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DISINFECTION OF THE HANDS OF SURGEONS AND NURSES

BY

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The hands of the nurse and the surgeon are undoubtedly two of the chief vectors of hospital infection. They often carry pathogenic organisms, in particular *Staphylococcus aureus*, which may be present in large numbers. Price (1938) has shown that scrubbing with soap and water for six minutes will reduce the numbers of bacteria on the hands by only about 50%. Devenish and Miles (1939) and others have found that about 30% of the rubber gloves worn at operations become punctured without the surgeon's knowledge, and bacteria can readily escape through the small holes which appear. Though these facts about hand scrubbing and gloves are quite well known, additional safeguards against manual contamination of wounds are not often used by surgeons; nurses, for their part, are generally not expected to do anything more to control their hand flora than washing with soap and water after certain ward duties.

Various antiseptics have been found to reduce the numbers of bacteria on the hands. Hexachlorophane soap (Traub, Newhall, and Fuller, 1944; Seastone, 1947) and "phisohex" (Hufnagel, Walter, and Howard, 1948) have been used for some years by surgeons in the United States, and a British paper in support of the latter has recently appeared (Smylie, Webster, and Bruce, 1959). Price (1951) has stressed the limitations of hexachlorophane soap when used irregularly, and finds that a conventional scrub with soap and water followed by three minutes' rinse in 70% alcohol before putting on gloves is more effective. The regular use of a hand cream containing chlorhexidine has been found to reduce the skin flora (Murray and Calman, 1955; Laurell, 1959), and its use by nurses in surgical and obstetric wards has been associated with some reduction in the incidence of cross-infection (Cook, Parrish, and Shooter, 1958; Gillespie, Simpson, and Tozer, 1958).

In this paper we describe experiments on the relative merits of several pre-operative antiseptic applications to the surgeon's hands, with particular reference to the numbers of bacteria emerging through holes in gloves. We also describe a study on the routine use of hexachlorophane soap and some other methods by nurses working in accident and burns wards.

The Surgeon's Hands

The efficiency of various antiseptic treatments of the surgeon's hands was measured by the numbers of bacteria that escape through holes in gloves after one hour's operation, and by the numbers of bacteria left inside the gloves after their removal.

Materials and Methods

The "surgeons" in this experiment were five members of the laboratory staff, and they wore rubber gloves for one hour (and in one series for three hours) while working at the bench. Before the experiment small pinholes were made with a No. 1 hypodermic needle at the tips of all fingers of one glove in each pair. The gloves were autoclaved at 10 lb. (4.5 kg.) for 20 minutes. Before putting on the gloves the operator cleansed his hands in one of the following ways: (1) a quick "social" wash with soap and water; (2) five minutes' scrub with a bristle brush and bar soap under running warm water; (3) five minutes' scrub, as described, followed by (*a*) three minutes' rinse in 70% alcohol (by weight), or (*b*) three minutes' rinse in 70% alcohol containing 0.5% chlorhexidine digluconate, or (*c*) a quick mopping of the hands with a swab soaked in industrial spirit (as used by some surgeons to dry the skin more quickly), or (*d*) the use of a glove powder containing 5 mg. of neomycin sulphate and 5 mg. of bacitracin per gramme of powder; (4) the use of 2% hexachlorophane soap ("medisoap") for all ablutions and baths during the week before the experiment, and for the five minutes' scrub in the experiment; and (5) the use of "phisohex" in place of hexachlorophane soap as described under (4), except that the pre-operative scrub was for two minutes only. Phisohex is a combination of 3% hexachlorophane with a cream containing an anionic detergent, "phisoderm" (Hufnagel *et al.*, 1948).

Each operator made an experiment with each antiseptic treatment. The experiment on antiseptic treatment was always made approximately one week after a control experiment with five minutes' scrub only, so that the consequences of possible cumulative action of antiseptics should be avoided. No experiment was made on any subject for a period of four weeks after the tests with antiseptics, so that the skin flora should be completely restored before the next control experiment.

