A BACTERIOLOGICAL INQUIRY INTO THE STERILIZATION OF HANDS.

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THERE exists still a remarkable uncertainty as to the best method to be used for disinfecting the skin. At a recent meeting of the Gloucestershire Branch of the British Medical Association opinions ranged from the use of very strong chemical solutions to the opinion, skilfully maintained, of using no chemical whatsoever for the preparation of the hands before an operation.

In the simple experiments given here an attempt has been made to represent in a practical way the changing bacteriological picture presented by the hands of the surgeon in the successive stages of the ordeal through which they pass prior to an operation.

Sterile Petri dishes with a layer of agar-agar at the bottom were prepared in the usual way. An imprint was then taken on the surface of the agar-agar of Plate I. of the first three fingers of each unwashed hand. The hands were then scrubbed and dried either with a sterilized towel or by holding them in front of the fire so as to avoid any liquid, septic or antiseptic, remaining on the plate, and an imprint of the same six fingers was taken on Plate II. The hands were then soaked in an antiseptic solution, dried as before, and an imprint of the same fingers was taken on Plate III. The three plates were then placed in the oven and the number of the colonies which grow counted. In the washing the whole of both hands and the arms up to the elbows were scrubbed, the finger imprints representing six separate samples of the area of skin cleansed.

The effects on the skin of a chemical antiseptic were found to persist for a considerable time, for this reason each of the experiments recorded was performed at intervals of, roughly, twenty-four hours, no antiseptic being applied to the hands in the interim.

In the first two experiments, the nail-brush employed was one which was kept in the soap-dish in the surgery. After these two experiments this brush was promptly seized and burnt by the house surgeon, and the nail-brush was in future kept in carbolic acid 1 in 40. With this carbolized brush the remainder of the experiments were performed. When washing in plain water, three changes of water were used; when washing in antiseptics two changes. The soap used throughout the experiments was unmedicated.

Non-Carbolized Nail-brush: Number of Colonies.

Plate I. Unwashed.	Plate II. Washed 10 min. in warm water.	Plate III.	
		Antiseptic.	Antiseptic used.
12	70	o	Carbolic acid, 1 in 40, 5 min.
17	44	o	Hg.Cl ₂ , 1 in 1,000, 5 min.

Carbolized Nail-brush: Number of Colonies.

Plate I. Unwashed.	Plate II. Washed 10 min. in warm water.	Plate III.	
		Antiseptic.	Antiseptic used.
8	3	o	Carbolic acid, 1 in 40, 5 min.
Overgrown	35	o	Carbolic acid, 1 in 40, 3 min.
Overgrown	6	o	Carbolic acid, 1 in 40, 3 min.
56	4	o	Hg.Cl ₂ , 1 in 1,000, 3 min.

Number of Colonies.

Plate I. Unwashed.	Plate II. Washed 5 min. in tepid water.	Plate III.	
		Antiseptic.	Antiseptic used.
45 62 + overgrown	51 61 163 35 Overgrown	o o o o 8	Carbolic acid, 1 in 40, 3 min. Carbolic acid, 1 in 40, 3 min. Carbolic acid, 1 in 40, 3 min. Carbolic acid, 1 in 40, 3 min. Perchloride of mercury, 1 in 1,000, 3 min.
29	130	o	Perchloride of mercury, 1 in 1,000, 1 min.
150	200	3	Perchloride of mercury, 1 in 1,000, 1 min.
33	7	o	Perchloride of mercury, 1 in 500, 1 min.
196	2	1	Perchloride of mercury, 1 in 500, 1 min.
47	0	o	Perchloride of mercury, 1 in 500, 1 min.
105 40 312 76 + overgrown 62 + overgrown 132 191 + overgrown	4 5 18 106 65 12 34 Washed 5 min. in very hot water.	o o o o 7 1 o	Carbolic acid, 1 in 40, 3 min. Carbolic acid, 1 in 40, 3 min. Carbolic acid, 1 in 40, 3 min. Carbolic acid, 1 in 40, 2 min. Carbolic acid, 1 in 40, 2 min. Carbolic acid, 1 in 40, 1 min. Perchloride of mercury, 1 in 1,000, 1 min.
90	40	20	Perchloride of mercury, 1 in 1,000, 1 min.
122	50	o	Perchloride of mercury, 1 in 500, 1 min.
13	1	o	

The effect was now tried of introducing an antiseptic into the first scrubbing and shortening the final soaking to one minute, making thus a period of six minutes for the entire process.

Number of Colonies.

