PAPERS AND ORIGINALS

Preoperative Disinfection of Surgeons' Hands: Use of Alcoholic Solutions and Effects of Gloves on Skin Flora

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Summary

A single application of about 10 ml of 95% alcoholic chlorhexidine (0·5%) or tetrabrom-o-methyl phenol (0·1%) rubbed on to the hands until they were dry led to mean reduction in viable bacterial counts from standard handwashings of 97·9 ± 1·09% and 91·8 ± 4·63% respectively. After six of such treatments, three on each of two successive days, the mean reductions in relation to viable counts before the first treatment were 99·7 ± 0·09% for alcoholic chlorhexidine and 99·5 ± 0·17% for tetrabrom-o-methyl phenol. These reductions were greater than those obtained with 4% chlorhexidine detergent solution—87·1 ± 3·5% and 98·2 ± 1·6%, and with 95% or 70% ethyl alcohol and with aqueous 0·5% chlorhexidine. Preoperative washing of the surgeon's hands with alcoholic chlorhexidine used without addition of water is more effective and less expensive than handwashing with antiseptic detergent preparations and running water.

The viable counts of washings from hands treated with various antiseptics, including ethyl alcohol, were lower in relation to the pretreatment levels when gloves had been worn for three hours than when samples for counts were taken immediately after the antiseptic treatment. No such difference was found in samplings from hands washed with unmedicated soap.

Tests for residual action of antiseptics on the skin showed a greater effect with alcoholic chlorhexidine than with tetrabrom-o-methyl phenol, though both showed greater residual activity than an Irgasan DP 300 detergent preparation. No residual action was shown after 70% ethyl alcohol.

Introduction

Preoperative cleansing of the surgeon's hands by prolonged scrubbing with soap and running water has been gradually superseded by washing with running water and detergent preparations containing hexachlorophane, providone iodine, chlorhexidine, and, recently, Irgasan DP 300 (2, 4, 4′ trichloro 2′ hydroxydiphenyl ether). Each of these methods progressively reduces the resident skin flora. For example, a 4% chlorhexidine detergent solution (Hibiscrub), the most rapidly effective of these preparations, caused a reduction of about 87% in the mean estimated numbers of bacteria on the skin after a single two-minute wash and a reduction of about 99% after six successive washes, three on each of two successive days (Lowbury and Lilly, 1973). Further reduction of about 95% could be obtained by a second phase of disinfection with 0·5% chlorhexidine in 70% ethyl alcohol.

The surgeon's routine of washing under running warm water has been retained in the use of antiseptic detergent preparations, which aims to combine disinfection and cleansing. The benefits of this time-saving procedure, however, are not unmixed for while the added water helps physical cleansing it dilutes the antiseptic. In 1964 we reported that the resident flora could be reduced more (about 99%) by a single two-minute standard handwash with 0·5% chlorhexidine in 70% ethyl alcohol without addition of water than by a single two-minute wash under a tap with antiseptic-detergent preparations (Lowbury *et al.*, 1964). A reduction nearly as great was obtained with aqueous 0·5% chlorhexidine solution. In these experiments the hands were washed by a standard technique with 100 ml of antiseptic solution in a bowl. A solution containing 0·1% tetrabrom-o-methyl phenol in 95·3% ethanol (Desderman, Schülke, and Mayr) has been widely used for disinfection of the hands of surgeons and nurses in Germany. In using this product the solution is allowed to evaporate to dryness while being rubbed on to the hands.

We report here an assessment of the disinfection of the hands by alcoholic and aqueous solutions of 0·5% chlorhexidine and by alcoholic tetrabrom-o-methyl phenol.

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Use of Alcoholic Solutions

METHODS

The following antiseptic preparations were studied: (*a*) a solution of chlorhexidine digluconate (0·5%) in 95% ethyl

alcohol; (*b*) a solution of 0·1% tetrabrom-o-methyl phenol in 95·3% ethyl alcohol; (*c*) an aqueous solution of 0·5% chlorhexidine digluconate; and (*d*) 95% aqueous ethyl alcohol. Because of the drying effects of alcohol, which cause discomfort on some hands, 1% glycerol was added to preparations (*a*) and (*d*) in more recent studies. Aqueous solutions of chlorhexidine gluconate were dissolved in distilled water.

