A METHOD OF EVALUATING THE BACTERIA REMOVED FROM THE HANDS IN PREOPERATIVE HAND PREPARATION

by

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INTRODUCTION

The problem of determining quantitatively the bacteria removable from the skin has not held the attention of bacteriologists in their investigations of the flora of the human skin.

Theoretically, the number of bacteria on the skin should be proportional to the source of the contamination, frequency of contact with this source, and the condition of their site on the skin. It is bacteriologically accepted that each organism removed from the skin in a viable state is able to produce a single colony when grown on the proper media under proper conditions.

Therefore, if a given area of the human body should be subjected to a physical means of bacterial removal for a given length of time and a measured fraction of the removed sample be grown on a proper medium, the number of colonies derived would be proportional to the number of organisms removed. Evidence partially substantiating these conclusions has been furnished by the work of Price[1].

History of bacterial studies of the human skin has its origin mainly in the field of surgical asepsis. The initial inspiring work was performed by such great scientists as Semmelweis, Pasteur, Lister, Gordon and Haller[2]. These men advanced certain fundamental basic principles for surgical asepsis. Semmelweis[2] was one of the earliest workers to show clinically that the hands of the surgeon were potential sources of wound infection and that the flora of the hands could be, and frequently were, composed of virulent organisms. He suggested the use of chemical hand disinfectants as a means of eliminating the virulent organisms.

Louis Pasteur[2], the father of bacteriology, acutally proved experimentally that pathogenic bacteria were the cause of post-operative wound infections. He clearly described the microscopic, grape-like clusters of the staphylococcus and the chain formation of the streptococcus.

Joseph Lister[2] proved clinically that the disinfectant action of certain chemicals was of essential importance in proper surgical asepsis. He was one of the first to demonstrate that phenol destroys bacteria.

Late in the nineteenth century, the surgeons began to apply the technic of preoperative hand preparation as a routine. Wyeth's[3] Textbook of Surgery in 1888 advanced the principles of

personal cleanliness. He was one of the earliest to advocate specifically a preoperative hand treatment. Briefly, he states that the surgeon's finger nails should be cut short and cleaned before every operation that hands and arms should be scrubbed with a brush in soap and water, and that this procedure should be followed by the rinsing of the hands in a 1:3000 sublimate solution.

DaCosta's[4] Textbook of Surgery of 1912 gives several methods of preoperative hand preparation. He advocated the mechanical cleansing of the hands and forearms by brush, soap and hot water as follows: "Scrub for five minutes with soap and hot sterile water, giving special attention to the nails and creases in the skin. The water should be as hot as can be borne with comfort, as hot water stimulates the sweat glands and the flow of sweat washes out the ducts before the operation; during the operation then, secretions will be slight. The brush is rubbed in the long axis of the extremity and also transversely. The creases on the backs of the hands and fingers will be partially opened by flexing the fingers and transverse scrubbing will clean the furrows. Creases on the palm surface will be opened by extending the fingers and will be best cleaned by transverse scrubbing. An excellent soap is the ethereal soap of Johnston which is a solution of castile soap in ether." DaCosta relates additional

methods of hand cleansing and sterilization, where he in detail describes specific hand treatments advocated by certain operators in surgery. Four methods are described: (1) Furbinger's Method--Essentially this is a chemical sterilization of the hands and forearms following a specific soap and water scrubbing routine. He advocates the use of a 95% alcohol dip for three minutes, which is followed by scrubbing with hot mercuric bichloride (1:3000) for at least one minute. (2) The Welch-Kelly Method --Involves mechanically soap and water cleansed hands and forearms followed by immersion into a warm saturated potassium permanganate, then oxalic acid, followed by an immersion in a 1:500 corrosive sublimate. Hands are than rinsed in sterile water and dried on a sterile towel. (3) The Weir Stimson Method --Involves the scrubbing of the hands in hot running water with a brush and green soap. No specific time limit is given. The hand-scrub is followed by a three-to five-minute wash in a creamy mixture of washing soda. Hands are rinsed in hot sterile water and then immersed in ammonia water, one-half per cent. (4) The Sublimate Alcohol Method--Preferred by DaCosta; the hands are to be scrubbed in soap and warm water followed by immersion in 70% alcohol. This is then followed by an immersion in 70% alcohol containing corrosive sublimate. The forearms are rubbed thoroughly with a wet gauze pad while immersed in the alcohol sublimate solution . The cleansed parts are then washed in sterile

water. Wyeth[5] in 1908 suggested that in operator's hand preparation, the hands should be soaked in warm soap and water for several minutes. They should then be scrubbed with a sterile brush for several minutes and rinsed in sterile saline. This procedure is followed by cleansing the finger nails, scrubbing the hands again in soap and water, and concluding with a second rinse in sterile saline and a two or three minute immersion in mercuric bichloride solution.

