An Intraoperative UV Air Decontamination Device Does Not Interfere with the Central Unidirectional Airflow of a Simulated Operating Room

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Abstract

Operating rooms (ORs) contain central unidirectional downward air flow to inhibit surgical site infection. Deployment of air decontamination devices in operating rooms helps maintain clean air. These devices occasionally raise questions regarding whether they interfere with the central unidirectional air flow. We measured the air flow in a simulated OR with a corner-stationed air recirculation *on* and *off*. The average (standard deviation) vertical air flow in the central part of the OR was 0.28 (.10) m/s when the device was *off*. The average (standard deviation) vertical air flow in the central part of the OR was 0.30 (.09) m/s when the device was *on*. Air flow in the center of the OR was not significantly affected by the air recirculation device.

Introduction

Preventing surgical site infections is an ongoing challenge in hospitals.[1-5] The air in an OR is subject to contamination from a number of sources including human occupation and movement,[6-8] electrosurgical smoke,[8-11] bone cement mixing[12] and door openings.[13,14] In order to help maintain sterility and improve the overall quality of the environment, standard operating rooms (ORs) have HEPA filtered, unidirectional airflow that is emitted from central overhead vents.[15,16] Downward, unidirectional airflow in the center of the room helps to maintain clean air at the surgical site and is a preventive measure to inhibit infection. The flow of air from the center of the room to the perimeter results in a higher level of contamination in the periphery, which contains various equipment and healthcare workers. Understanding the air flow in the OR is an ongoing challenging topic and merits further attention.[17,18] While the center of the room is expected to have higher air flow, dynamic and complex airflow physics in the OR can produce a complicated system. Measuring and documenting the air flow patterns in an OR will facilitate our understanding of the spatial heterogeneity of OR airflow and bring greater awareness to the differences in hygiene between the center and periphery of the OR.

While some studies show that laminar airflow reduces the occurrence of bacterial colony forming units in ORs, it does not guarantee clean air as a variety of factors influence air cleanliness including staff behavior.[19-21] Technological interventions that improve air quality have been employed to mitigate the incidence of SSI.[22] Supplemental air recirculation systems containing various air cleaning technologies including UVC lights, HEPA filters, activated carbon and catalytic foam provide further safety for patients and staff.[23-25] A common field question is whether or not the flow of air into and out of air recirculation devices affects the downward, unidirectional air flow in the middle of the OR.[26] When stationed in the perimeter of an OR an air recirculation device is not expected to interfere with air

coming from a ceiling mounted vent. In this study, we measure the airflow in the vertical direction in a simulated OR. We map the airflow by taking anemometer readings at designated locations in the perimeter and center of the OR. We perform measurements with and without a medical-grade air recirculation system running in order to understand whether or not the horizontal air flow of the device in the perimeter of the room affects the downward central unidirectional airflow.

Methods

Testing was performed with a 50 m^3 simulated operating room containing a single entry/exit door that automatically closes. The room included a ceiling mounted 44 $ft.^2$ array delivering unidirectional HEPA-filtered supply air and four lower wall mounted air return ducts. The system supplied 20 air exchanges per hour (ACH) and 0.03 in. H_20 (7.5 Pa) of positive pressure to the outside environment. The room was equipped with typical OR air flow obstructions including surgical lights, tables and medical equipment (Figure 1). The room also contained healthcare worker manikins. Images of the simulated OR and overhead vent are shown in Figure 1.