Assessing Disinfection of Hands

As in previous studies (Lowbury *et al.*, 1964; Lilly and Lowbury, 1971; Lowbury and Lilly, 1973) each preparation was tested on each of a series of volunteers, with an interval of about 10 days between experiments to allow the normal density of natural skin flora to be restored before each experiment.

Viable counts of bacteria were made from pour plates of standard washings of the hands in 100 ml of Ringer's solution containing neutralizers (1% Lubrol W, 0·5% lecithin, 1% Tween 80, and 1% sodium thiosulphate). Neutralizers were included also in the nutrient agar used for pour plates, and tests of "carry-over" of antiseptic were made in sampling fluid and on plates when no bacterial growth or very scanty growth was present. Such tests for the presumptive density of natural skin flora were made immediately before the first use of the preparation (after a "social" wash to remove superficial transient flora); immediately after the first use of the preparation; immediately before the sixth of a series of treatments with the preparation, three on each of two successive days; and immediately after the sixth treatment.

Applying Antiseptic Preparations and Controls

The alcoholic solutions of chlorhexidine and tetrabrom-o-methyl phenol were poured in two successive applications of about 5 ml into the cupped hand. Each application was rubbed vigorously over all surfaces of both hands and wrists until the fluid had evaporated to dryness. When the first application had dried the second application was made and rubbed over the surfaces until dry. This procedure took about two minutes to complete. Immediately before drying the hands felt sticky for a few seconds.

The aqueous solution of chlorhexidine was applied similarly in two successive amounts of about 5 ml which were rubbed vigorously over all surfaces of the hands and wrists for about two minutes. The hands were then rinsed under running water and dried on a sterile towel.

Washing with unmedicated bar soap and running water for two minutes was the standard control treatment, as used in previous studies on skin disinfection (see Lowbury and Lilly, 1973).

RESULTS

The reduction in viable counts from skin samplings taken immediately after a single handwash, and immediately before and after the sixth of the series of handwashes is shown in table I for each of the preparations tested. We also show the results of a similar assessment of the 4% chlorhexidine detergent preparation which was applied in a two-minute standard wash under running warm water, as previously reported (Lowbury and Lilly, 1973).

The alcoholic solution of chlorhexidine produced a mean reduction of 97·9 ± 1·09% in viable counts of bacteria from handwashings immediately after a single standard wash. This was appreciably better than the result of washing with 4% chlorhexidine detergent and water (87·1 ± 3·1%) and slightly better than that with tetrabrom-o-methyl phenol in alcohol. Aqueous 0·5% chlorhexidine digluconate gave smaller and more variable mean reductions in bacteria from handwashings. Single experiments with 70% and 95% ethyl alcohol showed smaller reductions in viable counts than those obtained with alcoholic chlorhexidine or tetrabrom-o-methyl phenol but similar to those obtained with 4% chlorhexidine detergent (82·0% and 89·3% respectively after a single treatment and 98·6% and 97·4% respectively after six treatments). At the sixth wash with alcoholic solutions of chlorhexidine there was hardly any further reduction beyond that obtained with a single wash. A low equilibrium was almost reached on a single application, in contrast with the progressive reduction in bacterial counts obtained on successive handwashings with 4% chlorhexidine detergent solution and to an even greater extent with hexachlorophane and Irgasan DP 300 (Lilly and Lowbury, 1974).

TABLE I—*Disinfection of Hands by Various Preparations: Reduction in Bacterial Counts from Hand Samplings, expressed as Percentage of Initial Count*

Preparation	No. of Experiments	Mean % Reduction in Viable Counts		
		After 1st Application	Before 6th Application	After 6th Application
0·5% chlorhexidine digluconate in 95% ethyl alcohol	6	(A) 97·9 ± 1·09	96·8 ± 1·81	(D) 99·7 ± 0·09
0·1% tetrabrom-o-methyl phenol in 95·3% ethyl alcohol	6	(B) 91·8 ± 4·63	96·8 ± 1·47	(E) 99·5 ± 0·17
0·5% chlorhexidine digluconate in distilled water	6	65·1 ± 8·66	84·5 ± 4·71	(F) 91·8 ± 2·37
4% chlorhexidine digluconate detergent solution	8	(C) 86·7 ± 3·0		(G) 99·2 ± 0·2
Bar soap (control)	6	12·6 ± 2·6		26·4 ± 6·5

Comparison of treatments:
(A) *v.* (C): $t = 3·11$; $P < 0·01$.
(D) *v.* (F): $t = 3·33$; $P < 0·01$.
(E) *v.* (F): $t = 3·24$; $P < 0·01$.
(F) *v.* (G): $t = 3·62$; $P < 0·01$.
(A) *v.* (B): N.S.
(B) *v.* (C): N.S.
(D) *v.* (E): N.S.
(D) *v.* (G): N.S.
(E) *v.* (G): N.S.

