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Failure of hand disinfection with frequent hand washing: a need for prolonged field studies

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SUMMARY

In a prolonged field trial a 4% chlorhexidine digluconate detergent scrub (Hibiscrub^{R}), that had earlier proved to be an effective hand disinfectant, was studied in hospital wards. Finger tips were found to harbour more bacteria than the hand dorsum and the samples collected from them yielded more information on the bacteriological and dermatological effects of hand disinfectants in practice.

In wards with a relatively low hand-washing frequency (less than 20 times in 8 hours) the bacteriological results resembled those obtained by in-use tests with volunteers. In the neonatal unit where the hand washing frequency was remarkably high, even occasionally over 100 times/8 h shift, an increase in the bacterial colony counts of the majority of the staff was recorded both before and after hand washing already after using the preparation for 1 week. Age, occupation and hand-washing frequency all correlated with the bacteriological results. Twenty-seven out of 37 persons complained of side effects such as wounds of finger tips and redness or heavy drying of the skin. Wounds, particularly on finger tips, resulted in the failure of disinfection. An increase in bacterial counts was sometimes noted without any dermatological or subjective changes. Drying of the skin was complained of less often when no increase in skin bacteria occurred.

After the changeover of washing practice to a detergent followed by a rinse with spirit solution containing chlorhexidine and glycerol a decrease was recorded in the bacterial counts. It is concluded that more attention should be paid to long-term testing of hand washing and disinfection methods to ensure optimum final results in practice. It is obvious that the knowledge obtained from short time in-use testing cannot be applied to all conditions of use.

INTRODUCTION

Hand washing is generally regarded as one of the most important measures in preventing nosocomial infections. The use of hand disinfectants may further increase hand hygiene. Several studies have evaluated the effectiveness of disinfectants used in surgical hand washing (Lowbury & Lilly, 1960, 1973; Lowbury, Lilly & Bull, 1960, 1964*a*, *b*; Joress, 1962; Lilly & Lowbury, 1971, 1974), but only few studies deal with hand washing and disinfection in wards (Bruun, Bøe & Solberg, 1968; Wilson, 1970; Ojajärvi, 1976). The latter studies have either been

performed in laboratory conditions or as in-use tests of short duration with selected test persons. The information thus obtained, however, may not be relevant in hospitals.

The purpose of this study has been to measure the antimicrobial effectiveness and effects on the condition of the skin of a hand disinfectant that in earlier studies has been found microbiologically effective. The study was carried out during a prolonged period in hospital wards with varying hand-washing frequencies of the staff.

MATERIALS AND METHODS

(1) In the first phase of the study 4% chlorhexidine digluconate detergent scrub (Hibiscrub^{R}, ICI Ltd) was used for hand washing and disinfection in The Radiotherapy Clinic, University of Helsinki. The study group consisted of nurses, auxiliary nurses and laboratory technicians, altogether 26 persons (Table 1).

From the second week onwards the finger tips and the dorsum of hands were sampled for bacteria on week-days for 2 weeks. Cultures were taken before and after hand washing. The total number of hand washing events was 187. Each person was thus sampled on an average of seven times during the 2 weeks.

Table 1. *The mean ages and hand-washing frequencies of study groups*

	Number of persons	Mean age (years)	Hand-washing freq./8 h	
			Mean	Range*
The Radiotherapy Clinic	26			
Laboratory	9	37	10	
Out-patient ward	9	36	15	
Ward	8	26	20	
The Children's Hospital, neonatal unit	37			
Nurses	14	27	27	(10, 39)
Auxiliary nurses	23	34	42	(26, 56)

* Range of individual hand-washing frequencies.

(2) In the second phase of the study the same chlorhexidine emulsion (Hibiscrub^{R}) was used at the neonatal unit of The Children's Hospital, University of Helsinki. The unit consists of two separate wards for altogether 44 patients. The patients of the ward are newborn and premature babies. The staff changes internally between the wards. The staff works in 8-h shifts. During the night shift the hand-washing frequency may occasionally exceed 100 times.