Ochsner's[6] method of preoperative hand preparation in 1904 suggested that every evening before retiring, the surgeons and assistants should scrub their hands with the same care as that which is employed in disinfection before operation. His basic method of preoperative hand cleansing involved the scrubbing of the hands in a porcelain basin full of warm water, using green soap with a moderately stiff brush. Finger nails are then cleaned with the point of a dull scalpel. The hands are then scrubbed again and rubbed with a piece of gauze. The gauze seems to rub off all the loose epithelium. The hands are then rinsed under the faucet with boiled warm water and immersed in a 1:2000 mercuric chloride solution for a few minutes. This treatment is followed by a rinse with strong commercial alcohol. Empirically, Ochsner found that the above treatment of the surgeon's hands resulted in aseptic wounds. He found no appreciable clinical difference between

washing with soap and water alone and this treatment followed by chemical disinfection. Ochsner insisted that all persons who were not free from breaks in the skin but who were connected with the operative procedure should wear rubber gloves. He required all his assistants to wear gloves, but wore gloves himself only when operating in an infected field.

Tinker[7] in 1932 worte that the early work of Lawson Tait of Birmingham, England, Joseph Price of Philadelphia, Schleich of Berlin and others showed that the skin may be freed sufficiently from pathogenic bacteria by mechanical methods alone to give excellent operative results in major surgery. Schleich used marble dust soap as an adjunct to scrubbing. Tinker's method recommends that the hands should first be washed to remove the ordinary contamination. The nails should then be cleaned and the arms scrubbed thoroughly at least twice with soap and tap water. The brush is then discarded, a fresh sterile brush substituted and the hands gone over twice more, scrubbing in sterile running water. The hands are finally disinfected by rinsing them in 1:1000 bichloride of mercury, followed by another rinse in 95% ethyl alcohol.

Meleny's[8] technic of preoperative surgical hand preparation recommends five minutes as an appropriate time for the cleansing procedure. Starting with soap and warm running water , using a sterile scrubbing brush, this process is followed by rinsing

five minutes by the clock in lime and soda and then in a 70% alcohol solution. He modifies the chemical disinfection by suggesting ten minutes in the alcohol solution if the soda lime is found too irritating to the operator's hands.

Richardson[9] in 1934 advocated a soap, water and brush scrub followed by immersion of the hands and arms in seven per cent tincture of iodine, and then in a saturated solution of sodium thiocyanate in 70% alcohol .

Elman and Cole[10] state that a soap, water and brush scrub should be performed for five to ten minutes and followed by the use of a germicide. They also say, "Scrubbing the hands for ten minutes is a much more effective method of sterilization than the use of antiseptics." Coombs[11], however states that two minutes in 70% alcohol is equal to six and one-half minutes of scrubbing. He believes that the important stage of the procedure is the germicidal treatment.

In "Practice of Surgery," edited by Dean Lewis, the article on Aseptic Surgical Technic written by Urban Maes[12] states that the method most commonly employed by many modern surgeons is to scrub thoroughly with soap and water for ten minutes, then rinse in a thin stream of alcohol, dry with sterile talcum and put on sterile rubber gloves. A further method proposed by Maes[12] consits in the treatment of the hands after scrubbing, as follows: Immerse them in a solution of 1:2000 mercuric

chloride or in a saturated solution of $KMnO_4$ which has been decolorized by a saturated solution of oxalic acid. He also gives a method used in a New York hospital wherein the hands are scrubbed in the usual manner then treated with a commercial chloride of lime rubbed into a paste with sodium carbonate crystals. This is followed by rinsing in sterile water.

