

Comparison of two methods for assessing the removal of total organisms and pathogens from the skin

BY G. A. J. AYLIFFE, J. R. BABB, KIM BRIDGES, H. A. LILLY,
E. J. L. LOWBURY, JANET VARNEY AND M. D. WILKINS

*MRC Burns Unit, Birmingham Accident Hospital, and
Hospital Infection Research Laboratory,
Summerfield Hospital, Birmingham*

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SUMMARY

A standard hand-wash sampling technique was compared with a simple finger-streak sampling method in assessing the relative effectiveness of a number of alternative preparations used for disinfecting the surgeon's hands (alcoholic 0.5% chlorhexidine, alcoholic 0.1% tetrabrom-*o*-methyl phenol, a 4% chlorhexidine detergent solution, aqueous 0.5% chlorhexidine, 2% 'Irgasan' detergent solution and, as control, bar soap). There was a fairly good correlation between the results of assessment by the two methods after a single disinfection and after six disinfections, three on one day and three on the next. Significant differences were shown in 21 comparisons between treatments when the hand-wash sampling test was used, and 16 of these comparisons also showed a significant difference by the finger-streak test.

Staphylococcus aureus was found in hand samplings from 5 out of 8 nurses in the Burns Unit of Birmingham Accident Hospital by the hand-wash sampling method and from 2 of the same 8 nurses by the finger-streak method; the numbers were small, and no *Staph. aureus* were isolated from the same hands after 1 min. wash in 70% ethyl alcohol. Similar sampling on 29 nurses in other wards showed *Staph. aureus* on 3 nurses (one in large numbers) by the hand-wash technique and on 1 nurse by the finger-streak test; in only 1 nurse whose hands showed *Staph. aureus* before disinfection was the organism found, by hand-wash sampling, after disinfection.

Parallel sampling of nurses' hands after washing with soap and water and after disinfection with 95% ethanol showed larger numbers of *Staph. aureus* in a hospital for skin diseases than in a general hospital, and a lower incidence and somewhat lower density of *Staph. aureus* after ethanol treatment than after washing with soap and water; Gram-negative bacilli, on the other hand, were commoner on hands in the general than in the skin hospital, and present in much smaller numbers after disinfection with ethanol than after washing with soap and water.

Antibiotic sensitivity tests showed the frequent recurrence on the hands of some nurses of multi-resistant *Staph. aureus* with resistance patterns similar to those found in infective lesions in some of the patients; different sensitivity

patterns were usually found in staphylococci isolated from the nose. Even in wards where many patients were infected, carriage by nurses' hands of a particular strain of *Staph. aureus* did not seem to last for more than a few days.

INTRODUCTION

Disinfection of the skin has been assessed (*a*) by applying bacteria to the skin and estimating the reduction in their numbers after disinfecting the inoculated area, and (*b*) by estimating the reduction in numbers of natural skin bacteria, both resident and transient, after disinfection. The first method illustrates the effect of disinfection on the superficial, transient flora only (Lowbury, Lilly & Bull, 1964*a*). Though most of the resident organisms are not pathogenic for healthy persons or tissues, *Staphylococcus aureus* sometimes behaves like a resident organism (e.g. in the greater resistance of natural skin staphylococci to disinfection than that shown by bacteria deliberately applied to the skin), and bacteria sometimes dismissed as commensals may have pathogenic properties (as opportunists) in patients with diminished anti-microbial resistance. It is therefore usual, in assessing the value of antiseptics used for the surgeon's hands or the operation site, to test their effects on the resident (or resident plus transient) bacteria by a method which shows the reduction in natural flora after disinfection. The methods used for this purpose include (i) standard hand-washing techniques, involving colony counts from washings taken before and after disinfection (e.g. Price, 1938; Lowbury, Lilly & Bull, 1960, 1963), (ii) surface sampling techniques, such as contact impression plates or finger-streak plate cultures (e.g. Smylie, Logie & Smith, 1973), and (iii) colony counts from biopsies of disinfected and undisinfected areas of skin, a method suitable for use on cadaver skin or in animal experiments (Selwyn & Ellis, 1972; Lawrence & Lilly, 1972).

Of the two types of method suitable for use on living human subjects, colony counts from hand washings are time-consuming, but generally considered to give the most reliable results. Surface sampling, by contact or finger-streak plate tests, is quick and easy, but because of the smaller area and the more superficial layer of skin bacteria sampled by this method, it is commonly thought to give a less reliable indication of the effect of disinfection on the resident flora. However, similar opinions on the value of individual antiseptics have been reported by different workers, one group using a hand-wash technique while the other group used a finger-streak method (Lowbury & Lilly, 1973; Smylie *et al.* 1973).