Initially 47 persons participated in the trial. Four nurses and 6 auxiliary nurses were excluded because of too few samplings. The mean age and hand-washing frequencies of the remaining 14 nurses and 23 auxiliary nurses are shown in Table 1.

Before the onset of the study the ward had been using liquid detergent (contains: triethanolamine soap, coconut diethanol amide, polyethylene glycol and glycerol) for hand washing. After washing and drying the hands were disinfected

with a solution of 0·5 % chlorhexidine digluconate and 5 % glycerol in 70 % (w/v) ethanol later referred to as 'spirit solution'. The solution was rubbed on hands until dry. After the examination of the hands by the dermatologist the unit changed over to chlorhexidine emulsion. The preparation was used for 4 weeks during which the skin of the hands was sampled daily for 5 days of each week (Fig. 1). After this 4-week period the unit changed back to the former practice of hand washing with detergent and spirit solution for 2 weeks, with sampling on 5 days each week as before. After an interval of 2 weeks, hands were sampled again for 5 consecutive days. During the use of chlorhexidine emulsion bacterial cultures were taken altogether at 370 hand-washing events and during the use of detergent and spirit solutions at 228 events. Samples were obtained daily on an average from 19 persons.

Bacteriological samples

After an approximately 15 s washing of hands and forearms according to strict ward routine the hands were carefully rinsed with water and dried with a disposable paper towel. The faucet was turned off with a non-touch technique. Special care was paid to rinsing of hands before sampling to avoid the carry-over of possible remnants of the disinfectant to bacterial plates.

After the skin was dry the finger tips were sampled for bacteria, by pressing four fingers of both hands, one hand at a time, on the surface of blood agar medium whereafter the thumbs were pressed on the middle of the plate. Before and after washing samples were also taken from the hand dorsum by a contact plate (Hall & Hartnett, 1964). The medium was nutrient agar with 1 % Tween 80 (meat extract (Difco), 3 g, peptone (Evans) 10 g, NaCl 5 g, agar 9 g, 50 % yeast water 20 ml, water to 1 litre). The samples were taken by the same two persons throughout the study. On night shift nurses took samples themselves according to the given instructions.

The plates were incubated overnight at 35 °C before counting of colonies. The plates were left at room temperature for another day to let the pigmentation of *Staph. aureus* colonies develop. The identification of *Staph. aureus* strains was based on colony morphology, coagulase positivity and pigmentation, that of gram-negative bacilli on colony morphology, gram-staining and biochemical reactions. The phage typing of staphylococci was done by using the international set of phages initially obtained from Public Health Laboratory Service, London.

The personal acceptability of the preparations and the dermatological evaluation

At the beginning of both studies the participants were seen by the dermatologist who checked the condition of the skin of the hands. In the first phase of the study (The Radiotherapy Clinic) the staff was interviewed to discover the effects of the hand-washing practices. In the second part of the study (The Children's Hospital) the participants were seen by the dermatologist after 2 weeks use of Hibiscrub^{R} and 1 week after the change-over to the previous routine of hand washing with detergent and spirit solution. The interviewing of the staff for the personal acceptability and the history of previous skin symptoms was done after the change-over to detergent and spirit solution.

Statistical methods

Student's *t*-test was used to test the differences between percentages. The multivariate linear regression and discrimination analyses (Cooley & Lohnes, 1962) were performed by the statistical program packages of a Burroughs 6700 computer. Moving averages of order 5 were used to smooth the curves (Spiegel, 1961).

RESULTS

Total bacterial counts

The mean bacterial colony count of the finger tips of the staff (first phase of the study) before the hand washing was 48 colonies, after it 7 colonies. Before the hand washing the ward staff had the lowest mean, 9 colonies, laboratory and outpatient staff had a mean of 57 colonies. After hand washing the mean colony count of the ward staff was also the lowest. High counts were obtained from the hands of 7 persons, on an average 21 colonies. One of them was a nurse who had had an atopic eczema. *Str. pyogenes* strains were frequently found on her finger tips before hand washing, but not after it. Another one was a permanent *Staph. aureus* carrier and three other persons had a history of mild allergy or irritation of the skin. Two of them only occasionally had high colony counts on the finger tips. The mean colony counts of the remaining 19 persons after hand washing was only 2 colonies. None of them had previously had special problems with the skin of their hands.

