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Effectiveness of hand washing and disinfection methods in removing transient bacteria after patient nursing

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SUMMARY

The effectiveness of various hand washing and disinfection methods in removing transient skin bacteria was studied in hospital after dry or moist contamination of the hands when nursing burn patients. The results were compared with those of laboratory tests with volunteers. A fairly good correlation of the bacterial reductions existed between hospital and laboratory tests. All other methods removed *Staph. aureus* from the hands more effectively than liquid soap. Gram-negative bacilli were more easily removed than staphylococci, even with soap wash alone.

In hospital, none of the washing and disinfection methods always removed all patient-borne bacteria from the hands. After dry or moist contamination and subsequent washing with soap only, colonies of *Staph. aureus* were often detected in finger-print samples. Staphylococci were more often completely removed by a 4% chlorhexidine detergent scrub and alcoholic solutions (either with or without previous soap wash) than by liquid soap, hexachlorophene or iodophor preparations. Gram-negative bacilli were more easily removed by all the washing and disinfection methods. After moist contamination, Gram-negative bacilli were more often completely removed from the hands by ethanol than by other treatments.

The results of the present study emphasize the importance of always using gloves when nursing a profuse spreader of bacteria or one who must be protected from infection.

INTRODUCTION

The main goal of hand washing in hospital is to cut the route or transmission of pathogenic micro-organisms to patients. Usually the removal of transient microbes is sufficient, although in special circumstances the reduction of resident bacteria is of additional advantage. The effectiveness of some disinfectants in removing various transient bacteria has been studied in a simplified test design after artificial contamination of the hands (Lowbury, Lilly & Bull, 1964; Mittermeyer & Rotter, 1975; Lilly & Lowbury, 1978). Such studies, however, overlook many variables common in everyday hospital practice. In hospital, prolonged use of soaps or disinfectants, high hand washing frequency, differences in the skin of hospital staff or other factors may yield results unlike those obtained in tests with volun-

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teers who normally have good skin and a short history of hand washing (Ojajärvi, Mäkelä & Rantasalo, 1977). Only few field studies have been conducted comparing the effectiveness of various treatments on transient hand contaminants (Brodie, 1965; Ericson, Juhlin & Willard, 1968; Sprunt, Redman & Leidy, 1973; Ayliffe *et al.* 1975) and their conclusions have been somewhat contradictory.

The purpose of the present study has been to evaluate the effectiveness of some customary hand washing and disinfection methods in removing patient-borne bacterial contamination of the hands in hospital. In-use tests in laboratory conditions were also carried out to compare the results with those obtained in hospital.

MATERIALS AND METHODS

Tests in the laboratory

The study group consisted of nine physicians with no skin problems. None of them was working with patients at the time of the study. A bacterial suspension was prepared by growing bacteria (*Staph. aureus* 209, Oxford strain, or *Pseudomonas aeruginosa* NCTC 6749) in nutrient broth overnight. The suspension was then centrifuged and bacterial cells resuspended in sterile physiological saline with a density of 10^7 bacteria/ml. The hands were contaminated by pressing the fingertips against a gauze moistened in the bacterial suspension. After contamination the hands were allowed to dry for 2 min. A sample was then taken from the fingertips of one hand by rubbing them against each other in 50 ml of a mixture of 10 % nutrient broth and saline with neutralizers (3 % Tween 80 and 2 % lecithin).

The hands were washed with 5 ml of the preparation studied for 15 s or 2 min and rinsed carefully with water. The hands were shaken dry before sampling. The second bacterial sample was then taken from the other hand. After rubbing the hands with alcohol they were allowed to dry before sampling. During the study the sampling fluid was repeatedly tested with sensitive bacteria to find out possible inhibitory effects of disinfectants, but these were not detected. The preparations studied were: a 3 % hexachlorophene emulsion (Septo^R), a detergent iodophor with 0·75–0·81 % available iodine (Betadine^R), a 4 % chlorhexidine gluconate detergent solution (Hibiscrub^R), a 70 % (w/w) solution of ethanol (with 3 % glycerol) with and without preceding soap wash, and a liquid soap (detergent: triethanolamine soap). The trials were conducted according to latin square design with several days between experiments to allow sufficient time for skin bacteria to re-establish.

