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A laboratory model for the investigation of contact transfer of micro-organisms

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SUMMARY

The model was based on grasping a fabric-covered bottle contaminated with a strain of *Staphylococcus saprophyticus*, then grasping a sterile fabric-covered bottle and counting the organisms transferred. When the donor fabric was moist 10% of the available cells passed onto the hands, but this fell to 0·05% when the inoculum dried. Transfer from wet hands to the fabric amounted to 85%, but in the complete model only 0·06% of the available cells were transferred. The model was used to assess simple methods of degerming the hands. Washing the hands reduced transfer by 95%, while washing in 70% alcohol reduced transfer by 99·99%. Lesser procedures investigated included applying 0·2 ml of 80% ethanol to the hands, which reduced transfer by 93%.

INTRODUCTION

Contact-transfer of pathogenic organisms on the hand is an important means by which patients acquire infection in hospitals, and numerous tests have been used to evaluate the efficacy of procedures designed to interrupt spread by this route. In the pre-operative preparation of the hands of the surgeon and his assistants, the object is to reduce as much as possible the total number of organisms on the skin, and a prolonged 'scrubbing-up' procedure may be acceptable. Assessment of such procedures has usually been made by counting the number of skin organisms that can subsequently be removed from the skin, e.g. by the multiple-basin technique of Price (1938) or some modification of it. The numbers of bacteria left on the hands may become so low when topical agents with a cumulative action are under test that comparisons between active agents are difficult (Lowbury & Lilly, 1973).

There is a growing interest in the assessment of hand treatments that it is practicable for nurses to perform very many times in the course of a work-shift. Here, the complete surgical scrub is clearly impracticable, but the limited objective of removing the 'transient' flora of recently acquired organisms may be attainable by less time-consuming means. These treatments might be assessed by studies on naturally contaminated nurses' hands, but the irregularity of such contamination would introduce difficulties into the design of the experiment. Artificial contamination of the hands with a test bacterium might be an acceptable alternative if a

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test procedure that corresponded well with the natural situation was employed. Rotter, Koller & Kundi (1977) could distinguish between the degerming effects of different alcohols in a study in which hands were artificially contaminated with *Escherichia coli*, though the susceptibility of these organisms to desiccation caused some difficulties in interpretation. The use of a recognizable gram-positive test organism that survives well on the skin might answer some of the theoretical objections to this type of test.

The present investigation began with an attempt to obtain quantitative information about the indirect contact-transfer of micro-organisms on the hands, particularly when these had been contaminated from hospital bedding or nurses' uniforms (Speers *et al.* 1969; Lidwell *et al.* 1974; Hambraeus *et al.* 1973). We used a laboratory model in which the transfer of micro-organisms from an artificially contaminated fabric to a sterile fabric was measured. Subsequently, this model was used to compare several methods of hand disinfection suitable for use in general hospital work.

MATERIALS AND METHODS

Test organism

A strain of *Staphylococcus saprophyticus*, no.CRF31, was used as the test organism. It was selected because its resistance to novobiocin allowed a selective medium to be formulated and because the strain is pigmented, facilitating recognition on non-selective media. Although it was isolated from a patient with a urinary-tract infection, we believe it to have a lower virulence than strains of *S. aureus* when inoculated on to the skin of healthy human volunteers.

Test fabrics

(1) Nurses' dress material ('Sarille', DHSS pattern 8391A) made from terylene (67%) and crimped viscose (33%).

(2) Kitchen cloth ('J Cloth', Johnson and Johnson) made from viscose fibre.

(3) Paper wipe ('Kleenex' Medical Wipe, Kimberley-Clark).

(4) Standard gown material made from balloon cloth.

Donor and recipient objects

The fabrics, cut with pinking shears into rectangles 10 cm × 20 cm, were attached with autoclave tape to 300 ml round bottles (Winchester design, United Glass). Each fabric-covered bottle was placed in a paper bag and autoclaved before use. It was removed from the paper bag by grasping the neck of the bottle and stood in a sterile half-petri dish before being contaminated.

