

The effect of surgical gowns made with barrier cloth on bacterial dispersal

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(Received 25 February 1985; accepted 12 March 1985)

SUMMARY

A dispersal chamber (body box) technique has been used to compare bacterial dispersal from the skin of subjects carrying out a stepping test under controlled conditions while wearing four differing garment systems namely:

(a) basic underwear, cotton 'blues' (standard pyjama style jacket and trousers for men or dress for women), ankle socks, boots for men and shoes for women, mask and theatre hat; (b) the basic set covered with a cotton gown; (c) the basic set covered by a gown with a front made from GORE-TEX fabric in which an expanded polytetrafluoroethylene membrane is sandwiched between layers of woven or knitted polyester; (d) the basic set covered with a fully enclosed suit of the same fabric.

A slit sampler was used to measure the number of bacteria liberated in a downward current of air. Six subjects (three female and three male) were studied. Males liberated more bacteria. Covering the 'blues' with a cotton gown increased the bacterial count; a gown of the new material reduced the increase by 50%, and the suit cut the dispersal to virtually zero.

Preliminary work suggests that GORE-TEX garments survive laundering better than cotton, and may be cost-effective, but are not yet as comfortable. Research is presently in progress to improve this aspect.

INTRODUCTION

The effect of different types of operating room clothing on dispersal of bacteria has recently been studied. Whyte, Vesley & Hodgson (1976) compared conventional gowns with those of a total body exhaust system and disposable ones made of non-woven fabric. They used a dispersal chamber to determine bacterial dispersal from subjects dressed in each system in turn and found this was significantly reduced by the Charnley gown.

Moylan (1982) reviewed previous work and suggested that disposable gowns are superior to reusable ones in terms of wound infection rates; and that direct 'strike through' the gown by bacteria is the major cause of the difference. Laufman

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(1982) pointed out that permeability is crucial in resisting 'strike through', and suggested that all untreated cotton garments should carry a warning about their lack of resistance to bacterial transfer, particularly when wet. He also stressed the importance of recording the number of times Quarpel-treated material was used as this finish becomes ineffective after 75 use/laundry cycles.

Bernard (1982) summarized the desirable characteristics of gown and drape materials: permeability, cost, user appeal and hazard level (flammability, electrostatic properties, linting or production of toxic degradation products). He considered that a 'Ventile' (Quarpel-finished pima cotton, woven with a high thread count) garment was equal or better than muslin throughout its life, which was 33 uses (compared to 13 for muslin).

Whyte *et al.* (1983) compared a total-body exhaust system with gowns made of non-woven fabric (Johnson & Johnson type 450). The latter were more comfortable, but just as good as a barrier to bacteria. They also demonstrated the need for the complete 'body exhaust system', because the gown component alone was ineffective.

Thus several considerations must be taken into account in choosing operating room clothing. Garments should resist transfer of bacteria, be comfortable, cheap, durable and not produce toxic degradation products. Most current garments are inadequate in these respects so there is a need for improvement. As an initial project we decided to investigate some of the properties of a new laminated expanded polytetrafluoroethylene fabric (GORE-TEX) in gown construction.

MATERIALS AND METHODS

Clothing

GORE-TEX is a three-layer laminate with a membrane of expanded polytetrafluoroethylene (PTFE) sandwiched between two warp-knitted layers made from continuous filament polyester yarn. The material has an effective pore size of 0.2 μm , which enables the passage of air and water vapour, but resists the transmission of liquids and bacteria. A scanning electron micrograph of the material is shown in Fig. 1.

The bacteria-retaining properties were measured by stretching a 5 cm diameter disc of fabric across the jaws of an airtight holder which was sealed into an airway. From one end of the airway a challenge of 10^4 spores of *Bacillus subtilis var. globigii* (NCTC 10073), in an aerosol of approximately 1 μm diameter particles, was sprayed at the fabric and 60 dm³ of air were sampled using a Casella slit sampler attached to the distal end.

The clothes selected were standardized. For all experiments underwear and basic 'blues' (a pyjama style suit consisting of a jacket pulled on over the head and trousers with a draw string fastening for men, or a tunic-style dress for women) were worn. Each subject wore the same clothes beneath any experimental garments. In addition subjects wore a standard theatre cap and mask, socks and rubber theatre boots for men and overshoes for women.

