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Attempts to control clothes-borne infection in a burn unit

I. Experimental investigations of some clothes for barrier nursing

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SUMMARY

Clothes-borne transmission is an important way of spread of infection from patient to patient which is not interrupted by common cotton gowns. New barrier garments were designed from spun-bonded olefin that, in particle penetration tests, was 100 times better as a filter than cotton cloth. Three designs, a gown, a loose coverall and a close coverall, were compared with each other and with conventional cotton gowns in experimental exercise and nursing procedures. *Staphylococcus aureus* from burned patients were used as markers. The close coverall was 4–7 times better than the loose coverall or gown in preventing the soiling of clothes worn underneath it, but appeared to permit substantially more transfer from garments underneath it to a mock 'patient' and to the air than did the looser garments. A cotton gown reduced the soiling of clothes underneath it by more than 10 times and the contamination of a mock patient by more than 30 times as compared with no barrier garment. The close coverall further diminished the contamination of clothes but not the transfer to the patient. The possible mechanisms for the discrepancy between particle transmission tests and experimental procedures are discussed.

INTRODUCTION

Cross contamination carried by clothing is an important problem in burned patients (Hambraeus, 1973), who often have exogenous infection rates of over 60% (Wickman, 1970). Transmission of bacteria through clothes have been studied by many investigators, but most of them have concentrated on bacteria originating from the skin of people nursing patients (Alford, Ritter, French & Hart, 1973; Charnley & Efthekar, 1969; Bethune, Blowers & Parker, 1965; Hill, Howell & Blowers, 1974; Mitchell & Gamble, 1974; Whyte, Vesley & Hodgson, 1976). The passive carriage of bacteria on nurses' clothes from one patient's wound infection to another patient is probably a far more important route of contamination than either the airborne transfer or the transfer of bacteria emitted by carriers among the staff in burn units (Hambraeus & Sanderson, 1972) and in general wards (Lidwell *et al.* 1975).

Earlier investigations have shown that conventional protective clothing does not effectively prevent this passive carriage of bacteria (Hambraeus, 1973).

Table 1*a*. *General properties of examined materials*

Material	Fibre	Weight/m² (g)	Threads/10 cm
Green cotton	100 % cotton	165	285 × 250
Storalene	Cellulosa + rayon	46	Non-woven (binding: 100 % Primal HA8)
White Tyvek 1443	Olefin (polyethylene)	39	Spun bonded
Ventile L19	100 % cotton	220	330 × 230
Ventile L24	100 % cotton	186	420 × 290
Ventile L32	100 % cotton	137	560 × 420
Ventile L34	100 % cotton	154	500 × 390

Table 1*b*. *Penetration of artificial and natural aerosols*

Penetration in % (mean of 10 measurements/sample).

Q 0·3 = monodispersed quartz aerosol, particle size 0·3 μm.
Q 0·7 = polydispersed quartz aerosol, mean particle size 0·7 μm.

Room air
R 0·5 = particles larger than 0·5 μm.
R 1·0 = particles larger than 1·0 μm.
R 2·0 = particles larger than 2·0 μm.

Material	Q 0·3	Q 0·7	R 0·5	R 1·0	R 2·0
Green cotton	98	100	42·2	48·6	64·2
Storalene	96	100	62·5	64·0	36·4
White Tyvek 1443	20	6	1·3	2·5	0
Ventile L19	62	54	4·9	1·9	6·9
Ventile L24	64	65	7·7	9·5	8·8
Ventile L32	71	76	17·8	23·2	14·8
Ventile L34	46	37	7·3	0·5	0

We have attempted to develop a more efficient protective costume suitable for barrier nursing. In order to do this we have tried to evaluate some methods for testing the barrier effects of materials.

MATERIALS AND METHODS

Selection of materials for protective clothing

Seven different materials intended for protective clothing were examined. The general properties of the materials are shown in Table 1*a*. Their effectiveness as aerosol filters was tested by conventional methods. An aerosol was sucked or blown through the materials, and the percentage of particles penetrating them estimated. Particles from a quartz dust, monodispersed size 0·3 μm or polydispersed median size 0·7 μm, and particles from room air, larger than 0·5, 1·0 or 2·0 μm were used. The results are shown in Table 1*b*. (This investigation was carried out by G. Ringqvist, M.E., Swedish National Defense Research Institute.)