In this study we have compared hand-wash and finger-streak plate techniques in assessing the effectiveness of a number of alternative preparations for disinfection of the skin. The finger-streak method was selected because it samples an area of skin most likely to acquire transient contaminants and to transmit them. Reductions in the numbers of bacteria and also of individual species or groups of pathogen on the skin were used as criteria of effectiveness of the method of disinfection. In the studies on nurses working in hospital wards the special interest was in effects of disinfection or cleansing on *Staph. aureus* and Gram-negative bacilli present on the skin, and in the frequency of carriage of these organisms as shown by the two methods of assessment.

MATERIALS AND METHODS

Experiments

Three studies were made: (1) an assessment, by hand-washing and finger-streak plate methods, of the effectiveness of five antiseptic preparations and of a bar soap control, used once or used repeatedly, in reducing the numbers of bacteria on the hands of volunteers; (2) an assessment, by both methods, of the effects of disinfection with 70 % ethanol (ethyl alcohol) on the numbers of total organisms and of *Staph. aureus* isolated from the hands of nurses in a burns unit and in other wards of Birmingham Accident Hospital; and (3) a comparison, by both methods, of the use of soap and water with that of 95 % ethanol in removing *Staph. aureus* and Gram-negative bacilli from the hands of nurses in a general hospital (Dudley Road Hospital) and at a hospital for diseases of the skin (Skin Hospital).

Experiment 1

Preparations tested. These were (a) a solution of chlorhexidine digluconate (0.5 %) in 95 % ethanol with 1 % glycerol (Lowbury, Lilly & Ayliffe, 1974); (b) a solution of 0.1 % tetrabrom-*o*-methyl phenol in 95.3 % ethanol ('Desderman'); (c) a 4 % chlorhexidine digluconate solution in a detergent base ('Hibiscrub') (see Lowbury & Lilly, 1973); (d) an aqueous solution of 0.5 % chlorhexidine digluconate; (e) a 2 % 'Irgasan DP 300' bactericidal washing cream ('Zalclense') (see Lilly & Lowbury, 1974); and (f) bar soap and water (control application).

Methods of using the preparations. Preparations (a) and (b) were applied, as described elsewhere (Lowbury *et al.* 1974), by rubbing approximately 10 ml. (two successive applications to cupped hands of 5 ml.) vigorously, without addition of water, on all areas of the hands and wrists until the skin was dry. Preparation (d) was similarly applied, but after 2 min. the hands were rinsed and dried on a sterile towel. Preparations (c), (e) and (f) were applied with vigorous rubbing over all areas of hands and wrists and repeated additions of warm water from a running tap, for 2 min., after which the hands were rinsed thoroughly under running water (see Lowbury *et al.* 1964*b*; Lowbury & Lilly, 1973).

Assessing disinfection of the hands. As in previous studies (e.g. Lowbury *et al.* 1964*b*; Lowbury & Lilly, 1973; Lowbury *et al.* 1974), each preparation was tested on each of a group of volunteers, with an interval of 10 days between successive experiments, so that the natural skin flora could return to normal before each new series of tests.

In each series of tests the hands of volunteers were sampled for bacteria (i) immediately before the first treatment (i.e. the first use of the antiseptic or control preparation), (ii) immediately after the first treatment, and (iii) after a series of six treatments, three on the first and three on the second of two consecutive days. Before the first sampling the hands were given a quick social wash with soap and water.

Hands were sampled by two methods: (1) a finger-streak test, in which the four fingers of each hand were drawn with gentle pressure across the surface of a plate of horse blood agar (with 4 % New Zealand agar); counts of bacterial colonies

in each finger-streak were made after 24 hr. incubation of the plates at 37° C.; (2) colony counts from standard hand-washing tests were made, as described elsewhere (Lowbury *et al.* 1964*b*), by a measured number of rubbings of the hands, palm to palm, palm over dorsum, and with fingers interlaced, using a bowl with 100 ml. Ringer's solution containing neutralizers (1% 'Lubrol W', 0.5% lecithin and 1% 'Tween' 80); counts of total viable bacteria were made after 48 hr. incubation of pour plates at 37° C. Tests for carry-over of antiseptic were made on plates obtained by either sampling method which showed no bacterial growth, and on control nutrient agar plates, by incubation of small numbers of *Staph. aureus* from calibrated dropping pipettes; numbers of staphylococci growing on test and control plates after 24 hr. incubation were compared.

Experiment 2

In 1960 (Lowbury *et al.* 1960) we reported that nurses working in the Burns Unit of the Birmingham Accident Hospital often carried *Staph. aureus* on their hands; after 1 min. rinsing of the hands in 70% ethyl alcohol the numbers of staphylococci sometimes fell in a proportion similar to the fall in numbers of total organisms, and sometimes in a larger proportion, from which we inferred that the staphylococci were sometimes carried as resident and sometimes mainly as transient bacteria of the skin.