Plate I. Unwashed.	Plate II. Washed 5 min. in lysol 1 in 1,000 hot.	Plate III.	
		Antiseptic.	Antiseptic used.
248	o	o	Perchloride of mercury, 1 in 500, 1 min.
186	o	o	Perchloride of mercury, 1 in 500, 1 min.
148	o	o	Perchloride of mercury, 1 in 500, 1 min.
255	o	o	Perchloride of mercury, 1 in 500, 1 min.
41 + overgrown	o	o	Perchloride of mercury, 1 in 500, 1 min.
290	o	o	Perchloride of mercury, 1 in 500, 1 min.
103	o	o	Perchloride of mercury, 1 in 500, 1 min.
234	o	o	Perchloride of mercury, 1 in 500, 1 min.
211	o	o	Perchloride of mercury, 1 in 500, 1 min.
74 + partly overgrown	o	o	Perchloride of mercury, 1 in 500, 1 min.
204 280 62 + overgrown 68 63 + overgrown 108 19 196 42 + overgrown 94	o o o o o o o o o o Washed 5 min. in biniodide of mercury 1 in 1,000, hot.	o o o o o o o o o o	Carbolic acid, 1 in 40, 1 min. Carbolic acid, 1 in 40, 1 min. Carbolic acid, 1 in 40, 1 min. Carbolic acid, 1 in 40, 1 min. Carbolic acid, 1 in 40, 1 min. Carbolic acid, 1 in 40, 1 min. Carbolic acid, 1 in 40, 1 min. Carbolic acid, 1 in 40, 1 min. Carbolic acid, 1 in 40, 1 min. Carbolic acid, 1 in 40, 1 min.

The precise nature of the micro-organisms present is not given as it is irrelevant to the main point at issue. They were those usually present on the skin.

When the plate is mentioned in the above tables as being overgrown, it is meant that a rapidly-growing mould had spread over the surface of the agar-agar. It will be noticed that this occurs in only one case after washing, apparently moulds do not penetrate the skin as deeply as do bacilli and cocci.

The period of the scrubbing was then shortened to five minutes, and the difference between hot water (meaning water as hot as one could comfortably bear) and tepid water contrasted. At the same time different antiseptics for different periods of time were used for the final cleansing.

A brief consideration of the structure of the integument which has to be cleansed will show that we might have arrived, reasoning *a priori*, at the same conclusion as we are led to by practical experiment.

The skin presents a surface of superposed, flat, horny, scale-like cells; loosely attached and overlapping one another. The more superficial cells are continually undergoing desquamation, while fresh cells are thrust up in their place from the deeper layers as they pass through the successive stages from stratum Malpighii to stratum corneum. There is thus a thin outer porous coating on the epidermis, the interstices of which are swarming with micro-organisms. If the hands be placed in an antiseptic solution for a short time the micro-organisms on the surface are killed, but any friction removing these outer cells will lay bare the remainder of this porous coating rich in micro-organisms. The following experiment exemplifies this. The unwashed hands gave a growth of seventeen colonies on agar-agar; the hands were then immersed for three minutes in 1 in 1,000 perchloride of mercury solution, dried in front of the fire, and an imprint taken on a second plate. This second plate showed a thin lineal growth along one finger print. The hands were then rubbed on a sterilized towel and an imprint was taken on a third plate. This third plate showed all the finger prints rich in growth, and from them a large part of the surface of the agar-agar was overgrown.

The first step to be taken in the cleansing of hands is to remove by friction this outer coating of feebly adherent cells with the contamination they enclose. Strict asepticists maintain that they can perform this without any chemical disinfectant whatever. My experience is against this, and if the washing is not prolonged it probably only aggravates matters by simply ploughing up without detaching the coating of loose cells. It is important to dissolve off the outer layer of the soap which must be considered septic. When this is done the soap is probably aseptic, inasmuch as it has to be boiled in the making; and such tests as I have done on the interior of an unmedicated soap prove it to be so.

At the same time I believe that people vary much in the septicity of their skins. The frequent use of antiseptics renders the skin hard and glazy, and in that case the hands are more easily sterilized. Mr. Curtis, late house surgeon to this hospital, very kindly performed for me some experiments under precisely the same conditions as I employed on my own hands, with, as will be seen, very different results.

Number of Colonies.

Plate I. Unwashed.	Plate II. Washed 5 min. in hot water.	Plate III.	
		Antiseptic.	Antiseptic used.
154	0	0	Perchloride of mercury, 1 in 500, 1 min.
Overgrown	13	0	Perchloride of mercury, 1 in 500, 1 min.
314	0	0	Perchloride of mercury, 1 in 500, 1 min.
Overgrown	8	0	Perchloride of mercury, 1 in 500, 1 min.
214	16	0	Perchloride of mercury, 1 in 500, 1 min.