A volume of 0·1 ml of the sampling fluid was cultured on blood agar, phenolphthalein and mannitol salt agar plates (*Staph. aureus*) or blood agar and cetrimide agar plates (*Ps. aeruginosa*). The fluid sample was spread with a bent glass rod and the plates were incubated overnight at 37 °C and kept for another day on the laboratory bench before identification and counting of bacterial colonies.

Studies in the burns unit

The field study was carried out in the Burns and Plastic Surgery Unit of Helsinki University Central Hospital. The patients were chosen on the basis of previous bacterial samples positive for *Staph. aureus* or Gram-negative bacilli.

Altogether 55 persons participated in the study, but 80 % of the experiments were performed with a group of 10 persons. The mean age of the staff was 33 years and their hand washing frequency averaged 20–30 times a day. None of them complained of skin problems such as excessive drying or dermatitis.

The patients had burn lesions, which were covered with dressings and kept clean by the application of gauze compresses moistened with saline. The compresses were changed three to four times a day. In the study the nursing staff, instead of using gloves, intentionally made patients' beds or changed dressings and compresses barehanded to cause bacterial contamination of the hands by dry or moist material, respectively. The hands were then washed for 15 s according to strict ward routine with the preparation studied. For rigid supervision of the hand washing techniques, the author participated in all experimental events as a test person.

The following washing and disinfection methods were studied: a 3 % hexachlorophene emulsion (Septo^{R}); a detergent iodophor scrub (Betadine^{R}); a 4 % chlorhexidine detergent solution (Hibiscrub^{R}); 70 % (w/w), 94 % and 80 % solutions of ethanol, all with 3 % glycerol and the last with 0·5 % chlorhexidine; the same alcoholic solutions with preceding soap wash; a liquid soap. The staff employed each washing method at least for 2 weeks before bacterial sampling was started.

Bacterial samples

Bacterial samples were taken after dry or moist contamination of the hands and, secondly, after hand washing and disinfection. Four fingertips were pressed, one hand at a time, on a blood agar plate, and both thumbs thereafter in the middle. Before the first sampling, moist hands were allowed to dry to facilitate counting of bacterial colonies. The hands were then washed or disinfected with the preparation studied and dried with a disposable paper towel. Special care was taken to rinse the hands thoroughly with water after washing to prevent a possible transfer of inhibitory amounts of disinfectants to the culture medium. When alcohol was used, it was allowed to evaporate and the bacterial samples were taken after the hands were visibly dry. In preliminary experiments no difference in bacterial counts was recorded regardless of whether neutralizers were used or not. Thus in the study they were not included in the blood agar medium. Tests with sensitive bacterial strains were repeatedly done to discover any disinfectant effect on the plates, but this was never detected.

The identification of *Staph. aureus* colonies was based on morphology, pigmentation, and the tube coagulase test; that of Gram-negative bacilli on morphology, biochemical tests and Gram-staining. The plates were incubated and the colonies identified and counted as in the first part of the study.

Statistical methods

Mean percentage reductions and the standard error of the mean were calculated from the bacterial counts before and after hand washing and disinfection. For statistical analysis the data were transformed to logarithmic scale. One-way analysis of variance was used to test the difference between all treatments. In further pairwise testing of reductions Student's *t*-test of the proportions was used.

RESULTS

Tests in the laboratory

Hand washing for 15 s with plain liquid soap reduced the number of *Staph. aureus* colonies on fingertips by almost 77 % (Table 1). The most effective treatments were rinsing with ethanol and washing with chlorhexidine detergent scrub, whereas washing with soap followed by rinsing with alcohol was slightly less effective. *Ps. aeruginosa* was more easily removed from fingers than *Staph. aureus* by all the washing and disinfection methods. The reduction with only liquid soap was over 92 %. All other treatments, except hexachlorophene, showed over 98 % reduction of original *Pseudomonas* counts.