The total colony counts of the hand dorsum were low in all groups: the mean daily figure was 10–19 colonies before washing and 1–6 colonies after. Counts exceeding 100 bacteria were recorded in only two events, both before washing. *Staph. aureus* and gram-negative bacilli were isolated in less than 3% of the samples both from the finger tips or hand dorsum. In most cases the counts were less than 10 per sample.

In the neonatal unit with the high hand-washing frequency, the mean colony counts increased in 1 week's time during the use of chlorhexidine emulsion in the samples both before and after hand washing (Fig. 1). The increase was more pronounced before hand washing. The colony counts again decreased after the staff returned to the previous practice with detergent and spirit solution. The same phenomenon was less obvious in the colony counts of the hand dorsum.

No single factor, such as hand-washing frequency, age, occupation or the condition of the skin of the hands was found to be responsible for the increase in the colony counts. Therefore, graphs of successive colony counts of each person were drawn. The pattern of the graphs divided the persons into three main groups:

Group 1. The colony counts of the finger tips showed increase both before and after hand washing during the use of chlorhexidine emulsion. After 2 weeks' use the mean counts after washing were even higher than those before washing in the beginning of the study period. The counts fell to the earlier lower level after returning to the previous routine of washing with detergent and spirit solution. Five of the 14 nurses and 12 of the 23 auxiliary nurses belonged to this group (Fig. 2A).

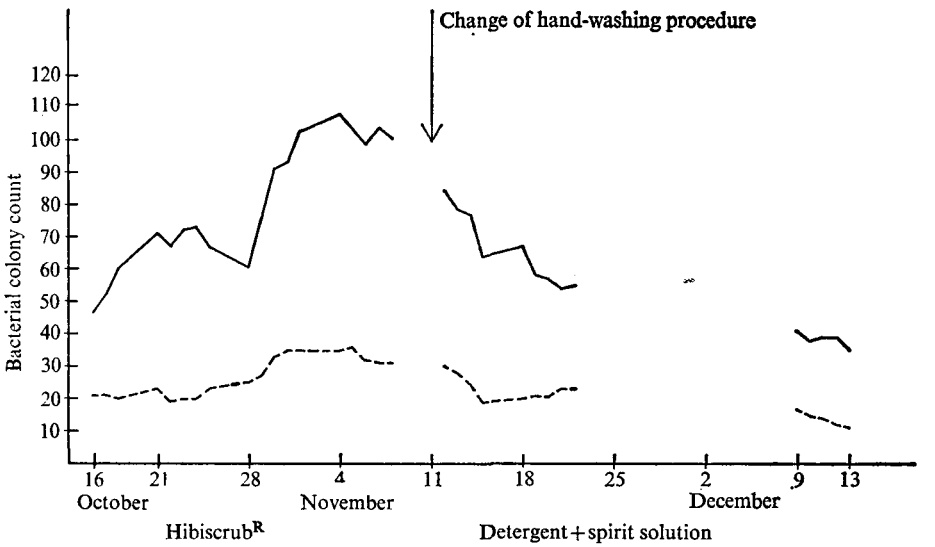

Fig. 1. Daily mean bacterial colony counts of finger tips of the staff (the neonatal unit, Children's Hospital). ——, Before hand washing; – – –, after hand washing.

