The Effect of a Novel Air Decontamination-Recirculation System on Viable Airborne Particulates

W.R. Walsh, PhD; N. Bradford; G. Davies MD, R. Oliver, PhD; R. Verhuel MBBS FRACS; W. Bruce, MBBS FRACS

Surgical & Orthopaedic Research Laboratories
Prince of Wales Clinical School
University of New South Wales
Prince of Wales Hospital, Sydney, Australia

Presented at the European Bone and Joint Infection Society (EBJIS) 36th Annual Meeting September 7 – 9 2017 in Nantes, France

The European Bone & Joint Infection Society

Aims and Study Design

The prevention of surgical-site-infections (SSIs) is of great clinical importance to patients, surgeons and healthcare system globally. The size variability and amount of airborne particulate contamination generated during surgical procedures has not been extensively studied. SSIs continue to present major challenges in terms of morbidity as well as socioeconomic factors [1]. Airborne microbial load has been shown to strongly correlate with SSI incidence [2-4]. Increased airborne particle counts often translate into elevated microbial air burden and , therefore, can be used as a surrogate measure of surveillance of the operating room (OR) environment[5, 6].

In this study we evaluated the timing and characteristics of the airborne particles generated in a variety of surgical procedures. Viable particles were sampled using a real time Laser-Induced - Fluorescence (LIF).The efficacy of a novel HEPA/UV-C Air Recirculation/Filtration System (HUAIRS) on reducing airborne bacterial contamination in the orthopaedic OR was also examined .

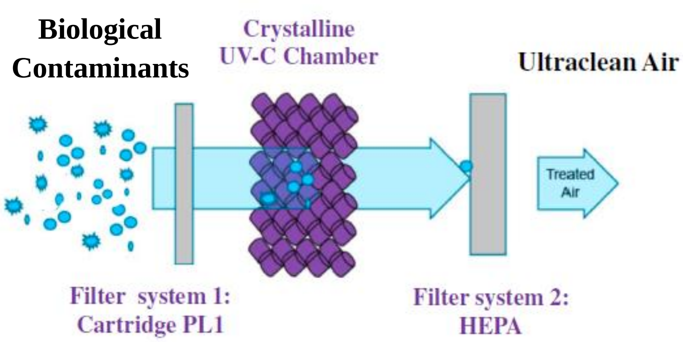
Background

Outdated engineered air quality controls, lack of regulatory standards, increased OR occupancy, personnel traffic and surgical equipment including bone saws and electrosurgical instruments collectively contribute to air pollution in active ORs by releasing a wide range of viable and non-viable particulates[5-9]. Environmental carriers of viable bacterial cells include dust, skin scales, fabric fibers and respiratory or mechanically-generated aerosols[10].

High quality OR air is crucial for 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[11, 12]. The implementation of preventative measures, such as installation of supplemental air decontamination devices during high risk surgical procedures could help reduce airborne particulates during surgery and mitigate SSI risks.

AEROBIOTIX (ABX) has developed a portable, in-room HEPA/UV-C air recirculation filtration device (HUAIRS) as an adjunct technology for utilization in high-risk surgical procedures, where OR air quality is an important SSI risk factor[2-4, 7]. The HUAIRS technology is specifically designed to decontaminate OR air from airborne biological and chemical hazards including bacteria, viruses, spores and volatile organic compounds respectively. The key innovation is a reactor system with UV-C light focused over the reaction chamber filled with clear cylindrical silicate crystals. The silicate crystals provide a solid UV-permeable media filter to increase the exposure of airborne microorganisms to the UV-C light (>0.25 sec). A unique

FIGURE 1



HUAIRS: Systems overview. Incoming contaminated air is filtered via cartridge Performance level 1 (PL1) designed to trap debris and particulates such as dust, textile fibers and skin scales. Smaller particles are directed towards the C-UVC (254nm) reactor located in the middle of the system along the path of the airflow. The silicate crystals within the reactor form a solid UV-permeable media prolonging C-UVC exposure of airborne pathogens for maximum killing of viable bacteria, viruses and spores. The C-UVC irradiated microorganisms and smaller particles are removed by clean air exhaust/HEPA filter assembly to generate ultraclean air.