Two of the materials (Green cotton, and Storalene^{R}) had a particle penetration rate of over 30 %. These are materials often used for conventional protective gowns. The penetration rates for the two tightest materials (Ventile and Tyvek) were below 15% for large particles. Tyvek 1443 DuPont, a non-woven material of spun-bonded olefin, a polyethylene fibre, was selected for further investigation.

Clothes

Cotton suit

Jacket and trousers of cotton/polyester (not included in the penetration tests) was worn as working uniform in the non-patient area of the burn unit.

Cotton gown

A conventional surgical gown made of green cotton (see Tables 1*a* and *b*) was worn as protective dress on top of the cotton suit.

Tyvek clothes

These, made from Tyvek 1443 (see Tables 1*a* and *b*), were tailored after our design as: (*a*) gown, (*b*) loosely fitting coverall, and (*c*) coverall with closely fitting neck and cuffed sleeves and legs (Plate 1).

Sampling of bacteria

Staphylococcus aureus originating from a dispersing burn patient were used as marker bacteria. They were typed with the international set of phages (Blair & Williams, 1961).

Bacteria from clothes

Bacterial contamination of clothes was measured by a wash method (Hambraeus, 1973). The garment to be tested was washed during a standardized time in peptone broth which was then Millipore-filtered, the filter eluted in peptone broth and the bacterial count in the elution broth determined by colony count on blood agar.

Airborne bacteria

Settle plates were exposed in patient rooms for 4 h/day. Colonies of *Staph. aureus* up to a maximum of 8 per plate were phage typed. Bacterial contamination of air during mock nursing was determined with a Casella slit sampler run for 2×5 min before and 5×5 min during each experiment at a rate of 700 l/min.

Methods for estimating the transfer of Staph. aureus *through barrier garments*

Standardized exercise

A technician wore a sterile cotton suit and over that the barrier garment to be tested. A gown previously worn and contaminated during burn patient nursing was put on inside-out over the combination. Thus dressed she carried out a standardized exercise of 75 golf strokes. After that, the amount of *Staph. aureus* on the barrier gown and on the jacket worn underneath it was determined by the wash method.

During nursing

A routine nursing of a burned patient was carried out by a unit nurse wearing a barrier garment over a standard cotton suit. On leaving the burned patient's

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Table 3. *Results of model nursing experiments with barrier garments. Numbers of* Staph. aureus *of the burn patients' strain*

		Tyvek garments			Cotton garments		
		Gown	Loose coverall	Close coverall	Bar-Bac gown*	Cotton gown*	No protective dress*
(i)	Air count in source room (c.f.u./m^3)	29	33	32	32	56	45
(ii)	Nos. recovered from the suit jacket	5500	9500	1500	1580	7500	64000
(iii)	Air count in mock patient's room (c.f.u/m^3)	0·58	0·24	0·15	0·09	0·22	0·89
(iv)	Nos. recovered from mock patient	64	30	70	15	35	1050
(v)	Ratio, jacket/source room air	190	288	45	49	134	1422
(vi)	Ratio, mock patient's room air/jacket	104×10^{-6}	25×10^{-6}	104×10^{-6}	57×10^{-6}	29×10^{-6}	14×10^{-6}
(vii)	Ratio, mock patient/jacket	11×10^{-3}	3×10^{-3}	49×10^{-3}	$9{\cdot}5 \times 10^{-3}$	$4{\cdot}7 \times 10^{-3}$	16×10^{-3}
(viii)	Ratio, mock patient/source room air	2·21	0·91	2·19	0·47	0·63	23·3

* After Hambraeus (1973) (see text).

