

Transfer of *Staphylococcus aureus* via nurses' uniforms

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(Received 9 April 1973)

SUMMARY

The contamination of gowns and uniforms worn in a burns unit and the transfer of patient's staphylococci by means of nurses' uniforms was investigated. The median values of staphylococci found on gowns and jackets worn during a routine nursing procedure were 3.0×10^4 and 1.4×10^3 respectively. From the results of model nursing experiments it appeared as if the fraction of staphylococci transferred from a patient's room to the air in a receiving room was 4 to 10 times less when protective gowns were worn than when no gowns were worn. The corresponding transfer directly to the model 'patient' was 100 times less. The protection afforded by a gown seemed mainly to be due to protection against contamination of the uniform worn underneath when nursing a burned patient. The discrepancy between the transfer of an airborne particle tracer and *Staph. aureus*-carrying particles earlier found in the ward could be explained by the dispersal of *Staph. aureus* from nurses' clothing.

INTRODUCTION

There is evidence that bacteria-carrying particles rather easily pass from the surgeon's skin into the air when a conventional surgical outfit is worn (Duguid & Wallace, 1948; Hare & Thomas, 1956; Bethune, Blowers, Parker & Pask, 1965; Charnley & Eftekhar, 1968; Sykes, 1970), and several workers have tried to diminish this source of infection in operating rooms by introducing new materials as well as by altering the design of the outfit (Blowers & McCluskey, 1965; Bernard, Cole & Gravens, 1967). Although it has been shown that nurses' clothing becomes contaminated with staphylococci common in the ward during work (Speers *et al.* 1969; Lidwell & Towers, 1972), the importance of this has been very little studied. It may well be that this is an important means of secondary transmission in ordinary ward work as well as in barrier nursing when common protective gowns are worn.

In a previous investigation in a burns ward (Hambraeus, 1973) it was shown that the transfer of staphylococci within the ward was much greater than the transfer of an airborne tracer particle. This indicates that transfer of *Staph. aureus* is not only due to air movement.

The aim of the present investigation was to study the importance of transfer of *Staph. aureus* by means of nurses' clothing in this ward.

The contamination of protective gowns and the uniform worn underneath during work in the ward has been studied. The effectiveness of four different kinds of commercially available protective gowns has been investigated experimentally. An attempt to measure the patient-to-patient transmission of staphylococci by means of nurses' clothing has been made.

MATERIALS AND METHODS

Ward design

The ward has been described in detail in an earlier paper (Hambraeus & Sanderson, 1972). It has five bedrooms and a 6th room containing an airbed, all with individual air-locks. The ventilation rate in the bedrooms is about four air changes/hr.

Uniforms and nursing routines

The uniform used in the ward consisted of a short-sleeved cotton jacket and cotton trousers (Plate 1). When nursing a newly burned patient a cotton surgical gown (Plate 2) was used. This was also used with a plastic apron underneath when bathing a patient. In all other nursing procedures a semisynthetic protective gown was used. The nurses put on a gown in the air-lock before entering the room. The gowns were kept in the air-lock and changed once a day. Gloves were used in all nursing procedures. The morning nursing procedure generally lasted for from 30 to 70 min. It included washing the patient, bed-making and tidying the room. The floor was cleaned by staff from the central cleaning department common to the whole hospital.

Sampling techniques

Among the most common methods used when sampling bacteria from fabrics are the sweep plate-, contact plate-, and vacuum sampling methods (Blowers & Wallace, 1955; Williams & Shooter, 1963; Hall & Hartnett, 1964; Robinton & Mood, 1968; Nicholes, 1970). These three methods were compared on 13 protective gowns contaminated in ordinary ward work. Two sweep plates, six contact plates (Rodac plates) and two plates from vacuum samplings (Casella slit sampler, air flow 150 l./min.) each run for 2 min. were used on the front part of each gown. Using the vacuum sampling method about 10 times as many c.f.u. of *Staph. aureus* were isolated as by the two other methods. As shown in Table 1 about twice as many strains with different phage patterns were also found by this method.

All these methods only sample a portion of the possible micro-organisms on the gown and a fourth method, the wash method, was therefore introduced. Two litres of 1% peptone water were used for each washing. A litre of the wash fluid was filtered through millipore filters (0.45 $\mu\text{m.}$, 47 mm.), using 5–10 filters per litre, and bacteria were eluted from the filters by shaking them with glass beads in 10 ml. nutrient broth. Colony counts were made on 0.25 up to 2.5 ml. of the 10 ml. lots. The volumes chosen depended on the assumed contamination of the gown. There were very small variations in the number of staphylococci found in each filtered portion from the same wash fluid. At first washing was done by hand,

Table 1. Number of strains with different phage patterns isolated by three different sampling methods

	Strains found	% of max.*
Sweep plates	16	34
Rodac plates	18	38
Vacuum sample	34	72

* i.e. % of the total number of strains recovered by all three methods used simultaneously.