His duties necessitated frequent scrubbing of his hands and the use of strong chemical antiseptics, with the result that the septic porous layer was reduced to a minimum, and the deeper layers of the skin were probably imbued to a considerable extent by chemical substances. The penetrating power possessed by these chemical agents is shown by the cases of poisoning arising from the external application of strong mercurial and carbolic lotions. The following experiment indicates the durative of the effects of antiseptically cleansing the skin.

After performing a *post-mortem* examination lasting some hours the hands were cleansed in lysol 1 per cent. and then soaked in perchloride of mercury 1 in 1,000. The exact duration of the washing was not timed but the whole did not, I think, exceed five minutes. Three hours later when examined in the usual way by plates the result was:—

Number of Colonies.

Plate I. Hands unwashed.	Plate II. Washed 5 minutes in hot water.	Plate III. Carbolic acid 1 in 40 for 3 minutes.
Lineal growth along one finger print.	0	0

The use of very hot water in scrubbing the hands is important. In the first place it softens and removes the outer layer of skin more easily than tepid water. In the second place, passing through the skin are the ducts of sweat and sebaceous glands. The heat and increased circulation will aid in squeezing out the possible septic contents of these glands, and if the hands are then immersed in a cold antiseptic solution the physical result must be to suck up some of this solution into the ducts and thus seal them off from all fear of their contents doing harm.

As surgeons are naturally anxious to cleanse their hands rapidly, not to use an antiseptic miscible with soap in the preliminary washing, seems, to say the least of it, an unnecessary waste of valuable time, inasmuch as the final soaking in an antiseptic must be in that case longer.

To test the genuineness of the sterility of the hands produced by the last two methods adopted, lysol, followed by corrosive sublimate and biniodide of mercury, followed by carbolic acid, the following experiments were performed. A sterile jar containing sterile nutrient broth was prepared. After the completion of one out of each of the series of plate experiments recorded in the above tables, the whole hand and wrist was inserted in this jar so that the entire surface of the hand and wrist was submerged in the broth and was kept there for one minute. The jar was then closed and incubated. The broth remained sterile in the case in which lysol and corrosive sublimate had been used, in the case of the other jar where biniodide of mercury and carbolic acid had been used to cleanse the hands, a fungus growth formed on the surface of the broth. The opportunity for aerial contamination in the passage of the hands from the lotion to the broth is very great, and the fact that the infection was a mould renders it likely that this was the cause of the failure of the hands to stand the test in this instance. I hope, however, to repeat this experiment which, I think, must be regarded as a stringent test.

As it has been definitely established that some micro-organisms have relatively a selective tolerance for certain antiseptics a different antiseptic was used in the final soaking from that which was used in the primary scrubbing. There are, of course, many other antiseptics which would act as well, but those mentioned were selected as being the commonest of the two great groups of tarry extracts and mercurial compounds. They also have the advantage of costing little.

The biniodide of mercury solution was an aqueous solution of the potassio-mercuric iodide, HgI_2 , 2KI., prepared by the interaction of perchloride of mercury and potassium iodide. I think it is worth mentioning that there are three solutions of biniodide of mercury in common use, a solution in potassium iodide and water, a solution in 90 per cent. of alcohol, and a solution in ether. The alcohol and ether solutions have the objections that in the first place they cannot be used with soap, in the second place they readily evaporate, leaving solid particles of the red mercuric iodide which is excessively irritating to the skin and, being practically insoluble in water, is not readily washed off. The addition, also, of more than 10 per cent. of water will cause precipitation of HgI_2 , from even an absolute alcohol solution.

One of the factors which has delayed the determination of the best method of sterilizing the skin more than anything else is the extraordinary power healthy tissues possess of overcoming and apparently killing micro-organisms. The result is that good and even brilliant results have been obtained with faulty methods; and when in a weak individual suppuration takes place after an operation performed under similar conditions as provided at the previous successes, the tissues of the patient are blamed, and not the technique of the surgeon. I believe that when surgeons operate with the same scientific accuracy in every detail of an operation as must prevail at any bacteriological experiment, he will be as little inclined to blame the tissues of his patient for post-operative suppuration as is the bacteriologist to blame his culture media and not technical error for any contamination taking place during his experiments.

I think the above experiments, as far as they go, at least point to, if they do not justify, the following conclusions:

1. The nail-brush used should be either boiled before use, or better still, kept always in an antiseptic solution.
2. Vigorous scrubbing is required for at least five minutes.
3. The water should be as hot as can be comfortably borne.
4. Chemical antiseptics of efficient strength should be used for cleansing the skin, and it is preferable that they should be used in the primary washing as well as in the final soaking.
5. With sufficient time and care sterilization of the skin is not impossible.

The mode of preparing the skin of the patient for operation will be similar to that found best for sterilizing the hands of the surgeon, though probably less friction will be required in cleansing the skin of other parts of the body than is required in the cleansing of the hands and feet.

