cork University Hospital, Ireland. The ward is ventilated by a heat recovery ventilation system with a HEPA filter delivering 12 air changes per hour. As the ward had been refurbished with antimicrobial devices, including plasma air treatment devices, which had not yet been activated, it was decided to test the effect of activating the plasma air treatment of bioaerosols. Plasma treatment devices (Novaerus) are designed to achieve electrostatic precipitation of airborne particles into the proximity of an electrical plasma generator coil [6]. Discharge from the coil generates localized electrons, ions, reactive radicals and ultraviolet light which are thought to underly inactivation of airborne bacteria, fungi and viruses observed *in vitro* with the device [7]. Bacterial numbers cultured using air and surface sampling would be assessed. A period of at least 14 days without plasma treatment (control) was compared with a period of at least 14 days with plasma treatment.

Methods

This study was performed in a four-bedded bay. Impaction and settle plate samples were taken during twice-daily visits to the ward on weekdays over a total of 28 days. Samples were taken at two timepoints (11:30 h and 13:00 h) at locations ~1 m off the floor. A MAS-100 microbial air sampler (Merck, Whitehouse Station, NJ, USA) was operated with an air intake of 100 L/min for 1 min, and settle plates were left for 1 h. Bacterial counts and fungal loads were assessed using tryptic soy agar (TSA) and Sabouraud dextrose agar (SDA), respectively, in 90-mm Petri dishes, and the plates were incubated at 30°C for 5 days. Cotton swabs were used, and surface swabbing was performed daily at specific sites not touched by patients or subject to daily cleaning (Figure 1). Swab site 1 was a horizontal shelf at a height of 1.8 m, swab site 2 was a horizontal plastic surface at a height of 1.5 m, and swab site 3 was a vertical, metal sliding door housing 2 m outside the entrance to the bay. Swab tips were moistened in sterile water and applied to a 10-cm^2 area before streaking on to TSA and SDA agar plates. Plates were incubated as described above. Curam Medical (Dublin, Ireland) performed colony counts on coded (blinded) plates.

An IRC5716-NW Gazelle DualView IP Counter 60° Master Unit footfall counter (Axiomatic Technology, Nottingham, UK) was used to monitor footfall continuously in and out of the ward bay. This was located 2.2 m above the entrance to the bay (Figure 1).

Ethical approval was granted by the Clinical Research Ethics Committee of the Cork Teaching Hospitals Application ECM 4 (b) 07/03/17.

Plasma treatment unit

Plasma treatment units comprised one NV800 at the entrance to the bay and four wall-mounted NV200 (Novaerus Ltd, Dublin, Ireland). The locations are marked in Figure 1, and the number of units installed was as advised by the manufacturer. The claimed air passage rates are 220 and 80 m^3/h for NV800 and NV200, respectively.

Statistical analysis

P-values were calculated with Student's *t*-test (parametric) or Mann–Whitney *U*-test (non-parametric), using the Benjamini–Hochberg method to control the false discovery rate.

Results

Cultures

There was no significant difference in colony-forming unit (cfu) counts for the impaction or settle plate samples at either 11:30 h or 13:00 h between the plasma treatment period and the control period (Table I). Like the MAS-100 and settle plate samples, the swab samples taken from three different sites showed no significant difference for either sampling timepoint between the plasma treatment period and the control period. The swabs taken within the ward (swab sites 1 and 2) resulted in higher cfu/m^3 than the swab taken from swab site 3 just outside the ward, but the latter was a vertically oriented metal surface, rather than a horizontal painted or plastic surface. Recorded mean cfu counts (Table I) for swab sites 1 and 2 were higher at 11:30 h than 13:00 h, suggesting that the overnight accumulation was collected with the first (11:30 h) sample.

The mean and summed half-hourly diurnal footfall counts did not vary between observation periods, and no significant difference ($P<0.01$) was found between the plasma treatment and control periods for any time of day. Mean footfall counts were lowest overnight (00:00–04:30 h), and peaked in the mornings at 07:00 h [41±10 per half-hour (phh)] with the plasma treatment units on, and at 08:00 h (42±15 phh) with the plasma treatment units off. Lesser peaks followed at 11:30 h (35±12 phh), 15:00 h (29±12 phh), 13:00 h (20±12 phh) and 18:00 h (20±9 phh). The consistent diurnal footfall pattern reflected regular ward events, where the largest number of staff were active on the ward when the day shift nursing staff (N=6–9) arrived for handover at 07:45 h. Beds were usually made between 08:30 h and 10:00 h.