Experimental garments used in the trial were of three types; a cotton gown made from 40 \times 40 count muslin (as reference), a GORE-TEX gown of a normal operating theatre design and a one-piece experimental GORE-TEX suit which

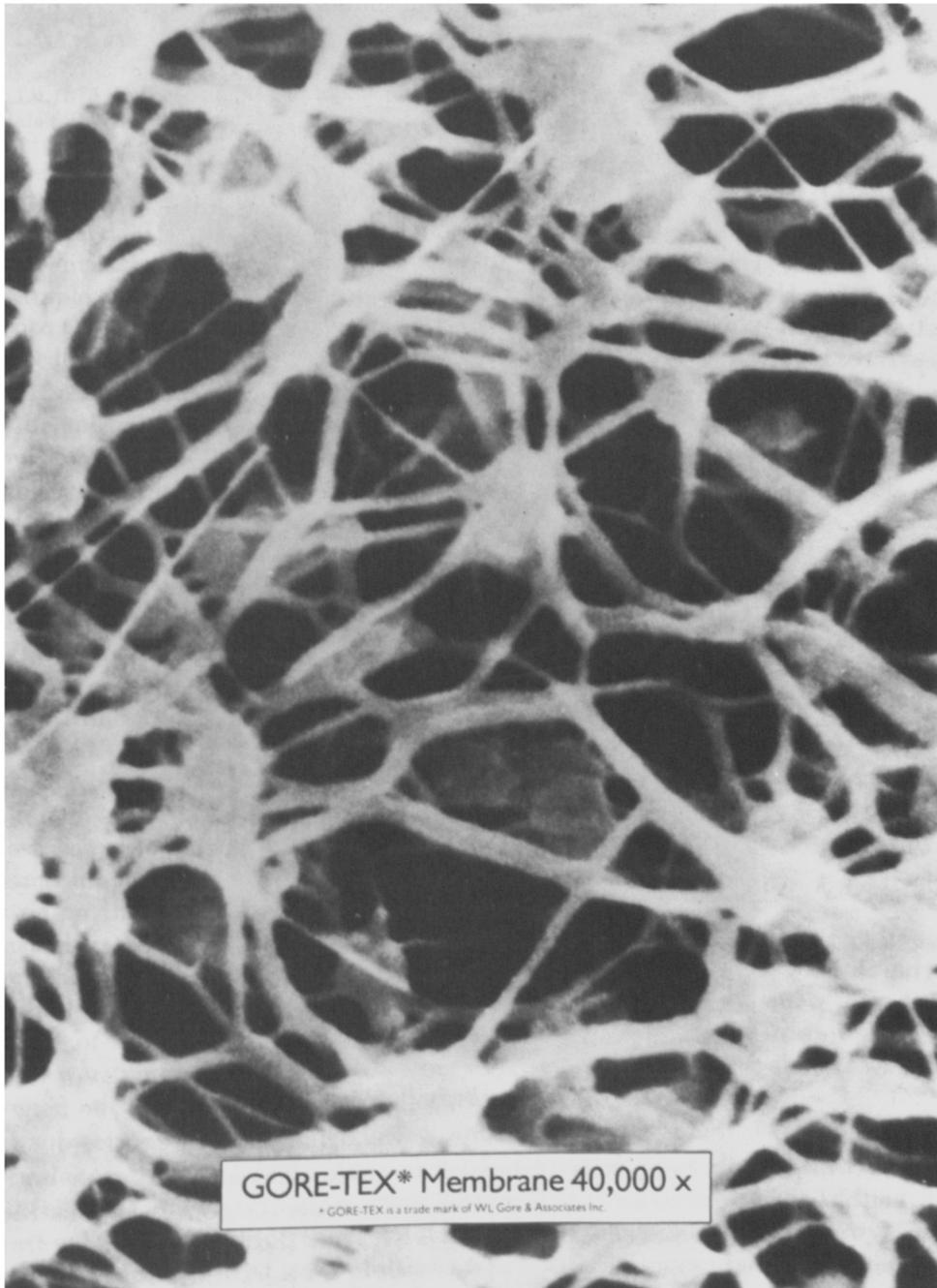


Fig. 1. Scanning electron microscopy photograph for expanded polytetrafluoroethylene membrane $\times 40000$.