Contamination of donor objects

The test organism, grown overnight at 30 °C in nutrient broth or rubbed up in broth from an overnight plate culture and diluted appropriately, was applied to the fabric by pipette. A volume of 1 ml was applied in lines vertically down the carrier bottle sufficiently far apart to moisten the entire surface of the fabric. The broth suspension and the first and last pieces of fabric inoculated were cultured and the organisms enumerated.

Enumeration of organisms on fabric pieces

The method employed was a modification of that of Petersen, Collins & Marshall (1973). The fabric rectangle was transferred aseptically from the carrier bottle to a wide-mouth jar containing 100 ml of 0·1 % Triton X-100 in 0·75 M phosphate buffer, pH 7·9. The jar was agitated on a horizontal mechanical shaker for 5 min. Serial tenfold dilutions were prepared in the buffered detergent solution diluted 1/2 with distilled water, and single drops (0·023 ml) placed on nutrient agar (NA), nutrient agar containing 1 % Tween 80 (NAT), and casein yeast-extract glucose agar containing novobiocin 4 μg/ml (CYLG+Nv). A volume of 0·2 ml of the undiluted sample was placed on a single plate each of NAT and CYLG+Nv and the inoculum spread with the tip of the pipette. Where the count was expected to be low, volumes of 5 ml and 50 ml of the sample fluid were removed with a volumetric pipette. Each volume was passed through a membrane filter (Millipore HAWG047), the filter removed aseptically from the filter holder and placed face up on the surface of a NAT plate. The filter was cut in half with a sterile scalpel blade and one half of the filter was transferred to a CYLG+Nv plate. All the plates were incubated aerobically at 30 °C for 48 h. Counts were made of (1) the test organism (typically pigmented novobiocin-resistant colonies were considered to be the test organism) and (2) other organisms. The final count recorded took into account all the plates available.

Survival of the test organism on fabric pieces

This was assessed by inoculating a series of fabric-covered bottles and counting the organisms as above at intervals of 15 min, 30 min, 1, 2, 4 and 24 h after inoculation. Each fabric was studied in duplicate. Because the dress material (Sarille) was patterned with dissimilar front and back surfaces, survival of the inoculum was studied with the fabric applied to the bottle both rightside out and inside out. The effect of laundering and of autoclaving in detergent on the properties of the dress material was similarly investigated.

Transfer from fabric to hand

Bottles carrying kitchen-cloth rectangles were prepared and contaminated. The volunteer grasped a fabric-covered bottle firmly in one hand and the cloth was then removed for counting as above. The contaminated cloth from a second but untouched bottle was removed and treated similarly.

The size of the bottle was such that the fingers and much of the palm came in contact with the cloth. Preliminary experiments of grasping bottles carrying rectangles of graph paper with hands covered in coloured chalk indicated that the area of the hand that came in contact with the test object was approximately 60 cm^2 and that the thumb and the ball of the index finger were always in contact while the central area of the palm did not touch the contaminated surface.

Counting of organisms on the hand. Two methods were employed.

(1) Organisms were eluted from the ball of the index finger by the detergent-scrub method of Williamson & Kligman (1965) as modified by Stringer & Marples

(1976). The sample fluid was plated on NA, NAT and CYLG+Nv and the colony counts of the test strain and other organisms were assessed as detailed above. Membrane filtration was not performed.

(2) Organisms were eluted from the thumb by rubbing the thumb in a 2 ml pool of buffered Triton X-100 (as above) contained in the lid of a small petri dish (RODAC plate). The organisms in the sample fluid were counted as above.

The effect of drying of the inoculum on transfer to the hand. Contaminated bottles were prepared and kept for 1 h at a relative humidity of 26% as determined with a sling psychrometer. The volunteer grasped one bottle with the opposite hand from that employed in the first part of the experiment. Fabrics from this bottle and from an untouched bottle were counted and the numbers of organisms transferred to the hand were assessed as before.