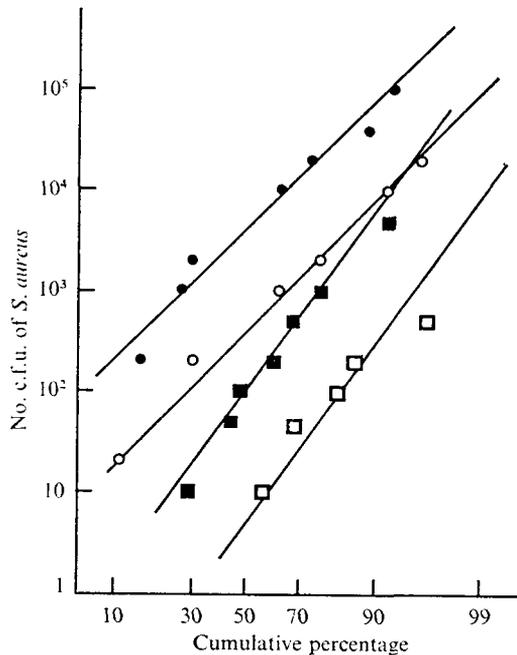


Fig. 1. Distribution of total number of *Staph. aureus* found on jacket and gown by vacuum sampling method and wash method. Number *Staph. aureus*: number c.f.u. per single wash or per two vacuum sample plates.

- Protective gown } Vacuum sampling method
- Jacket } Vacuum sampling method
- Protective gown } Wash method
- Jacket } Wash method

always by the same person; later a small washing machine in which the drum was replaced by a special autoclavable drum was used. There were no important differences in the results from the two washing methods.

In order to compare the vacuum method and the wash method, 28 pairs of gowns and jackets worn during the morning nursing of patients were investigated by the two methods. Fig. 1 shows the distribution of the total number of *Staph. aureus* found by the two methods. The median number of *Staph. aureus* colonies found in samples from protective gowns was 4.0×10^3 from a single wash and from the jackets 4.0×10^2 per single wash. With the vacuum sampling method the

Table 2. *Number of strains with different phage patterns isolated from protective gowns and jackets by vacuum sampling method and wash method*

	Protective gown		Jacket	
	Strains found	% of max.*	Strains found	% of max.*
Vacuum sample	76	65	67	54
Wash method	92	79	103	82

* i.e. % of the total number of strains recovered by the two methods used simultaneously.

median values were 1×10^2 and five per two slit sampler plates for gowns and jackets respectively. The larger values found in the wash fluids probably result in part from dispersal of clumps of organisms. However, as is shown in Table 2, more strains with different phage patterns were also collected by the wash method. Being the most effective method and the one showing a lower variability, the wash method was adopted for the investigation. Six consecutive washings of seven gowns and four jackets showed that only a portion of the micro-organisms on a piece of cloth was recovered in 2000 ml. wash fluid by a single wash. Although the results from repeated washings were somewhat variable, about 56 % were recovered from a jacket and about 38 % from a gown. The washing of the gowns was probably less efficient because they were larger. To estimate the total number of *Staph. aureus*, the number recovered in 1000 ml. wash fluid (the portion filtered) from the jacket has been multiplied by 2×1.8 , and the number recovered from the same volume from a gown or bottom sheet has been multiplied by 2×2.7 . In what follows it is these estimated total numbers of *Staph. aureus* that are given.

Methods for measuring the transfer of Staph. aureus-carrying particles through protective gowns

(1) Transfer through gowns worn in normal work was examined using pairs of protective gowns and jackets worn during a routine morning nursing of a patient. Before entering the room the nurse put on sterile jacket and trousers and a sterile gown. After the nursing procedure the jacket and the gown were taken off the nurse and put in different plastic bags for transport to the laboratory where they were immediately washed.

(2) Pairs of gowns and jackets worn during a standardized exercise were examined in the following way: a standardized exercise, 75 golf strokes, was performed by a laboratory assistant. The protective gown being tested was worn over a sterile uniform (jacket and trousers). A contaminated gown was put on (inside out) over the combination. The contaminated gown had been used in the ward so that the contamination was representative of that produced by use. After the experiment the contamination of the gown being tested and the jacket was determined by the wash method. As long as the test person was not a *Staph. aureus* carrier no phage typing was done. When she became a carrier of staphylococci, all staphylococci from the jacket and all up to a maximum of 8 per colony count plate from the barrier gown were phage typed.

Table 3. *Materials used for protective gowns*

Name	Fibre	Weight/m. ²	Threads/cm.	% Transmission	
				0.5- 1 μ m.	1- 10 μ m.
Cotton gown	100 % cotton	165	19 × 25	58	50
Poplin gown	65 % polyester 35 % cotton	160	42 × 22	57	47
Bar-Bac gown	100 % cotton	187	38 × 31	75	58
Disposable gown	50 % rayon 50 % cellulose	60	non-woven	66	54

Methods for estimating the transfer of Staph. aureus from one patient to the other by means of nurses' clothing

In these experiments a nurse dressed in sterile jacket and trousers and a sterile protective gown performed the routine nursing of a patient. She then undressed and the jacket and trousers were put on by a laboratory assistant who carried out a model nursing procedure with a volunteer from the laboratory acting as patient. The model nursing procedure resembled the real nursing routine as closely as possible. Thus the laboratory 'nurse' also wore a sterile gown, sterile gloves, cap, mask, and shoe covers. The 'patient' wore a sterile protective gown, sterile gloves, cap, mask, and shoe covers. The experimental nursing procedure lasted for about 25 min.