feature of silicate crystal is that it can be efficiently penetrated by UV-C irradiation (C-UVC). Therefore, while organisms are slowed or trapped in the solid crystalline matrix, they are inactivated by the penetrating UV-C light. Built-in zirconium oxide-driven photocatalytic oxidation feature promotes elimination of volatile chemical by-products and noxious odors from electrocautery. In addition, the C-UVC component is further augmented by two filter systems to physically remove biological and chemical air particulates (**Figure 1**).

Methods

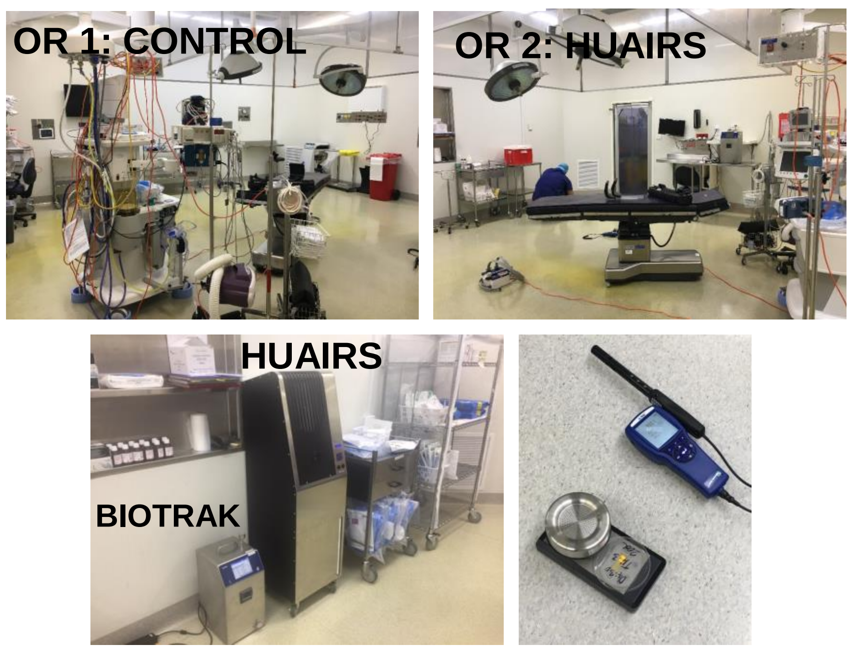
The study was performed in two phases. In **Phase 1** the levels of airborne particles were measured with the LIF airborne particle counter (BIOTRAK) during arthroplasty, sports medicine, plastic surgery and spinal cases of eight surgeons (**Figure 2**). Total and viable particles were measured in 2 minute intervals from before patient entry until after their relocation.

In **Phase 2**, two ORs with the same number and type of surgical procedures (total knee replacement or total hip replacement) were evaluated for air contamination (**Figure 3, Top**). During the study period, 26 agar plate cultures were collected to assess bacterial load with or without deployment of HUAIRS device. In addition, total and viable particles were samples in 2 minute intervals during a test day (**Figure 3, Bottom**).

FIGURE 2

LIF (BIOTRAK) was used in this study to monitor viable and non-viable particulate.