Transfer from hand to fabric

The volunteer washed his hands. A volume of 1 ml of a broth suspension of the test organism was pipetted onto the hands, which were then rubbed together to distribute the inoculum. The volunteer then grasped a sterile fabric-covered bottle with each hand. The organisms remaining on the centre of the palm, an area that did not come in contact with the fabric, were eluted by the detergent-scrub method and counted as detailed above. The fabric pieces that had been touched were removed and the organisms counted.

Transfer from fabric to fabric via the hand

In the remaining experiments the basic design was to measure the number of organisms transferred from the donor-contaminated fabric ('Sarille') to a sterile recipient fabric (kitchen cloth) and to compare the number transferred when the grasping procedure was modified in various ways. The experiments were designed so that one hand performed the standard procedure and the other hand the modified procedure. The effects of multiple grasping, of moistening the recipient cloth, of wearing a glove and of variations in the surface of the recipient cloth, were investigated.

Effect of hand treatments on manual transfer of bacteria

The volunteer grasped a contaminated bottle in each hand; a recipient bottle covered with moistened kitchen cloth was then grasped with one hand, alternately left and right for successive volunteers. This transfer acted as the control. The hand treatment was then carried out and a second recipient bottle was grasped with the other hand. In some experiments, both hands were then rinsed in a bowl containing 500 ml of buffered Triton X-100 wash-fluid to determine residual organisms. In half of the washing experiments, the hands were allowed to dry for 15 min after the contaminated bottle had been grasped but before the control bottle was grasped, the hand treatment was then carried out and the second recipient bottle grasped.

Table 1. *Recovery from and survival of* S. saprophyticus *on different fabrics*

Time	Average percentage of inoculum* surviving on Sarille (10 trials)	J Cloth (2 trials)	Paper wipe (2 trials)	Balloon cloth (2 trials)
0	82·2	90·0	58·1	16·3
15 min	59·5	61·7	23·1	6·9
30 min	41·6	64·4	13·9	2·3
1 h	24·3	53·6	16·5	0·8
2 h	16·4	58·0	6·1	0·7
4 h	13·3	40·2	4·0	0·4
24 h	9·8	21·8	0·2	0·3

* Inocula ranged from $10^{5\cdot5}$ to $10^{6\cdot2}$ c.f.u.

Hand treatments tested. The five methods tested were:

(1) Washing in still detergent. After the control transfer both hands were washed for 30 sec in 500 ml of buffered Triton X-100 wash fluid and dried on a new paper towel.

(2) Washing with bar soap. The hands were washed with bar soap under running tap-water for 30 sec and dried on a paper towel.

(3) Washing in alcohol. The hands were washed in 500 ml of 70% ethanol for 30 sec and air-dried.

(4) Rubbing with alcohol-impregnated towellete. The hands were wiped with the towelette ('Clean Hands', Spectra Chemicals Ltd) and air-dried.

(5) Rubbing with a small volume of alcohol. A volume of 0·2 ml of 80% ethanol was applied to the centre of the palm by pipette and distributed over the hands by washing movements. No drying was needed.

RESULTS

Recovery from and survival of the test strain on different fabrics

The results, expressed as a percentage of the inoculum, of the trials of recovery from the four fabrics are summarized in Table 1, which also shows the results of the survival studies. An average of 90% of the inoculum could be recovered from J Cloth, the kitchen cloth, immediately after the contamination procedure. Recovery from Sarille, the dress material, was almost as good with an average of 82% of the inoculum recovered. Smaller proportions of the inoculum could be recovered from the paper wipe and from balloon cloth.

The number of organisms that could be cultured fell rapidly as the inoculum dried, then more slowly. Even after 24 h about 10% of the inoculum could be recovered from Sarille and from J Cloth. Only small numbers of viable cells could be recovered from the paper wipe and from balloon cloth. On the basis of these findings the paper wipe and balloon cloth were not further investigated.