Extending the washing time to 2 min resulted in greater bacterial reductions and less variation between individual results. Compared with washing for 15 s, only minor changes in the ranking order of effectiveness between different treatments were recorded. In separate single experiments, *Ps. aeruginosa* was largely removed also by rinsing with water alone, whereas staphylococci were not: even after 2 min rinsing half of the original numbers of staphylococci were still found on the fingers.

The differences between all treatments were found to be statistically significant in all four comparisons (*Staph. aureus* and *Ps. aeruginosa*, both washing times; one-way analysis of variance, $P < 0{\cdot}001$). In further pairwise analysis, the disinfection with chlorhexidine detergent scrub or 70 % ethanol with or without preceding soap wash were found to be more effective in removing *Staph. aureus* in either washing time than washing with soap alone ($P < 0{\cdot}01$, t-test). In 2 min chlorhexidine scrub or ethanol were also more effective than iodophor scrub ($P < 0{\cdot}01$). Other differences between treatments were not statistically significant.

In removing *Pseudomonas*, 70 % ethanol rinse for 15 s with or without soap was more effective than liquid soap or hexachlorophene ($P < 0{\cdot}01$). Iodophor and chlorhexidine scrubs were also more effective than hexachlorophene ($P < 0{\cdot}01$). In 2 min, all other treatments were more effective than hexachlorophene or soap ($P < 0{\cdot}01$).

Studies in the burns unit

Samples taken from the fingers of the test persons before nursing the patients were negative for *Staph. aureus* or Gram-negative bacilli. After both dry and moist contamination of the hands (bedmaking and changing of dressings, respectively), colonies of *Staph. aureus* were isolated in over 90% of the finger-print samples. Their phage typing confirmed that they originated from the patient. After bedmaking, Gram-negative bacilli were isolated in only a small proportion of the samples and only after nursing some highly contaminated patients, but they were found in about 50 % of the samples taken after moist contamination. The mean number of *Staph. aureus* colonies on fingertips after dry contamination was 126, and that of Gram-negative bacilli nearly the same. After moist contamination, the mean counts of both *Staph. aureus* and Gram-negative bacilli were about four times higher. The initial number of colonies on fingertips varied, depending on the

Table 1. *Mean percentage reduction of colony counts* ± S.E. *after contamination of the hands in laboratory by* Staph. aureus *or* Pseudomonas aeruginosa *and subsequent washing or disinfection or both. The ranking order of effectiveness is indicated in parentheses*

Washing/disinfection method	Hands contaminated by *Staph. aureus*		Hands contaminated by *Ps. aeruginosa*	
	Washing time		Washing time	
	15 s	2 min	15 s	2 min
3% hexachlorophene emulsion	85·1 ± 5·0 (5)	90·6 ± 3·7 (5)	87·9 ± 3·5 (6)	98·5 ± 0·5 (5)
Iodophor detergent scrub	92·4 ± 2·9 (4)	96·9 ± 0·9 (4)	98·1 ± 0·8 (4)	99·8 ± 0·1 (4)
4% chlorhexidine detergent scrub	99·4 ± 0·2 (2)	99·8 ± 0·1 (2)	98·4 ± 0·6 (3)	100·0 ± 0·6 (2)
70% ethanol	99·8 ± 0·2 (1)	100·0 ± 0·0 (1)	100·0 ± 0·0 (1)	100·0 ± 0·0 (1)
Liquid soap followed by 70% ethanol	96·5 ± 1·7 (3)	98·6 ± 0·7 (3)	99·0 ± 0·4 (2)	99·9 ± 0·1 (3)
Liquid soap	76·6 ± 6·2 (6)	85·0 ± 4·0 (6)	92·4 ± 2·0 (5)	97·8 ± 0·6 (6)

extent and condition of the patient's lesions. However, within different study groups, the distributions of colony counts after contamination were fairly similar. Gram-negative bacilli predominantly consisted of *Ps. aeruginosa*.