Bacteriological sampling was carried out as follows. After the "operation" the gloved hands were washed with ordinary soap under a running tap, and dried on

a sterile towel. The tips of the fingers of both hands were then inserted into short flat-bottomed tubes (3 in. by 1 in.; 7.5 by 2.5 cm.), containing small glass beads and 5 ml. of sterile Ringer's solution with a neutralizer (see below). Each finger was rubbed for three minutes against the beads; the corresponding fingers of right and left hands were taken in pairs to minimize differences in the sampling of the two sides. The gloves were then removed. 100 ml. of Ringer's solution, with neutralizer when required, were pipetted into the gloves, which were shaken in a standard way; 5-ml. amounts of the sampling fluid were then transferred from the gloves to sterile tubes.

Pour plates were prepared by mixing 1-ml. amounts of 10^0 and 10^{-1} dilutions of all the sampling fluids with nutrient agar containing an appropriate neutralizer—for hexachlorophane and phisohex, 1% "Tween 80" (Lawrence and Erlandson, 1953; Smylie *et al.*, 1959), for chlorhexidine, 1% "lubrol W" and 0.5% lecithin (Gillespie *et al.*, 1958). For neomycin and bacitracin no neutralizer was available, but in four of the five experiments with these antibiotics we tested for the transfer of inhibitory concentrations by inoculating tubes of the sampling fluid and the pour plates with 0.02-ml. drops of a 10^{-4} dilution of a broth culture of highly sensitive organisms (*Staph. aureus*); similar inocula were made in control tubes of Ringer's solution and on control plates of nutrient agar. There was no consistent difference in the numbers of colonies growing from the sampling and the control fluids and culture media, and it was concluded that inhibitory levels of neomycin and bacitracin were not being transferred in these tests.

The plates were incubated at 37° C. for about 42 hours and colonies were counted, when possible, on the plates both from 10^0 and from 10^{-1} inocula, or alternatively on the one showing the optimum density of growth.

Results

Table I gives an example of the bacterial counts obtained from four punctured and four intact glove fingers in one experiment, including results from the control test (five minutes' scrub) and for the treatment test (scrub followed by chlorhexidine-alcohol rinse). For the assessment of the numbers of bacteria emerging through holes we subtracted the counts of bacteria rubbed on the fingers of intact gloves from the counts of bacteria rubbed off the corresponding punctured glove fingers. The results are expressed as counts (per ml.) of viable bacteria emerging through glove holes.

Table II shows the effect of five minutes' surgical scrub with ordinary bar soap. The mean estimated count of bacteria emerging through glove holes and the mean count of bacteria remaining in the glove were

TABLE I.—*Example of Experiment on Emergence of Bacteria Through Glove Holes*

Treatment of Hands	Viable Counts per ml. of Washings from Fingers of							
	Left Hand (Holes in Gloves)				Right Hand (No Holes)			
	2	3	4	5	2	3	4	5
5 minutes' scrub	242	420	130	210	4	1	3	3
5 minutes' scrub + 3 minutes' rinse in 70% alcohol with chlorhexidine 0·5% ..	14	5	4	4	10	2	9	4

TABLE II.—*Effect of Pre-operative Scrub and Length of Operation on Flora of Hands*

Treatment of Hands	Gloves Worn For	Mean Viable Counts per ml. Glove Washings		Mean Estimated Counts, per ml. Washings, of Bacteria Emerging through Holes in Gloves	
		Bacteria per ml.*	No. of Samples	Bacteria per ml.*	No. of Samples
Social wash	1 hour	133·9 ± 24	10	163·8 ± 5·6	20
5 minutes' scrub ..	1 ,,	62·5 ± 18	10	81·0 ± 12	19
,, ,,	3 hours	128·2 ± 38	10	69·9 ± 4·7	20

* Here and in Tables III and V ± indicates the standard error of the mean.