The air contamination during the model nursing procedure was investigated using a Casella slit sampler with an air flow of 700 l./min. This was run for five consecutive periods of 5 min. each, i.e. a total of 25 min. during each nursing period. Samples were also taken before each experiment. The contamination of the jacket, the protective gowns used by the volunteer 'nurse' and 'patient' and the sterile bottom sheet which was used during the performance was investigated by the wash method.

Characterization of the material of the protective gowns used in the investigation

Four different kinds of protective gowns were used; a cotton surgical protective gown of the kind routinely used in the hospital, a polyester-cotton (poplin) gown, also in routine use, a closely woven cotton (Bar-Bac)* surgical protective gown, and a non-woven disposable surgical protective gown. These will be referred to as cotton gown, poplin gown, Bar-Bac gown and disposable gown respectively. Fibre weight/m.², threads/cm. and % transmission of particles are given in Table 3. Percentage transmission refers to an investigation in which room air was sucked through the fabric and the difference in particle concentration in filtered and non filtered air measured with a Royco particle counter.†

* Angelica Uniform Company, New York.

† Performed by B. Martensson, Stora Kopparbergs specialprodukter.

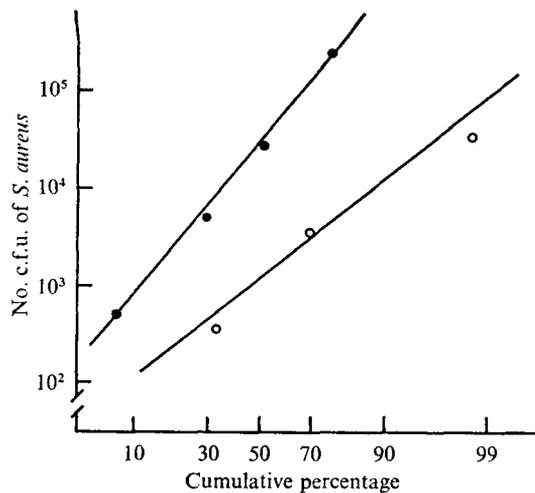


Fig. 2. Distribution of total number of *Staph. aureus* on gowns and jackets worn in routine nursing. ●, Protective gown; ○, jacket.

Bacteriological methods

Sedimentation plates were exposed in the patients' rooms 3–5 days/week. From the patient, samples were taken from the upper respiratory tract, skin, perineum and wound once weekly and, in most cases, also on the day of the experiment. Samples from the upper respiratory tract of all persons taking part in the experiment were taken on the day of the experiment. Samples were taken from the hands of the volunteer 'nurse' and 'patient' after each experiment. Cultures were made on blood and phenol-mannitol agar. Blood agar was used for the air and textile sampling plates. The plates were incubated for 48 hr. at 37° C. Presumptive *Staph. aureus* colonies were tested for deoxyribonuclease production (Di Salvo, 1958). From human specimens, one representative of each morphologically distinguishable type was phage typed (Blair & Williams, 1961). All *Staph. aureus* colonies up to a maximum of eight found on each plate from the textile samples and all colonies from the air samples taken during experiments were phage typed, except in a few experiments with an extremely high air contamination. Strains were assumed to be distributed in the sample in the same ratio as in the colonies that had been phage typed.

RESULTS

Transfer of Staph. aureus-carrying particles through protective gowns

Contamination of the protective gown and of the jacket worn underneath, during routine nursing procedures

Fifty-seven pairs of protective gowns and jackets that had been worn during routine nursing of a patient were examined. Both gowns and jackets had been sterilized before use and were worn over the nurses' own underclothing. Cotton, poplin and disposable gowns were used, but as there were no measurable differences between them the results have been combined. Fig. 2 shows the distri-

Table 4. Number of gowns and jackets from which patients' and staff strains of staphylococci were isolated

Source of <i>Staph. aureus</i>	Protective gowns		Jackets	
	No.	% of total no. <i>Staph. aureus</i>	No.	% of total no. <i>Staph. aureus</i>
Patient	19	89	15	54
Staff	4	0.07	8	2
Other*	19	11	20	44
Total no.	21	—	21	—

* These were often strains present in the ward carried by other patients or staff.

bution of the estimated total number of *Staph. aureus* recovered from the gowns and from the jackets. The median values were 3.0×10^4 and 1.4×10^3 for protective gowns and jackets respectively.