We have repeated the experiment, but this time obtained samplings from nurses in all wards of the hospital, and used both a hand-wash sampling and a finger-streak technique in parallel. The medium used for these tests was a modification of phenolphthalein diphosphate (PPD) agar (Barber & Kuper, 1951) containing 1% horse serum. For detection of presumptive *Staph. aureus*, characteristic pink phosphatase-positive colonies were counted after a short exposure of the plates over a jar of ammonia. A selection of phosphatase-positive typical colonies were picked, tested by a tube coagulase method, and phage typed.

Experiment 3

Nurses in the wards of two other hospitals, a large general hospital (Dudley Road Hospital) and a hospital for diseases of the skin, were studied for the effects of a routine wash with soap and water and of disinfection with a solution containing 95% ethanol and 1% glycerol rubbed on the hands until they were dry; the effects were assessed, in parallel, by the standard hand-wash test and the finger-streak test.

The nurses streaked four fingers and thumb of one hand (control sample) on a nutrient agar plate containing phenolphthalein diphosphate (PPD) with 1% serum. This was followed by either (1) a routine short (untimed) wash, using non-medicated bar soap, followed by drying of hands on a paper towel, or (2) an application of 5 ml. 95% ethyl alcohol containing 1% glycerin, which was rubbed well into the hands until dry. The fingers and thumb of the other hand were then similarly streaked across a PPD serum agar plate (test sample). In tests on series of nurses, the left and right hands were used alternately for test and control sampling. Finally, both hands were sampled by a standard hand-wash

sampling technique in a sterile bowl containing 100 ml. of 0.75% lecithin-tween broth.

Colony counts were made from the washings by the method of Miles, Misra & Irwin (1938) using PPD and blood agar plates. Plates were incubated for 24 hr. at 37° C. and counts made of presumptive *Staph. aureus* (typical phosphatase producing colonies) and Gram-negative bacilli (GNB). Representative colonies of presumptive *Staph. aureus* were confirmed by the slide coagulase test and tested for antibiotic sensitivity; strains were also saved for phage typing if necessary. Presumptive Gram-negative bacilli were confirmed by Gram-negative staining and representative colonies were identified by the API system (Smith, Tomfohrde, Rhodes & Balows, 1972).

Nurses sampled

Nurses' hands were sampled at intervals in three wards at the hospital for skin diseases; 67 samples were taken from 16 nurses. Nurses were also sampled in a general hospital (Dudley Road Hospital); 112 samples were taken from 47 nurses. Nasal swabs were also taken from most of the nurses and cultured on PPD medium.

RESULTS

Experiment 1

Table 1 shows the results of parallel assessment, in terms of reduction of total bacterial colonies, by hand-wash sampling and by the finger-streak test, of five antiseptic preparations used for disinfection of the hands. There is a fairly good correlation between the results shown by the two methods. The ranking order of effectiveness corresponds in four of the tests (one and six applications of the most effective agent, alcoholic chlorhexidine, six applications of the least effective agent, bar soap, and one application of an agent of intermediate activity, aqueous chlorhexidine). Only one of the results (one application of tetrabrom-*o*-methyl phenol in alcohol) was considerably different by the two testing methods, but this was associated with a single highly anomalous result. Several of the preparations showed greater variance in tests by the finger-streak than by the hand-wash sampling tests, but the results with highly effective agents (e.g. alcoholic chlorhexidine and 4% chlorhexidine detergent solution) showed relatively low variance by both methods. Of the 21 experiments in which preparations compared with each other showed significantly different effectiveness by the hand-wash sampling test, 16 showed a significant difference also by the finger-streak test (see Table 2); no comparisons showed a significant difference by the finger-streak method but not by the hand-wash test. The numbers of observations in the series of finger-streak tests were smaller than those in hand-wash sampling series because several of the finger-streak samples yielded confluent growth of bacteria in which colony counts could not be made.

The parallel testing by hand-wash and finger-streak methods on single application of a larger series of antiseptic preparations is shown in Fig. 1.

Table 1. *Comparison of hand-wash and finger-streak sampling methods for assessment of skin antiseptics*

Antiseptic used	Hand-wash sample test			Finger-streak sample test			Number of subjects
	No. of applications	Mean percentage reduction in numbers of total bacteria after treatment	Ranking order of effectiveness	Mean percentage reduction in numbers of total bacteria after treatment	Ranking order of effectiveness		
(1) 0.5% chlorhexidine in 95% alcohol	1	97.9 ± 1.09	1	99.9 ± 0.10	1	6	
	6	99.7 ± 0.09	1	99.97 ± 0.03	1	6	
(2) 0.1% tetrabrom- <i>o</i> -methyl phenol in 95% alcohol	1	91.8 ± 4.63	2	59.0 ± 15.24	3	6	
	6	99.5 ± 0.17	2	90.8 ± 6.93	5	6	
(3) 4% chlorhexidine detergent solution	1	88.1 ± 2.43	3	98.6 ± 0.74	2	6	
	6	98.2 ± 1.6	3	99.5 ± 0.44	2	4	
(4) 0.5% chlorhexidine aqueous solution	1	65.1 ± 8.66	4	59.1 ± 13.15	4	6	
	6	91.8 ± 2.37	5	96.3 ± 2.48	4	6	
(5) 2% Irgasan DP 300 detergent preparation	1	22.4 ± 14.8	5	-36.0 ± 29.34	6	6	
	6	95.8 ± 1.8	4	98.7 ± 0.35	3	4	
(6) Soap and water (Control)	1	14.6 ± 2.87	6	-19.8 ± 21.6	5	5	
	6	30.5 ± 17.37	6	30.2 ± 19.69	6	5	

* ± = standard error of the mean.