Sarille, the dress material, was studied rightside out and inside out in duplicate. No difference in recovery of the test organism nor in its survival was detected. Duplicate studies were carried out on new Sarille, Sarille autoclaved in detergent

Table 2. *Transfer from fabric to hand*

	Number of c.f.u. from					
	fabric after transfer		palm scrub		thumb wash	
Subject no.	Strain CRF31 (millions)	Other	Strain CRF31	Other	Strain CRF31	Other
Immediate transfer (geometric mean recovery from 4 untouched fabrics = $1{\cdot}02 \times 10^6$ c.f.u.)						
1 L	1·6	3000	1550	500	730	770 000
2 R	1·0	0	4490	1670	1290	170 000
3 L	0·9	0	5490	120	2600	365 000
4 R	0·8	0	1500	1320	3800	66 000
1 h later (geometric mean recovery from 4 untouched fabrics $0{\cdot}68 \times 10^6$ c.f.u.)						
1 R	0·8	1500	5	2200	115	460 000
2 L	0·6	0	10	1630	10	840 000
3 R	0·9	0	20	1940	175	1 800
4 L	0·8	2000	10	500	100	9 240 000

L, Left; R, right.

and Sarille laundered in a hospital laundry. No differences in recovery or survival of the test organism were found, and the results of all trials were included in the average shown in Table 1. Slight differences in the rate of absorption of the inoculum into the cloth were noted. The fabric that had been autoclaved in detergent and rinsed, absorbed the inoculum more quickly and evenly than new or hospital-laundered fabric. The laundered fabric was the least satisfactory of the fabrics as an experimental material.

Transfer from fabric to hand

The results of an experiment carried out with four volunteers are given in Table 2. When the hand grasped the bottle immediately after inoculation, no diminution of the number remaining on the cloth after grasping could be detected and normal skin organisms could be detected on only 1 of 4 touched bottles. The scrubs from the ball of the index finger yielded the test organism in all four samples at a geometric mean count of 2750 colony forming units (c.f.u.) and a few other organisms (geometric mean 600 c.f.u.). The thumb washes also all yielded the test organism (geometric mean = 1750) but also many normal skin organisms (geometric mean = 240000).

The percentage of the inoculum transferred to the skin was calculated as follows. The inoculum was spread over 200 cm^2, so that the number of c.f.u. available for transfer was $(1{\cdot}02 \times 10^6)/200 = 5100$ c.f.u./cm^2. The area of skin under the sampling cylinder was 5·5 cm^2, so the number of c.f.u. of the test strain that were recovered from the skin was $2750/5{\cdot}5 = 500$ c.f.u./cm^2, i.e. about 10% of the cells on the fabric were transferred to the skin. The results for the thumb wash, where the area in contact with the fabric was somewhat less than the area of the cylinder, were of the same order of magnitude.

Table 3. *Transfer from moist hand to fabric**

	Number of c.f.u. recovered from			
	kitchen cloth		scrub from centre of the palm	
Subject no.	Strain CRF31	Others	Strain CRF31	Others
1 L	155 000	264 000	19 000	79 000
1 R	188 000	418 000	39 000	57 000
2 L	84 000	12 400	13 500	8 800
2 R	89 000	15 400	19 000	2 600
3 L	572 000	12 000	27 000	100
3 R	392 000	5 000	35 600	530
4 L	264 000	220 000	19 000	22 400
4 R	173 000	286 000	11 400	12 300
Geometric mean	196 000	54 600	21 100	5 930

* Inoculum of $1{\cdot}9 \times 10^6$ c.f.u. in 1 ml broth applied to hands, which were then rubbed together. Kitchen-cloth-covered bottle grasped with each hand.

After the fabrics had dried at room temperature for 1 h, $6{\cdot}8 \times 10^5$ c.f.u. of the test organism was still viable on the untouched fabric pieces and a similar number were recovered from the test pieces after grasping. The number of c.f.u. that were recovered from the ball of the index finger after grasping was about 10 in all four volunteers and somewhat higher but still low on the thumb. The numbers of skin organisms found were similar to those found in the first part of the experiment. The percentage transfer from a dried inoculum calculated in the same way as above was 0·05% of the cells available per cm^2 of fabric.