Fig. 2. The 'Body Box' in use.

enclosed the wearer completely from neck to ankles. The suit was made entirely of the fabric with sleeve and ankle stretch cuffs, while the gown was constructed with a front panel and sleeves of GORE-TEX, but the back was made from a continuous filament yarn, textured and woven in a 2×1 twill pattern.

Equipment

A dispersal chamber (body box) similar to that specified by Whyte, Vesley & Hodgson (1976) was used to test the efficiency of gowns in preventing bacterial dispersal from the subjects. The chamber was made from clear heavy gauge plastic film mounted on a metal frame, and had a zip-fastened entry aperture (Fig. 2).

Table 1. Die-off of bacterial dispersal following a shower average (of three tests) counts*

289	239	194	55	38	28
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* c.f.u./375 dm³ air sampled in sets of three from a subject wearing 'blues' done at 20 min intervals following a shower.

The internal dimensions were: height 2.1 m, width and depth 0.6 m. A step 10 cm high occupied 30% of the floor space. The box was flushed with HEPA filtered air from a ventilation unit on its roof. The air could be directed out of the box through two sample ports; one near the floor, and the other half way up the side wall opposite the entry aperture. The remainder of the box was sealed. Any bacteria dispersed could be trapped by attaching a slit sampler set for 175 dm³/min to either port and sealing the other. Nutrient agar plates (Difco Blood Agar Base no. 2) were used for culture and colonies were counted after 18 h incubation at 36 °C. The airflow velocity could be varied between 0.2–0.55 m/sec so that volume exchange rates of 0.07–0.2 m²/s could be achieved.

Test method

Preliminary work in the box established that the highest bacterial counts were obtained with the airflow at maximum, the sampler attached to the bottom port and the zip of the entry aperture fully closed. These 'maximum turbulence' conditions ensured the trapping of 100–500 c.f.u. of bacteria in 350 dm³ of air sampled while a subject performed a stepping exercise for 2 min. The stepping sequence was 'left up, right up, left down, right down' in time to a metronome set at 132 beats per minute. The box could be cleared of residual bacteria by flushing for 4 min with the zip one third open. The effect of taking a shower before the test was pronounced; in successive tests the numbers of bacteria dispersed by the same subject decreased significantly (Table 1).

Based on these observations a standard procedure was devised. Each subject was asked to devote half a day to the tests, and to shower thoroughly one hour beforehand. The purpose of the shower was to reduce as far as possible any individual variations of dispersal, and the delay was intended to allow time for the effect of a shower on dispersal to have lessened. In addition tests on each garment were performed in strict sequence so that any effects of the shower would be evened out between the different clothes.

The subject put on clean underclothes, and a set of basic 'blues' before entering the test laboratory. The body box was flushed for 20 min to allow for an initial equilibrium of airflow and temperature. The subject then donned a hat and mask and entered the box wearing the test garments (q.v.). He or she then adjusted the entry zip to the two-thirds closed position and stood still for 2 min to allow bacteria carried in from the room air to be flushed away. The subject then closed the zip, read the temperature inside the box and began to step at the standard rate. After 30 sec the slit sampler was started and two sequential 2-min samples were taken without interruption of the stepping. Subsequently the subject stopped stepping, read the temperature again and left the box, which was flushed with clean air for 5 min before the next trial.

Table 2. *Full set of bacterial counts for one subject*

Test	Bacteria c.f.u./350 dm ³ air				
	Blues	Cotton	G-gown	G-suit	Control
1	55, 59				
2		123, 109			
3			53, 37		
4				10, 8	
5	45, 32				
6		109, 97			
7					7
8			48, 48		
9				8, 6	
10	73, 49				
11		122, -			
12					7
13			29, 37		
14				9, 5	

G-Gown, G-Suit, GORE-TEX gown and suit respectively.

Table 3. *Mean dispersal of bacteria from six subjects*

Test*	Bacteria c.f.u./350 dm ³ air				
	Blues	Cotton	G-Gown	G-Suit	Control
M-1	49	114	42	8	7
M-2	83	136	66	19	22
M-3	118	231	145	20	28
F-1	10	56	22	7	13
F-2	24	42	36	10	7
F-3	20	19	10	5	6
MEAN - M	83	160	84	16	19
MEAN - F	18	39	23	7	9
MEAN	50	100	54	12	14

* Three Male (M-1 to 3) and three Female (F-1 to 3).