Table 2. *Characteristics of three groups formed on the basis of successive bacterial colony counts of the hands (the staff of the neonatal unit, Children's Hospital)*

	n	Occupation	Mean age	Mean hand-washing freq./8 h
Group 1 (high counts during Hibiscrub, lower levels after change-over to detergent and spirit solution)	5 12	Nurses Aux. nurses	33{27 35	40{26 46
Group 2 (continuously high counts during the study)	2 8	Nurses Aux. nurses	35{32 35	33{13 38
Group 3 (continuously low counts during the study)	7 3	Nurses Aux. nurses	26{27 26	34{32 40

Group 2. The colony counts of the hands after washing were high during the use of Hibiscrub^R emulsion, but stayed at the same level even after the change of hand-washing practice (Fig. 2B). Two nurses and 8 auxiliary nurses were in the group.

Group 3. The colony counts of the hands were low after washing throughout the study (Fig. 2C). Somewhat higher colony counts before washing were recorded even in this group before the change-over of the hand-washing practice. Seven nurses, but only 3 of the 23 auxiliary nurses, were in this group.

According to the daily records kept by each person the individual hand-washing frequencies were unchanged throughout the study period. The auxiliary nurses belonged more often than the nurses to groups 1 and 2, in which the total colony counts were higher. Their hand-washing frequency and mean age were higher than that of the nurses (Table 2). The mean age was the lowest in group 3, but the

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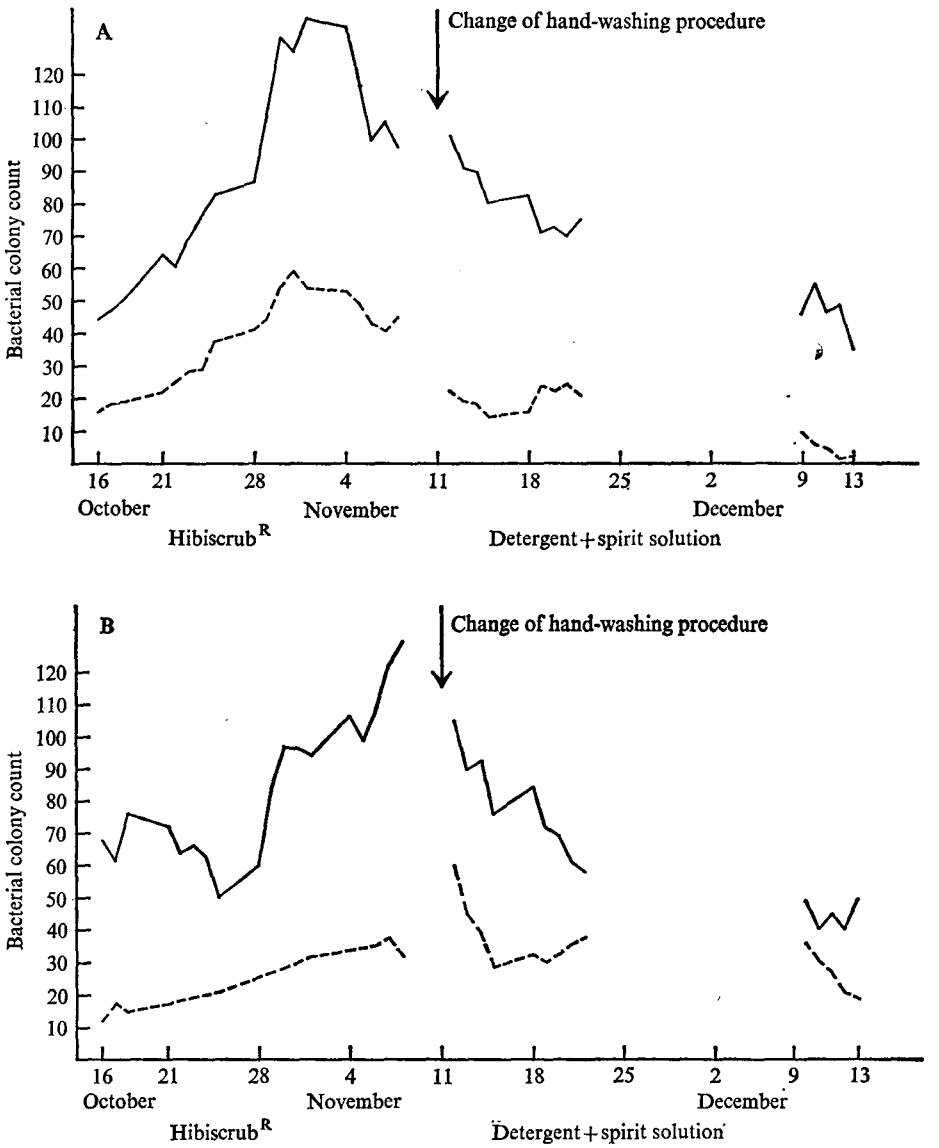