FIGURE 3

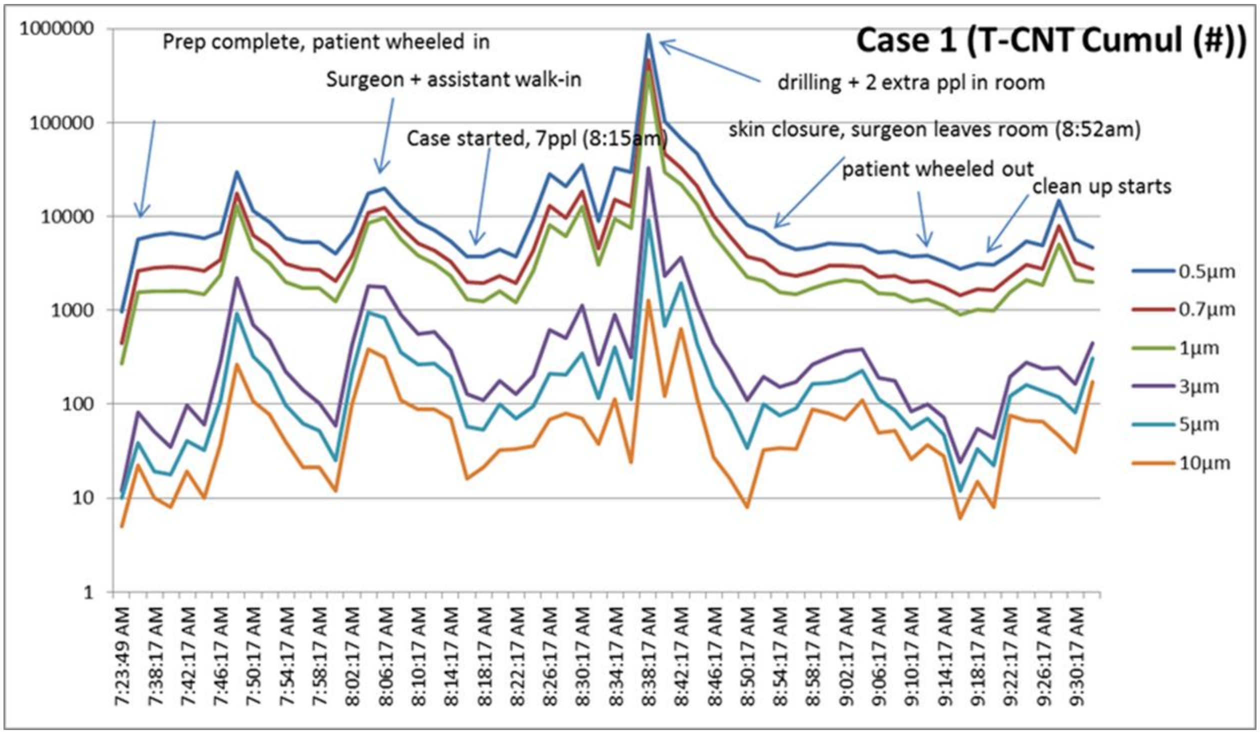


ORs evaluated in the study (Top). Viable and non-viable particles were measured using the LIF (BIOTRAK) with and without the HUAIRS system. Standard air sampling and agar plates were used for bacterial counts.

Results

A wide variety of airborne particles are produced during surgery. In general, the relative quantity, size and timing of particle emission peaks correlated well with traffic patterns and the type of surgical procedure performed such as diathermy, drilling/reaming/moving the patient etc. (**Figure 4**).

FIGURE 4

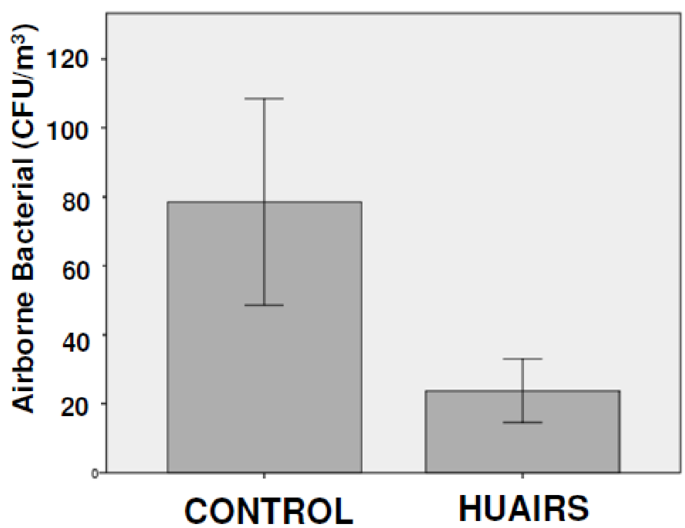


Typical results during a total knee arthroplasty revealed a range of particles generated during different activities.