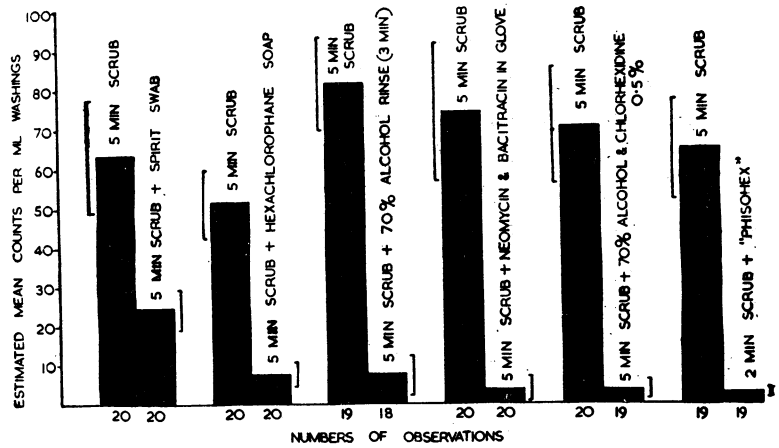

FIG. 1.—Effect of various methods of hand disinfection on the emergence of bacteria through holes in rubber gloves. For each method the mean count after use of an antiseptic (column on right) is compared with the mean count in a control experiment (column on left). Brackets indicate the standard error of the mean.

TABLE III.—*Effect of Antiseptic Treatment on Flora of Hands*

Antiseptic Treatment of Hands	Mean Bacterial Counts per ml. Glove Washings After				Mean Estimated Counts, per ml. Washings, of Bacteria Emerging through Holes in Glove After			
	Scrubbing Up + Antiseptic Treatment	No. of Samples	Scrubbing Up Only (Controls)	No. of Samples	Scrubbing Up + Antiseptic Treatment	No. of Samples	Scrubbing Up Only (Controls)	No. of Samples
Neomycin and bacitracin in glove powder	0·6 ± 1·1	10	332·5 ± 120	10	3·7 ± 3·1	20	73·6 ± 17	20
70% alcohol rinse (3 minutes) ..	3·0 ± 0·7	10	62·5 ± 18	10	7·5 ± 5·4	18	81·0 ± 12	19
70% alcohol with 0·5% chlorhexidine rinse (3 minutes)	3·1 ± 0·7	10	151 ± 48	10	3·25 ± 2·1	19	69·9 ± 14	20
Spirit swab	79·5 ± 36	10	392 ± 140	10	24·2 ± 4·1	20	63·2 ± 14	20
Hexachlorophane soap (for scrub and previous week)	14·9 ± 6	10	169 ± 66	10	7·3 ± 2·8	20	51·2 ± 8·7	20
Phisohex (for scrub and previous week)	1·9 ± 0·7	10	127 ± 39	10	2·7 ± 1·3	19	63·8 ± 13	19
Total (controls)	—	—	206 ± 38	60	—	—	67·0 ± 4·5	118

about half of the means found in such tests after a social wash. Table II also shows that larger numbers of bacteria were obtained from the glove washings (though not through holes in the gloves) when the operations lasted three hours instead of one hour.

Table III shows the mean viable counts from control and treatment series, including both the glove washings and the estimated numbers of bacteria emerging through holes in gloves; a summary of the latter is shown in Fig. 1. The relative merits of the different methods of hand disinfection were found to be approximately the same by both methods, except in the case of neomycin and bacitracin, which showed a larger effect in the tests of glove washings. Each method of disinfection, except the use of a spirit swab, showed a striking suppressive effect on the hand flora when compared with its own control or with the mean of all the control results. Neomycin and bacitracin in glove powder were outstandingly effective, especially on the glove washings. Phisohex was also outstanding, and more effective than hexachlorophane soap. Chlorhexidine with alcohol was excellent, and somewhat better than alcohol alone in both forms of test. There was considerable variation in the mean control counts in different series of experiments. The highest counts of bacteria in glove washings were obtained during periods of hot weather, and were associated with profuse sweating; except in the experiments on one subject, there was no corresponding association of hot weather with high counts of bacteria emerging through holes in gloves.

Bacteria in Glove Washings from Real Operations

In a series of clean surgical operations, 20 gloves were taken from surgeons after use, and glove washings were examined by the method described above. The operations were of varying duration, some shorter and some longer than one hour; the gloves were sent to the laboratory when pinholes had been detected during or after operation by the method of Penikett and Gorrill (1958), and a proportion of the gloves were in use for only part of the operation. Fifteen of the gloves were from one surgeon, who had scrubbed up for five minutes, using ordinary soap and swabbing with a spirit swab before putting on gloves; approximately the same method was used by the other surgeons. The mean count of bacteria per ml. of glove washings was 37.4 ± 5.2. This was lower than the mean count from mock operations with the same pre-operative hand treatment, but the data for the latter were obtained during a period of hot weather when the bacterial counts from controls were exceptionally high (see Table III); the samples from the surgeons' hands were taken in winter and early spring.