Footfall counts did not show significant correlation with MAS-100 [$r(34) = +0.17$, $P>0.05$] or settle plate counts [$r(34) = +0.05$, $P>0.05$].

Discussion

This study characterized the indoor air in a hospital respiratory ward using plate count cultures of air and surface samples over 20 weekdays. Movement activity (known to have a

Table I
Summary statistics for MAS-100 air sampler and settle plates with *P*-values calculated between plasma treatment period and control period

Sample	Time (h)	*N*	Plasma disinfection unit				*P*-value
			On		Off		
			Mean ± SD	5th–95th percentiles	Mean ± SD	5th–95th percentiles	
MAS-100 TSA[a]	11:30	20	509 ± 368	189–927	507 ± 284	209–941	0.34
	13:00		629 ± 439	210–1391	526 ± 273	199–1103	0.45
MAS-100 SAD[a]	11:30	20	44 ± 28	20–82	38 ± 27	4–67	0.44
	13:00		36 ± 23	7–67	43 ± 44	5–120	0.84
Settle TSA[b]	11:30	20	25 ± 10	12.1–42	24 ± 17	15–46	0.43
	13:00		23 ± 13	7.7–45	22 ± 24	4.7–52	0.53
Settle SAD[b]	11:30	20	0.4 ± 0.7	0–2	0.5 ± 0.8	0–2	0.91
	13:00		1 ± 1	0–3	4 ± 5	0–12	0.24
Footfall[c]	11:30	20	33 ± 10	23–47	38 ± 15	22–65	0.43
	13:00		22 ± 12	7–41	19 ± 11	7.2–35	0.40
Swab site 1[b]	11:30		190 ± 211	31–649	148 ± 116	21–379	0.81
	13:00		78 ± 70	17–192	63 ± 46	13–143	0.743
Swab site 2[b]	11:30	20	195 ± 247	29–700	124 ± 125	35–46	0.662
	13:00		138 ± 180	20–533	96 ± 102	20–335	0.621
Swab site 3[b]	11:30		19 ± 34	3–57	22 ± 20	2–59	0.302
	13:00		21 ± 44	2–84	13 ± 16	2–35	0.945

TSA, tryptic soy agar; SDA, Sabouraud dextrose agar; SD, standard deviation.
[a] Colony-forming units per m^3.
[b] Colony-forming units per plate.
[c] Footfall per half-hour.

significant effect on indoor air in itself [8], and a correlate of occupancy) was continuously monitored remotely by an infra-red people counter at the entrance to the bay. This confirms the practicality of modern monitoring technology in assessment of the hospital environment.

Over the sampling periods, the MAS-100 cultures varied considerably, exhibiting a standard deviation of $\pm$341 cfu/m^3 and a mean of 542 cfu/m^3 (Table I), similar to high sample variations observed by O'Brien *et al.* [9]. Likewise, the surface swab samples exhibited large standard deviations in all sample areas (Table I).

The effect of activating plasma treatment units on ward air was observed using culture. Testing of air samples using impact and settle plates found no significant change in cfu counts with plasma treatment at either of the two time points studied (11:30 h and 13:00 h) ($P>0.01$) (Table I). Similarly, surface swab samples taken from three different sites showed no significant difference at either time point between the plasma treatment period and the control period.

Infra-red footfall counts did not correlate with cfu counts in cultures. A previous study of an intensive care unit linking occupancy with airborne bacterial culture numbers [10] required intensive sampling (every 15 min for 10 h), which would be difficult to sustain over a 4-week study.

The data collected during this study do not support the efficacy of these plasma air treatment units in disinfection, as determined by culture (colony counts). The fact that interval cultures could not detect an air-modifying effect of devices capable of airborne bacterial and fungal inactivation *in vitro* may be due to the complexity of the hospital environment tested, containing multiple (albeit typical) bioaerosol sources, and including activity-related peaks at the entrance to the bay. Before concluding that this method of air disinfection is ineffective in this environment, further study involving the use of units with higher air passage rates (m^3/h) and a longer duration of plasma treatment is required.

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Conflict of interest statement
None declared.

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