The bacterial counts were greatly reduced by all washing methods (Table 2). The mean reductions were not counted for all the groups owing to difficulties and consequently small number of experiments especially in the contamination of the hands by Gram-negative bacilli during bedmaking. Washing with liquid soap reduced the number of *Staph. aureus* by 79% and 84% after dry and moist contamination respectively. The reduction of Gram-negative bacilli was considerably higher both after bedmaking and changing of dressings. The reductions were about the same as those obtained in laboratory studies, after artificial contamination of the hands. In ranking order, alcohol solutions and chlorhexidine scrub were generally foremost. The exceptions were 70% ethanol which was slightly inferior to other alcoholic solutions, and chlorhexidine scrub showing a lower reduction of Gram-negative bacilli after moist contamination of the hands than of staphylococci. After both dry and moist contamination, all other treatments reduced *Staph. aureus* more effectively than washing with liquid soap alone, but the superiority of other treatments was not always statistically demonstrable (Table 2). The bacterial reduction of Gram-negative bacilli after dry contamination and subsequent hand washing was high by all the methods. After moist contamination of the fingers, washing even with liquid soap was found very effective with over 97% bacterial reduction.

None of the washing and disinfection methods were efficient enough always to remove all *Staph. aureus* or Gram-negative bacilli from the fingertips. After dry contamination in bedmaking and subsequent washing with soap, only 9 of 32 (28%) samples were found to be entirely free from *Staph. aureus* (Table 3). All treatments except iodophor, hexachlorophene and liquid soap followed by 70%

Table 2. *Mean percentage reduction of colony counts* ± S.E. *after dry (bedmaking) or moist contamination of the hands (changing of dressings) and subsequent washing and disinfection. The ranking order of effectiveness is indicated in parentheses. The number of experiments from which the means are calculated are presented in Tables* 3 *and* 4

Washing/disinfection method	Dry contamination		Moist contamination	
	Staph. aureus	Gram-negative bacilli	*Staph. aureus*	Gram-negative bacilli
3 % hexachlorophene emulsion	95·8 ± 2·3 (8)	99·1 ± 0·7 (6)	95·9*** ± 1·3 (8)	96·5 ± 1·4 (8)
Iodophor detergent scrub	96·5* ± 1·1 (7)	92·4 ± 5·5 (7)	93·4* ± 1·9 (9)	92·5 ± 7·1 (10)
4 % chlorhexidine detergent scrub	98·2*** ± 0·9 (3)	99·2 ± 0·5 (5)	99·8*** ± 0·1 (1)	96·6 ± 1·4 (7)
70 % ethanol	98·2 ± 1·4 (4)	nc	96·6*** ± 1·0 (7)	95·6 ± 4·4 (9)
94 % ethanol	98·1** ± 0·9 (5)	nc	97·7*** ± 0·8 (6)	99·6 ± 0·3 (5)
0·5 % chlorhexidine in 80 % ethanol	98·6* ± 1·0 (2)	100·0 ± 0·0 (1)	98·3*** ± 0·8 (4)	100·0 ± 0·0 (1)
Liquid soap + 70 % ethanol	94·9** ± 2·0 (9)	99·8 ± 0·8 (3)	97·9*** ± 1·2 (5)	99·9 ± 0·1 (2–3)
Liquid soap + 94 % ethanol	97·4 ± 1·7 (6)	nc	99·1*** ± 0·7 (2)	99·8 ± 0·1 (4)
Liquid soap + 0·5 % chlorhexidine in 80 % ethanol	99·1** ± 0·6 (1)	100·0 ± 0·2 (2)	98·4*** ± 0·7 (3)	99·9 ± 0·1(2–3)
Liquid soap	79·3 ± 5·7 (10)	99·5 ± 0·5 (4)	84·0 ± 2·8 (10)	97·5 ± 1·1 (6)

nc, mean reductions not calculated.

* ** and ***, the reductions statistically greater than those obtained by soap ($P < 0{\cdot}05$, $P < 0{\cdot}01$ and $P < 0{\cdot}001$, respectively).

ethanol, yielded also statistically more often completely negative results than washing with liquid soap alone ($P < 0{\cdot}01$). Complete removal of Gram-negative bacilli was often achieved by liquid soap alone: in 11 of 14 (79 %) cases. No statistically significant difference between treatments existed in the removal of Gram-negative bacilli.