The Nurses' Hands

We set out to find if the numbers of bacteria, and especially of staphylococci, on the hands of nurses could be reduced by regular use of hexachlorophane soap or by chlorhexidine cream, or by the combination of these methods.

Materials and Methods

Eighteen nurses (six from each of two accident wards and six from the burns unit) were chosen for the experiment.

For periods of a fornight each nurse used a particular form of hand hygiene; these were, in order of use: (1) ordinary bar soap; (2) hexachlorophane soap while the nurse was on duty in the ward (burns unit only); (3) the use of hexachlorophane soap for all ablutions and baths, in hospital and off duty; (4) hexachlorophane soap for all ablutions and baths and 1% chlorhexidine ("hibitane") hand cream applied after washing three or four times a day; (5) ordinary bar soap, and chlorhexidine hand cream applied three or four times a day after washing in the ward; and, finally, (6) ordinary bar soap again. Ordinary cotton towels were used in the ward, and no details of routine were changed. If a nurse was absent for some days she was required to be on duty in the ward for about a week before re-entering the experiment, so that her hands could again acquire a representative sample of the ward flora.

At weekly intervals—twice during each treatment period of the study—the nurses were asked to wash their hands "socially" with soap and water, dry them on a clean cotton towel, and then provide a sample of standard hand washings in sterile physiological saline containing 5% nutrient broth. These washings were collected as follows. Broth-saline (100 ml.) was poured into a stainless-steel basin. The nurse then moistened both surfaces of both hands with the broth-saline solution, and rubbed the hands together 20 times (with single strokes) in each of the following ways: (1) palm to palm, (2) right palm over left dorsum, (3) left palm over right dorsum, and (4) with fingers interlocking. The hands were thoroughly rinsed after each of these manœuvres. Nose swabs were taken from nurses in the accident wards. Approximately 10 ml. of washings from each nurse was transferred to a screw-cap bottle and taken to the laboratory.

Measured inocula (0.5 ml. of 10^0 and 0.04 ml. of 10^{-1} dilution) of these hand washings were spread with a sterile glass spreader on plates of phenolphthalein phosphate agar (Barber and Kuper, 1951) containing the appropriate antiseptic neutralizer (see above). The plates were incubated for 48 hours at 37° C. and counts of total organisms were made. Presumptive *Staph. aureus* colonies were counted immediately after exposure of the plate over strong ammonia. Nose swabs from the nurses were inoculated on horse-blood agar and incubated at 37° C. for 24 hours; colonies resembling staphylococci were tested by a tube coagulase test. Coagulase- and phosphatase-positive staphylococci (one colony per plate) were phage-typed and tested for sensitivity to penicillin, tetracycline, erythromycin, chloramphenicol, and novobiocin by a ditch-plate method with sensitive controls.

Results

Figs. 2 and 3 show the effect of the use of hexachlorophane soap in the accident wards (C and D) and in the burns unit. The counts of total organisms and of presumptive *Staph. aureus* were consistently lower in the samples taken when the nurses were using hexachlorophane soap. The differences were small compared with those observed in the study on gloved hands. This may be due to differences in the techniques (and purposes) of the two experiments, and perhaps also to the greater likelihood of repeated contamination of hands among members of the nursing staff. Though the reduction in the numbers of staphylococci on hands of nurses using hexachlorophane soap might seem

disappointing, the frequency of contamination (see Table IV) was significantly reduced (by about 50%).

Hexachlorophane used by nurses while on duty only and chlorhexidine cream applied three or four times a day were of dubious value (see Table V). The use of chlorhexidine cream in this way by nurses who were using hexachlorophane soap for all ablutions and baths did not lead to any further reduction in the mean numbers of bacteria in hand washings. There was some further reduction in the hand flora during the use of the combination in the burns unit, but when the findings in all the wards were taken into account there were somewhat larger numbers of bacteria isolated from hands treated by the combination of hexachlorophane and chlorhexidine than from those treated with hexachlorophane soap alone.