Fig. 2A and B.

hand-washing frequency was virtually the same as in group 2. The washing frequency was highest in group 1. Seven of 10 married persons were in group 2. Thus persons of this group more often had a household of several persons. All three persons with a household of more than four persons belonged to group 2.

For the regression analysis groups 1 and 2 were combined. The distribution of the persons into these groups in which the colony counts were higher, or into group 3 with lower colony counts, was best explained by age and occupation ($P < 0{\cdot}01$ and $P < 0{\cdot}02$, respectively), but not by the hand-washing frequency. Since this was partly due to the high correlation between hand-washing frequency and occupation, a discrimination analysis was performed. On the first function

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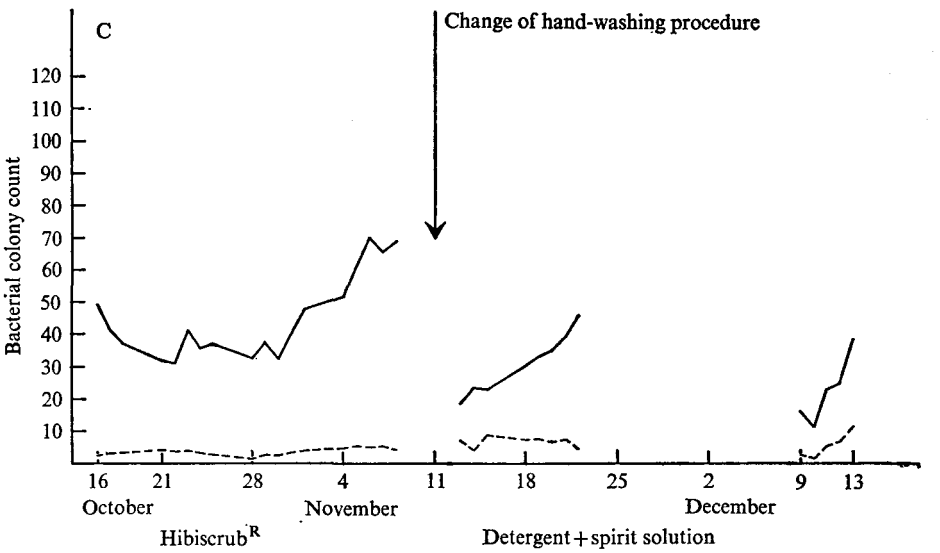
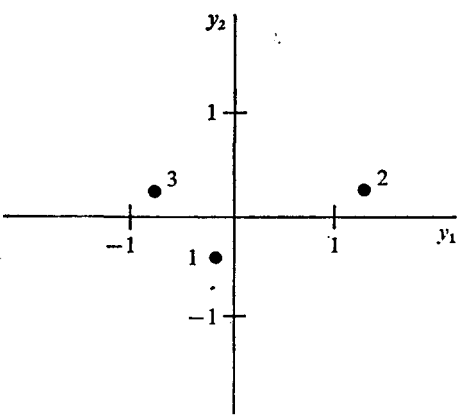


Fig. 2C

Fig. 2. (A) Daily mean bacterial colony counts of persons of (A) group 1, (B) group 2 and (C) group 3 (see text). ——, Before hand washing; – – –, after hand washing.

	Function 1	Function 2
Variable 2 (age)	0·646	−0·538
Variable 3 (hand-washing frequency)	−0·115	−0·964
Variable 4 (occupation)	0·577	−0·646

Correlations between variables and discriminating functions.