Transfer from hand to fabric

Four volunteers (eight hands) completed the experiment. The results are given in Table 3. It should be noted that the inoculum was applied to the hands of each volunteer in a volume of 1 ml immediately before the fabric-covered bottles were grasped and therefore the hands were wet at the time of transfer. The calculations for interpretation of the results were as follows:

Inoculum on two hands = $1{\cdot}89 \times 10^6$ c.f.u. Assuming the inoculum to be spread over approximately 360 cm^2 of skin,

Number of c.f.u. per cm^2 = 5250
Expected number on area sampled = 28900
Observed number = 21100

Expected potential number on the fabric if the contact area of the hand is

60 cm^2 and all cells are transferred = 230000
Observed number on fabric = 196000
Therefore transfer percentage = 85%

Transfer of normal skin organisms calculated in the same way gave a percentage transfer of 84%.

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Table 4. *Transfer from donor fabric to recipient fabric*

Procedure	No. of experiments	Number of c.f.u. of CRF31 recovered from donor fabric	Number of c.f.u. of CRF31 recovered from recipient fabric	Transfer (%)*
Single handling	4	35600000	3980	0·011%
Tenfold handling	4	32600000	8850	0·027%
Recipient dry	4	1360000	87	0·006%
Recipient moist	4	1570000	190	0·012%
Hand bare tenfold handling	4	9880000	13900	0·140%
Hand gloved tenfold handling	4	13500000	13400	0·099%
Recipient kitchen cloth (moist)	10	19800000	7800	0·039%
Recipient plastic apron	10	19800000	386	0·002%
All single handling recipient dry	40	14300000	2460	0·017%

* Percentage of the number on the recipient cloth of the number on the donor cloth. Result should be multiplied by 3·3 to give the percentage of available c.f.u. transferred.

Transfer from donor fabric to recipient fabric

The results of four experiments in which a modification of the procedure was compared with the standard procedure are shown in Table 4, which also lists the average of 40 trials with the standard procedure from these and other experiments.

Tenfold handling of the donor and recipient fabrics increased the number of cells transferred, but only by a factor of 2. A similar increase was obtained by moistening the recipient fabric with 1 ml of sterile distilled water. No difference in the number of organisms transferred was seen when the bare hand was compared with the hand wearing a disposable plastic glove. However, when plastic apron material was used as a recipient very few cells were detected on it.

In other experiments (results not shown) no difference could be found between the two faces of the donor dress material.

When all the standard-procedure transfers were collected and combined (40 trials), the number of cells of the test organism recovered from the recipient kitchen cloth was only 0·017% of the number recovered from the donor fabric. Because the donor fabric was evenly contaminated over the area of 200 cm^2 and the area actually touched by the hand was only 60 cm^2 the percentage of the cells available for transfer that were transferred would be 3·3 times the value (0·057%). This figure is very different from the 8·5% transfer expected as the product of the 10% transfer from fabric to hand and the 85% transfer from hand to fabric found previously. An important difference in the conditions for transfer from hand to recipient in the two experiments was the presence of moisture in the first study and the relative dryness of the hand and cloth in the second series of experiments.

Effect of washing procedures on transfer

Table 5 summarizes the results of six experiments in each of which the same four volunteers participated. The donor fabric was contaminated with very large numbers of the test strain, up to 10^8, to increase the chances of finding the organism

Table 5. *Effect of washing procedures* on the number of organisms transferred*

Procedure	Number of c.f.u. in inoculum on donor (millions)	Number of c.f.u. on fabric grasped before procedure: Strain CRF31	Number of c.f.u. on fabric grasped before procedure: Others	Number of c.f.u. on fabric grasped after procedure: Strain CRF31	Number of c.f.u. on fabric grasped after procedure: Others	Percentage reduction, strain CRF31 (%)
Immediately after grasping donor object						
Still detergent	25·2	15900	8980	682	18900	95·7%
Bar soap	21·7	5680	4150	92	8750	98·4%
70% ethanol	33·6	32800	639	4	9	99·99%
15 min after grasping donor object						
Still detergent	69·3	5020	5820	79	12800	98·4%
Bar soap	78·5	16000	1700	732	4160	95·4%
70% ethanol	107·8	17200	6060	0	172	100%

