

Occlusive clothing and ultraviolet radiation in hip surgery

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In a randomized study of 20 total hip arthroplasties, the staff wore shirts and trousers of a fabric impervious to bacteria underneath operating gowns of a non-woven material. Volumetric air sampling demonstrated a low number of colony-forming units with this clothing, further reduced by ultraviolet radiation to below 10 colony-forming units/m³, the upper limit of "ultraclean air," in all the cases (median 2.6, range 1.1-7.1).

The efficacy of ultraclean air enclosures, with or without exhaust gowns, as a prophylaxis against infections in total joint surgery can no longer be questioned (Lidwell et al. 1987). Two alternative methods to reduce the number of airborne bacteria carried by particles in the operating room are ultraviolet radiation (Moggio et al. 1979) and occlusive staff clothing (Whyte et al. 1983a). We have found a fivefold reduction of colony-forming units by using ultraviolet radiation (Carlsson et al. 1986). However, the air contamination could not regularly be reduced to below 10 colony-forming units/m³, the suggested upper limit for air contamination in operating rooms during arthroplasty (Whyte et al. 1983b).

We report the combined effect of occlusive staff clothing and ultraviolet radiation on the levels of air contamination in the operating room during total hip surgery. Changes in the rate of infection were not assessable with the number of patients studied.

Materials and methods

The investigation was designed as an open randomized study of 20 total hip procedures. Occlusive staff clothing was used in all the operations and ultraviolet radiation in half of them. Random allocation to

either group was undertaken on the day of the operation.

All the operations were performed according to a modification of Charnley's original technique with the patients in a supine position. The scrubbed staff consisted of 2 surgeons and 1 nurse, and there were 3 nonscrubbed members of the team present in the operating room: 1 attendant, 1 anesthesiologist, and 1 technician.

Ultraviolet radiation and occlusive clothing

The operations were performed in an operating room equipped with an Allander zonal ventilation system having an air-exchange rate of 70/h in the zonal area (Abel and Allander 1966). In 10 operations, eight ultraviolet lamps (Philips TUV 40W, wavelength 253.7 nm), mounted in the ceiling, were turned on when the initial skin incision was made and turned off when wound closure was complete. The irradiance from the lamps was 25-30 $\mu\text{W}/\text{cm}^2$ at the level of the operating table. A detailed description of the arrangements has been published by Carlsson et al. (1986). The total cost of the installation was SEK 25,000 in 1984.

All 6 members of the operating room staff wore clean room garments consisting of a two-piece suit with long sleeves containing a layer of expanded polytetrafluoroethylene, a material with pores about 0.2 μm (Gore-tex[®], W.L. Gore & Associates Inc., Elkton, MD, USA). The material is impervious to bacteria, but permits transmission of water vapor. The garments had elastic closures, with the same

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Table 1. Results of air sampling close to the wound and in the periphery of the operating room in 20 total hip procedures (colony-forming units/m³). All the staff wore occlusive clothing and UV radiation was used in half the cases

| | UV | Median | Range | P-value ^a |
|--------------------|----|--------|---------|----------------------|
| Close to the wound | - | 9.8 | 5.5-23 | < 0.01 |
| | + | 2.6 | 1.1-7.1 | |
| In the periphery | - | 8.6 | 4.6-22 | < 0.01 |
| | + | 1.6 | 0.7-3.1 | |

^a Mann-Whitney rank sum test

material at all the openings. On top of the occlusive garments, the scrubbed members of the team used disposable operating gowns of nonwoven material (Mölnlycke AB, Sweden), and wore double latex gloves. Double hoods of the same nonwoven material were used. Safety goggles (Visorgoggles, American Ultraviolet Company) and a sun-protection cream (Eversun ultraviolet blocker) protected the eyes and uncovered skin against the ultraviolet radiation.

Air sampling

Air sampling was conducted with a Sartorius filter sampler, MD 8, with a capacity of 133 L/min, connected to a filter holder within 20 cm of the wound. A 120-mm-long brass tube protected the filters from the ultraviolet radiation. Samples were taken from 30-min periods throughout the operations. The gelatine filters (SM 12602) were put on blood-agar plates after sampling. In the periphery of the operating room, air samples were collected for 1 min every 15 min with a Casella slit sampler MK II, having a capacity of 700 L/min.

Bacteriologic technique

The blood-agar plates were incubated aerobically at 37 °C for 48 h, and the total number of colonies were counted. All the bacteria isolated were identified according to current techniques (Cowan 1974). Among the isolated bacteria, we found coagulase-negative staphylococci, diphtheroids, and *Bacillus* and *Micrococcus* species. No *Staphylococcus aureus* or gram-negative rods were identified. No attempts were made to culture anaerobic bacteria.

Results

There was a substantial reduction of the air contamination when ultraviolet radiation was added to the occlusive clothing, with all the values of air contamination below 10 colony-forming units/m³ (Table 1). No side effects of the ultraviolet radiation on staff or patients were noted.