After moist contamination of fingers, completely negative samples were less often found after washing with liquid soap, than after dry contamination: no *Staph. aureus* were detected in 5 of 31 (16 %) samples and no Gram-negative bacilli in 15 of 27 (56 %) samples (Table 4). All methods except iodophor, hexachlorophene and 70 % ethanol resulted in a total removal of *Staph. aureus* more often than washing with soap alone ($P < 0{\cdot}01$). In the disinfection of Gram-negative bacilli, the results point to the superiority of alcohol over liquid soap alone, but the differences between treatments were not statistically significant. When the results of all washing methods in which alcohol was used with or without previous soap wash were pooled and then compared with those of soap, the former methods also statistically more often gave completely negative results than washing with soap alone ($P < 0{\cdot}01$ and $P < 0{\cdot}05$, respectively).

Table 3. *Range of bacterial colony counts of finger-prints after dry contamination of the hands in bedmaking and subsequent washing or disinfection or both*

Washing/ disinfection method	Number of colonies of *Staph. aureus*					Number of colonies of Gram-negative bacilli				
	N	0	1–9	10–49	50–	*N*	0	1–9	10–49	50-
3% hexachlorophene emulsion	28	17 (61%)	5	2	4	18	15 (83%)	—	3	—
Iodophor surgical scrub	26	13 (50%)	10	2	1	9	6 (67%)	3	—	—
4% chlorhexidine detergent scrub	48	39 (81%)	3	6	—	35	29 (83%)	3	3	—
70% ethanol	18	13 (72%)	4	—	1	6	5 (83%)	—	1	—
94% ethanol	28	18 (64%)	10	—	—	4	4 (100%)	—	—	—
0·5% chlorhexidine in 80% ethanol	24	21 (88%)	3	—	—	7	7 (100%)	—	—	—
Liquid soap + 70% ethanol	41	17 (41%)	18	4	2	20	19 (95%)	—	1	—
Liquid soap + 94% ethanol	15	11 (73%)	4	—	—	6	5 (83%)	1	—	—
Liquid soap + 0·5% chlorhexidine in 80% ethanol	25	18 (72%)	6	1	—	13	12 (92%)	1	—	—
Liquid soap	32	9 (28%)	10	7	6	14	11 (79%)	3	—	—

N, number of experiments in each group.

When the pooled results with only alcohol without soap were compared with those in which alcohol was preceded by soap, the latter method more often completely removed *Staph. aureus* after moist contamination from the fingers than disinfection with alcohol alone ($P < 0{\cdot}01$). No statistically significant difference between these two methods existed in the removal of Gram-negative bacilli nor in the removal of *Staph. aureus* after dry contamination.

This finding was also confirmed by the separate analysis of the hand washing results of the author, although the difference was of only borderline significance ($P < 0{\cdot}05$). In these experiments performed by the same person, other results were also consistent with those of the group. After dry contamination, *Staph. aureus* were more often entirely removed from the fingers by hexachlorophene, chlorhexidine scrub or alcoholic chlorhexidine than by other methods. Alcohol disinfection with or without soap wash almost invariably completely cleaned the fingers of Gram-negative bacilli, whereas other treatments, including chlorhexidine scrub, often failed to do so after moist contamination. The differences between treatments were not, however, statistically significant.

Although different treatment methods did not succeed in the complete eradication of patient-borne pathogens, their numbers were greatly reduced by washing and disinfection. After dry contamination and subsequent disinfection, all methods

Table 4. *Range of bacterial colony counts of finger-prints after moist contamination of the hands in changing of dressings and subsequent washing or disinfection or both*

Washing/ disinfection method	Number of colonies of *Staph. aureus*					Number of colonies of Gram-negative bacilli				
	N	0	1–9	10–49	50–	*N*	0	1–9	10–49	50–
3% hexachlorophene emulsion	30	12 (40%)	5	7	6	26	14 (54%)	5	3	4
Iodophor surgical scrub	26	7 (27%)	8	4	7	14	8 (57%)	5	1	—
4% chlorhexidine	34	28 (82%)	6	—	—	35	14 (40%)	11	6	4
70% ethanol	40	14 (35%)	14	6	6	16	13 (81%)	2	1	—
94% ethanol	39	18 (46%)	16	3	2	15	11 (73%)	3	1	—
0·5% chlorhexidine in 80% ethanol	23	17 (74%)	5	1	—	10	9 (90%)	1	—	—
Liquid soap + 70% ethanol	39	23 (59%)	9	3	4	23	20 (87%)	2	1	—
Liquid soap + 94% ethanol	26	21 (81%)	5	—	—	14	12 (86%)	2	—	—
Liquid soap + 0·5% chlorhexidine in 80% ethanol	25	17 (68%)	4	3	—	21	16 (76%)	5	—	—
Liquid soap	31	5 (16%)	3	9	14	27	15 (56%)	5	3	4