G-Gown, G-Suit; GORE-TEX gown and suit respectively.

The tests were carried out in a sequence of: basic 'blues', blues + cotton gown, blues + GORE-TEX gown, blues + experimental suit. After one sequence the box was flushed for 15 min and the entire sequence then repeated twice so that at any one session three complete sets of readings were obtained. Two blank readings were also taken during the test run, and comfort was assessed by noting any perspiration produced during the test and the subjective comments of each subject.

RESULTS

The test material was an excellent bacterial filter. The average recovery from the challenges of 10^4 cells in the bacteria retaining tests was two cells (in a set of six tests); when the test was repeated without the fabric in place, uncountable (> 500) numbers of spores were recovered.

Six subjects (3 male and 3 female) were used in the main trial. The complete results for one subject are given in Table 2. Table 3 gives the averages for all six. The bacteria found were predominantly coagulase-negative staphylococci. The females liberated significantly fewer bacteria, and staggering the tests in relation to the showers made for a fair comparison between the four test garment combinations. In all cases the use of a cotton gown caused an increased shedding of bacteria, while the GORE-TEX did not. Counts obtained with the suit were no different from the background.

DISCUSSION

Our results confirm the previous work of Bethune *et al.* (1965) in showing different dispersal between the sexes (i.e. women dispersing fewer). The practice of allowing an hour to elapse after a shower appeared to set up an equilibrium in the fall of bacterial shedding rate, and so the tests and controls in each set were evenly matched. The effect of temperature was found to be insignificant in comparison to variation of dispersal between individuals.

Use of the high, turbulent airflow produced maximal air counts, although paradoxically such conditions meant that a smaller proportion of the exhaust was sampled and such conditions do not relate to the practical situation in the operating theatre. Nevertheless the numbers liberated in control tests are comparable to those found by Whyte, Vesley & Hodgson, (1976) when allowance is made for the different rates of airflow.

The rise in counts found when the basic 'blues' were covered with a cotton gown was unexpected and interesting. Most other workers have compared test gowns with underwear alone, or with other gowns and so will have missed this effect. Our most significant finding was that the GORE-TEX gowns reduced dispersal by about 50% in all cases, while the suit produced counts no different from the empty box. The latter finding is in accord with the work of Blowers & McCluskey (1965) who demonstrated a significant reduction in bacterial dispersion when trouser openings were closed, and of Goldthorp (1981) who also used a GORE-TEX suit. Whyte *et al.* (1983) demonstrated even further reductions by use of a proper hat.

Thus use of GORE-TEX gowns caused a significant reduction in bacterial aerosol production despite the fact that the back of the gown was of a knitted construction and incapable of retaining bacteria. These results were obtained, however, under conditions more severe than normally found in an operating theatre since the rapid stepping rate produced appreciable perspiration in the subjects during the test, particularly with the new gowns. The gowns also ought to prevent bacterial 'strike through' from wearer to wound, as the water-resistant material is used for the front and sleeves. The suit should stop virtually all bacterial transmission.

Unlike other occlusive gowns, the new ones can be re-used. If a sufficiently long life can be achieved, they should be cost-effective in comparison with cotton garments and a project to monitor this is currently in progress. In the tests carried out so far the materials supplied have a life of 50–70 uses, based on the number of wash and autoclave cycles before the bonding of the materials started to fail. The GORE-TEX fabric is made from filament polyester which is more durable than cotton, so gowns made from it may be expected to last for more use cycles with

less maintenance. In addition it will not lint, an important consideration when the risk of foreign matter entering the wound could be critical.

The minor remaining problem is one of comfort. There was a small but noticeable difference in the speed of onset of perspiration between gowns of cotton or GORE-TEX. Many users may be prepared to accept this in view of the better bacterial protection produced by use of the gowns, but some design improvements (Slater & Slater, 1985) to improve ventilation without reducing resistance to bacterial flow and tests are now in progress to evaluate the effectiveness of these changes.

We are grateful to Mr P. Jones, District Linen Services Manager, Cambridge Health District for initiating this project, to the DHSS Engineering Division for funds to provide the Body Box, and to W. L. Gore Associates (U.K.) for the test gowns.

GORE-TEX is a trade mark of W. L. Gore and Associates.

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