The addition of 1% glycerol to the alcoholic solution of chlorhexidine made it acceptable to volunteers who had complained of excessive dryness of the hands after using the orginial alcoholic solution, and it did not interfere with the skin disinfectant activity of the solution.

Surgical Gloves and Skin Flora After Hand Disinfection

We also determined the effect of wearing surgical rubber gloves after skin disinfection on the estimated numbers of bacteria on the skin of the hands.

METHODS

The skin of the hands and wrists was disinfected or cleansed by two minutes' application with gauze of (*a*) 0·5% chlorhexidine digluconate (aqueous); (*b*) 0·5% chlorhexidine digluconate in 70% ethyl alcohol; (*c*) povidone iodine antiseptic solution (Disadine); (*d*) 2·5% chloroxylenol (aqueous); (*e*) 0·5% chlorhexidine digluconate in 70% isopropyl alcohol; (*f*) 70% isopropyl alcohol; and (*g*) 70% ethyl alcohol and also by a two-minute standard handwash with (*h*) 4% chlorhexidine detergent solution; and (*i*) unmedicated bar soap and water.

Viable bacterial counts were obtained from skin samplings taken immediately before the disinfection and again after wearing rubber gloves for three hours afterwards. In separate experiments with the same preparations the hands were tested for viable bacterial counts immediately before and immediately after treatment with the antiseptic preparations or control material. A Latin square design was used for the experiment in which gloves were worn for three hours. The results of tests in which sampling was done immediately after disin-

fection were derived from other experiments in which the same techniques were used.

RESULTS

The viable counts after the gloves had been worn for three hours after skin disinfection or washing are shown in table II. With every treatment except the use of soap and water the reduction in skin flora seemed to be greater when the sampling was made after wearing gloves for three hours than when it was made immediately after disinfection or washing of the skin.

TABLE II—*Effect of wearing Surgical Gloves on Skin Bacteria after Disinfection of Hands: Reduction in Bacterial Counts from Hand Samplings, expressed as Percentage of Count before Disinfection*

Skin Preparation	Mean % Reduction in Viable Bacterial Counts	
	After gloves worn for 3 Hours after Disinfection	Immediately after Disinfection
0·5% chlorhexidine in 70% ethyl alcohol	96·2±0·97	81·5±3·4
70% ethyl alcohol	90·9±1·5	73·6±5·7
0·5% chlorhexidine in 70% isopropyl alcohol	96·9±0·86	89·3±3·3
70% isopropyl alcohol	93·8±1·53	84·8±3·1
0·5% chlorhexidine in water	94·2±1·35	60·7±6·0
2·5% chloroxylenol in water	72·6±3·5	37·3±3·9
povidine iodine antiseptic solution (aqueous)	89·4±2·27	62·3±5·9
4% chlorhexidine digluconate detergent solution	97·4±0·98	87·1±3·5
Bar soap	12·3±2·18	17·7±3·7

Residual Action of Antiseptic on Skin

METHODS

Tests for the residual action of antiseptic on the skin were made with methods reported elsewhere (Lowbury and Lilly, 1973) for testing bactericidal effects against cultures of Staphyloccus aureus and Escherichia coli. The cultures were inoculated, spread, and allowed to lie on the hands for one hour after handwashing, with alcoholic chlorhexidine and tetrabrom-o-methyl phenol and with a 2% Irgasan DP 300 detergent preparation (Zalclense) (see Lilly and Lowbury, 1974). In a separate experiment by this method the possibility of residual action of 70% ethyl alcohol rubbed into the skin until the hands were dry was tested. This experiment was done because of the apparent continuing reduction in numbers of bacteria yielded by the hands during a three-hour period while gloves were worn after a handwash with ethyl or isopropyl alcohol. Control tests with soap and water were made in each of the two experiments. Replicate tests on separate subjects were made with the same bacterial suspensions, the replicate tests being shown as (*a*) and (*b*) in table III. In the test with 70% ethyl alcohol two separate experiments (experiment 2 and experiment 3) were made, the density of bacterial suspension inoculated in experiment 2 being much greater than that used in experiment 3.