Discussion

The importance of a low air contamination in the operating room to reduce deep periprosthetic infections in total hip and knee surgery has been demonstrated by Lidwell et al. (1982, 1987). Based on these results, Whyte et al. (1983b) suggested that the average number of airborne bacteria carrying particles at the site of the wound should not exceed 10/m³; a further reduction to 1 colony-forming unit/m³ was considered beneficial.

Ultraviolet radiation has been used in orthopedic surgery at the Duke University Hospital since 1937 with good results (Goldner and Allen 1973). Moggio et al. (1979) reported a reduction of air contamination to about 40 percent when ultraviolet radiation was used in an ordinary operating room. In our oper-

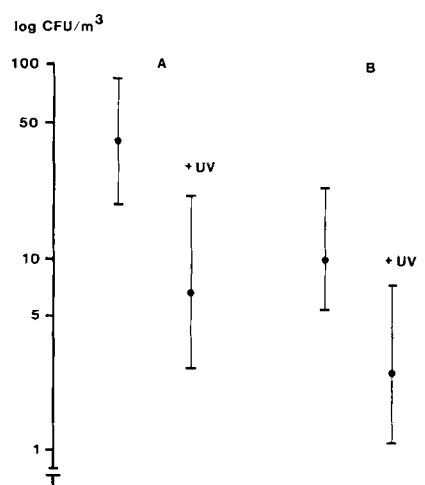


Figure 1. The median and range of air-contaminating colony-forming units (CFU/m³) close to the wound during two randomized series of 20 total hip arthroplasties each. All the staff wore disposable nonwoven operating gowns and underneath them a shirt and trousers made of either cotton (A; Carlsson et al. 1986) or an occlusive material (B; this investigation). In half of the operations, ultraviolet radiation was used (+UV).

ating rooms, ultraviolet radiation combined with cotton working clothes underneath nonwoven gowns with the Allander zonal ventilation reduced the median air contamination close to the wound from 41 to seven colony-forming units/m³ (Carlsson et al. 1986). However, in 7/15 operations the average level exceeded 10 colony-forming units/m³ (Figure 1). Use of ultraviolet radiation or occlusive clothing reduced the air contamination to about the same level. A further reduction occurred when occlusive clothing was used together with ultraviolet radiation.

In this study, we have used clothes of a material and design that contains most of the bacteria-carrying particles shed by the person inside the garment. In an experimental situation, a much lower bacterial dispersion rate with such clothing as compared with cotton has been found by Whyte and Bailey (1985).

The increased air-exchange rate centrally—i.e., within the zonal ventilation area—when compared with the periphery of the operating room decreases the time bacteria in the air are exposed to the ultraviolet radiation. This may explain why the bacterial counts were lower at the periphery than close to the wound when ultraviolet radiation was used (however, when the ultraviolet radiation was off, the bacterial counts were the same). The bactericidal effect of ultraviolet radiation is dependent on a controlled air humidity, which should not exceed 60 percent. This has not been a problem in our hospital with its air-conditioned ventilation. However, it must be considered if ultraviolet radiation is to be used.

A very effective way to reduce air contamination in the operating room is to use total body exhaust suits in an ultraclean air enclosure. With this equipment, about one colony-forming unit/m³ is measured during total hip procedures (Whyte et al. 1983a). However, exhaust suits with helmets are inconvenient due to the high noise level and restricted mobility. In 1985, exhaust suits were worn in Sweden dur-

ing THA procedures in only 12 of 23 orthopedic units with ultraclean air enclosures, the remaining using disposable, nonwoven gowns (Ahnfeldt 1986). An alternative to exhaust suits in the ultraclean air environment was proposed by Whyte et al. (1983a), who used disposable clothing made of a nonwoven material (Fabric 450, Johnson & Johnson, UK), which substantially reduced the discharge of particles. They found a median air contamination rate of 0.7 colony-forming units/m³, and that the disposable clothing was much more convenient and comfortable than exhaust suits with hoods. We found the occlusive clothing only slightly warmer than cotton working clothes.

The installation and maintenance of ultraclean-air enclosures are fairly expensive, and it has been calculated that about 200 joint replacements a year are needed to make the investment profitable (Persson et al. 1988). Building constructional considerations sometimes make it impossible to install downflow ultraclean-air enclosures in an existing operating room. Enclosures with horizontal, laminar flow may even do more harm than good. Salvati et al. (1982) found an infection rate in knee arthroplasties of 3.9 percent compared with 1.9 percent when the operations were performed in a conventional operating room. Therefore, alternative methods to reduce air contamination become interesting (Hambraeus 1988).

This study is the first one to report on the results of combining ultraviolet radiation and occlusive staff clothing. No side effects of the ultraviolet radiation were found, but the psychologic acceptance of the ultraviolet environment by our staff was low. Even if the reduction of the air contamination was not quite as good as reported for ultraclean-air enclosures, we consider the combination of ultraviolet radiation and occlusive clothing an acceptable alternative when ultraclean-air enclosures cannot be used.

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