REDUCTION OF CONTAMINATION AT TOTAL HIP REPLACEMENT BY SPECIAL WORKING CLOTHES

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We assessed wound, air and operative field contamination at 50 total hip operations, performed in a zonal ventilation system. Theatre staff wore either a specially designed polypropylene non-woven coverall or conventional cotton shirt and trousers. The surgeons wore partially impermeable operating gowns.

The polypropylene coverall was associated with significantly lower air and wound counts. The coverall was warmer than cotton but judged to be acceptable. The combined use of zonal ventilation and the coverall achieved ultra-clean air conditions.

The operating team is the most important source of the micro-organisms which may cause deep infection after total hip replacement. Micro-organisms on skin scales are transferred in the air. The use of an ultra-clean air environment with less than 10 colony forming units per cubic metre (CFU/m³) together with prophylactic antibiotics can practically prevent such infections (Lidwell et al 1987).

An ultra-clean air environment can be provided by the combined use of an enclosure with a large vertical flow of air passing through HEPA-filters and the use of body-exhaust suits of tightly woven cotton material (Lidwell et al 1987). In a laminar-flow operating enclosure clothing made from a hydrophobic, spunlaced, 70 g/m² polyester-pulp non-woven material is as effective as a total-body exhaust gown and is more comfortable and convenient (Whyte et al 1983b).

In a zonal ventilation system (Allander and Abel 1968), a total-body exhaust suit is more effective than a conventional cotton operating gown in reducing bacterial air contamination, but not more effective in reducing contamination of the operative field (Blomgren, Hambræus and Malmberg 1983). A non-woven polypropylene coverall provides a better barrier to air contamination

than conventional working clothes in the laboratory as well as in the operating theatre (Hoborn 1981; Bergman, Hoborn and Nachemson 1985), and can reduce levels of air contamination to those reached in an operating enclosure with conventional working clothes under a laminate gown.

We studied contamination of the air, the operative field and the wound in total hip replacement operations performed in a theatre with zonal ventilation, using either a polypropylene coverall or conventional cotton working clothes. We also recorded the relative comfort of the clothing systems.

MATERIAL AND METHODS

The operations were performed in theatres with zonal ventilation providing about 80 changes of air per hour above the operating table and including an air curtain (Allander and Abel 1968). A total of 50 primary total hip replacements were studied, all using the Howmedica HD2 implant (Howmedica, Rutherford, New Jersey, USA), bone cement without antibiotics (CMW Laboratories, Exeter, England) and cloxacillin prophylaxis. We recorded the underlying disease, the age and sex of the patient, the duration of the operation, the number of staff in the theatre and the number of door openings during the operation.

At all the operations, single-use laminate drapes with self-adhesive edges (Mölnlycke Health Care AB, Mölnlycke, Sweden) were used. The operative area was covered with an incision drape (Steridrape, 3M, St Paul, Minnesota, USA). The procedures were randomly allocated to one of two groups as regards staff clothing.

In one group, all staff in the theatre wore conventional cotton working clothes. In the other, all wore a prototype non-woven polypropylene coverall (Mölnlycke

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Health Care AB, Mölnlycke, Sweden). In both groups, non-woven gowns (Mölnlycke) were used by the sterile team. The lower sleeves and the front of these gowns contain a layer of impermeable polyethylene film. The surgeons always wore double gloves.

Air was sampled at three sites using three different samplers:

1) In the periphery of the theatre outside the zonal ventilation area (ZVA), a Biap slit sampler (MBT AB, Malmö, Sweden) with a capacity of 33 l/min was run during the entire operation.

2) Within the ZVA, a Casella slit sampler MK2 (Casella Co Ltd, London, England) with a capacity of 700 l/min was run for 5-minute periods, four to six times, evenly distributed throughout the operation. Both samplers used air from 1 m above the floor and blood agar plates.

3) A Sartorius filter sampler MD 2 (Sartorius Membranfilter GmbH, Göttingen, West Germany), capacity 30 l/min, with gelatine filters, type SM 12652, pore size 3 µm was placed 30 cm from the wound. It was run for 10-minute periods, four to five times evenly distributed, during the operation. The filters were placed on blood agar plates.

The exposed surface of the Steridrape was sampled at the end of each operation by means of a plastic applicator with a moist sampling pad of polyvinyl alcohol (PVA) foam (Mölnlycke Health Care AB, Mölnlycke, Sweden). The pad was placed inside a sterile cardboard frame with a 5 × 10 cm aperture and rubbed over the surface with five double strokes (Hambraeus, Hoborn and Whyte 1990).

Wounds were sampled at the end of the operation, before the final rinse and closure. Five sterile 4 × 7.5 cm PVA pads were allowed to absorb wound fluid to their full capacity.

All air sampler plates were incubated aerobically at 37°C for 48 hours and the total number of colonies counted. All PVA pads were stomached in a Stomacher 400 (Seward Laboratories, London, UK) and cultured by the method reported by Hoborn and Nyström (1985) after the addition of 2000 IU/ml of penicillinase (BBL, Div. Becton, Dickinson and Co, Cockeysville, Maryland, USA) to the homogenisation fluid.