TABLE IV.—*Use of Hexachlorophane Soap and Isolation of Staph. aureus from Nurses' Hands in Three Wards*

Soap Used	Wards	*Staph. aureus* in Hand Washings: Present	Samples	% +	Significance Tests
Ordinary	C, D, and burns	48	56	86	C, D, and burns: $\chi^2 = 15{\cdot}8$. $P < 0{\cdot}001$
	C and D	31	39	79	
Hexachlorophane	C, D, and burns	20	43	46	C and D wards: $\chi^2 = 11{\cdot}3$. $P < 0{\cdot}001$
	C and D	11	30	33	

TABLE V.—*Effect of Various Forms of Disinfection on Hand Flora of Nurses in Accident and Burns Wards*

Treatment of Hands	All Colonies: Mean Counts per 0·1-ml. Washings	All Colonies: No. of Samples	*Staph. aureus*: Mean Counts per 1-ml. Washings	*Staph. aureus*: No. of Samples
Bar soap 1st series	504 ± 72	35	72·1 ± 13	36
Bar soap 2nd ,,	635 ± 74	27	127 ± 52	27
Hexachlorophane soap (exclusive use)	186 ± 27	42	29·7 ± 8·5	42
Hexachlorophane soap* (in ward only)	317 ± 31	12	162 ± 56	12
Hexachlorophane soap (exclusive use) and chlorhexidine cream (3 or 4 times a day)	202 ± 51	36	42·7 ± 48	36
Chlorhexidine cream (3 or 4 times a day)	352 ± 67	36	57·6 ± 14	36

* In burns wards only.

Tests for Mutual Inactivation of Chlorhexidine and Hexachlorophane

The minimal inhibitory concentration (M.I.C.) of hexachlorophane and of chlorhexidine against four strains of *Staph. aureus* was tested by a tube dilution test. Further tests were then carried out with mixtures of the antiseptics in the proportions of their M.I.C.s; in the mixture, the M.I.C.s of hexachlorophane and of chlorhexidine were reduced in respect of one of the strains, and unaltered in respect of the others. It was inferred from this experiment that there is no mutual inactivation of these antiseptics.

Bacterial Flora of Nurses' Hands

All of the 18 nurses who took part in this study carried *Staph. aureus* on their hands in at least a proportion of the samples taken during the period when ordinary soap was in use. Sensitivity tests and phage-typing showed that these strains were typical of the ward environment. For example, 14 of the 17 staphylococci isolated in the burns unit, 14 of the 18 isolated in ward C, and 15 of the 16 strains from ward D were resistant to penicillin. Five of the strains from the burns unit were also resistant to erythromycin and novobiocin, antibiotics which were sometimes used in the treatment of burns patients; in the other wards, however, where these antibiotics were hardly ever used, all the staphylococci from the nurses' hands were sensitive both to erythromycin and to novobiocin.

Some nurses yielded consistently high or low counts of bacteria; some tended to keep the same type of staphylococcus for long periods, others to acquire new types. The hands were more often found to carry staphylococci than noses (only one of the six nurses in the burns unit yielded *Staph. aureus* from a nose swab). Coliform bacilli of types commonly present in burns were sometimes found in large numbers on the hands of nurses in the burns unit; these organisms are not sensitive to hexachlorophane, and the use of hexachlorophane soap cannot be expected to reduce their numbers on the skin.