Table 2. Comparison of hand-wash and finger-streak tests: significance of differences between mean reductions in total bacterial colonies by the two methods

Comparison of antiseptics	No. of applications	Hand-wash test		Finger-streak test		
		t	P	t	P	
1 and 3	1	3.670	< 0.01	1.737	> 0.1	
1 and 4		3.757	< 0.01	3.177	< 0.01	
1 and 5		5.074	< 0.001	4.632	< 0.001	
1 and 6		27.074	< 0.001	5.549	< 0.001	
2 and 4		2.718	< 0.05	0.031	> 0.9	
2 and 5		4.464	< 0.01	2.435	< 0.05	
2 and 6		14.149	< 0.001	2.348	< 0.05	
3 and 4		2.556	< 0.05	3.074	< 0.02	
3 and 5		4.369	< 0.01	4.586	< 0.01	
3 and 6		19.486	< 0.001	5.486	< 0.001	
4 and 5		2.485	< 0.05	2.926	< 0.02	
4 and 6		5.533	< 0.001	3.083	< 0.02	
1 and 4		6	3.329	< 0.01	1.486	> 0.1
1 and 5			2.685	< 0.05	3.721	< 0.01
1 and 6	4.394		< 0.01	3.928	< 0.01	
2 and 4	3.239		< 0.01	0.747	> 0.4	
2 and 5	2.527		< 0.05	1.138	> 0.1	
2 and 6	4.400		< 0.01	3.131	< 0.02	
3 and 6	3.429		< 0.02	3.898	< 0.01	
4 and 6	3.855		< 0.01	3.676	< 0.01	
5 and 6	3.304		< 0.02	3.854	< 0.01	

Experiment 2

Total bacterial and presumptive *Staph. aureus* counts were obtained on hand-wash and finger-streak samplings obtained from nurses in the Burns Unit and other wards of Birmingham Accident Hospital immediately before and immediately after a 1 min. standard rinse of hands and forearms with 70% ethanol.

Table 3 shows the mean percentage reduction in total bacterial counts obtained by the two sampling methods. The correlation was good, but there was a greater variance in the results obtained by the finger-streak than by the hand-wash samplings. The smaller number of observations in the series of finger-streak samplings was due to confluent growth in some of these tests which prevented colony counting.

Table 4 shows the frequency of isolation and numbers of presumptive *Staph. aureus* in samples obtained from the hands of nurses before and after disinfection with ethyl alcohol. A larger proportion of nurses carried *Staph. aureus* in the Burns Unit than in the other wards, but the numbers of *Staph. aureus* per 0.5 ml. washings were small, and none were found in samples taken after disinfection; two of the nurses working in other wards showed moderate or fairly large numbers of *Staph. aureus* in hand-washings, but very few or no staphylococci were found in samples taken after disinfection, suggesting that these organisms were carried as superficial transient rather than resident flora. Very few staphylococci were found on finger-streak samplings; three nurses lost staphylococci after disinfection,