Phage-typing was carried out in 25 of the pairs investigated. Table 4 shows the result of this. In four cases patient and staff carried *Staph. aureus* with the same phage type. These cases have been excluded. From 19 of the protective gowns and 15 of the jackets strains with the same phage type as those isolated from the patient were found. The contribution of these strains to the total number of staphylococci recovered varied considerably. 89% of the total number of *Staph. aureus* derived from the protective gowns were patient strains. From the jackets the corresponding figure was 54%. On four of the protective gowns and on eight of the jackets strains with the same phage types as those isolated from the upper respiratory tract of the staff were found. The proportion of these to the total number of colonies isolated was only 0.07% on the gowns and 2% on the jackets. Strains with phage patterns other than those of patient or staff strains were often recognizable as strains carried by other persons in the ward. The ratio of the number of *Staph. aureus* found on the protective gown to that found on the jacket was scattered over a wide range (from less than 1 to over 1000). For patient strains the median value of the ratio was 25.

Barrier effect achieved with different kinds of protective clothing worn during a standardized exercise

Four different kinds of protective clothing were used during standardized exercise as described. These were cotton gown, poplin gown, disposable gown and Bar-Bac gown (Table 3). Ten gowns of each fabric, all new and never laundered before, were tested two to three times each. In an additional series a plastic apron was worn underneath the cotton gown and in another a plastic bag was worn on top of the jacket, underneath a cotton gown. These combinations of clothing were tested 20 times each. In Table 5 the transmission of staphylococci is shown expressed as the proportion of staphylococci on the jacket to that on the barrier gown. There were rather small differences but the list order for the four materials was the same as that found for transmission of 1–10 μm . particles. Neither the plastic apron nor the bag showed any large effect.

Table 5. *Comparison of transmission through gowns*

Name	Median (%)	Quartiles	% transmission of particles (1-10 $\mu\text{m.}$)
Cotton gown	1.6	0.7-3.5	50
Poplin gown	0.7	0.5-1.8	47
Bar-bac gown	2.2	1.0-4.4	58
Disposable gown	2.4	1.7-5.4	54
Cotton gown + plastic apron	1.8	0.3-3.5	—
Cotton gown + plastic bag	0.6	0.2-0.9	—
Gowns used in routine nursing	4.0	0-6.3	—

Estimation of the transfer of Staph. aureus from one patient to the other by means of nurses' clothing

An attempt to quantitate the transfer of *Staph. aureus* from one patient to the other by means of nurses' clothing was made using model nursing experiments performed as described. In 15 nursing experiments cotton gowns were used by both the ward nurse and the person nursing the experimental 'patient', in 15 experiments Bar-Bac gowns were used by the two and in 15 experiments no protective gowns were used either by the ward nurse or by the volunteer 'nurse'.

Contamination of jackets during patient nursing

The jackets were heavily contaminated during the nursing procedure. The median value of the total number of *Staph. aureus* found was 9.0×10^3 when cotton gowns and 1.8×10^3 when Bar-Bac gowns were worn. These median values were slightly higher than those given earlier for the contamination of jackets worn during nursing procedures. This was probably due to the fact that as far as possible heavily dispersing patients were chosen for the model nursing experiments. When no protective gown was worn the median value was 1.1×10^5 . The majority (95, 70 and 97 % respectively) of the staphylococci were of the same phage type as those isolated from the patient.

In 36 experiments the ward nurse was a carrier of *Staph. aureus* and in 26 of these it was of another phage type than those isolated from the other participants in the experiment, in eight experiments it was the same phage type as the burned patient's, and in two the ward nurse and the volunteer 'patient' had *Staph. aureus* with the same phage type. In those experiments in which the ward nurse carried an easily distinguishable *Staph. aureus* this type was isolated from the jacket in four cases; the amount varied from 12 to 1.4 % of the total number of *Staph. aureus* found. When the ward nurse and the patient were infected with the same *Staph. aureus* type, those found on the jacket were assumed to be the patient's, as consecutive nursings of the burned patient performed by carriers and non-carriers gave the same results. The volunteer 'nurse' and 'patient' were intermittent carriers of *Staph. aureus*; these were usually easily distinguishable from the other *Staph. aureus* types isolated and they were very seldom dispersed.

In Fig. 3 the relation between the degree of air contamination in the real

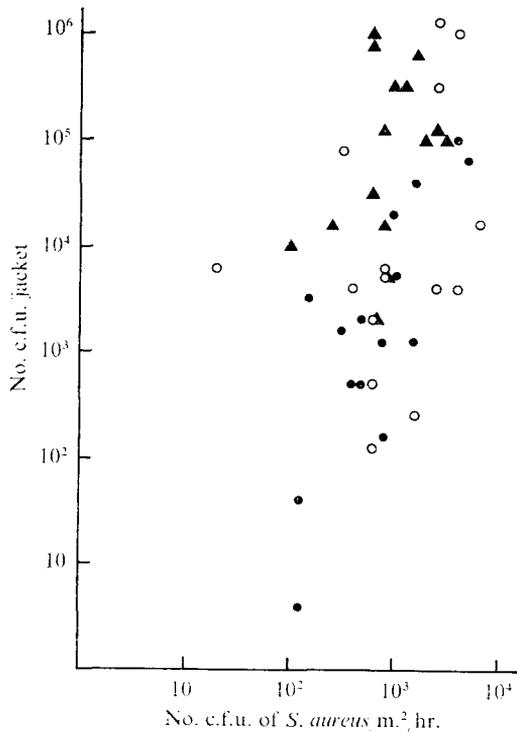


Fig. 3. Comparison between air counts in the patient's room (c.f.u./m.²/hr.) and contamination on the jacket. ○, Jacket worn under cotton gown; ●, jacket worn under Bar-Bac gown; ▲, jacket worn without gown. Fifteen experiments each.