* Each procedure was performed once immediately after the contaminated donor fabric was grasped and once on a separate occasion after 15 min drying of the contaminated hands. Results are geometric means of four observations.

after the procedure. Immediately after the hands had been contaminated, washing in still detergent and washing with bar soap under running water reduced the number of test organisms transferred by more than one order of magnitude, while washing in 70% ethanol reduced transfer by 4 orders of magnitude from that found on the hands not exposed to the procedure. When the contaminated hands were allowed to dry for 15 min the number transferred before the procedure was still of the order of 10^4 although a very large inoculum had been used. Still detergent and bar soap again reduced transfer by more than one order of magnitude but the test strain was not recovered after the alcohol treatment or in the detergent rinse taken after the procedure. The numbers of normal skin organisms passing onto the recipient fabrics before the procedures were about 10^3. After washing in still detergent, more normal skin organisms were recovered from the recipient fabric, there was no change in normal skin organism transfer after washing in bar soap under running water, but 70% alcohol dramatically reduced the number of skin organisms recovered.

Effect of rubbing procedures on transfer

Ten volunteers participated in the two experiments. The numbers of the test strain recovered from the recipient fabrics are listed in Table 6 and the individual percentage reduction for each volunteer is shown. There was more variability in the efficacy of these minor degerming procedures than of the washing procedures, but in four instances the alcohol-impregnated towellete reduced transfer by more than one order of magnitude. The small volume of 80% ethanol appeared to be more effective, with five instances of reduction of one order of magnitude and one of 2 orders of magnitude. In all, treatment with the alcohol-impregnated towelette

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Table 6. *Effect of rubbing procedures on the number of organisms transferred*

Volunteer no. (and sex)	Use of alcohol-impregnated wipe*: Number of c.f.u. of strain CRF31 recovered from fabric grasped before procedure	Use of alcohol-impregnated wipe*: Number of c.f.u. of strain CRF31 recovered from fabric grasped after procedure	Use of alcohol-impregnated wipe*: Reduction (%)	Rubbing with 0·2ml of 80% ethanol†: Number of c.f.u. of strain CRF31 recovered from fabric grasped before procedure	Rubbing with 0·2ml of 80% ethanol†: Number of c.f.u. of strain CRF31 recovered from fabric grasped after procedure	Rubbing with 0·2ml of 80% ethanol†: Reduction (%)
1 F	4530	1830	59·6	1860	545	70·7
2 F	1985	1375	30·7	905	70	92·3
3 F	14100	2940	79·1	2820	1740	38·3
4 F	1440	940	34·7	1800	39	97·9
5 F	46100	3310	92·8	2560	214	91·6
6 M	28500	2880	89·9	3450	450	86·9
7 M	4750	3470	26·9	1120	980	12·5
8 M	10300	900	91·2	1830	8	99·6
9 M	308000	22200	92·8	12300	158	98·7
10 M	48800	3750	92·3	11300	236	97·9
Geometric mean	13300	2650	80·1	2710	193	92·9

* Number of c.f.u. of the test organism on the donor cloth = $3{\cdot}6 \times 10^7$.
† Number of c.f.u. of the test organism on the donor cloth = 9×10^6.

reduced transfer by 80% and the small volume of alcohol by 93%. There was a significant difference between the response to the two treatments ($P < 0{\cdot}05$) when an analysis of variance was carried out on the logarithmically transformed data. A difference between sexes could be confirmed statistically but whether this was due to the sex of the volunteers or due to differences in the area of skin exposed to contamination was not determined.

DISCUSSION

In the course of developing a laboratory procedure as a model of contact transfer of bacteria by the hands, some factors important in regulating transfer became apparent. The importance of moisture in the efficiency of transfer of organisms from a contaminated fabric to the hand was particularly clear even though the test organism was not killed by drying. The studies on the effects of hand treatments indicated that such a minor procedure as rubbing the hands with 0·2 ml of 80% alcohol could have a statistically significant effect on the number of organisms transferred from one fabric to another.