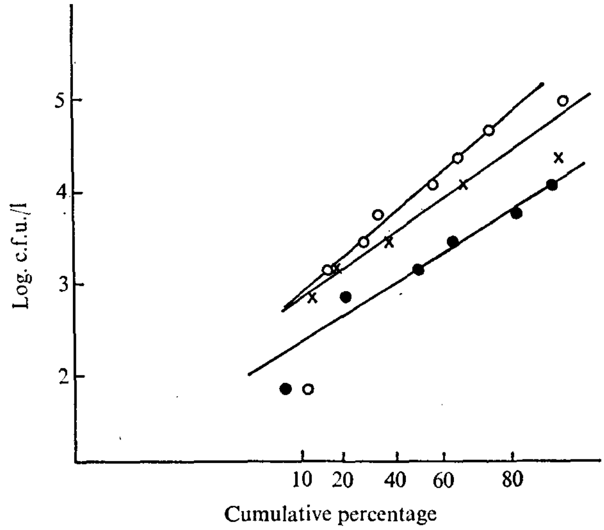

Fig. 1. Transfer of marker *Staph. aureus* in mock nursing with Tyvek garments. Numbers of c.f.u. on jacket worn by real and mock nurses. ×—×, gown; ○—○, loose coverall; ●—●, close coverall.

Transmission from burned patient to nurse (Fig. 1)

The contamination of the jacket (Table 3, row ii), expressed as the median number of marker *Staph. aureus* found on it, was 5500 with gown, 9500 with loose coverall, and 1500 with close coverall. In order to correlate the contamination of the jackets to their exposure to bacteria from the burned patients, the ratios of counts on the jackets to the counts in the air of the source room are also given in Table 3, row v. This ratio was 4–7 times less when a close coverall was worn than with a loose coverall or gown.

Transmission from mock nurse to mock patient (Fig. 2)

The mean numbers of marker staphylococci transferred to the mock patient during the nursing procedures were: with gown, 64 c.f.u.; with loose coverall, 30 c.f.u.; and with close coverall, 70 c.f.u. (Table 3, row iv). The ratio between the counts on the mock patient's gown and bottom sheet and the counts on the jacket are given in Table 3, row vii. The median transmission from jacket to mock patient was 1 %, 0·3 % and 5 % for the three garments respectively.

Transmission from mock nurse to air of mock patient's room (Fig. 3)

The contamination in the air of the receiving room during mock nursing was low in all the experiments performed and very close to the background contamination as found before the start of each nursing experiment. The air contamination with gown, loose coverall and close coverall was only 0·6, 0·2 and 0·2 c.f.u./m^3 respectively (Table 3, row iii). The ratio of air count in receiving room to counts on jacket (Table 3, row vi) was 4 times higher with the close coverall and with the gown than with the loose coverall, but in view of the background counts the difference is of doubtful significance.

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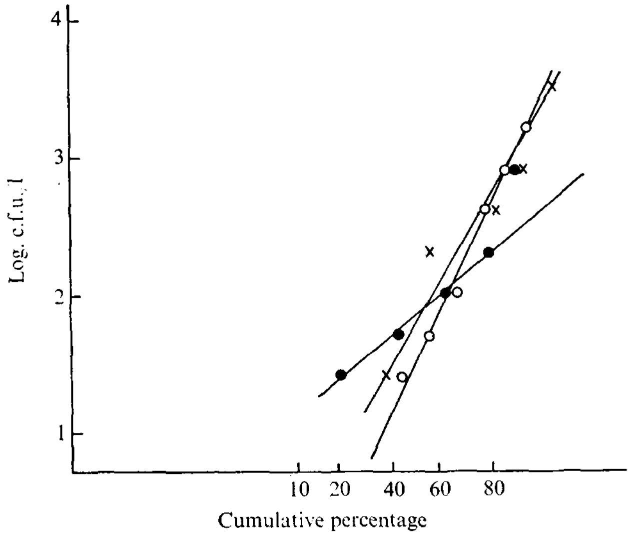

Fig. 2. Transfer of marker *Staph. aureus* in mock nursing with Tyvek garments. Numbers of c.f.u. on mock patient. ×—×, Gown; ○—○, loose coverall; ●—●, close coverall.