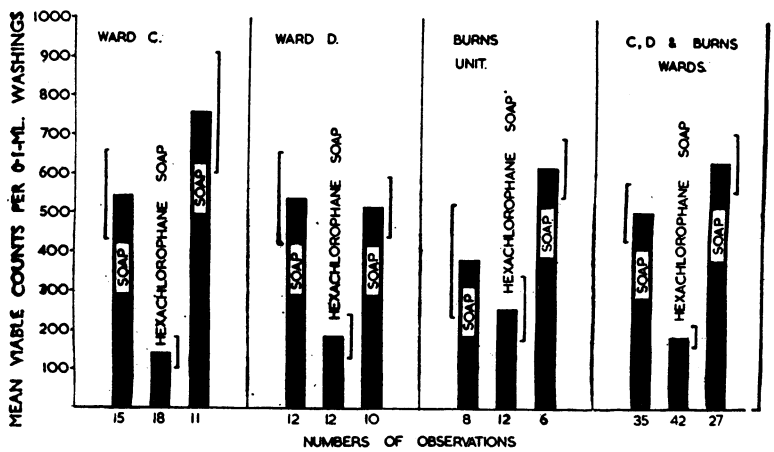

FIG. 2.—In each of three wards the mean counts from hand washings of nurses are shown before, during, and after a period when hexachlorophane soap was used for all ablutions.

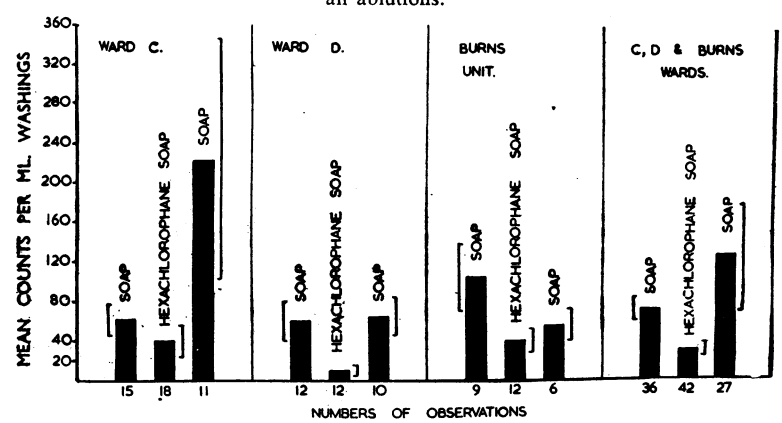

FIG. 3.—Mean counts of presumptive *Staph. aureus* on nurses' hands before, during, and after a period when hexachlorophane soap was used for all ablutions.

Sensitivity to Hexachlorophane of Staphylococci from Nurses' Hands

The minimal inhibitory concentration of hexachlorophane tested by a tube dilution method against 12 strains of *Staph. aureus* varied from 0.07 μg. to 1.5

μg. per ml. These and 12 other strains isolated from nurses' hands before hexachlorophane soap was introduced were tested by a ditch-plate sensitivity test, using 50 μg. of hexachlorophane in the ditch; identical zones of inhibition were shown by all of these strains, and by 33 strains of staphylococci isolated from hands and from the nose during and after the period when hexachlorophane soap was used. By ditch-plate tests there was no hint of the emergence of resistant staphylococci.

Sensitivity tests (to be reported elsewhere) on numerous staphylococci from burns during local prophylactic trials of neomycin, bacitracin, and chlorhexidine showed no evidence of the development of resistance to these agents.

Sensitivity of Nurses' Skin to Hexachlorophane

Apart from a few complaints of dryness of the skin, there was no experience of skin reactions in any of the nurses or laboratory workers who used hexachlorophane soap or phisohex; no reports of sensitivity were received during a period of two months while all the nurses in the burns unit were using hexachlorophane soap.

Discussion

In this paper we describe several alternative methods by which the contamination of operation wounds through holes in gloves might be reduced or even eliminated. Perhaps the combined use of two or more of these methods (assuming they are compatible) might prove more effective than any one of them alone. Like Price (1951), we have found a thorough rinse with 70% ethyl alcohol surprisingly effective, and this effect can apparently be enhanced by including 0.5% chlorhexidine with the alcohol; but the cursory mopping of the skin with a swab soaked in industrial spirit had only a small effect. Regular use of hexachlorophane, especially in the form of phisohex, was very effective and (like the inclusion of neomycin and bacitracin in glove powder) involved no additional manœuvre by the surgeon; indeed, three minutes can safely be taken off the time for scrubbing up when phisohex is used. A further potential advantage in the use of hexachlorophane for all baths and ablutions is the reduction of the general level of the skin flora, so that the risks of contamination of wounds from the skin by other routes —for example, through a wet sleeve of an operating-gown—should also be reduced.

