SHORTWAVE ULTRAVIOLET RADIATION IN OPERATING ROOMS

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We have evaluated the effect of shortwave ultraviolet radiation on bacterial levels in an operating theatre, both in experimental conditions and during 20 hip operations. When compared with the use of sham blue light, there was a significant reduction in the number of bacteria. The reduced level was comparable with that suggested for ultraclean air ventilation systems.

Many efforts have been made to reduce postoperative deep wound infection, especially in orthopaedic surgery. Peroperative shortwave ultraviolet radiation of 254 nm (UVC) was used in the 1930s by Hart and Sharp at Duke University, North Carolina, and this was the only efficient method among several attempts to reduce infection in thoracic surgery (Goldner and Allen 1973). Since then many authors have reported reduced frequency of infection after using UVC in operating rooms (Lowell and Kundsin 1977).

The correlation between the frequency of deep wound infection and the level of airborne bacteria in the operating room air was shown by Lidwell et al. (1982), but as far as we know, no comparison between the use of ultraclean air enclosure systems and UVC has been made. We here report the initial phase of a controlled comparative study of these two methods.

MATERIAL AND METHODS

An operating room with a basic ventilation of 30 changes of air per hour was equipped with eight UVC tubes (Philips TUW 40, Holland) in the ceiling (Fig. 1). Sham blue light bulbs were also installed in each fitting. The UVC and the sham lights could be controlled independently of each other. The humidity was under 60%, and room temperature was about 20°C.

The intensity of the UVC was recorded by a digital portable UVX radiometer (UVP Inc, San Gabriel, California, USA) with the sensor UVX-25 calibrated for 245 nm. To register any production of ozone, we used a portable direct reading chemiluminescence detector calibrated for ozone levels of 1 ppb. During tests oxygen was released from an anaesthetic apparatus at a maximum flow of 6 l/min.

**Clothing.** During an actual operation, all staff members wore short-sleeved cotton blouses and trousers, disposable hoods, multi-layer face masks and clean

![Fig. 1](https://example.com/fig1.png)

Diagrams of the siting of the UVC lights (shaded), and of UVC intensity one metre above floor level. At the top of the operating table in the centre, UVC intensity was 120 microWatt/cm² which was taken as 100%.
shoes. The scrubbed operating team wore standard disposable sterile gowns with plastic reinforced sleeves and front, and sterile surgical gloves.

Because the skin and the eyes are sensitive to UVC, all staff in the theatre also wore plastic eye glasses and one extra disposable hood. Non-scrubbed staff used disposable plastic gloves and wore an additional long-sleeved cotton cardigan. The patient was protected by normal draping and in addition the operative field was covered by an adhesive plastic sheet (Steridrape, 3M), and the head by a ‘tent’ of cotton sheets. The transmission of UVC through each clothing material used was measured by placing a sample over the UVC radiation detector, at a distance of one metre from a UVC tube.

**Bacterial sampling.** The sampling of airborne bacteria was performed using a sterile tube attached to the edge of the wound leading to an Andersen sampler, and by a Casella slit-sampler placed in the periphery of the room. Agar plates were incubated aerobically at 35°C for 48 hours before reading.

**First experiment.** Five male orthopaedic surgeons dressed as for operating and wearing protective eye glasses performed a standard 15-minute gymnastic programme in the operating theatre three times in succession while bacteriological measurements were performed by slit-sampler only. This procedure was repeated at an interval of one week with either UVC or sham light, the type of light being unknown to the participants.

**Second experiment.** Twenty operations for per trochanteric hip fractures using a Richards sliding screw and a 4-hole plate were randomised for performance in either UVC or sham light. The operation time and the number of persons present were recorded. The number of airborne bacteria at the site of the wound was recorded continuously, the peripheral level was monitored at the time of the skin incision, and during the drilling for the Richards screw, by the methods listed above.

**Statistics.** The statistical methods used for the two experiments were the Wilcoxon and the Mann-Whitney tests.

### RESULTS

**First experiment.** During the gymnastic programme, while the blue sham light was being used the number of airborne bacteria was very high, averaging 782 CFU/m³. By comparison, the average level under UVC was 16 CFU/m³. In Fig. 2, the results are compared with 10 CFU/m³ the level proposed as acceptable for ultraclean air by Lidwell et al. (1982).

**Second experiment.** Each of the three different measurements showed a significant reduction (p<0.01) in the number of airborne bacteria while using UVC (Fig. 3). The average count was reduced from 24 to 14 CFU/m³ at the site of the wound, and from 44 to 14 and 28 to 9

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**Fig. 2**

Result of the first experiment. For comparison, the result for ultraclean-air ventilation (Lidwell et al. 1982) is also given.

**Fig. 3**

Results during the operations in the second experiment. Key: 1, continuous sampling at wound site; 2, slit-sampling at time of skin incision; 3, slit-sampling at time of bone drilling (p<0.01 for 1, 2 and 3).
CFU/m$^3$ for the two peripheral measurements (Fig. 3). The number of people in the operating theatre and the duration of the operation did not differ in the UVC and sham light groups.

**UVC intensity.** The UVC intensity was somewhat uneven (see Fig. 1) but was about 120 microwatt/cm$^2$ at the wound site, one metre above the floor. The lowest intensity postulated to have a bactericidal effect is 25 microwatt/cm$^2$ (Goldner and Allen 1973). The transmission of UVC through the different materials varied from 6 to 8% for the disposable cap and 4% for the Steridrape to less than 1% for the gowns and drapes and under 0.1% for the plastic goggles, face mask and surgical gloves.

**Ozone formation.** The ozone level in the operating theatre was shown to be no different from that outdoors in the same region of the country, and was not increased by flooding the room with oxygen.

**DISCUSSION**

The number of airborne bacteria in the operating environment has been directly correlated with the frequency of deep infection in joint replacement surgery and it has been shown that an ultraclean-air ventilation system can reduce the bacterial number to a recommended level of 0 to 10 CFU/m$^3$ (Lidwell et al. 1982). The UVC system which we tested can reduce the bacterial count to about 15 CFU/m$^3$; this should be compared with a count of about 100 CFU/m$^2$ in an operating theatre with ordinary conventional ventilation.

The cost of ultraclean-air ventilation equipment in 1986 was about $US100,000, which can be compared with about $US2,000 for the UVC lights. The energy consumption of the UVC equipment is also low compared with that of the ventilation units. Persson et al. (1988) have shown, by a cost-benefit analysis, that a full ultraclean-air ventilation system is cost-effective only for clinics which carry out more than 200 joint replacement operations each year. The more general use of a UVC system would be cost-effective where expensive ventilation systems cannot be afforded and would be of value for other specialties such as thoracic and vascular surgery.

The need for savings in the cost of health services makes it necessary to economise without reducing the quality of prophylaxis against infection. The UVC radiation in the system we used does not reduce the number of bacteria quite as much as the best ultraclean-air systems, but we are continuing an analysis of the effect of UVC in combination with different types of special clothing (Bergman, Hoborn and Nachemson 1985).

All the bacteria samplings and readings were performed by Birgitta Komsell, Laboratory Technician, Mölnlycke Health Care AB, Mölnlycke. The UVC transmission measurements were performed by Åke Cederblad, Physicist, Radiation Physics Department, Sahlgren Hospital, Gothenburg. Ozone measurements were made by Gerd Sällsten MSc and Rolf Nordlinder MSc, Department of Occupational Medicine, Sahlgren Hospital, Gothenburg.

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**REFERENCES**