patient's room and the number of this patient's staphylococci found on the jacket is shown, the air count serving as an index of the level of contamination to which the nurse was exposed. In a few cases settle plates were not exposed in the patient's room the day of the model nursing, the mean number of the observations on the day before and after was then used. To estimate the protection against contamination given by the gowns log median values for air contamination in the patient's rooms and on the jackets were determined graphically by plotting the cumulative distribution; the median values, assuming a sedimentation rate of 0.3 m./min., were 56, 32 and 45 c.f.u./m.³ in the patients' rooms when cotton gown, Bar-Bac gown and no gown was worn. The corresponding median values for the jackets were 8.5×10^3 , 1.6×10^3 and 5.6×10^4 c.f.u. *Staph. aureus*. The log median values together with the ratio of counts on the jackets to those in the air, expressed as the log difference, are given in Table 6. The log difference when cotton gown was worn is 0.9 less than that when no gown was worn, the log difference when Bar-Bac gown was worn is 1.4 less than that for no gown worn; this would indicate that wearing a gown gives an 8 to 25 fold protection against contamination of the jacket.

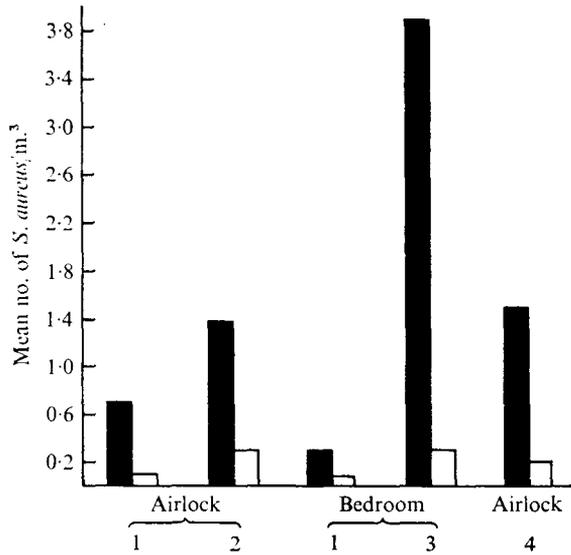


Fig. 4. Mean number c.f.u. *Staph. aureus*/m.³ in air-lock and bedroom during nursing experiments. Black column: *Staph. aureus* with the same phage type as those isolated from the jacket. White column: other staphylococci. 1, no activity; 2, dressing in the air-lock; 3, model nursing; 4, undressing in the air-lock.

Transfer of Staphylococci to the receiving room

Dispersion to the air. The air contamination in the bedroom during model nursing, and in the air-lock to this room during dressing and undressing, for the series of experiments in which both real and model nursing was performed in cotton gowns is shown in Fig. 4. The values given for dressing and undressing are mean values of 12 and 11 investigations respectively, the bedroom values are mean values of 15 investigations. The numbers of staphylococci with phage types other than those isolated from the jackets are fairly constant, but the numbers of staphylococci derived from the jackets are high during activity; the mean number of these found in the bedroom is 3.9/m.³ and in the air-lock it is 1.4/m.³. As shown in the figure, staphylococci with the same phage type as those isolated from the jacket were sometimes found in the air, especially in the air-lock before the experiments had begun. These staphylococci were often of a phage type isolated from more than one person in the ward.

In order to analyse more closely the transfer of staphylococci from a patient to a receiving room, those staphylococci were chosen that had the same phage type as those isolated from the burned patient but which were not present or present only in small numbers in air samples in the receiving room before the experiments. These staphylococci will be called 'marker' staphylococci. In Fig. 5 the air counts in the burned patients' rooms are compared with those found in the receiving room during model nursing. (The same method for plotting the cumulative distribution has been used as that given in an earlier paper, Hambraeus, 1973.)

The median values for the air counts in the receiving room were 0.22, 0.09 and 0.89 c.f.u./m.³, when cotton gowns, Bar-Bac gowns and no gowns were worn. The

