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Reduction in Airborne Bacterial Levels in Operating Room Using Supplemental Ultraclean Air System

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Study Aims and Design

Airborne bacteria-laden particles in healthcare settings are now being recognized as a contributing cause of hospital acquired infections (HAI), and surgical site infections (SSI). Air quality in most operating rooms (OR) is controlled exclusively by the engineered ventilation/filtration systems designed to maintain the minimum recommended standards for air circulation, pressure and humidity. Unfortunately, no guidelines for indoor air microbiological or particulate counts have been enforced for the ORs in the United States. Positive correlations between SSI occurence and OR traffic, surgical personnel behaviors and airborne bacterial levels were reported.

In light of recent scientific data there is increased interest in considering innovative supplemental technologies to support best air quality in high risk ORs. This study was designed to test the efficacy of the innovative HEPA/UV-C supplemental ultraclean air system (SUCAS) on reducing airborne bacterial levels in an active orthopedic OR.

Background

In spite of immense modern technological progress and the appearance of state-of-the art ORs, the contemporary scientific and medical communities are still struggling to prevent SSI occurence[1]. Patient-specific and environmental factors are considered to be among major contributors to this public health concern.

Patient-related risk factors are commonly associated with advanced age of patient population, rise in diabetes, obesity, malignancies and conditions causing immune suppression [2, 3]. Global situation is worsening as hospital infections cannot be eradicated with common antibiotics due to the rise of multidrug resistant microbial pathogens [4, 5].

Environmental risk factors include the presence of airborne viable microorganisms in the OR air, in close proximity to the surgical wound. Bacterial cells can be transported on dust, skin scales, fabric fibers and respiratory or mechanically-generated aerosols[6]. OR air quality should be scrupulously monitored during surgical procedures involving the use of implants. It is well established that contamination of a surgical implant and subsequent development of SSI can occur with a very small bacterial inoculum, eventually, leading to biofilm formation and establishment of a chronic, drug-resistant and costly infection[7].

Four main routes of pathogen access to the wound have been identified in literature such as patient’s endogenous flora [8], surgeon’s/staff skin flora [4, 5, 9-11], airborne microbes [12-15] and contaminated instruments. It is well established that humans naturally shed skin scales/particles carrying microorganisms[16], this is significantly augmented during displacements in the operating room (OR) in the presence of turbulent air currents. Particles carrying microorganisms can gain access to the surgical wound or, alternatively, settle onto the surgical instruments or implants. The ventilation guidelines established for the hospital OR are outdated and currently no additional risk prevention measures are put in place for high risk, high traffic orthopedic, cardiothoracic and bone marrow transplant ORs [17].

Multiple studies focused on indoor air contamination have been published [18-20]. The implementation of adjunct air “scrubbing” technologies to supplement engineered environmental OR controls is necessary to mitigate risks associated with airborne SSI causes.

Methods

The C-UVC/HEPA device was designed by AEROBIOTIX, Dayton, OH (Illustration 1). The unit was developed to accommodate the 450 ft^3/min (CFM) airflow in a standard OR environment. The 24x18 inch (61x46cm) air intake is located at the bottom of the unit, adjacent to the motor. The 24x12 inch (61x30.5 cm) clean air exhaust is positioned at the top of the device. Both air ports are supplemented with filtration systems: an inlet air filter cartridge (performance level 1=PL1) and a HEPA air outlet filter respectively. The C-UVC (254nm) reactor is placed in the path of the airflow, at the center of the unit between the two filtration systems. The silicate crystals within the reactor are designed to form a solid UV-C permeable media to slow down the airstream and prolong C-UVC exposure of airborne microorganisms.

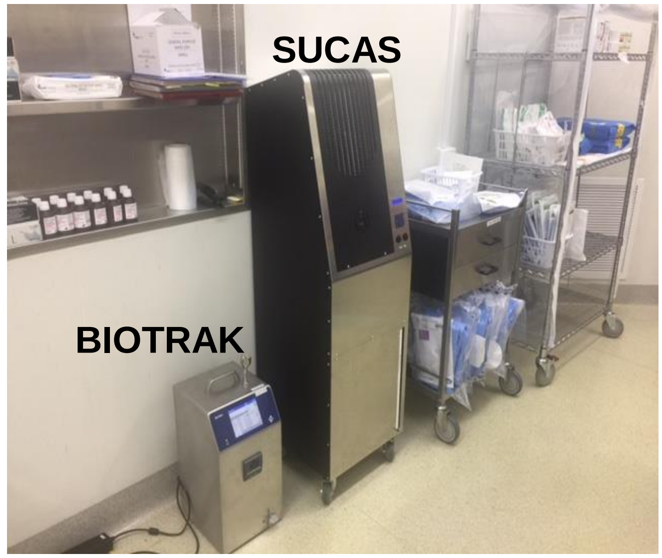


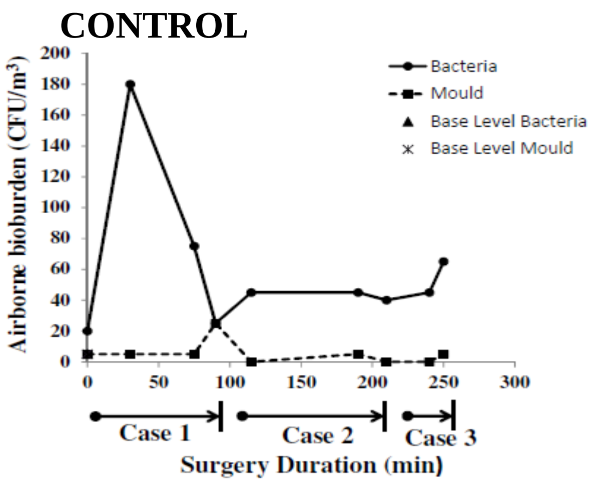
Illustration 1. SUCAS system positioning in the test OR.