Coombs'[11] method of hand cleansing is:(1) The hands are scrubbed with soap and water for at least seven minutes, removing the gross dirt, transient bacteria, fats and according to his reports, incidentally about one-half of the basic flora. (2) Resident flora is much more effectively removed by germicide than by scrubbing, which is contradictory to the claims of Elman and Cole[10]. Coombs follows the hand scrub by rubbing the extremities with gauze soaked in 70% ethyl alcohol. The hands and forearms should be dried with a sterile towel before the alcohol wash so as not to dilute the alcohol solution and lessen its germicidal powers. Time spent in the alcohol solution is an important point as stressed by this author. The alcohol wash should consume at least three minutes, or two minutes in the alcohol mixture solution, which is composed of 50 parts of ethyl alcohol, 30 parts propyl alcohol and 20 parts water. The author estimates that the scrub and alcohol treatment will effectively reduce the skin flora to less than two per cent. (3) Coombs[11] further advocates

that the hands between operations should be washed in a germicidal solution in order to counteract the increase of the cutaneous bacteria which has taken place beneath the gloves. A useful rule is a one minute wash in 70% ethyl alcohol for every hour the gloves have been worn. He stresses the fact that the hands of the operator can be the habitat of very virulent bacteria if they have come in contact with purulent wounds in the ungloved condition. According to this author's conclusions, the bacteria are reduced by 50 per cent when the hands are washed in 70% alcohol for three minutes. He also believes that six minutes of hand scrubbing is sufficient for preoperative hand preparation.

Thorek[13] in 1938 reported that liquid green soap or ordinary bar soap containing powdered pumice, when used with warm running water was found to be very effective in removing superficial bacteria. The hands and arms should be scrubbed to above the elbow with soap and hot water and the subungual dirt removed with an orange stick or file. With a soft brush, scrub first the thumb of the left hand, then in order, the index, middle, third and little fingers and then the palm across the nails up to and including the wrist. The person scrubbing should rinse frequently in the process which is then repeated on the right hand, each finger being scrubbed on all four surfaces. The arms should be kept flexed as much as possible at all times, this being especially important when the scrub is concluded following a thorough rinsing in cold water. Thorek allows a

minimum of five minutes for each hand preparation, the whole cleansing process requiring a minimum of 15 minutes. Too much scrubbing can be detrimental as it may be injurious to the skin and, since Staphlococcus albus organisms can never be completely removed by our present preoperative hand preparation methods they could become infectious for the operator's own tissues if the deeper epithelial structures were exposed, which is physically possible by excessive scrubbing. The chemical disinfection is carried out by scrubbing in a 1% Lysol solution, sterile water and a 50% alcohol solution. Each solution is placed in a properly labelled basin and the hands soaked one minute in each. Finally, the fingers are dipped in a 1:100 metaphen solution.

Pohle and Stuart[15] carried out further experiments with a modified Price[1] technic. Their method used no brushes, but each of the ten basins contained a measured quantity of water and granulated soap. Each subject washed his hands for two minutes, rinsed the extremities, and then repeated the process in the succeeding nine basins. Cultures taken quantitatively were then plated on plain agar and the colonies counted. They were able to plot curves very similar in nature to those which Price[1] obtained. The introduction of 70% ethyl alcohol in the fifth basin increased the speed of reduction of bacterial counts very decidedly. They also found that the use of sulphuric ether in the fifth basin did not appreciably reduce the bacterial count in succeeding basins.

In evaluating the foregoing surgical preoperative hand preparation methods it may be stated that not one is specific in the length of scrub required before the chemicals may be applied. The impracticability of many of the listed disinfectants is readily realized when considering the irritative and corrosive effects to the operator's hands. Furthermore, their efficacy in removing the flora of the skin is bacteriologically unproved. Quantitatively, did the cleansing process destroy all the bacterial flora or only part of it?

Bacteriologically, modern methods of preoperative surgical hand preparation have not been subjected to thorough experimental tests. Much literature is available in regard to the antiseptic value of certain chemical preprations in vitro, but the actual number of bacteria destroyed on the skin has not been solved by these authors. Investigations usually find clinical evidence of postoperative infection and this serves as the only guide of contamination. The actual source is searched for in many instances, but the number of successful searches are very few. The impracticability of evaulating an antiseptic by the absence of growth in a test tube is obvious when one observes the histology and physiology of the human skin. Whether the absence of growth in the culture tubes is due to the transference of some antiseptic ions into the culture tube or complete destruction

of the bacteria is not taken into consideration by many workers. Furthermore, if they do obtain growth in the culture tube, the question of how many bacteria were involved in the production of the growth and how many were destroyed is not answered. Simmons[14] used the cultural findings after contaminating the hands with live bacteria and then subjecting them to certain disinfectants. Just why the bacteria present at all times on the skin and in the skin pores were not satisfactory for the experimental work is not made clear.