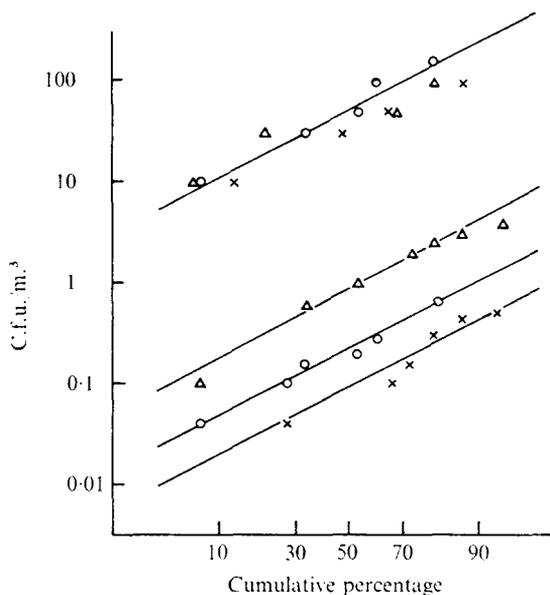


Fig. 5. Distribution of the air counts in patients' rooms and in the receiving rooms during model nursing. The number of *Staph. aureus* /m.³ given assumes a sedimentation rate of 0.3 m./min. The upper line refers to air counts in patients' rooms. Because of the closeness of the values for the patients' rooms, only one line is drawn. The lower lines refer to air counts in the receiving rooms during model nursing. ○, Experiments in which cotton gowns were worn; ×, experiments in which Bar-Bac gowns were worn; △, experiments in which no gowns were worn.

log median values as well as the ratio of the air counts in the receiving room to those in the patient's room, expressed as the log difference, are given in Table 6. The percentage *Staph. aureus* carrying-particles transferred varies from about 2 when no gown was worn to between 0.4 and 0.3 when a cotton gown or a Bar-Bac gown was worn, i.e. there was approximately a five- to seven-fold improvement on wearing a gown. In Table 6 the air counts in the receiving room are also expressed as a function of the air counts on the jackets, i.e. the log difference of the counts in the receiving room to those on the jackets are given. From these figures it appears that there was no protective effect of wearing the gowns, in fact the log difference seems to be smallest when no protective gown was worn. This indicates that the gowns did not reduce the dispersal of organisms from a contaminated uniform.

In three cotton gown experiments the dispersion was extremely high 8.9, 9.8, and 36.5 c.f.u./m.³. In one of these experiments the volunteer 'patient' was heavier than in the other experiments; in two the burned patient was a little girl dispersing heavily. Staff were carriers of an easily distinguishable phage type in 26 experiments; these were isolated from air samples in six cases. The median value of these six was 0.06 c.f.u./m.³ and the maximum value was 0.1 c.f.u./m.³. This was found in one of the experiments without protective gowns.

Transfer of Staph. aureus to the model 'patient'. Fig. 6 shows the comparison between the number of 'marker' *Staph. aureus* found on the jackets and those

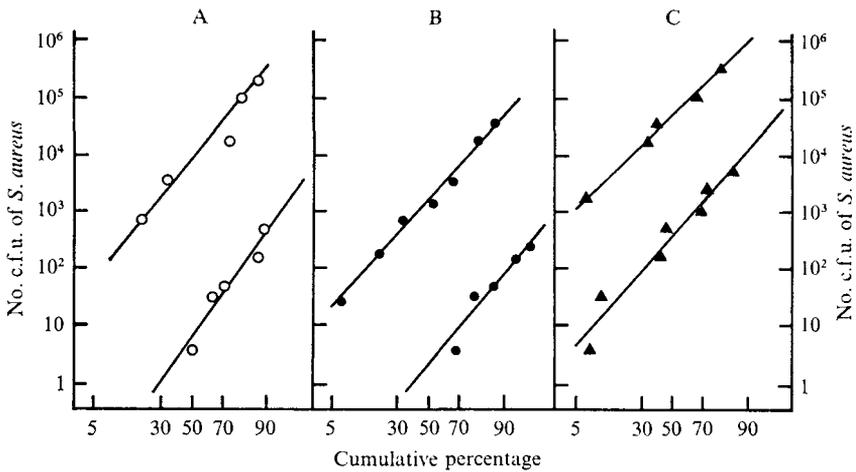


Fig. 6. Comparison between the number of 'marker' staphylococci found on the jackets and those found on the model 'patients' gowns and bottom sheets. The upper line shows the distribution of the number of 'marker' *Staph. aureus* found on the jackets: the lower line shows the distribution of the number of 'marker' *Staph. aureus* found on the model 'patients' gowns and bottom sheets. A, Experiments in which cotton gowns were used (○); B, experiments in which Bar-Bac gowns were used (●); C, experiments in which no gowns were used (▲).

found on the model 'patients' gowns and bottom sheets after the model nursing procedure when cotton gowns, Bar-Bac gowns and no gowns were worn. Median values for 'patient's' gown and bottom sheet were 6, 2 and 4×10^2 c.f.u. and maximum values were 3×10^3 , 7×10^2 and 2×10^4 respectively. Two items in the series with gowns had to be excluded, one because the model 'patient' had marker staphylococci on her hands after the experiment and the other because the model 'patient' and the burned patient carried staphylococci with the same phage type. To estimate the protection against contamination of the patient afforded by the gowns, the ratios between the counts on the model 'patients' gown and bottom sheet and those in the burned patient's room were calculated for the 3 different situations. The log difference between the median values are given in Table 6. The log difference when cotton gowns were worn is 1.88 less than that when no gowns were worn; the log difference when Bar-Bac gowns were worn is 2.12 less than that when no gowns were worn, this seems to indicate that wearing either gown reduced the transfer of *Staph. aureus* to the patient by about 75 to 130 times. The log differences between the number of staphylococci found on the model 'patient's' gown and bottom sheet and those on the jacket has also been calculated. There is some evidence that wearing either gown reduced transfer from the jacket to the patient but the effect was not very great, a reduction of between about 10 to 5 times (log difference when cotton gown was worn being 0.96 less than that when no gown was worn, log difference when Bar-Bac gown was worn being 0.72 less than when no gown was worn).