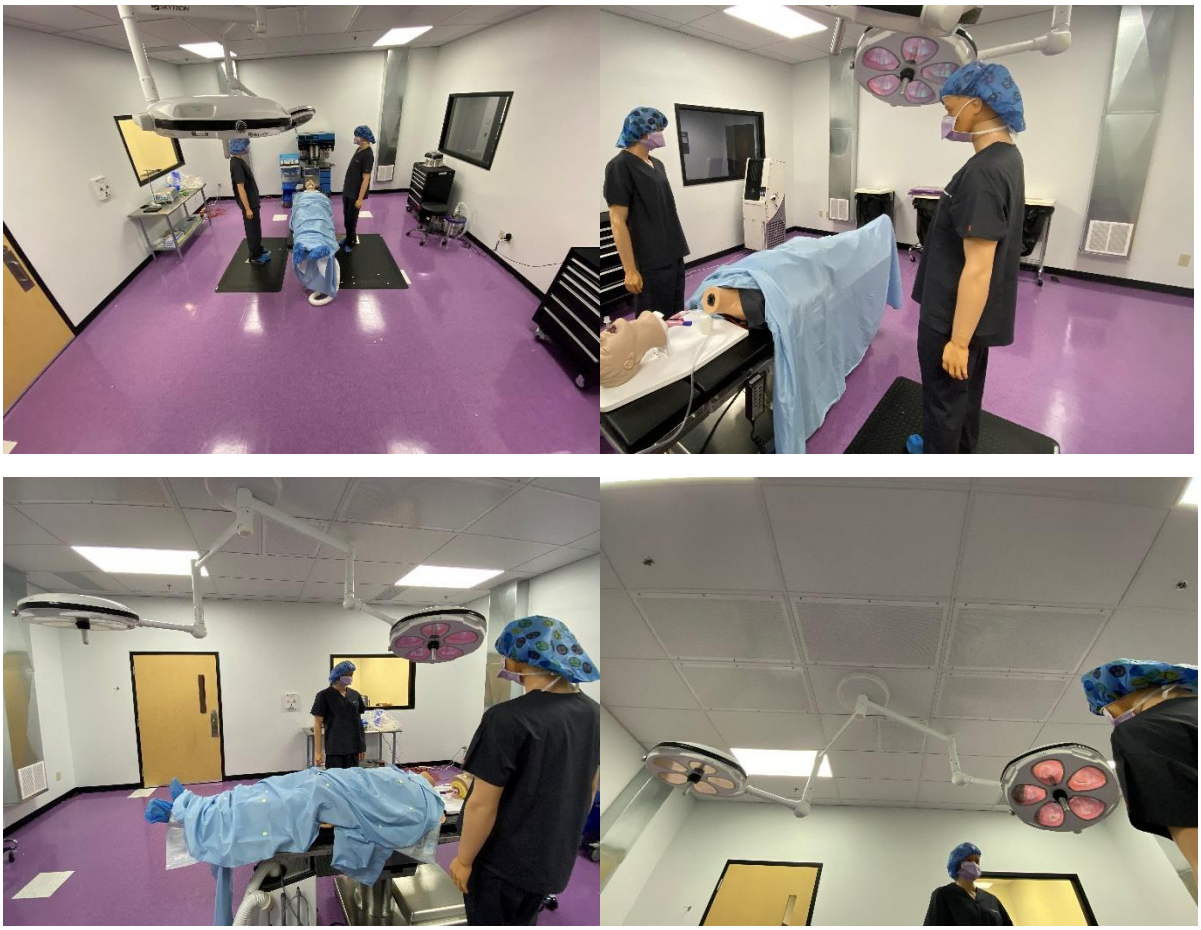

Figure 1: The configuration of the simulated operating room during airflow measurements is shown. The position of the Illuvia Sense is shown in the upper right image. The ceiling mounted vents are shown in the lower right image.

A hot wire anemometer (HT-9830) (HT Instruments, Guangzhou, China) was used for air flow measurements. The probe was clamped to a portable ring stand and mounted to a moveable cart. For each measurement, the probe was positioned at a specific location in the OR and the most stable air flow value was recorded. Measurements were made at approximately every two feet in both the x and y direction of the room. The height of the probe was kept at 46 in. above the floor. The measurement points follow a grid pattern as shown in Figure 2. The grid contains a central zone where ceiling mounted vents deliver unidirectional downward air flow, and a perimeter where overhead vents are not present.

An Illuvia air decontamination unit (Aerobiotix, Inc., Miamisburg, OH) was stationed in the corner of the OR. Air flow was mapped with the Illuvia *on* and *off*.

A) Vertical Air Flow Illuvia *OFF*

	A	B	C	D	E	F	G	H	I	J
1	0.05	0.11	0.08	0.1		0.08	0.11	0.08	0.08	0.09
2	0.08	0.12	0.11	0.08		0.09	0.13	0.1	0.11	0.1
3	0.08	0.09	0.12	0.12		0.09	0.13	0.1	0.11	0.1
4	0.08	0.13	0.1	0.09	0.29	0.16	0.11	0.11	0.11	0.1
5	0.08	0.12	0.08	0.14	0.33	0.18	0.11	0.08	0.1	0.09
6	0.08	0.1	0.08	0.36	.24	0.32	0.11	0.09	0.1	0.09
7	0.1	0.08	0.24	0.34	.26	0.25	0.1	0.09	0.09	0.09
8	0.12	0.1	0.12	0.28	.22	0.47	0.11	0.1	0.09	0.1
9	0.12	0.11	0.15	0.32	.29	0.41	0.1	0.1	0.11	0.16
10	0.09	0.12	0.08	0.24		0.28	0.1	0.1	0.11	0.09
11	0.08	0.1	0.09	0.09		0.11	0.12	0.11	0.08	0.1
12	0.1	0.11	0.08	0.1		0.1	0.1	0.09	0.09	0.1