Where observations could be shown to have a log-normal distribution (all air samples), we used a single-sided *t*-test. The results from the wound samples were not in a log-normal distribution and were therefore compared in pairs using a nonparametric sign test (Bickel and Doksum 1977). Arithmetical standard deviations (SD) have been given, since the results showed that the logarithmic SD did not as truly describe the distribution of the data.

Staff members reported their level of comfort when working in the coverall and an assessment of heat insulation was made according to BS 4745:1971, of water vapour permeability according to the Hohenstein skin model, and of air permeability according to SS 65 00 16. Whole-body thermal manikin assessments of the insulation properties were performed according to SS 88 23 04 (Hänel and Holmer 1986).

RESULTS

No significant differences were observed between the two groups regarding age and sex of patients, mean operating time, number of staff present or number of door openings in the operating theatre during operation. In the polypropylene coverall group, there were 23 cases of osteoarthritis (OA) and two of rheumatoid arthritis (RA). In the cotton working clothes group, there were 23 cases of OA, one of RA and one of osteonecrosis of the femoral head.

The results of the bacterial counts are presented in Table I. All the mean counts from samples taken when the polypropylene coverall was worn were lower than with cotton working clothes. For the air counts, the differences between the two groups were statistically significant (inside ZVA near wound, $p < 0.03$; inside ZVA periphery, $p < 0.001$; outside ZVA $p < 0.02$). In pair-wise comparisons of bacterial counts in the wounds the difference between the groups was significant at $p < 0.001$. The bacterial counts on the Steridrape were low and the difference between the two groups was not statistically significant.

The coveralls were felt to be warmer when worn under an operating gown. All the staff emphasised the

Table I. Bacterial counts in air, operative field and wound. Geometric mean (arithmetical standard deviation)

Clothing system	Site		Steridrape (CFU/50 cm ²)	Wound CFU
	Outside ZVA* (CFU/m ³)	Inside ZVA* Periphery (CFU/m ³) Near wound (CFU/m ³)		
Cotton	17 (47.3)	13 (8.4) 4 (5.3)	0 to 6	24/40.6
Polypropylene	6 (5.6)	6 (6.6) 2 (4.7)	0 to 4	20/37.6
Significance of difference (p value)	0.02	0.001 0.03	NS	0.001

* zonal ventilation area † colony-forming units

Table II. Comfort factors (means of five measurements)

Clothing system	Heat insulation manikin (tog)* (clo)†		Water vapour penetration (g/m ² /h)	Air permeability (l/min)
Cotton	0.17	0.27	1185	18
Polypropylene	0.39	0.25	1111	95

* 1 tog = 0.1 m² K/W, BS 4745: 1971

† 1 clo = 0.155 m²/°C/W, an empirical unit corresponding to the thermal insulation of an American business suit from the 1940s

importance of the design of the garment. The results from in vitro assessments of the various factors having an influence on comfort are found in Table II.

DISCUSSION

Lidwell et al (1983) have demonstrated a correlation at joint replacement operations between air and wound contamination, and the sepsis rate. Whyte, Hodgson and Tinkler (1982) have shown that most of the airborne bacteria contaminating a wound are transferred there secondarily, having first settled on to a nearby surface. Lidwell et al (1987) have shown that air contamination may be minimised by the combined use of a clean air ventilation system and body exhaust suits, and Whyte et al (1983a) suggested that 10 CFU/m³ is the highest acceptable air count in ultra-clean operating rooms. Blomgren et al (1983) recorded bacterial counts lower than this in an operating room with a zonal ventilation system (Allander and Abel 1968) when body exhaust suits were worn. Bergman et al (1985) obtained similarly low contamination rates in a conventionally ventilated theatre where all staff wore a polypropylene non-woven coverall and the operating team used partially laminated theatre gowns.

Whyte et al (1983a) stressed the importance of measuring air contamination less than 30 cm away from the wound. We selected our wound air sampling point accordingly. Our results show an improvement comparable to that achieved by Blomgren et al (1983) with body exhaust suits, though the level of our counts were about half of theirs. This difference may be explained by their use of textile operating gowns and cotton drapes.

Our study has shown that the combined use of a

zonal ventilation system and polypropylene coveralls can provide ultra-clean air to the standards suggested by Whyte et al (1983a). These methods, used in a sterile enclosure, should further reduce the air and wound contamination levels and provide more comfort for the operating team than body exhaust suits.

Some of the theatre staff found the coverall uncomfortably warm. This is caused partly by the higher insulation capacity of the polypropylene as against cotton and partly by the fact that polypropylene fibre is hydrophobic. This minor discomfort could probably be reduced by a better design for the definitive version of the coverall. However, the theatre staff were willing to accept the current design if it could be proved that it improved air cleanliness.

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