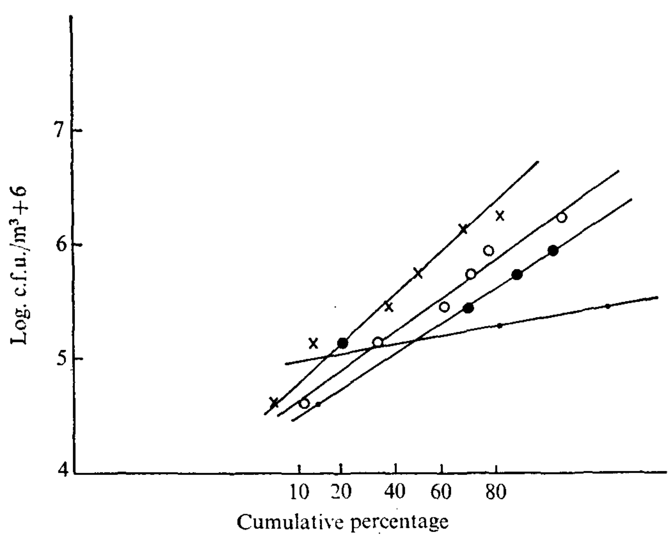

Fig. 3. Transfer of marker *Staph. aureus* in mock nursing with Tyvek garments. Numbers of c.f.u. in air or receiving room. ×—×, Gown; ○—○, loose coverall; ●—●, close coverall; •—•, background.

Comparison with other garments

Also shown in Table 3 are the results of earlier experiments without any protective dress, with a cotton gown (see Tables 1*a* and *b*) and with a close woven cotton gown, Bar-Bac, similar to the ventile fabrics. These data are derived from Hambraeus (1973) but have been recalculated as described under 'During nursing' in the Materials and Methods section above.

Transmission from burned patient to nurse

In Table 3, row v, it is seen that the cotton gown reduced this about tenfold, as did the Tyvek gown. The Tyvek loose coverall reduced it only about fivefold, but the close coverall and the Bar-Bac gown seemed to diminish it more than 30-fold.

Transmission from mock nurse to mock patient

The ratio of counts on the mock patients to counts on the jacket varied between 3 times lower with the cotton gown and 3 times higher with the coverall than without protective dress (Table 3, row vii).

Transmission from mock nurse to air of mock patient's room

The air of the receiving room was 4–5 times cleaner using a cotton gown or Tyvek coverall than without any protective dress (Table 3, row iii). The ratio of air counts in the receiving room to the counts on the jacket, however, was twice as high with the cotton gown than without the protective dress and 7 times higher with the coverall. The unreliable character of the values for the air count in the mock patient's room has already been referred to.

Transmission from burned patient to mock patient

In respect of the total transmission from burned patient to mock patient, the cotton gown appeared to be nearly 40 times better than no protection, the Tyvek garments 10–25 times better, and Bar-Bac about 50 times better (Table 3, row viii).

Summary of mock nursing results

The figures presented in Table 3 may be summarized as follows: All the protective garments reduced the contamination transmitted to the clothing worn beneath them by a factor of about 10 (range 5–30). The subsequent transfer to a second 'patient' when a sterile protective garment was worn over the contaminated clothing was only marginally, and in the experiments irregularly improved by the wearing of a second protective garment. Relative to the result without any protective garment the overall ratio was about 20 (range 10–50). The background counts render the extent of transfer of the marker organisms to the air of the second patient's room difficult to determine. The wearing of the protective garments did, however, reduce this to some extent.

DISCUSSION

The design of a barrier garment

It has been postulated (Bernhard, Speers, O'Grady & Shooter, 1965; Blowers & McCluskey, 1965; Hill *et al.* 1974), that the fit of a protective garment is important for prevention of bacterial shedding. To evaluate this three different garments, a gown, a loose coverall, and a close coverall were made from Tyvek, a material with good barrier properties in particle penetration tests. The three garments were compared during nursing. The close coverall seemed to protect the suit worn underneath it from contamination 3 times better than the gown or the loose coverall. There seemed to be no measurable difference in the abilities of the three garments to protect the mock patient from the few bacteria that had penetrated the original Tyvek suit to the jacket. The air contamination in the model patient room in the three sets of experiments was very low. Any valid comparisons between room to room transfer in the three sets are therefore difficult to make.

Comparison between barrier garments of different materials and designs

The size of bacteria-carrying particles dispersed from the skin of patients has been estimated at 10–15 μm (Noble *et al.* 1963). All three methods for testing particle separation were incomplete in that only small particles, usually less than 5 μm, were tested. The total number of particles larger than 2 μm in room air was low, and so the figures concerning this particle size are less valid than those concerning small particles. We have assumed that a material which highly reduces the transfer of small particles would be at least as effective in reducing the transfer of larger ones. Only one sample from each material was tested, and so variations in the same product have not been taken into account.