N, number of experiments in each group.

reduced the number of *Staph. aureus* colonies to less than 10 per plate in more than 80% of the experiments. The only exception was washing with soap in which case less than 10 colonies were found in 59% of the samples. After moist contamination, iodophor, hexachlorophene and soap more often than other treatments, yielded samples of more than 10 colonies per plate, the results with soap being often statistically significant ($P < 0{\cdot}01$).

After dry as well as moist contamination and subsequent washing and disinfection, samples with more than 10 colonies of Gram-negative bacilli were found most often after disinfection with hexachlorophene and chlorhexidine scrub, as well as after washing with soap after moist contamination of the fingers.

In the course of the study the nursing staff did not complain of any skin disorders.

DISCUSSION

Non-surgical, 'hygienic' hand washing, has been studied mostly by determining the effectiveness of different washing or disinfection methods on normal skin flora and, less often, on transient skin bacteria. The former method is based on the assumption that transient contaminants and normal skin flora react alike in the washing process. This may not be true and, outside the operation theatre, transient bacteria play a major role in the transmission of cross infections. In the present study therefore, the efficacy of different hand washing and disinfection methods to remove patient-borne pathogenic bacteria was investigated.

In the laboratory study, the 15 s washing time was selected, because the average hand washing time in wards is closer to that time than 30 s used in earlier studies (Lowbury *et al.* 1964; Lilly & Lowbury, 1978). The 2 min time was included to investigate the importance of the time factor and because it has been much used in studies with normal skin flora (e.g. Lowbury & Lilly, 1973; Lowbury, Lilly & Ayliffe, 1974; Ayliffe *et al.* 1975). The effectiveness of disinfection has been shown to be dependent on the method of contamination (Lilly & Lowbury, 1978). The contamination method chosen for this study lies between drop and rubbing techniques, and thus resembles bacterial contamination of the fingers in hospital practice.

Volunteers for laboratory in-use studies are usually deliberately selected as having no skin problems. Hospital staff, on the other hand, are at least to some extent unselected as to their skin. The skin of their hands is often dry and subject to repeated washing. Laboratory tests may therefore yield unrealistic information. In a previous field study, drying or cracking of the skin and frequent hand washing were shown to be associated with disinfection failures, which were unexpected on the basis of the laboratory trials in optimal test setting (Ojajärvi *et al.* 1977). In some persons disinfection failures were recorded with no apparent disorder of the skin.

The persons in this study had no special skin problems. Most of them had been engaged in hospital work for several years. They may therefore be regarded as better representatives of 'normal hospital staff' for hand washing trials than volunteers of laboratory studies.

Contact sampling of the hands by the finger-print (or finger streak) technique is more suitable for field studies than e.g. the plastic bag method (Salzman, Clark & Klemm, 1967). The simplicity and rapidity of the finger-print method makes it possible to take numerous samples without causing impatience in the clinical staff. It reveals bacteria on the fingertips – a site probably far more important in the transmission of cross infection than other parts of the hands. No neutralizers were added to the culture medium, as their incorporation in the agar did not affect the number of bacterial colonies. The 2-week use of different disinfectants before each study period lowers the numbers of resident bacteria of the hands, but has a hardly significant effect on transient bacteria. The study was designed also in this respect to resemble closely the conditions of the everyday ward practice.