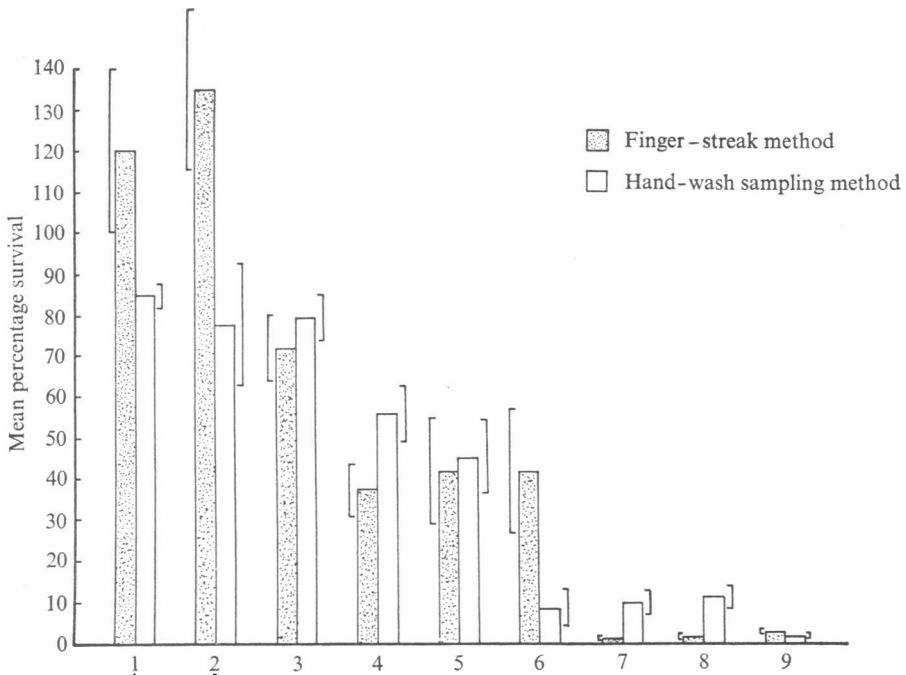


Fig. 1. Mean percentage survival of bacteria on skin, as shown by viable bacterial counts from finger-streak cultures (stippled columns) and from hand-wash samplings (white columns) after cleansing and/or disinfection of hands with (1) bar soap ('control'), (2) 2% Irgasan DP 300 detergent solution ('Zalclense'), (3) 0.75% Irgasan DP 300 bar soap ('Derl'), (4) a 3% hexachlorophane detergent cream ('Disfex'), (5) 0.5% chlorhexidine ('Hibitane') digluconate in water, (6) 0.1% tetrabrom-*o*-phenyl phenol in 95% ethyl alcohol ('Desderman'), (7) 0.5% chlorhexidine digluconate in 70% isopropyl alcohol, (8) 4% chlorhexidine detergent solution ('Hibiscrub'), and (9) 0.5% chlorhexidine digluconate in 95% ethyl alcohol. Detergent preparations were used with running water. Square brackets show standard errors of the means.

Table 3. Comparison of hand-wash and finger-streak sampling methods in assessing disinfection of nurses' hands with ethyl alcohol (Accident Hospital)

Nurses tested	Mean percentage reduction in total bacterial counts			
	Hand-wash sampling method	No. of nurses	Finger-streak sampling method	No. of nurses
Burns Unit	79.7 ± 9.4	7	67.7 ± 26.5	7
Other wards	75.2 ± 4.3	29	71.4 ± 7.9	15
Total	76.3 ± 3.9	36	70.2 ± 9.6	22

but in one nurse *Staph. aureus* was found only in the post-disinfection sample. One of the other nurses showed *Staph. aureus* on hand-wash sampling only in the post-disinfection sample.

Table 4. *Staph. aureus* on hands of nurses before and after alcohol disinfection (Accident Hospital)

Number of nurses sampled	Nurses with <i>Staph. aureus</i> on hands	Ward	Hand-wash sampling (counts of <i>Staph. aureus</i> in 0.5 ml.)		Finger-streak sampling (counts of <i>Staph. aureus</i> per 8 fingers)	
			Before	After	Before	After
			8	1	Burns Unit	9
	2	Burns Unit	2	0	0	0
	3	Burns Unit	1	0	1	0
	4	Burns Unit	16	0	0	0
	5	Burns Unit	35	0	0	0
29	6	Other wards	37	0	6	0
	7	Other wards	290	1	0	0
	8	Other wards	0	2	0	0
	9	Other wards	4	0	0	0
	10	Other wards	0	0	0	4

Table 5. Mean counts of *Staph. aureus* and Gram-negative bacilli per ml. hand-wash samplings after washing or disinfecting the hands

	After washing hands with soap and water		After disinfecting hands with ethanol	
	Dudley Road Hospital	Skin Hospital	Dudley Road Hospital	Skin Hospital
	Total bacteria	6305	8480	659
<i>Staph. aureus</i> , all washings	3.4	163	1.2	43
Washings containing <i>Staph. aureus</i>	185	287	35	126
Gram-negative bacilli, all washings	469	31.4	3.4	1.6
Washings containing Gram-negative bacilli	2150	550	32	30

Experiment 3

Tables 5, 6, 7, 8 and 9 show that 95% ethanol was more effective in reducing the numbers of *Staph. aureus* and of Gram-negative bacilli on the skin, as shown by finger-streak or hand-wash sampling methods, than was a routine wash with soap and water. A larger number of *Staph. aureus* remained on the hands after either treatment in the wards of the hospital for skin diseases than in the wards of the general hospital (Dudley Road Hospital), whereas the opposite occurred in the case of Gram-negative bacilli (Table 5).

Table 6 shows that *Staph. aureus* and GNB were more often detected by the standard hand-wash test than by the finger-streak technique. The difference between the techniques was greater with Gram-negative bacilli (hand-wash techniques, 22 isolations; finger-streak technique, 5 isolations) than with *Staph. aureus* (hand-wash technique 44 isolations; finger-streak technique 34 isolations). There was little difference between the two techniques in the isolation of *Staph. aureus* in the general hospital, but numbers were small.