Prolonged scrubbing with soap and water is much less effective than various forms of chemical disinfection, and can damage the skin. It may be argued that the surgeon's scrub is an unnecessary survival and should be abolished. In our studies we have considered the value of antiseptics only in their effect on hands after such a scrub, and it cannot be assumed that the results would have been so good if the hands had not been scrubbed. There is reason to suppose that the physical removal of the loose horny layer may have some value in hand hygiene by making the resident skin flora more accessible to antiseptics.

The use of hexachlorophane soap for nurses' hands was supported by our findings. It involves no additional effort, and has caused no sensitization in the nurses who used it. Phisohex was not included in this part of our study, but from its observed value on the hands of surgeons we may suppose that hexachlorophane in this preparation would be more effective also in suppressing the flora of nurses' hands. The staphylococci—including those which persisted on the skin after the regular use of hexachlorophane soap—were all sensitive to this antiseptic. A worth-while reduction of hand flora could be achieved only by regular and consistent use of the soap; neither hexachlorophane soap used only on duty nor chlorhexidine cream used three or four times a day after washing led to an adequate fall in the numbers of hand staphylococci and other bacteria.

The clinical value of these measures of hand hygiene can only be guessed in the absence of extensive controlled trials with analysis of the incidence of wound sepsis. A number of reports suggest that operation wounds can become clinically infected with staphylococci acquired from the surgeon—for example, McDonald and Timbury (1957), Penikett, Knox, and Liddell (1958), and Mitchell, Timbury, Pettigrew, and Hutchison (1959). Though some of these infections may have been airborne, the risk of infection by contact seems to be of comparable importance, and probably greater when the operation field is small. The importance of the nurse's hand as a vector of infection in the ward is generally recognized. Use of skin antiseptics—for example, hexachlorophane soap—and also, perhaps, of gloves for some ward duties should reduce the amount of clinical infection in the ward; but this, too, can be properly assessed only by controlled trials.

Summary

Viable bacteria emerging through pinholes in surgical rubber gloves and deposited inside the gloves after they had been worn for an hour were counted. These counts were used as criteria in a controlled study of several methods of hand disinfection. By both criteria the mean viable counts from five subjects were approximately halved after five minutes' surgical scrub with soap and water. When the five-minutes scrub was used as a control it was found that viable counts were reduced usually to less than one-tenth by the inclusion of 5 mg. of neomycin and 5 mg. of bacitracin per gramme of glove powder, by a three-minutes rinse with 70% alcohol, by a three-minutes rinse in 70% alcohol containing 0.5% chlorhexidine, and by using hexachlorophane soap or phisohex for the scrub and for all ablutions during the week before the experiment; phisohex was distinctly superior to hexachlorophane soap, and chlorhexidine in alcohol somewhat better than alcohol alone. Mopping the hands with a swab soaked in industrial spirit had a much smaller effect.

The regular use of hexachlorophane soap by nurses in two accident wards and a burns unit was associated with a mean reduction of about two-thirds in the counts of viable bacteria and of presumptive *Staph. aureus* in hand washings. The use of hexachlorophane during periods of duty only, and of chlorhexidine hand cream three or four times a day, was associated with much smaller reduction in the hand flora. The combined use of chlorhexidine cream with hexachlorophane soap for all ablutions did not lead to any consistent improvement upon the results obtained with hexachlorophane soap alone.

All the staphylococci isolated from hands of nurses were highly sensitive to hexachlorophane. No nurses developed sensitivity to hexachlorophane.

We thank the sisters and nurses of the Birmingham Accident Hospital, and members of the laboratory staff, who collaborated in this study. We are also grateful to Mr. W. Cater, A.I.O.T.T., and to the surgeons who supplied us

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FALLING ASLEEP OPEN-EYED DURING INTENSE RHYTHMIC STIMULATION

BY

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If one looks at translations of Russian literature in the field of medical psychology one frequently cannot but feel rather lost, for such papers are often couched in terms of the writings of Pavlov.