The participation of the author in the field study as a test person to motivate the staff and keep the hand washing techniques standardized proved to be essential. Nevertheless, inexplicably high bacterial counts after hand disinfection were recorded. These were not due to single individuals, but were scattered among test persons. Neither were these 'disinfection failures' due to abnormally high prewash counts, for they were recorded after high as well as low initial bacterial counts. Disinfection of staphylococci, but not of Gram-negative bacilli, succeeded somewhat more often with stronger alcoholic solution than with 70 % solution. This is consistent with the slight superiority of 95 % ethanol over 70 % solution (both with 0·5 chlorhexidine) in preoperative skin preparation (Lowbury & Lilly, 1975). The staff preferred 94 % ethanol solution, since its evaporation time was shorter than with 70 % solution.

Gram-negative bacilli tolerate dryness poorly (e.g. Noble & Somerville, 1974). Difficulties in this study were encountered in dry contamination of the fingers by Gram-negative bacilli during bedmaking. The contamination of the fingers by *Staph. aureus* was achieved much more easily. Sometimes the fingers were heavily contaminated by staphylococci even after a short time of touching bed-clothes. A good example of easy recontamination of the hands was once recorded, when the fingertips of a test person were found to be contaminated by the patient's staphylococci after removing protective clothing and leaving the room, although samples taken after hand disinfection a moment earlier yielded no *Staph. aureus* colonies. The contamination might have happened during changing of clothes or by touching the door handle.

The bacterial reductions produced by different methods were quite consistent with each other in the laboratory and field studies. The reductions obtained by alcoholic solutions or chlorhexidine detergent scrub were high in both studies. In laboratory testing liquid soap ranked lowest, but in ward studies it gave higher reductions of Gram-negative bacilli than hexachlorophene, iodophor or chlorhexidine detergent scrubs. Rather high bacterial reductions by soap only support the practice of using only soap and water for normal hand hygiene in many hospital situations.

The determination of only bacterial reductions produced by different washing methods may have little practical value. Heavy bacterial contamination of the skin before hand washing may yield high reductions due to looseness of the majority of transient contaminants, but the skin may still harbour enough pathogenic bacteria to initiate an infection. For a good washing and disinfection method it is also essential that it leaves as few pathogenic microbes on the skin as possible. None of the treatments studied were efficient enough always to remove all patient-borne *Staph. aureus* or Gram-negative bacilli from the hands. The poor results with soap alone in this respect suggest the use of certain disinfectants, at least in high-risk situations or after soiling or gross contamination of the hands. The relative ineffectiveness of the 4 % chlorhexidine detergent scrub after moist contamination of the fingers with Gram-negative bacilli clashes with results based on bacterial reductions, but is a true finding, since the hands were simultaneously cleared of *Staph. aureus*.

Previously field studies (Brodie, 1965; Sprunt *et al.* 1973) have suggested that soap would be as effective as antiseptics in removing transient contaminants. The poor disinfection effect of alcohol in the latter study may, however, be due to the 'creamy water-in-oil' composition of the alcoholic solution. In our experiments with combinations of detergents and alcohol, we have noted the inhibitions of the disinfection effect of alcohol (Ojajärvi & Mäkelä, unpublished). Some other studies concluded that no great difference exists between soap and antiseptics (Lowbury *et al.* 1964; Brodie, 1965), but in these soap was not compared with disinfectant preparations used nowadays. The field studies by Ayliffe *et al.* (1975) and the present study, as well as the laboratory studies by Lilly & Lowbury (1978) suggest, however, the superiority of certain disinfectants such as alcohol or chlorhexidine detergent scrub over soap alone.

It is difficult to define hospital situations that may with certainty be classified as 'dirty' or as 'clean'. Thorough hand washing and disinfection is necessary if the hands are visibly dirty or if accidental contamination with urine, faeces, blood, pus, etc. has taken place. Plain soap wash or disinfection with only alcohol may then be insufficient. The situations in which a true disinfection of the hands is necessary must be determined in each unit and thereafter proper hand washing urged. Casewell & Phillips (1977) pointed out that the hands are easily contaminated by bacteria even in minor nursing activities. Because of easy contamination of the hands and the ineffectiveness of washing and disinfection methods, it is advisable to use gloves always when nursing a patient who most likely profusely spreads bacteria or one who must be protected from infection.

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