Table 6. Comparison of hand-wash (bowl) and finger-streak sampling methods in assessing the removal of *Staph. aureus* and Gram-negative bacilli from the hands of nurses following treatment with ethyl alcohol or soap and water

Hospital	Treatment of hands	Nurses sampled	Nurses carrying <i>Staph. aureus</i> on the hands following treatment, shown by			Nurses carrying Gram-negative bacilli on the hands, following treatment, shown by		
			Both techniques	Bowl technique alone	Finger-streak alone	Both techniques	Bowl technique alone	Finger-streak alone
Dudley Road Hospital	Soap and water	56	6	4	1	2	10	0
	Ethanol	56	0	2	1	1	5	0
Skin Hospital	Soap and water	35	17	4	2	0	2	2
	Ethanol	32	4	7	3	0	2	0
	Total	179	27	17	7	3	19	2

Difference between effects of ethanol and soap: *v. Staph. aureus*: $\chi^2 = 6.33$, $P < 0.02$. *v. Gram-negative bacilli*: $\chi^2 = 2.09$, $P > 0.05$.

Difference between finger-streak and bowl sampling assessments:

soap and water *v. Staph. aureus*: $\chi^2 = 0.14$, $P > 0.05$.

soap and water *v. Gram-negative bacilli*: $\chi^2 = 4.99$, $P < 0.05$.

ethanol *v. Staph. aureus*: $\chi^2 = 0.86$, $P > 0.05$.

ethanol *v. Gram-negative bacilli*: (numbers too small).

Table 7. Range of colony counts in hand-wash samplings from hands after washing or disinfection

Range of colony counts per ml. of hand-wash sampling		Percentage hand-wash samplings yielding counts in each range			
		<i>Staph. aureus</i>		Gram-negative bacilli	
		After soap and water	After ethanol	After soap and water	After ethanol
Dudley Road	≥ 1000	2	0	5	0
Hospital	500-999	0	0	0	0
	100-499	4	0	2	2
	50-99	5	2	4	0
	1-49	7	2	11	9
	< 1	82	96	78	89
	Total samples	(56)	(56)	(56)	(56)
Skin Hospital	≥ 1000	6	0	0	0
	500-999	11	0	3	0
	100-499	6	19	3	0
	50-99	11	0	0	3
	1-49	26	16	0	3
	< 1	40	65	94	94
	Total samples	(35)	(32)	(35)	(32)

The range of colony counts obtained by the hand-wash sampling technique is shown in Table 7. This confirms the greater effectiveness of 95% ethanol, but also shows that *Staph. aureus* and Gram-negative bacilli were infrequently isolated in washings after either treatment; in the wards of the general hospital, 78.6-96.4% of washings showed less than one colony per ml. of *Staph. aureus* or Gram-negative bacilli. However, large numbers were occasionally present after treatment, and the mean count of Gram-negative bacilli (see Table 5) after a routine wash with soap and water was surprisingly high (469 per ml. in the wards of the general hospital).

Counts of organisms before and after treatment as shown by the finger-streaking method are presented in Tables 8 and 9. This again shows the infrequency of organisms on individual fingers and the general efficiency of treatment with ethanol.

The samples from the hands of 16 nurses in the hospital for skin diseases showed a variety of strains of *Staph. aureus* with 14 different antibiotic sensitivity patterns. Table 10 shows the isolations from the nose and hands of one nurse over a 15-day period. The strains from noses rarely corresponded with those from hands, which varied from day to day in most of the nurses sampled. Of the multi-resistant strains isolated from noses, the same type was found in two successive swabbings only on three occasions. A multi-resistant strain was isolated from the hands of 7 nurses on two consecutive days and not subsequently, and on three or four consecutive occasions in a further 3 nurses. Two of these nurses were also nasal carriers of the same strain. The multi-resistant strains isolated from the hands

Table 8. *Range of finger-streak sample counts before and after washing or disinfection*
 Finger-streak counts in range (per finger-streak)

Range of viable bacterial counts per finger-streak	Staph. aureus				Gram-negative bacilli			
	Before soap and water	After soap and water	Before ethanol	After ethanol	Before soap and water	After soap and water	Before ethanol	After ethanol
Dudley Road Hospital	100+	0	1	0	0	0	0	0
	11-100	1	1	0	8	3	5	0
	1-10	18	9	16	1	2	6	2
	0	259	270	262	279	275	269	278
Skin Hospital	100+	0	1	0	0	0	0	0
	11-100	13	6	10	1	2	0	0
	1-10	49	33	62	6	7	2	0
	0	113	135	87	153	173	158	160

Table 9. *Removal of Staph. aureus and Gram-negative bacilli from hands of nurses (finger-streak tests)*