It may be accepted and bacteriologically sound that certain chemicals destroy the bacteria in varying numbers on the human skin. It has also been proved that complete sterilization of the skin is impossible[13]. Grossly the principle of preoperative hand preparation may be divided by basic procedures: first, the mechanical cleansing and second the chemical disinfection. The mechanical portion of the procedure has never been subjected to a bacterial quantitative analysis, except by the work of Price . Just why everyone accepted the mechanical principles as a routine cleansing process which removed the dirt, grease and some of the bacteria, without really investigating the actual efficiency of such a procedure, is an unsolved problem. Some surgical textbook

authors advocate five minutes of scrubbing, whereas others favor ten to 15 minutes. The chemical treatment of the scrubbed hands is also subject to these considerations: (1) does the chemical destroy the bacteria on the skin? (2) is the disinfectant tolerated by the surgeon's skin?

In the mechanical treatment of the operator's hands Price[1] found that the bacterial flora could be classified into transient and resident varieties. The former were prone to a constant change, being almost wholly determined by the operator's environment. He regards resident flora a more constant form, being practically the same on the skin of all individuals. The transient flora being the type usually acquired by environment association should therefore be more superficial and the more subject to mechanical removal. It therefore is a logical conclusion that scrubbing the hands and arms with a mechanical means would serve as a mechanism for removing the transient flora, and should serve as a means of not only freeing the skin of the operator of grease and dirt, but also of reducing the transient and resident flora.

Price[1] claimed that he could mathematically calculate the bacteria removed by progressive one minute scrubs. His method briefly involved the placing of a series of basins in

a row and having each basin filled with a measured quantity of water. This he followed by a routine one minute soapless scrub in each basin. Being very adept in his personal scrubbing routine, he believed that he could be uniform in each basin scrub. From plate counts, he was able to calculate the total number of bacteria in each basin and then, by plotting his counts graphically he was able to show that there was a progressive reduction in the bacterial counts as the time of the scrub was lengthened until the eight minute basin count was reached. Following basins showed no increase in the number of bacteria removed by scrubbing.

Consciously or subconsciously, two motives are before the surgeon in carrying out hand preparation technics. First, he wishes to free his hands completely from any chance contaminants of a definite pathogenic nature and, second, he desires the normal flora of the skin to be reduced to the lowest possible limit quantitatively. A third factor affects his choice of a method for attaining these objectives, namely the necessity of keeping his hands in the best possible physical condition. There is some justification, in considering methods, for separating the two objectives mentioned. Pathogenic bacteria that have only very recently been picked up on the hands undoubtedly are very superficially attached

and may be removed or destroyed by methods that would have little effect in reducing the total number of organisms on the skin. However, even recently acquired bacteria may find lodgment under the nails, in the nail creases, or even in damaged hair follicles or other invisible abrasions, and hence require for their complete dislodgment more vigorous treatment. Furthermore, it seems clear (Price[1]) that it is far from impossible for pathogenic organisms to establish themselves with some degree of permanence on the skin and become in effect a part of the indigenous flora.Though both of the above cases may be considered as the exception rather than the rule, it is obvious that since the exception can be detected only by laborious bacteriological investigation, the only safe attitude is to regard them as the rule when selecting methods of hand preparation. The general premise remains that that technic of hand preparation is safest which most nearly reduces the total germ content of the hands to zero. Within certain limits the corollary of this may also be accepted, viz., that two methods are comparable in efficiency on the basis of their effect in reducing quantitatively the skin flora. But both premise and corollary appear purely academic when it is realized that there is no practical method of determining the total germ content of the skin. However, purely academic

reasoning has often led to practical values. Perhaps we may be still more academic, therefore, and say that the surgeon, after all, is interested not in the bacteria that remain on his hands, but in those that come off and reach the field of operation. May we not then restate our premise thus?--That method is most efficient which reduces to the greatest extent the removable bacteria on the hands. Actually, of course, we must regard all of the bacteria on the skin as capable of coming off under some circumstances. If, therefore, for practical purposes a method of removal is chosen which is both vigorous and capable of being fairly accurately standardized, and which permits the quantitative estimation of the removed organisms, we should not only be justified in accepting the numbers obtained as indicating the efficiency of hand preparation technics, but we should expect those numbers to have a constant relationship to the total germ content of the hands. If such a standard procedure is applied to the hands before beginning and again after finishing hand preparation, the ratio between the two counts obtained should give a figure that indicates, at least for purpose of comparison, the efficiency of the hand preparation technic.