Pavlov's concepts are not directly compatible with Western neurophysiology, yet, since it is held that those concepts are a guide to therapy and to successful indoctrination, and since, indeed, they have been adopted by Sargant (1951, 1957) to explain sudden political and religious conversion, it is necessary that we should examine Pavlov's writings in order to reconcile them with our own neurophysiological system of knowledge. A partial attempt is made to do so here because the experimental observations with humans to be reported are closely similar to some of the phenomena Pavlov observed in his dogs, and which he believed were manifestations of "internal inhibition" in the cerebral cortex. The "external inhibition" of which he also wrote need not here concern us—it referred to the disorganization of the task in hand by an unexpected and distracting stimulus.

Internal Inhibition

Pavlov was chiefly interested in internal inhibition; "I shall call it simply inhibition, without the adjective, although each time implying internal inhibition" (Pavlov, 1955, p. 232). This inhibition was evoked in the cerebral cortex by any sensory stimulus to which, from the point of view of the dog's general economy or well-being, it was better that the dog should not respond. Throughout Pavlov's writings we find one recurring clue to the nature of this inhibition which it is possible for us to relate to our own system of knowledge—"internal inhibition and sleep are fundamentally one and the same process" (Pavlov, 1928, p. 307). "We observed that as soon as we applied the inhibitory stimulus, a somnolent state of the animal, in the form of drowsiness or sleep, immediately intervened" (Pavlov, 1955, p. 372) . . . "anyone that makes a thorough study of them will be convinced that inhibition and sleep are one and the same phenomenon" (Pavlov, 1955, p. 375).

Transmarginal Inhibition

One means by which the state of inhibition could be produced was by exposing the dog to certain stimuli which would have evoked a response had they not been excessively intense—"such conditioned stimuli too strong to give the maximal conditioned reflex, Pavlov termed transmarginal or supramaximal" (W. H. Gantt, in his introduction to his translation of Pavlov, 1941, p. 14).

Sargant (1951, 1957) interpreted human reactive collapse, after intense mental tension or excitement, in terms of the "transmarginal inhibition" caused by these transmarginal stimuli. This inhibition was held to be protective, and to be manifest in its effect on behaviour by three distinguishable phases, the "equivalent," "paradoxical," and "ultraparadoxical." These appeared when, respectively, all stimuli, whatever their strengths, acted equally; when only the weak stimuli had any apparent action; when the previously elaborated inhibitory agents alone had a *positive* effect. Pavlov wrote of this last, ultraparadoxical, phase as follows: "*In certain stages of drowsiness* [my italics] in normal dogs there occurred a distortion of the effects of conditioned stimuli. The positive stimuli lost their effect, but the negative became positive" (Pavlov, 1928, p. 345). Finally, "after this follows a state of complete inhibition" (Pavlov, 1928, p. 347)—that is, sleep supervened.

It is apparent that not only did Pavlov identify internal inhibition, as most often produced in his laboratory, with sleep, but that the variety he called transmarginal inhibition was believed by him to be of a similar nature

Human Internal Inhibition

In some experiments, described elsewhere (Oswald, 1959), in which electroencephalographic and other physiological variables were recorded, it was found, with larger numbers of human volunteers than it has been possible to use in the experiments to be reported below, (*a*) that signs of sleep appeared in persons subjected to repeated strong electric shocks, (*b*) that signs of sleep could come and go rhythmically in time with regular stimuli at intervals of only a few seconds, (*c*) that signs of sleep appeared while subjects continued to move in time with prolonged, rhythmic music. It is obvious that condition (*a*) could be labelled "transmarginal inhibition," and Sargant (1957) laid great emphasis on the use of prolonged movement, to rhythmic music, as a means of inducing this state of inhibition, quoting with approval the view of Hecker that the state induced is "like that of small animals when they are fascinated by the look of a serpent." This latter condition of fascination, or "animal hypnosis," was shown by Gerebtzoff (1941), and others subsequently, to be electroencephalographically a state of sleep. However, in the experiments with human volunteers mentioned above, the eyes were always closed. Would comparable signs of sleep appear under such circumstances in persons whose eyes were open?

The example borne in mind was that of a prolonged tribal dance where not only does the individual move in time with the rhythm of the auditory stimuli, so