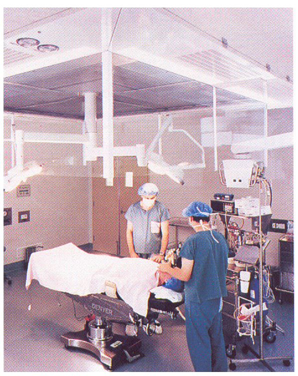
# Evidence Review

ALBERTA BONE & JOINT HEALTH INSTITUTE

**Topic**: Ultraclean ventilation and postoperative infection following THA or TKA

## Background

Surgical site infections (SSI) that develop following joint replacement surgery are responsible for approximately 7% of all revisions performed (Puolakka et al., 2001). The costs associated with healthcare resources and patient suffering with these revisions can be significantly reduced by using measures that reduce the risk of SSI development following hip and knee arthroplasty. Although the factors that cause SSI are multifactorial (e.g., type of operation, insertion of implant, antimicrobial prophylaxis use), the ventilation in the operating room (OR) is a significant factor that can be efficiently managed.



Air quality in the OR is linked to SSI rates. A rather small number of organisms are required to cause orthopaedic implant infection and failure. Lidwell et al (1982) estimated that as few as 10 colony forming units are enough to cause SSI in hip or knee arthroplasties. Where do most bacteria found in the wound come from? 98% is estimated to come directly or indirectly from the air, of which 30% are directly deposited from the air (Whyte et al., 1982). Furthermore, the number of airborne bacteria in the OR is almost exclusively dependent on the number and movements of the personnel within the room (Gosden et al., 1998). Ventilation systems within ORs that prevent the airborne bacteria released from OR staff to enter the surgical site may provide superior protection against SSI development compared to conventional ventilation ORs.

We have been asked to utilize evidence-based principles and techniques to investigate the ability of ultraclean air ventilation (UCV) ORs to reduce SSIs following hip or knee arthroplasty compared to conventional air ORs.

## Review Design

The aim of this review is to summarize the findings of Cochrane systematic reviews, other assessments, and RCTs.

## Search Strategy

A search of the Cochrane Database of Systematic Reviews found no relevant reviews on this subject.

> Search term used: (surgical or surgery or operation or site).mp AND (ventilation or air).mp AND (room or theatre).mp

Search of EMBASE, MEDLINE and CINAHL were performed next.

> Search term used: (laminar OR flow OR ventilation OR ultraclean OR ultra-clean) AND (arthroplasty OR hip OR knee OR orthopaedic OR orthopedic) AND (room OR theatre OR rooms OR theatres) AND English[la] AND (infection OR complication)

Articles selected:

- Chow and Yang. (2004). Ventilation performance in operating theatres against airborne infection: review of research activities and practical guidance. 56(2):85-92 REVIEW
- Gruenberg et al. (2004). Ultraclean air for prevention of postoperative infection after posterior spinal fusion with instrumentation: a comparison between surgeries performed with and without a vertical exponential filtered air-flow system. 29(20):2330-4 REVIEW
- Gosden et al. (1998). Importance of air quality and related factors in the prevention of infection in orthopaedic implant surgery. 39(3):173-80 REVIEW
- Chow and Yang. (2005). Ventilation performance in the operating theatre against airborne infection: numerical study on an ultra-clean system. 59(2):138-47
- Lidwell et al. (1982). Effect of ultraclean air in operating rooms on deep sepsis in the joint after total hip or knee replacement: a randomised study. 285 (6334):10-4

## Results

### History

The development of UCV operating theatres dates back to the 1940s when it was found that delivering filtered fresh air over the operating table in ORs with a positive-pressure ventilation system results in reduced bacterial content within the room (Chow and Yang, 2004). More importantly, it was realized that bacterial-free air in such a setup serves to 'wash out' the surgical area from airborne bacteria that could settle in the wound. The decade that followed saw the formal introduction of OR designs that incorporated clean-air measures.

The ventilation systems of clean-air ORs were continuously improved upon since the 1960s. In turbulent ventilation setups, air is delivered through grills that produce turbulent airflow patterns within the OR. Although bacteria liberated close to the surgical site are washed away by air, it was discovered that microbes from the floor and peripheral areas of the room could be swept back into the surgical zone (Chow and Yang, 2004). Displacement ventilation had several advantages over turbulent air designs, such as better air quality, no reintroduction of bacteria into the surgical zone, and lower OR temperatures could be maintained. However, the heat release from operating lamps and OR staff was found to reduce the effectiveness of displacement ventilation systems.