EXPERIMENTAL

On the basis of the reasoning advanced in the preceding section, the following procedure was selected as the method best fitted to our objective. The subject under study first scrubbed his hands and arms to the elbow for one minute in a basin of sterile water, using a sterile brush and a previously standardized technic. He then applied the particular hand-preparative procedure which was to be studied and concluded with another one-minute scrub in a second basin. A plate count was made on each basin and the total number of countable bacteria in each basin calculated. These figures were called "total counts". Subjects must not have scrubbed their hands surgically or subjected them to chemical disinfection for at least 24 hours previous to the test. Before each test the individual was given thorough instruction regarding the routine to follow. The scrubbing surface involved included the hands and forearms. Stress was given to the following of a definite process in the application of the brush; the dorsum of the hand and forearm were usually covered in one complete stroke, the same method being employed on the volvar surface. Each interdigital space and finger nail was given individual

attention. One extremity was scrubbed for one-half minute. The initial test-scrub was performed without soap in a basin containing a known quantity of sterile tap water. The subject was then required to scrub beneath running tap water with a non-alcoholic liquid soap and brush for various lengths of time, after which the extremities were rinsed thoroughly in running water. The subject next scrubbed for one minute with another sterile brush in a second basin containing a measured quantity of sterile water without soap. Measured samples were taken from the first and second basins, diluted properly, plated-out, and counted in 48 hours.

Approximately 300 tests were performed in this manner. The running-water portion of the scrub was the portion of the test that was subjected to variations in time. The scrubs utilized the following time periods: two, three, four, six, eight, ten and twelve minutes.

After performing 20 or more individual tests for each time period the figures obtained were arranged in tabular form. Mathematically a figure of percentage reduction was obtained by subtracting the second basin count from the first basin count and dividing this figure by the first basin count.

It is obvious that in a procedure of this kind there are many variable factors that cannot be eliminated or adequately

controlled, such as the texture of the skins of different people, the character of brushes used, the amount of pressure exerted in scrubbing, the initial number of bacteria on the hands, the particular distribution of the bacteria, and the kinds of bacteria present. It seemed, therefore, that the only way to obtain evidence regarding the actual reliability of our method would be to try it in germ-removing processes that differ from each other only in a single quantitative factor that is known to influence the process in some relation to its quantity. Among such factors time may be accepted as fulfilling the conditions. If, then, we apply some constant process of removing bacteria to the hands for varying lengths of time, determining by our method the supposed percentage of reduction attained in each time interval, and the figures obtained show the expected relation to the length of the time interval, the experiment will constitute evidence in favor of the validity of our method of measurement.

If mechanical cleansing of the hands results in decreasing the bacterial flora present on the scrubbed extremities, then would not the application of a disinfectant to the same area further reduce the flora present? The application of a chemical agent to the skin in the above-mentioned mechanical procedure, followihg

the running water-soap portion of the test, should result in further reducing the number of bacteria obtained in the second basin. If this supposition were found to be true in experimental test, then it would appear to validate further our method of measuring the bacteria removable from the hands. With the foregoing ideas in mind the author conducted a series of experiments with several well-known antiseptics, the results of which are given in Table XII.

The method of introducing a chemical disinfectant was as follows: The hands were scrubbed in the first basin as described above, then scrubbed under the running tap-water with soap and rinsed in clear running tap-water. The antiseptic was then applied following the tap-water rinse it being placed in a non-reacting container and applied by a handwashing process with a one minute duration of action. The extremities were again rinsed in tap water and finally scrubbed in the usual manner in the last test basin. Qualitative tests were conducted on samples from the last water basin at frequent intervals to determine the presence of growth-inhibitory concentrations of the particular antiseptic used.