Besides the skin, there exists as a source of infection the instruments and dressings, and the air of the operating theatre. The instruments and dressings can be sterilized by heat. There remains the air of the theatre, the importance of which as a septic agent and the adequacy of the methods adopted to meet it I hope to show by experiments shortly, together with further investigations on the question of skin sterilization.

FURTHER OBSERVATIONS ON THE THERAPEUTIC VALUE OF RADIUM AND THORIUM.

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In January of this year my colleague, Mr. Mackenzie Davidson, contributed a paper to the BRITISH MEDICAL JOURNAL on some cases treated by exposure to radium bromide. The results obtained in two of these cases which I had the opportunity of watching while under treatment were so striking that I was induced to try the effect of this powerful salt in a number of cases under my care at Charing Cross Hospital. I have employed this treatment in suitable cases since last autumn, and though sufficient time has not yet elapsed to be certain with regard to the permanence of the results, still brief notes on a few of these cases and a record of my experience of radium as a local therapeutic agent may be of some interest.

The principal cases in which I have tried the effect of radium bromide have been lupus vulgaris, both the nodular and verrucose varieties, lupus erythematosus, rodent ulcer, and epithelioma, and, with the kind permission and under the supervision of my colleague, Dr. Amand Routh, two cases of cancer of the cervix uteri.

The radio-activity of the radium bromide which I employed has been estimated at 600,000 units, taking the activity of uranium as the unit. It was put up in quantities of 5 mg. in sealed glass tubes. I also used a tube containing the same quantity of radium bromide of two or three times the activity of the other tubes. In this communication I will designate the two types of tubes as "strong" and "weak" tubes.

MODE OF APPLICATION.

The fact that the radium bromide was contained in a sealed tube made of glass has been criticized as interfering with the full activity of the salt. Various forms of apparatus have been introduced to obviate this, in which the radium is contained in a small metal capsule with a platinum end, which is believed to be more transparent to the rays than glass, or in capsules of vulcanized rubber covered with mica and enclosed in a sheet of brass with a central aperture. Practical experience, however, has shown that the rays which penetrate the glass are sufficiently active not only to have a therapeutic effect on the skin, but, unless their action be carefully limited, to produce a radium burn. I will not attempt to discuss the subjects of the various types of rays which are given off by radium in the solid state, and of the relative value of the different radiations; these problems I must leave to the physicist. Suffice it to say that the general consensus of opinion seems to be that it is the so-called beta rays which have the chief therapeutic value, and that these readily pass through glass. Recent researches have shown that radium has the power of inhibiting the growth of various bacteria, and certain experimenters, such as Dixon and Wigham, con-

sider it probable that it is to the beta rays that radium owes this inhibitory power.

Another obvious criticism of the method of application of radium bromide in a sealed glass tube of about $1\frac{1}{2}$ in. in length is that such a small quantity as 5 mg. of the salt is apt to get spread about the tube, and will not keep in one position. This is a just criticism, and though in most cases the radium may be satisfactorily applied in such a tube with care, still it is practically impossible to do so when it has to be applied in situations such as the inside of the nostrils. To obviate this difficulty I have had a special tube made with an hour-glass constriction at one end containing the salt. This small tube can be easily inserted into the nostrils, and with the patient in the recumbent position can be retained there with no difficulty or discomfort.

At first I was in the habit of fixing the tubes in position on the skin by means of adhesive plaster. This necessitated considerable handling of the tubes, and, to minimize the risk of breaking them, I now place them in a metal tray (Fig. 1) on a bed of sterilized cotton-wool and fix them by a bandage. The tray and the tube are contained when not in use in a metal box, as shown in the diagram.*

Fig. 1.

For the purpose of applying the tubes in cavities such as the throat and vagina I have also had a catheter-like holder made with a malleable metal extension on which a piece of indiarubber can be fixed for the teeth to bite against (Fig. 2).

Fig. 2.

Every part of the diseased area was exposed *seriatim* and then at least a week was allowed to elapse. If no inflammatory reaction occurred daily exposures were given for a week, and then the treatment was intermitted for a fortnight and followed by a second cycle of exposures, and a third if necessary.

The length of time of the exposures depended chiefly on the purity and activity of the radium bromide in the tube, and also on the characters of the diseased area. With the strong tube exposures of ten minutes' duration were ample, but to get the same effect with a weak tube an hour or more was required. Where there was much thickening of the epidermis, as on the border of a rodent ulcer or in the verrucose type of lupus vulgaris, longer exposures could be given with safety than in the case of a nodular lupus where the epidermis was thin. Every precaution was taken to under-expose rather than over-expose the lesions, as the best results were

* For the trouble in preparing the apparatus and for the loan of the more active radium tube I am deeply indebted to Mr. W. Martindale.