Hospital	Treatment of hands	Isolation of bacteria from	Numbers of nurses and of fingers sampled which yielded				Numbers
			Staph. aureus		Gram-negative bacilli		
			Before treatment	After treatment	Before treatment	After treatment	
Dudley Road Hospital	Wash with soap and water	Nurses	13 (23.2%)	7 (12.5%)	12 (21.4%)	2 (3.6%)	56
		Fingers	21 (7.5%)	10 (3.6%)	23 (8.2%)	5 (1.8%)	280
	Disinfection with ethanol	Nurses	14 (25.0%)	1 (1.8%)	7 (12.5%)	1 (1.8%)	56
		Fingers	18 (6.4%)	1 (0.4%)	11 (3.9%)	2 (0.7%)	280
Skin Hospital	Wash with soap and water	Nurses	25 (71.4%)	19 (54.3%)	2 (5.7%)	2 (5.7%)	35
		Fingers	62 (35.4%)	40 (22.9%)	9 (5.1%)	2 (1.1%)	175
	Disinfection with ethanol	Nurses	26 (81.2%)	7 (21.9%)	2 (6.2%)	0	32
		Fingers	73 (45.6%)	7 (4.4%)	2 (1.2%)	0	160

Table 10. *Strains of Staph. aureus isolated from the nose and hands of a nurse in a dermatological ward*

Date of sampling	Antibiotic resistance patterns of strains from	
	Nose	Hands
15. vii. 1974	P T E K F L (±)	T P T E K F P T E K F L
16. vii. 1974	—	O
17. vii. 1974	—	P T E K F
22. vii. 1974	Sens (+ +)	T Sens
23. vii. 1974	—	O
24. vii. 1974	Sens (±)	P T E K F L
30. vii. 1974	Sens (±)	Sens

Sens, sensitive to all antibiotics tested; P, penicillin; T, tetracycline; E, erythromycin; K, kanamycin (or neomycin); F, fusidic acid; L, lincomycin; ±, scanty growth in nasal swab; + +, moderate growth in nasal swab; O, no *Staph. aureus* isolated; —, no swab taken.

of nurses corresponded with those isolated from lesions in the patients. The results suggest that, even in an area of heavy staphylococcal contamination, regular nose and hand carriage of ward strains is rare and does not usually persist for more than a few days.

DISCUSSION

The parallel assessment of alternative methods of skin disinfection by a hand-wash sampling and a finger-streak sampling technique showed fairly good correlation between the two methods in respect of reduction in numbers of total bacteria, but the finger-streak test results showed somewhat greater variance, and in some tests it was impossible to count the numbers of bacteria on the site of finger-streak inocula because of confluent growth of bacteria. It might be thought that finger-streak sampling would show only the transient bacteria of the skin because it takes up only the most superficial bacteria. However, the removal of the surface layer of bacteria on desquamating cells by cleansing or disinfection will reveal a new surface layer previously overlaid by the organisms removed; reduction in the proportion of total resident bacteria after disinfection shown by a surface sampling method might therefore be expected to parallel the reduction in resident bacteria shown by hand-wash sampling methods, and this was found to be the case.

In the case of pathogens the situation is more complex. Disinfection (e.g. by rinsing for 1 min. in 70% ethanol) will reduce the mean numbers of resident bacteria, as shown by reduced hand-wash sampling counts, by only about 60–70%. The transient bacteria, as shown by tests in which bacterial cultures applied to the skin were exposed to alcohol disinfection (Lowbury *et al.* 1960; Ayliffe & Babb, unpublished results), were completely or almost completely eliminated by such disinfection. The relative reduction in counts of total bacteria and of

pathogens (*Staph. aureus* and GNB) can, perhaps, be used as an index of resident or transient status of the latter; if the reduction in the numbers of staphylococci or GNB after disinfection parallels that of the total organisms, they can be regarded as behaving like residents; if their numbers fall, after disinfection, to a much greater degree than the numbers of total organisms fall, they (or much of their number) would appear to be transients. In our earlier studies (Lowbury *et al.* 1960) we found *Staph. aureus* on the hands of nurses in the Burns Unit of the Accident Hospital to be present, by this criterion, sometimes as resident and sometimes as transient organisms.