The laboratory model was designed to simulate conditions that frequently occur in the hospital ward and to permit counting of the organisms transferred. We chose as the test organism a strain of *Staphylococcus saprophyticus*, because a selective medium containing novobiocin could be used to distinguish the novobiocin-resistant test organism from the generally novobiocin-sensitive flora of the normal skin. As the strain was characteristically pigmented, the colonies could be

recognized on non-selective media. Studies of survival of the test organism on nurses' dress material pieces showed that about 10% of the inoculum could be recovered even after 24 h. This survival is unlike the findings when enterobacteria are used as test organisms (Rebell *et al.* 1950). *S. saprophyticus*, although capable of causing urinary infection, was felt to have a lower degree of virulence than *S. aureus* and to be less of a hazard to the volunteers, who were exposed to up to 10^8 c.f.u. *S. saprophyticus* closely resembles *S. aureus* in response to physical agents and simple degerming methods. Whether they respond similarly to other agents likely to be used for hand disinfection remains to be shown.

Recovery of the test organism from different fabrics was almost complete from the dress material and the kitchen cloth but was lower from the paper wipe and the surgical gown material. For the purposes of studying quantitative aspects of contact transfer we chose the first two fabrics for the model system, but the ability of the other two fabrics to trap bacterial cells may be of significance.

In the complete model, rectangles of dress material were fixed to a carrier bottle and contaminated with a broth suspension of the test organism. The fabric-covered bottle was grasped firmly by the volunteer who then grasped a bottle carrying sterile moistened kitchen cloth, and the number of organisms on the recipient material was measured. Only 0·02% of the organisms on the donor fabric could be recovered from the recipient fabric.

The attempts to quantify the process of transfer were not wholly satisfactory but showed the importance of moisture. The number of c.f.u. available for transfer from the fabric to the hand was, of course, less than the number contaminating the fabric as the area of skin in contact with the fabric was about 60 cm^2 while the area of the fabric rectangle was 200 cm^2. The number of c.f.u. transferred to the hand was about 10% of the c.f.u. available for transfer if the carrier was grasped immediately after the fabric was contaminated and the surface was still moist but fell to only 0·05% when the fabric was allowed to dry for 1 h at room temperature.

Contaminating the hand with 1 ml of a broth suspension and immediately grasping a sterile fabric-covered bottle led to a transfer of 85% of the c.f.u. available for transfer yet in the complete model where the volume of fluid passing to the hands from the contaminated fabric was very small, transfer was of the order of 0·1% of the cells available. The number of cells transferred to a plastic surface was much less than that recoverable from the kitchen cloth.

The model was employed to study the effect of washing procedures on transfer of organisms. The results confirm previous findings by many authors. Washing the hands either in still detergent or with bar soap under running water reduced the number of c.f.u. of the test organism transferred by 95%, but exposure to alcohol was more efficacious. It was of interest that the proportion of c.f.u. transferred without the washing procedure in the control samples was detectably smaller when the contaminated hands had been allowed to dry for 15 min than when transfer was performed immediately after contamination. The lesser procedures of wiping the hands with an alcohol-impregnated towelette or rubbing the hands with 0·2 ml of 80% alcohol showed reductions in the number of organisms transferred to the recipient fabric of 80% and 93% respectively.

The results reported here suggest that our experimental model may give a realistic estimate of the relative efficacy of various hand treatments in preventing the transfer of pathogens by indirect contact. This, however, is only one of the factors to be considered when choosing a routine procedure for use by nurses in busy hospital wards. Others include the time taken to perform it, and whether or not very frequent use of it has a deleterious effect on the skin; Ojajärvi, Mäkelä & Rantsalo (1977) have shown that repeated treatment of the hands with some apparently effective agents may be bacteriologically counter-productive.

We do not know how great a reduction in the transient flora is necessary to bring about a clinically significant reduction in the risk of transmitting infection. This will depend upon the number of organisms transferred by contact with the naturally contaminated hand, and this in turn on the nature of the contaminating procedure and of the subsequent contact of the hand with the patient. Quantitative studies of the flora of the hands of 'real' nurses in the ward environment should provide this information.

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