RESULTS

The results of tests for residual action against *Staph. aureus* are shown in table III. Tests with *E. coli* suggested that other factors—in particular, varying bactericidal effects of evaporation—could reduce the viable counts of bacteria inoculated on skin disinfected with alcohol compared with those inoculated on control areas. The results with *E. coli* are, therefore, not included in the table.

Alcoholic chlorhexidine had a very large residual action, as compared with the results in the control tests. Alcoholic tetrabrom-o-methyl phenol also had a large residual effect though not as large as that shown by alcoholic chlorhexidine. The 2% Irgasan DP 300 showed a relatively small residual action. In two experiments in which the hands were washed with 70% ethyl alcohol and allowed to dry no residual activity against *Staph. aureus* was shown.

TABLE III—*Residual Effects of Antiseptics after Disinfection of Hands. Results expressed as Mean Viable Counts/ml Washings from Areas inoculated with Suspensions of Staphylococcus aureus*

Handwashing Preparations	Method of Application		Mean Bacterial Counts/ml Washings
Experiment 1			
0·5% chlorhexidine in 95% ethyl alcohol	Rubbed in till hands dry	(*a*)	18
		(*b*)	26
0·1% tetrabrom-o-methyl phenol in 95·3% ethyl alcohol	Rubbed in till hands dry	(*a*)	940
		(*b*)	300
2% Irgasan DP 300 detergent solution	Rubbed on with water, hands rinsed and dried on towel	(*a*)	4,520
		(*b*)	2,950
Bar soap	Washed with water, hands dried on towel		54,000
Experiment 2			
70% ethyl alcohol	Rubbed on till hands dry	(*a*)	81,000
		(*b*)	44,000
Bar soap	Washed with water, hands dried on towel		78,500
Experiment 3			
70% ethyl alcohol	Rubbed in till hands dry	(*a*)	4,750
		(*b*)	3,900
Bar soap	Washed with water, hands dried on towel		5,100

Discussion

When antiseptic soaps and detergent preparations were introduced in the 1950s for disinfecting surgeons' and nurses' hands their use seemed a rational way of combining the two functions of cleansing and disinfection. Cleansing with soap and water contributes very little to the reduction of the numbers of the resident bacteria, however, and washing with a detergent antiseptic preparation is an inefficient method of disinfection because of the diluent effects of water added from the tap. A single standard two-minute wash with alcoholic or aqueous solutions of 0·5% chlorhexidine digluconate was shown (Lowbury *et al.*, 1964) to eliminate a much larger proportion of the resident skin flora than could be removed by a single two-minute handwash with detergent antiseptic preparations of hexachlorophane or providone iodine. Even a two-minute 4% chlorhexidine detergent wash (Lowbury and Lilly, 1973) is much less effective than a single two-minute rinse with alcoholic 0·5% chlorhexidine. The latter is not only more effective but also much cheaper than detergent antiseptic preparations. Its potential value as an antiseptic for preoperative disinfection of the surgeon's hands was shown by experiments in which the emergence of bacteria through holes in rubber gloves was almost eliminated by a single three-minute wash in a solution of 0·5% alcoholic chlorhexidine (Lowbury and Lilly, 1960).

Hence it may be argued that a separation of the functions of disinfection and cleansing of the hands is more rational than their combination. Our results support this view and show that alcoholic solutions of chlorhexidine or tetrabrom-o-methyl phenol in 95% ethyl alcohol rubbed on to the skin until the alcohol has evaporated are effective and practicable methods of skin disinfection, in which a low equilibrium level of resident skin flora at about 1% of the initial level is almost reached after a single treatment. To reach a similar low equilibrium level with 4% chlorhexidine detergent solution, povidone iodine, or hexachlorophane detergent preparations the hands have to be washed repeatedly over two or three days to achieve a cumulative effect of progressive reduction in skin flora to a low equilibrium. In single tests

with 70% and 95% ethyl alcohol a similar though smaller effect was obtained. Previous studies had shown that cursory swabbing of the hands with 70% ethyl alcohol had relatively poor effects (Lowbury and Lilly, 1960). The incorporation of 1% glycerol in alcoholic solutions makes them acceptable to individuals who complain of excessive dryness of the skin after repeated use of alcohol. Aqueous solutions of chlorhexidine applied in the same way as the alcoholic solutions but followed by rinsing and drying of the hands were effective but less so than the alcoholic solutions or alcohol.