Group means in discriminant space

Fig. 3. Multiple discrimination of groups 1, 2 and 3 (see text).

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Table 3. *The isolation frequencies (percentages of positive samples) of* Staph. aureus *and gram-negative bacilli on finger tips and hand dorsum (the staff of the neonatal unit) during the use of the two hand-washing practices studied*

	Before hand washing			After hand washing		
	Chlorhexidine emulsion (n = 370) (%)	Detergent and spirit solution (n = 230) (%)	P-value (t-test)	Chlorhexidine emulsion (n = 370) (%)	Detergent and spirit solution (%)	P-value (t-test)
Finger tips						
Staph. aureus	16·8	8·3	$P < 0·01$	7·3	3·5	$P < 0·05$
after exclusion of two staph. carriers	11·6*	4·7†	$P < 0·01$	4·1*	1·7†	NS
Gram-negative bacilli	11·4	7·9	NS	3·2	1·7	NS
Hand dorsum						
Staph. aureus	6·2	2·2	$P < 0·05$	0·5	1·3	NS
Gram-negative	2·4	2·6	NS	0·8	0·9	NS

* n (total number of samples) = 344.
† n = 211.
NS = the difference between figures statistically not significant ($P > 0·05$).

group 2 was discriminated from the other two groups by age and occupation (Fig. 3) (older auxiliary nurses were typical to this group) and these two variables were found to correlate strongly to this function. On the second function group 1 was discriminated from other groups by hand-washing frequency.

The occurrence of Staphylococcus aureus *and gram-negative bacilli*

During the use of chlorhexidine emulsion *Staph. aureus* were found on finger tips in 16·8 % of the samples before hand washing, after it in 7·3 % (Table 3). The figures were thus considerably higher than those of the first phase of the study. Two *Staph. aureus* carriers repeatedly showed abundant amounts of coagulase positive staphylococci. After exclusion of these two the figures were 11·6 and 4·1 %. In each case the number of colonies varied from a few to 30, the number seldom exceeding 100.

After the ward had returned to the previous hand-washing routine with detergent and spirit solution, *Staph. aureus* were isolated less often than during the use of chlorhexidine emulsion. Excluding the two *Staph. aureus* carriers, the isolation frequency of *Staph. aureus* before hand washing was 4·7 %. This figure is significantly smaller than that found during the use of chlorhexidine emulsion ($P < 0·01$, Table 3).

Staphylococci were isolated less often from the dorsum of the hand than from finger tips (Table 3). They were also isolated less often during the use of detergent and spirit solution than during the use of chlorhexidine emulsion. Only one *Staph. aureus* carrier showed staphylococci frequently on the dorsum of the hand as well as on the finger tips.

Table 4. *Skin reactions reported by staff of the neonatal unit during the use of chlorhexidine emulsion (groups* 1, 2 *and* 3; *see Table* 2)

	Group 1	Group 2	Group 3	Total
Wounds on finger tips	5	2	—	7
Redness of the skin	3	1	2	6
Severe drying	4	6	4	14
Mild drying/no complaints	5	1	4	10

The phage type 77+ excreted by the other carrier was occasionally cultured from the hands of other persons, from 9 persons during the use of chlorhexidine emulsion and from 3 during the use of detergent and spirit solution.

Gram-negative bacilli were isolated from finger tips with about the same frequency as *Staph. aureus* (Table 3). During the use of Hibiscrub^{R} gram-negative bacilli were isolated more frequently from persons of group 2 than from persons of the other groups. This difference was highly significant ($P < 0{\cdot}001$).

Effects on the skin

During the use of chlorhexidine emulsion 7 persons (6 auxiliary nurses and 1 nurse) complained of minor fissures of finger tips and simultaneous severe drying of the hands (Table 4). All of them belonged to groups 1 or 2. Three persons reported previous drying of the hands, and two others had often had signs of skin irritation. The remaining two persons had not had difficulties with their skin before. Another nurse had chapping of the skin of the dorsum of the hand during the first week of the study but the reaction disappeared later.