The effects of disinfection on *Staph. aureus* and Gram-negative bacilli shown in the studies reported above (see Table 4) threw further light on this subject, and have helped us to assess the relative usefulness of finger-streak and hand-wash sampling in assessing the value of disinfection against specific pathogens. In the studies at the Accident Hospital, *Staph. aureus* was found, by hand-wash sampling before disinfection, on 5 out of 8 nurses in the Burns Unit; only two of these showed *Staph. aureus* by finger-streak sampling. The numbers of *Staph. aureus* were smaller than those found on the hands of several nurses in our previous study (Lowbury *et al.* 1960); none were found after disinfection, but the numbers of *Staph. aureus* present before disinfection were too small to show, from this result, whether they were carried as resident or transient organisms. The apparent reduction in carriage of *Staph. aureus* by nurses in the Burns Unit, as compared with earlier findings, may be due to the much more frequent use of rubber or plastic gloves today, to the reduced incidence of infection, and to a smaller proportion of extensively burned patients, in the wards. In other wards of the hospital a smaller proportion of nurses (3 out of 29) were shown to be carrying *Staph. aureus*; only one of these nurses showed *Staph. aureus* on finger-streak sampling. One nurse (no. 7) showed large numbers of *Staph. aureus* in the hand-wash sampling before disinfection, and only one colony from 0.5 ml. hand-washings after disinfection; this was presumably a superficial contaminant which had not been removed by the 'social' wash before the pre-disinfection sampling, and probably localized, as the pre-disinfection finger-streak sample did not show the presence of *Staph. aureus*. Since more nurses were found to be carrying *Staph. aureus* by the hand-wash technique than by the finger-streak technique, the former appeared to be more useful as a method of assessing the numbers of specific organisms on the skin and the efficacy of disinfection in reducing their numbers.

More data about the effects of disinfection on *Staph. aureus* and also on Gram-negative bacilli by hand-wash and finger-streak sampling were shown in studies at a large general hospital and at a hospital for disease of the skin. These showed that in samplings taken after a wash with soap and water, more nurses in the skin hospital than in the general hospital carried *Staph. aureus*; this was shown both by hand-wash and by finger-streak tests. Gram-negative bacilli, on the other hand, were more commonly found on the hands of nurses in the general hospital than at the skin hospital. A comparison of counts after washing with soap and water and after disinfection with 95% ethanol showed, in both hospitals and by both sampling methods, a larger proportion of nurses with no *Staph. aureus* after

ethanol disinfection than after soap and water washing. The possible resident status of *Staph. aureus* on the hands of some nurses was suggested by the fact that the ratio of numbers of *Staph. aureus* after washing to that found after disinfection was similar to the corresponding ratio in numbers of total organisms. Since a single washing with soap and water has a negligible effect on the numbers of total organisms (e.g. Lowbury, 1973), this suggests that *Staph. aureus* was present as a resident organism on the hands of these nurses. Gram-negative bacilli on the other hand were much less numerous after disinfection than after washing.

The discrepancy between the standard hand-wash and finger-streak tests in Experiment 3 was mainly due to the carriage of large numbers of Gram-negative bacilli on the hands of nurses in the general hospital. It seems likely here that although the finger tips are the main areas of contact for *Staph. aureus* the whole hand is more likely to be contaminated with GNB in certain circumstances (e.g. handling a urinal, or after washing an incontinent patient).

Since GNB are unlikely to have been colonizing the undamaged skin, it seems probable that a short routine wash with soap and water was sometimes inadequate for the removal of transient organisms. Carriage of *Staph. aureus* on the hands was infrequent in general wards, both before and after washing. In the wards of the skin hospital, carriage was more frequent and organisms were more difficult to remove by routine washing. This may be due to difficulties in physical removal, because of a residue of ointment on the hands, or because *Staph. aureus* was behaving as a resident. The results of phage typing suggest that in highly contaminated areas, such as dermatology wards, strains may become temporary residents, remaining for a few days only, but daily recontamination with the same strains cannot be excluded.

The relevance, in terms of transferring infection, of the numbers of surviving *Staph. aureus* or GNB after hand treatment is uncertain. In general wards the mean counts of *Staph. aureus* were little higher after washing with soap and water than after treatment with alcohol, though 2% of samples showed more than 1000 organisms per ml. after washing with soap and water. If an acceptable count in washings after treatment were considered to be 100 *Staph. aureus* or GNB per ml., only 2% samplings after treatment with alcohol were unacceptable in the general hospital, whereas 19% were unacceptable in the hospital for skin diseases. The results with soap and water washing in the skin hospital were much less satisfactory and probably unacceptable. However, the routine washing procedure was usually less than 30 sec.; washing for at least 1 min. by a correct technique would probably lead to a considerable reduction in the number of surviving organisms.

A previous study showed that an application of alcohol was at least as effective as washing with soap and water in reducing the numbers of potential pathogens on the hands of nurses (Noy *et al.* 1974). The more extensive study reported in this paper shows that ethyl alcohol is more effective in this respect than soap and water. Colonization or heavy contamination of the hands with *Staph. aureus* was uncommon in wards of the general hospital and less common in the Burns Unit today than it was in an earlier study (Lowbury *et al.* 1960). A thorough

wash with soap and water might, therefore, be adequate for normal use in general medical and surgical wards, but an application of alcohol or of another effective antibacterial preparation (e.g. an antiseptic soap or detergent preparation) must be considered necessary or at least desirable in special areas and for certain aseptic procedures.

The application of alcohol to the hands for wound-dressing and other aseptic procedures has other advantages. It can be applied at the bed-side; wash-basins, soap and containers, and towels are unnecessary. The hand preparation technique is therefore safer as well as more effective than a soap and water wash, and time is saved.

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