Table 6. Transfer of marker staphylococci in model nursing experiments

	Gowns used			Log difference between not wearing and wearing	
	Cotton gown	Bar-Bac gown	No gown worn	(a)	(b)
				Cotton gown	Bar-Bac gown
Air count patient's room (log med c.f.u./m. ³ *)	1.75	1.50	1.65	—	—
Counts on jacket (log med c.f.u.)	3.93	3.20	4.75	0.82	1.55
Ratio counts on jacket—air count patient's room (log difference)	2.18	1.70	3.10	0.92	1.40
Air count receiving room (log med c.f.u./m. ³ + 6)	5.35	4.94	5.95	0.60	1.01
Ratio air count receiving room—air count patient's room* (log difference + 6)	3.60	3.44	4.30	0.70	0.86
Ratio air count receiving room— counts on jacket (log difference + 6)	1.42	1.74	1.20	-0.22	-0.54
Counts on model patient†	4.77	4.28	6.55	1.78	2.27
Ratio counts on model patient†—air count in patient's room* (log difference + 4)	3.02	2.78	4.90	1.88	2.12
Ratio counts on model patient†— counts on jacket (log difference + 4)	0.84	1.08	1.80	0.96	0.72

* Assuming a sedimentation rate of 0.3 m./min.

† Protective gown and bottom sheet.

DISCUSSION

The aim of this investigation was to obtain an estimate of the degree of contamination of nurses' clothing with *Staph. aureus* during work in the ward and to calculate the risk of transfer of *Staph. aureus* from room to room by means of nurses' clothing. For the isolation of *Staph. aureus* from the textiles four different sampling techniques were tried; sweep-plates, Rodac plates, vacuum sampling and the wash method. Of these, the wash method was the most effective. One of the advantages of this method was that the whole item could be investigated. Some of its effectiveness might be due to the fact that *Staph. aureus*-carrying particles were split during the washing procedure. However, the method was also more effective in recovering different strains of *Staph. aureus*.

It was shown that the clothes, both the protective gown and the jacket worn underneath, were heavily contaminated during the nursing of a burned patient. The proportion of staphylococci that penetrated the protective gown during a nursing period varied considerably. This might be due to differences in the work performed by the nurse according to whether an extensively burned patient, a baby or a nearly well patient was treated. Because of these variations it would not have been possible to compare the protection given by different kinds of protective gowns by using them in routine work.

An attempt to investigate the barrier effect of six different kinds of protective clothing by using them in a standardized pattern of movement was therefore made. Only very slight differences in protection could be shown, which was in agreement with the results achieved with a particle penetration test. The Bar-Bac fabric did not seem to be better than the other fabrics used. This is not consonant with the findings of other authors (Bernard, Cole & Gravens, 1967; Michaelsen, Halbert, Sorensen & Vesley, 1968). There is probably not much difference between the transmission through the fabrics if the particles are small and this may explain the results. The range of particles in room air is probably more near $1\ \mu\text{m}$. than $10\ \mu\text{m}$. and it has been shown in an earlier paper (Hambraeus, 1973) that burned patients often disperse a portion of small bacteria-carrying particles. The best results were achieved when a plastic bag was worn on top of the jacket and under the barrier gown.

In the model experiments on transfer of *Staph. aureus* from a burned patient to a receiving room, cotton gowns, 'Bar-Bac' gowns and no protective gowns were used, each in 15 experiments. The results from these experiments are summarized in Table 6. From the log median values it appears as if the dispersal of staphylococci into the receiving room was 4 to 10 times less and the transfer of staphylococci to the model 'patient' about 100 times less when protective gowns were used than when no gown was used. This effect, however, seems to be mainly due to protection against contamination of the jacket when nursing the burned patient. When the number of air borne staphylococci in the burned patient's room served as an index of the level of contamination to which the nurse was exposed then this protection seemed to be 8- to 25-fold. When worn over a contaminated uniform, neither of the two gowns appeared to have any effect in reducing the dispersal of the contaminating organisms into the air of the receiving room. This may have been because of a greater release of bacteria-carrying particles from the jacket due to friction between jacket and gown; similar results have been found by other authors (Bethune, Blowers, Parker & Pask, 1965). There did seem to be a rather small reduction in transfer to the model patient's clothes and bed linen when the gowns were worn, compared with transfer during the same procedures performed without a gown.