0-0.9
.1-.14
.15-.19
.20-.29
.30-.39
.4->.4

B) Vertical Air Flow Illuvia *ON*

	A	B	C	D	E	F	G	H	I	J
1	0.1	0.1	0.08	0.1		0.12	0.1	0.09	0.44	0.43
2	0.08	0.1	0.1	0.1		0.09	0.11	0.33	0.14	0.28
3	0.08	0.1	0.1	0.1		0.11	0.1	0.23	0.16	0.1
4	0.08	0.08	0.11	0.1	0.25	0.3	0.1	0.16	0.12	0.09
5	0.11	0.08	0.08	0.15	0.29	0.44	0.13	0.17	0.15	0.11
6	0.08	0.09	0.11	0.37	0.25	0.43	0.1	0.22	0.14	0.15
7	0.05	0.09	0.11	0.34	0.26	0.33	0.11	0.13	0.24	0.2
8	0.08	0.1	0.11	0.34	0.35	0.41	0.1	0.22	0.15	0.1
9	0.08	0.11	0.1	0.28	0.24	0.28	0.11	0.21	0.22	0.13
10	0.11	0.09	0.11	0.28		0.33	0.11	0.22	0.15	0.11
11	0.08	0.1	0.09	0.1		0.13	0.1	0.1	0.1	0.11
12	0.09	0.1	0.11	0.09		0.09	0.1	0.09	0.1	0.1

0-0.9
.1-.14
.15-.19
.20-.29
.30-.39
.4->.4

Figure 2: The OR is divided into a grid pattern. Air flow values (m/s) are shown for each section of the grid. The Illuvia was stationed in the lower right-hand corner. The OR door is in the lower left-hand corner. The central zone is demarcated by a box with a thick black outline and contains the OR table and the overhead vents. The boxes are color coded based on the air flow range with green corresponding to higher air flow and red corresponding to lower air flow. A) Data for vertical air flow with Illuvia *off*. B) Data for vertical air flow with Illuvia *on*.

Results and Discussion

Air flow values were measured in the vertical direction, which is the same direction as the air emerging from the ceiling-mounted vent. Measurements were initially conducted with the Illuvia *off*. For comparison, the center of the OR where the ceiling vents and operating table are located is distinguished from the perimeter of the OR as shown in Figure 2. The average (standard deviation) vertical air flow in the central part of the OR is 0.28 (.10) m/s. The average vertical air flow in the periphery of the OR is 0.1 (.03) m/s. The higher airflow in the center of the room compared to the perimeter of the room is statistically significant ($p = 6X10^{-7}$). When the measurements were performed with the Illuvia *on*, the central and periphery values are 0.30 (.09) m/s and 0.13 (0.07) m/s. Again, the

central air flow is significantly different than the periphery ($p = 1X10^{-7}$). Importantly, there is no significant difference between the central air flow when the Illuvia is *off* vs *on* (p = 0.4113).

The Illuvia is an air cleaning and disinfecting device that is stationed in the perimeter of the room. The device delivers directed air flow at a rate of 450 cfm. It is important that portable air flow devices not interfere with the downward, unidirectional air flow in the center of the room. The results show that there is no significant difference in the detected levels of vertical air flow in the middle of the room when the Illuvia is *on* and *off*. The disinfecting and particle trapping benefits of the Illuvia are not at the expense of uninterrupted air flow in the middle of the room, showing that the air cleaning unit is a beneficial technology for enhanced OR hygiene that does not negatively impact the existing OR controls.

Conclusions

The vertical airflow is approximately 3 times higher in the center of the simulated OR compared to the perimeter. Operation of an Illuvia air disinfecting device in the perimeter of the room does not negatively impact air flow in the center of the room.

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