Particles in the 0.3, 0.5, 0.7 and 1 micron (µm) size range were consistently generated throughout the surgical procedures, while larger particles were produced after a more aggressive surgical intervention (**Figure 4**).

FIGURE 5

The deployment of HUAIRS device in active OR decreased bacterial colony-forming units per cubic meter (CFU/m^3) by over 50% (**Figure 5**) to substantially improve OR air quality and potentially reduce the risk of SSI event. Overall, it appears that the type and composition of airborne particles generated during different types of surgeries are determined by the type of a surgical procedure performed as well as surrounding environmental factors including OR displacements, personnel traffic and general behaviors.



Discussion and Conclusion

According to published experimental findings, the probability of wound infection increases with the quantity of airborne pathogens present. Liberation of airborne particles during surgery is influenced by the procedure type and surgery-specific environment such as displacements in the OR, behavior and traffic patterns of OR personnel. Efforts to further understand how and when particles are generated, disseminated, settled and/or eliminated warrants further investigation.

In this study, total and viable particles and bacterial CFU/m^3 were reduced with the implementation of a new-to-market HUAIRS device. The addition of HUAIRS supplemental air decontamination system should be considered as part of a comprehensive environmental management plan in ORs performing high-risk, lengthy surgical procedures.

References

1. Brachman, P.S. *et al.* Nosocomial surgical infections: incidence and cost. *Surg Clin North Am* **60**, 15-25 (1980).
2. Lidwell, O.M. *et al.* Effect of ultraclean air in operating rooms on deep sepsis in the joint after total hip or knee replacement: a randomised study. *Br Med J (Clin Res Ed)* **285**, 10-14 (1982).
3. Lidwell, O.M. *et al.* Airborne contamination of wounds in joint replacement operations: the relationship to sepsis rates. *The Journal of hospital infection* **4**, 111-131 (1983).
4. Lidwell, O.M. *et al.* Bacteria isolated from deep joint sepsis after operation for total hip or knee replacement and the sources of the infections with Staphylococcus aureus. *The Journal of hospital infection* **4**, 19-29 (1983).
5. Birgand, G., Saliou, P. & Lucet, J.C. Influence of staff behavior on infectious risk in operating rooms: what is the evidence? *Infect Control Hosp Epidemiol* **36**, 93-106 (2015).
6. Birgand, G. *et al.* Air contamination for predicting wound contamination in clean surgery: A large multicenter study. *American journal of infection control* **43**, 516-521 (2015).
7. Noble, W.C., Lidwell, O.M. & Kingston, D. The Size Distribution of Airborne Particles Carrying Micro-Organisms. *J Hyg (Lond)* **61**, 385-391 (1963).
8. Lynch, R.J. *et al.* Measurement of foot traffic in the operating room: implications for infection control. *American journal of medical quality : the official journal of the American College of Medical Quality* **24**, 45-52 (2009).
9. Young, R.S. & O'Regan, D.J. Cardiac surgical theatre traffic: time for traffic calming measures? *Interact Cardiovasc Thorac Surg* **10**, 526-529 (2010).
10. Javad Parvizi MS, M., FRCS , Sue Barnes RN, CIC , Noam Shohat MD, Charles E. Edmiston Jr. MS, PhD Environment of care: Is it time to reassess microbial contamination of the operating room air as a risk factor for surgical site infection in total joint arthroplasty? *American journal of infection control* (2017).
11. Edmiston, C.E., Jr. *et al.* Microbiology of explanted suture segments from infected and noninfected surgical patients. *Journal of clinical microbiology* **51**, 417-421 (2013).
12. Parvizi, J., Barnes, S., Shohat, N. & Edmiston, C.E., Jr. Environment of care: Is it time to reassess microbial contamination of the operating room air as a risk factor for surgical site infection in total joint arthroplasty? *American journal of infection control* (2017).