As the cotton gown was the one used when nursing newly burned patients in the ward, the results of this series of experiments are the most interesting from the epidemiological point of view. The median airborne dispersal of $0.22\ \text{c.f.u./m}^3$ during an experimental nursing period of 25 min. would correspond to a settling of $1.7\ \text{c.f.u./m}^2$ during this time. The maximum value achieved during an experiment was $36.5\ \text{c.f.u./m}^3$. This would correspond to a settling of $273.8\ \text{c.f.u./m}^2$ during a nursing period. The real nursing of a patient generally takes slightly longer than the model nursing, and the staff probably moves around a little more; this together with the fact that the protective gowns used in a bedroom were only changed once a day unless they were visibly dirty, and the jacket and trousers were worn throughout the day, probably means that the real dispersal from clothing in the ward would be somewhat higher than the median value found experimentally.

In an earlier investigation (Hambraeus, 1973) it was shown that the fraction of

Staph. aureus-carrying particles transferred from a source room to a receiving room was 0.5×10^{-3} , whereas the fraction of an airborne tracer particle transferred was 0.17×10^{-4} . The median value of *Staph. aureus*-carrying particles found in a receiving room was 0.9 c.f.u./m.²/hr. This was calculated from the settling of *Staph. aureus* on plates exposed for 4 h. Assuming that there is one nursing procedure during a plate exposure, 1.7 c.f.u./m.² would be equivalent to 0.43 c.f.u./m.²/hr. As there would also be other nursing activities during the 4 hr. period, this figure is clearly of the same order as that of the median value of *Staph. aureus*-carrying particles found in the receiving room. Thus dispersion from clothing could account for the whole discrepancy found between the transfer of *Staph. aureus* and that of airborne tracer particles in the ward.

Besides the presence of airborne staphylococci dispersed from clothing, it was also possible to isolate staphylococci derived from the burned patient on the protective gown and bottom sheet used by the volunteer 'patient'. In only three experiments were no staphylococci found on the protective gown or bottom sheet; the maximum value found was 3×10^3 c.f.u.

Little is known about the infective dose of staphylococci. Shinefield *et al.* (1963) could set up a carrier state in the nose of 50 % of newborn infants by the inoculation of between 200 and 400 cocci. In experimental colonization of burns on rabbits an inoculum of 10^4 to 10^5 c.f.u. *Staph. aureus* was necessary for 100 % colonization (Anthony & Wannamaker, 1967). Most experimental models of staphylococcal disease, however, bear little resemblance to the natural disease in man. It would seem that, even when protective gowns were used, secondary transfer of staphylococci by nurses' clothing to the air in the ward as well as directly to the patient could reach such levels as to afford a risk to the newly burned patient. Although the protective gown was insufficient for the conditions in this ward it did offer some protection to the patient. This protection may be sufficient for wards in which the amount of contamination is less than in a burns unit.

This investigation was supported by grants from the Swedish Delegation for Applied Medical Defence Research.

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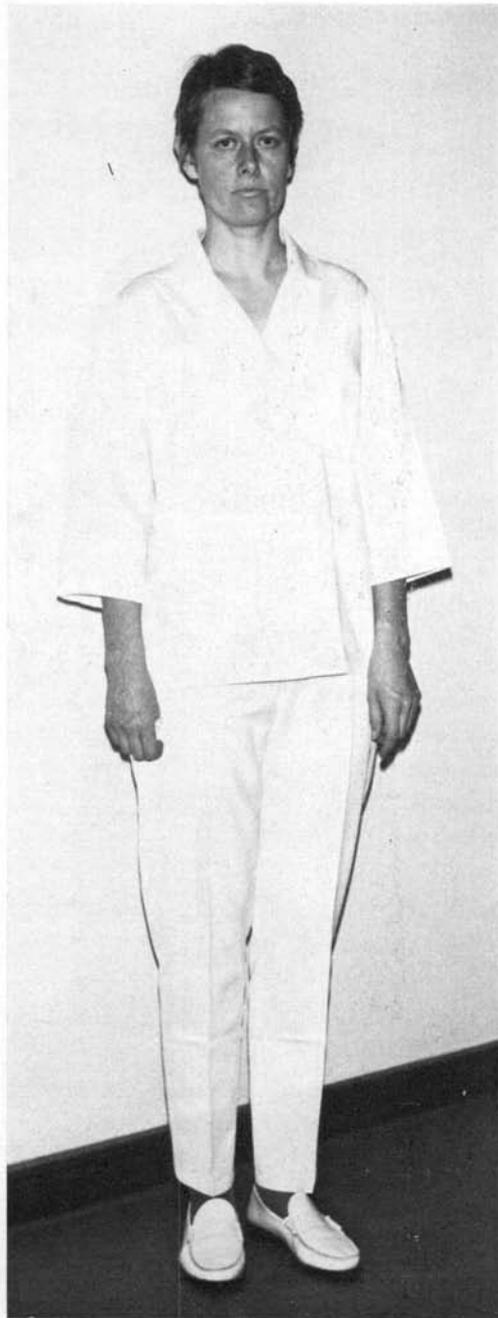
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EXPLANATION OF PLATES

Plate 1. Jacket and trousers used by ward staff.

Plate 2. Cotton surgical protective gown.



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(Facing p. 814)



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