Six persons (5 auxiliary nurses, 1 nurse) complained of redness of the skin during the use of chlorhexidine emulsion. One of them was allergic to turpentine, another one had previously had occasional skin irritation. The persons were evenly distributed in groups 1, 2 and 3.

Fourteen other persons complained of heavy drying of the skin (with no fissuring or redness) during chlorhexidine emulsion. The remaining 9 persons complained of minor drying of hands with no special problems. The mean hand-washing frequency of these two latter groups was 37 times per shift, that of the persons complaining of fissures or redness of the skin 43 times per shift. The difference is statistically significant and shows that the appearance of more serious skin reactions (wounds, redness) correlates with the hand-washing frequency ($P < 0{\cdot}005$). The groups did not differ by age.

In group 1, 12 of 17 persons complained of wounds, redness or severe drying (Table 4). In group 2, 9 of 10 persons and in group 3, 6 of 10 persons complained of these severe symptoms. Four out of 8 persons with a history of skin irritation belonged to group 1. Most of those reporting a history of skin dryness belonged to group 2.

Although the bacterial colony counts increased in the course of the study the clinical condition of the skin proved to be fairly good, if only slight discomfort or drying was complained of. The dermatologist confirmed the dryness of the skin of 6 out of 7 persons later complaining of fissures. Four of 6 persons complaining

of skin redness, as well as most of the persons complaining of severe drying of the skin, also had dry skin at the dermatological examination. All the persons with pronounced dryness of the skin belonged to groups 1 or 2, the drying in group 3 was only mild or partial.

DISCUSSION

It is not unusual for the nursing staff to complain of irritation of the skin of the hands caused by soaps, detergents or hand disinfectants. An auxiliary nurse working in our hospital got a severe toxic eczema after using a new hand disinfectant and was compelled to quit her work for several months. Since the disturbances of the skin have been claimed to lead to difficulties in cleansing of the skin (Walter, 1965; Walter & Kundsin, 1969; Bruun & Solberg, 1973), both dermatological and bacteriological evaluations were made in the study.

The technique chosen for the sampling methods was the 'finger printing method', since the finger tips are the parts of hands most likely to acquire and transmit transient contaminants. The results obtained by this method of sampling – as well as by the finger-streaking method – have been found to be in accordance with those obtained by hand washing technique (Ayliffe *et al.*, 1975; Ojajärvi, unpublished results). The simplicity of the method makes it possible to carry out prolonged studies in practical conditions. Since the signs of skin irritation often first appear on the dorsum of the hand where the skin is thin, it was selected as the other sampling site.

In preliminary laboratory experiments it was found that, when the hands were carefully rinsed with water and were dry at the moment of sampling, no detectable amounts of disinfectants were transmitted to culture media, even with no addition of neutralizing agents. The colony counts of the hand dorsum were low throughout the study compared with those of the finger tips. The sampling of the finger tips seems to be more informative and is thus to be preferred in this type of field study.

The good bacteriological results of the first phase of the study were in accordance with those obtained by the short-time in-use tests with volunteers using chlorhexidine emulsion Hibiscrub^{R} (Lowbury & Lilly, 1973; Ojajärvi, 1976). The only exceptions were a few persons with sensitive skin. Even these persons did not claim any special skin problems during the study period. The failure to disinfect the rough or eczematous skin earlier noticed in tests with volunteers (Ojajärvi, unpublished) was seen already in this part of the study.

Increase in the bacterial colony counts of the hands during the use of chlorhexidine emulsion was recorded in the neonatal unit where the hand-washing frequency of the staff was remarkably high. The appearance of fissures on the finger tips and redness of the skin are a sign of a toxic influence of a product (Polano, 1968). Eleven of 13 persons complaining of these skin symptoms belonged to groups 1 or 2 in which 'failures of disinfection' were recorded and higher colony counts were seen after a few weeks use of chlorhexidine emulsion.