Modern ultraclean air ORs use laminar airflow (LAF) systems, which was originally developed for use in science-based industries to remove air particles (Chow and Yang, 2004). LAF setups convey unidirectional airflow that moves in a large uniform volume of parallel lines. This system uses a 3-stage filtration (including a HEPA filter) to send the fresh air through a large supply diffuser positioned on the ceiling or a wall of the OR, and the air flows over the surgical field only once. The air speed of this system (0.46 m/s) is able to wash out airborne particles and bacteria in the surgical field while also overcoming interference effects due to heat release by staff and equipment (Chow and Yang, 2004). LAF ventilation systems produce an OR air quality that is significantly better than conventional ventilation ORs (Gosden et al. 1998).

### UCV and post-arthroplasty SSI rates

In their review, Chow and Yang (2004) cite Dr. John Charnley of the UK as the first physician to report on the infection rates following total hip replacements in the 1960s. Charnley reported that over the course of 5,800 hip replacements the switch to UCV rooms from conventional ORs lowered the rate of postoperative infection from 7% to 0.5%. According to Charnley, UCV was the most important technique introduced against postoperative infection (Gruenberg et al., 2004).

Chow and Yang also cite the findings of Salvati et al who, in the 1970s, examined the infection rate outcomes of 3,175 total hip and total knee replacements that were performed in conventional air and in horizontal LAF ORs. Salvati et al reported that LAF rooms, when compared to conventional rooms, decreased the postoperative infection rate after total hip arthroplasty (1.4% versus 0.9%), but a significant increase after total knee replacement (1.4% versus 3.9%). In LAF rooms, the rate of infection after knee replacement (3.9%) was significantly higher than those after hip replacement (0.9%). The unexpectedly high rate of infection following knee replacements was determined to be due to the positioning and movement of the OR personnel during this procedure. Specifically, in a horizontal LAF setup, the movement of staff and objects across the airflow direction increases the number of airborne particles in the surgical zone. Consequently, the most efficient LAF configurations in ORs are considered to be vertical and downward (Chow and Yang, 2004).

In a randomized study of over 8,000 total hip or knee replacement patients, Lidwell et al (1982) viewed the records of patients that were randomly assigned to have their surgery in conventional ORs (control group) and in UCV rooms. The authors reported that deep sepsis was significantly higher in the control group (1.5%) compared to the rate observed in the UCV group (0.6%).

The reduction in SSI rates with the use of UCV technology is also observed in other orthopaedic surgeries. For example, Gruenberg et al (2004) compared the deep and superficial SSI rates of 179 patients who had spinal fusion surgery performed in either a conventional ventilated room versus an LAF OR. In this study, the authors found that no infections occurred in the UCV room, compared to a 12.9% infection rate in patients that had spinal surgery in conventional ORs.

### UCV setups

The design of UCV systems is complex, and computational fluid dynamics simulations are often used to factor in room dimensions and details prior to LAF system selection and installation. Numerous factors and requirements must be taken into account in room setup, and different countries have adopted different engineering standards for the design of ORs. For example, specifications outline the air supply speed, the area in the protected surgical zone, the use of partial walls, positioning of operating lamps, and OR staff activities during surgery (Figure 1, from Chow and Yang, 2004). Overview of technical issues in UCV OR setup can be found in Chow and Yang 2004; Chow and Yang, 2005.

There are potential drawbacks to the use of UCV technology. Lighting may be limited and troublesome, the LAF system tends to be noisy, and operating costs are higher than conventional ORs (Gruenberg et al, 2004). Use of body exhaust systems in such rooms could make communication difficult among OR staff. However, reduction of postoperative SSI rates and revisions should outweigh these difficulties.

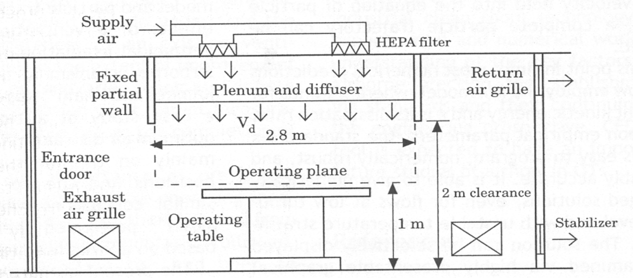



**Figure 1** Typical ultra-clean ventilation arrangement in an operating theatre.

## Summary

- UCV operating theatres reduce postoperative SSI rates follow total hip or total knee arthroplasties
- Designing UCV systems is complex

## Conflict of interest

Non known.

## Reference List

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## Enquiries and Contact Information:

Kursat Barin, Information Analyst
Email: akbarin@albertaboneandjoint.com

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