Judging from the tests performed, particle transmission through Ventile L 34 and Tyvek 1443 seemed to be about a hundredfold less than that through the cotton cloth used in common protective gowns. Tyvek was available in Sweden and was selected for tailoring. Tyvek garments were compared to an ordinary cotton surgical gown and to no protective dress.

In the standardized exercise the differences in transmission of *Staph. aureus* when wearing the conventional gown or any of the Tyvek suits were very small, if any.

During mock nursing the best of the Tyvek coveralls seemed to offer a moderate advantage over the conventional cotton gown in preventing the soiling of the nurse's working dress, but the difference, 5 times, was not striking and may be of no practical importance. In the protection of the mock patient from cross-infection the cotton gown appeared to have some effect. The Tyvek coverall showed no measurable improvement on that. Bacteria that had passed through the first barrier garment and soiled the working dress underneath seemed to pass more easily to the model patient with the Tyvek coverall (5 %) than with the cotton gown (0·5 %). The air of the mock patient's room was 4–5 times cleaner with the cotton gown and with the Tyvek coverall than without the barrier garment. This was due to a lesser contamination of the source jacket. Whatever bacteria were present on the jacket, these appeared to be more effectively spread to the air with any barrier garment than when none was worn, twice more so with a cotton gown and 8 times more so with the close Tyvek coverall. This may indicate that bacteria present on the jacket are rubbed off it more thoroughly with a close coverall than with a looser garment (Rubbo & Saunders, 1963). If the air count in the source room can be taken as representing the contamination potential from the burned patient, the ratio mock patient/source room air should give the overall effectiveness of the garments. Here the differences between the five garments are small indeed.

Conclusion

We have not been able to prove that a closely fitting protective dress is more effective than a loose gown in prevention of patient–nurse–patient transmission of *Staph. aureus*.

Clothes made from materials that in particle transmission tests were 100 times more effective than ordinary cotton were only 5 times better as barrier garments when examined in experimental nursing procedures.

Particle transmission of aerosols blown or sucked through the textile is the main principle commercially used at present for testing the barrier properties of clothing. When nursing a patient the wearer of a garment comes into close contact with wound bacteria which may be rubbed into the cloth rather than blown through it. There is no way of testing this at present. What is valid for prevention of cross-contamination can only be determined when these clothes have been tried in clinical use.

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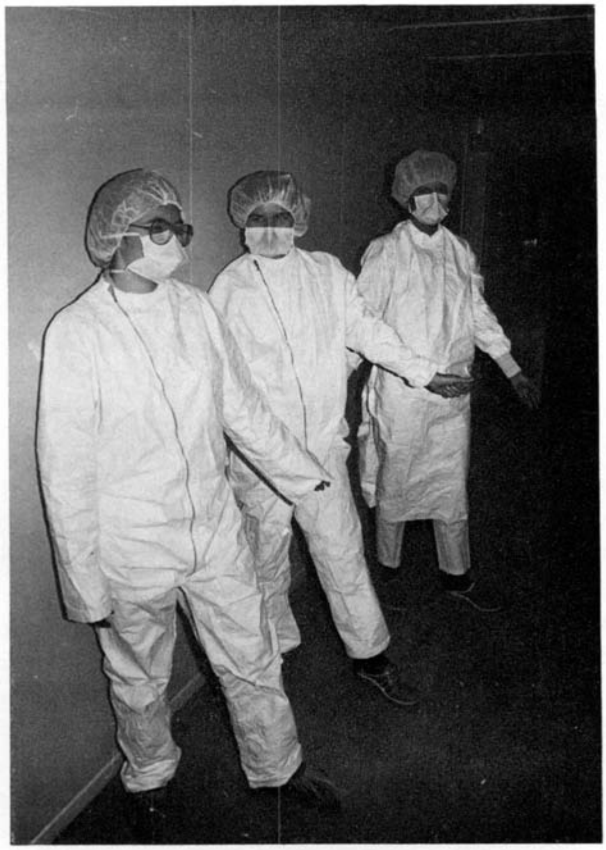
EXPLANATION OF PLATE 1

Tyvek loose coverall, close coverall and gown.



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