The study was conducted in the community tertiary care hospital in New South Wales, Australia. ORs were standard, positive pressure rooms. One operating room (Operating theatre 1) continuously utilized HEPA/UV-C SUCAS system, while another one served as a control (Operating theatre 3). BIOTRAK particle counter was used to measure airborne particle content in the OR air during surgeries. Similar types of arthroplasty procedures were performed in both ORs (**Case 1**-total knee replacement; **Case 2**-total hip replacement; **Case 3**-total knee replacement). Baseline levels of bacterial and fungi in the ORs were sampled at 4:30 am, at least 2 hours prior to the start of surgical procedures.
Air Sampler BIOTRAK ™ REAL TIME VIABLE PARTICLE COUNTER was used to collect viable airborne microorganisms in the operating room air by impaction. The contact agar plates were sent for analysis to an accredited laboratory. Results were displayed at colony-forming units per cubic meter (CFU/m^3).

Results

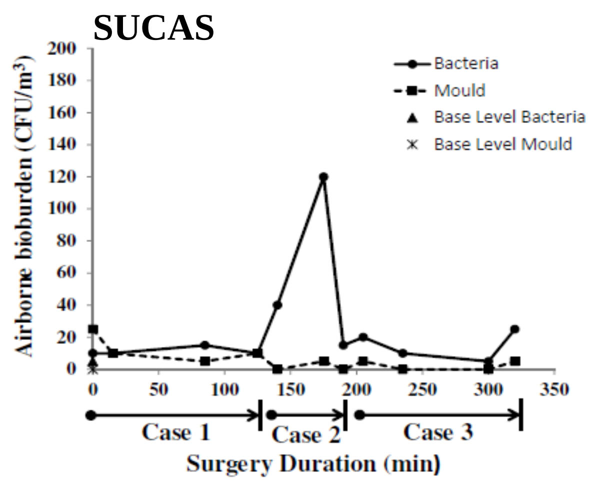
To test the efficacy of SUCAS system in reducing airborne bioburden, two arthroplasty operating rooms were selected for evaluation. The air from both ORs was sampled continuously over the span of three arthroplasty procedures. Fluctuations in CFU/m3 are displayed as a function of time (minutes) in **Figure 1** (Control) and **Figure 2** (SUCAS). It is evident that certain periods of time are associated with very high air bacterial content, a potential risk of surgical wound contamination. Overall, presence of SUCAS system reduced mean bacterial CFU/m^3 by 57%, the difference is statistically significant, $p=0.004$ (**Figure 3**).
Even though this study did not control for case dependent factors such surgeon's skill and staff activity among others, the significance of findings shows significant promise for implementation in risk prevention purposes.

FIGURE 1



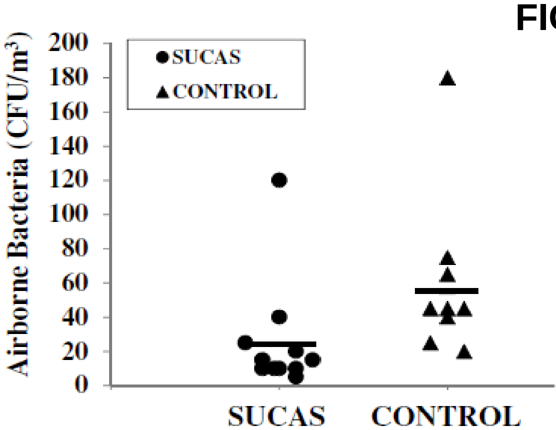
Airborne bacteria and mould contamination in the orthopedic OR during three arthroplasty procedures.

FIGURE 2



Airborne bacterial and mould contamination in the orthopedic OR during three arthroplasty procedures in the presence of HEPA/UV-C Supplemental Ultraclean Air System (SUCAS).

FIGURE 3



Bacterial colony-forming units per cubic meter in operating rooms with (SUCAS) and without (CONTROL) supplemental ultra-clean air filtration technology. Differences in microbial counts are statistically significant, $p=0.004$, Student's t-test.

Discussion and Conclusion

SUCAS technology combines germicidal short wavelength UV-C irradiation (UVGI) with HEPA filtration to generate ultraclean air. Its high-volume air recirculation function provides an effective control measure for air contamination problems produced by bystander microbial carriers, primarily healthcare workers [21]. The number of airborne particles produced per person is 100,000/min at rest and over 30,000,000 during exertion [16, 21]. A statistically significant correlation exists between the median number of people in the OR during orthopaedic surgery and airborne contamination[21]. Human traffic adversely affects the air-exchange, pressure and other air control parameters in the OR [21]. Given that SSI account for 14-20% of all hospital acquired infections and result in significant morbidity and mortality, there is a need to better manage risk factors of SSI such as environmental air quality controls. HEPA/UV-C SUCAS system is a promising air quality control technology shown to significantly reduce airborne bacterial burden. Installation of SUCAS system should be considered by healthcare facilities to limit the spread of infectious airborne pathogens.

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