The degree of dryness of the skin of the hand was found difficult to assess both by the dermatologist and by the persons themselves and a clear correlation

between drying and bacterial results was not found. It is noteworthy that even though no change was noticed on the skin, there could be an increase in bacterial colony counts. The increase in the microcolonization may predict future worsening of the skin.

When the two groups formed on the basis of successive bacterial colony counts of the individuals (the dependent variable) were studied by regression analysis, all the variables (age, occupation and hand-washing frequency) strongly correlated with this variable. Since the groups were too small to standardize them by age and occupation the discrimination analysis was performed to reveal the effect of hand-washing frequency on the bacteriological results, although the method is slightly too sophisticated for this kind of small-scale study. On the second function it was found that the hand-washing frequency had the highest correlation with the dependent variable. This indicates that the hand-washing frequency had an effect on the bacteriological results even though the effect was hidden by other variables (age and occupation).

Auxiliary nurses and older persons were more often in groups where higher colony counts were common. This may be explained by the different nature of the nurses' and auxiliary nurses' career. The nurses get to leading positions with less nursing contact and less wear of the skin of the hands as they get older. Auxiliary nurses have the same kind of work independently of age. The persons with large households more often got into group 2 in which the colony counts of the hands were high independent on the washing procedure. After the change-over of hand-washing practice the skin symptoms of the staff started to subside and fewer complaints of skin disorders have arisen when detergent and spirit solution has been used for several months thereafter.

The phage type of a *Staph. aureus* carrier was occasionally isolated from the hands of the other staff during the study. No clinical infections caused by this strain were, however, verified. The finding suggests that the transmission of staphylococci by a carrier may be more difficult to prevent than, for example, that originating from the sources of the inanimate environment. Fortunately, the strains of carriers are often less pathogenic, but the risk that they may shed virulent staphylococci still exists. The bacterial reduction rate of a disinfectant varies in practice from person to person and even individually. Despite the high reduction rate, bacteria may stay on finger tips and the risk of cross infection may thus increase. Therefore notice should also be paid to the skin, and the efficient washing and disinfection practice together ensure the optimum result.

This study emphasizes the importance of field evaluation of hand disinfectants in hospitals. The results do not refute those of previous studies, but complement them. The knowledge obtained from the short-time in-use testing is applicable to the washing of hands at the 'normal' frequency, but cannot be applied to all hospital practices and all individuals. It should be noted that the study was conducted in winter when the relative humidity in Finland is very low. The hands are thus subjected to greater drying than in countries with higher atmospheric humidity.

No attempt was made to find out the part in the composition responsible for

skin irritation. This irritation is probably caused by detergents in the preparation. Washing of the hands with any medium tends to dry the skin. For atopic persons frequent washing even with plain water may be harmful. The use of hand emollients in the ward is not desirable because of the risk of contamination (Knights & Harvey, 1964; Rubenstein & Morse, 1967; Morse & Schonbeck, 1968; France, 1968); therefore hand disinfectants or other hand-washing agents should not be too damaging to the skin.

In this study, age, occupation of the staff and hand-washing frequency were found to correlate with the microcolonization of the skin. Special care should therefore be taken not to place staff with a history of possible allergy to areas of high aseptic demands, since their skin will suffer from frequent hand washing, and the risk of cross infection increases. The skin of older persons is also less resistant to wear.

The content of glycerol in spirit solution during the study was rather high, 5%, and it has been later decreased to 2%. The colony counts of the hands have still remained low, but the complaints of skin irritation have somewhat increased. The disinfection of the hands with spirit solution presupposes careful guidance, since the disinfection result varies depending on the technique and the amount of spirit used (Ojajärvi, 1976).

In the evaluation of hand disinfectants the antimicrobial effectiveness is important. More attention, however, should be paid to the condition of the skin of the staff to ensure optimum results also in practice. The ultimate goal is to promote the safety of the patient, but the working ability of the nursing staff must also be protected.

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