Alcoholic solutions rubbed into the skin have been widely used in Germany for disinfecting surgeons' hands (Molitor and Godry, 1972), and there are strong arguments for a more general adoption of this method. An incidental convenience in using alcoholic chlorhexidine for the surgeon's hands is that the same concentrate is used for preparing the solutions commonly used for disinfection of the operation site. There remains a need for detergent cleansing of the hands to remove dirt, blood, and other physical contaminants and probably for the first operation in a list. A "social" wash with soap and water should be adequate for this, but it is probably more convenient to combine the functions of cleansing and disinfection by the use of an antiseptic detergent preparation, such as 4% chlorhexidine detergent solution when a detergent is required. One of our experiments showed chlorhexidine to have greater skin disinfectant activity in isoproyl alcohol than in ethanol, and we found consistently lower viable counts, relative to pretreatment counts, when gloves were worn for three hours before sampling than when samples were taken immediately after disinfection of the hands. This effect could be attributed to residues of antiseptic left on the skin after the use of chlorhexidine, hexachlorophane, or Irgasan DP 300, but some other factor must be responsible in the case of the volatile alcohols, which also showed this effect. The alcohol might marginally damage bacteria, allowing them to recover if inoculated immediately on to culture media but not if left on the skin for three hours before inoculation of the medium. Another possibility is the destruction by drying of some bacteria which survived exposure to alcohol; this effect would be present only in the experiment in which gloves were worn. The self-disinfecting properties of the skin do not seem to be involved as there was no evidence of any reduction in the numbers of bacteria on the skin when gloves were worn after the use of non-antiseptic soap. Clinically, the reduction rather than increase in the bacterial flora of the skin during a three-hour period of wearing surgical gloves was a welcome finding. As such low levels of bacterial flora are maintained during the course of operations it seems unnecessary to disinfect the hands thoroughly before every clean operation in a long list, and three or four treatments on one day with an antiseptic should be quite sufficient for the maintenance of a low equilibrium level of skin flora.

Cleansing the hands with 5-10 ml of 70% ethyl alcohol solution containing 1% glycerol has been considered effective for nurses before they carry out aseptic ward procedures. A study on contamination of nurses' fingers when dressing operation wounds (Noy *et al.*, 1974) showed, by contact plate samplings, that three out of 32 hands (9·4%) carrying pathogens (*Staph. aureus* or coliform bacilli) lost less than 90% of these organisms on washing with soap and water, compared with a similar loss in three out of 47 (6·4%) hands disinfected with alcohol. Ethyl alcohol (70%) was therefore judged to have at least as great an effect in removing these organisms as soap and water. From our studies on the resident flora and from the evidence that *Staph. aureus* is often carried as a resident (Lowbury and Lilly, 1960) ethyl alcohol treatment of nurses' hands may be assumed to have a larger effect than soap and water in reducing the risks of contamination of wounds with staphylococci.

In a preliminary test for acceptance of alcoholic chlorhexidine handwashing by surgeons in operating theatres at this hospital the method was found to be comfortable and convenient. Further trials over a longer period will be required.

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Disinfection of the Skin with Detergent Preparations of Irgasan DP 300 and Other Antiseptics

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Summary

An evaluation of the relative effectiveness of 2% hexachlorophane and 0·75% Irgasan DP 300 bar soaps in disinfection of the hands showed that the former caused a significantly larger reduction in natural skin bacteria than the latter after one handwash and after six handwashings, three on each of two successive days. Repeated use of Irgasan DP 300 bar soap caused a significantly greater reduction in skin flora than repeated handwashings with unmedicated bar soap, but a single handwash gave no significant reduction in skin flora compared with a single use of the unmedicated soap.

In a comparison of a 4% chlorhexidine detergent solution a 3% hexachlorophane detergent crēam and a 2% Irgasan DP 300 detergent solution the 4% chlorhexidine detergent gave the largest mean reduction in skin bacteria after one handwash and after six handwashings and 2% Irgasan DP 300 a poor and erratic reduction after a single handwash. After six handwashings all three preparations gave large

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