In discussing the tables, it was decided to approach the mechanical cleansing results first. Several tables are then introduced which present some interesting comparisons of mechanical cleansing plus antiseptics is discussed.

The figures in Table I show that a wide variation exists when individuals are permitted to perform but one scrub, for a two minute period. The unusually wide range of the percentage reduction figures do not permit any accurate conclusions to be drawn.

TABLE I

Data Obtained for Two Minutes of Mechanical Cleansing

SUBJECT	NUMBER OF TWO MINUTE SCRUBS	PER CENT REDUCTION
Neilson,R.	1	0
Russell	1	0
Fearl	1	0
Scales	1	17
Anderson	1	0
Larson, R.	1	11
Davis	1	2
Pease	1	6
Johnson	1	10
Ito	1	0
Humphreys	1	4
Larson, V.	1	2
Smick	7	4 (average)
Hubert	2	2.5 "

Table II again does not permit any definite conclusions to be drawn. Even though the time of scrub is increased to three minutes, there is a marked variation when the same individual repeats his scrub tests. It is seen however, that the percentage reduction figures in Table II tend to be somewhat higher than those of Table I.

TABLE II

Data Obtained for Three Minutes of Mechanical Cleansing

SUBJECT	NUMBER OF THREE MINUTE SCRUBS	PER CENT REDUCTION
Holcomb	1	10
Burr	1	11
Cottrell	1	20
Davis	1	11
Pease	1	10
Judd	2	21
Russell	2	5
Neilson, R.	2	18
Fearl	2	11.1
Scales	2	19.11
Anderson	2	15.5
Hubert	1	9
Smick	1	5

Table III shows that the variation of percentage reduction figures for individual scrubbing is becomming less as compared to the similar figures in Tables I and II. There is a definite tendency toward a grouping level. In Table I there was an average reduction of 4.1 per cent, whereas; in Table II the average percentage reduction was 10.4 per cent. The 45% average in Table III indicates a massive removal of bacteria by the cleansing process.

TABLE III

Data Obtained for Four Minutes of Mechanical Cleansing

SUBJECT	NUMBER OF FOUR MINUTE SCRUBS	PER CENT REDUCTION	MAX. & MIN. PER CENT REDUCTION	
Russell	3	41.6	48	35
Scales	2	67	72	62
Hurd	2	43	47	39
Johnston	1	53		
Neilson	4	48.7	63	26
Judd	5	35.8	55	20
Fearl	6	41.6	71	19
Davis	2	31.	38	24
Pease	1	28		
Larson	2	67.5	72	63
Cottrell	2	44	50	38
Wooliver	1	29		
Smick	8	42.5	64	18
Sears, H.J.	8	38	65	30
Aumann	4	51.2	69	42
Wynia	5	57.8	78	42

Tables IV and V present definite evidence that there is a higher percentage of bacteria when scrubbing time is lengthened. This is further substantiated by the counts recorded in Table VII. The average percentage reduction in Table III was 45%, in Table IV the average reduction percentage has increased to 62%, again showing that there is a progressive increase in bacteria removed per unit time. It should also be noted that the individual variations of subjects in percent reduction is less extreme as the time is lengthened.

TABLE IV

Data Obtained for Six Minutes of Mechanical Cleansing

SUBJECT	NUMBER OF SIX MINUTE SCRUBS	PER CENT REDUCTION	MAX. & MIN. PER CENT REDUCTION	
Aumann	4	60.2	79	53
Schauffler	1	67		
Smick	8	58.3	85	36
Sears, H.J.	3	61.3	82	41
Nurses-one scrub ea.	2	80.5	88	73
McConnell	1	48		
Wynia	7	62.2	85	38

Table V significantly shows that the average variation in percentage reduction for different individuals scrubbing eight minutes is wider than those performed for shorter durations of time. Another fact shown by this table is the only relatively slight advantage of the eight- over the six-minute scrub. A similar decrease at this point in removal efficiency per unit of time was also observed by Price[1], and by Pohle and Stuart[15]. Price proposed the therapy that this decrease was due to the removal of the transient flora which is displaced early and much more easily in the scrubbing process.

TABLE V

Data Obtained for Eight Minutes of Mechanical Cleansing

SUBJECT	NUMBER OF EIGHT MINUTE SCRUBS	PER CENT REDUCTION	MAX. & MIN. PER CENT REDUCTION	
Fearl	1	31		
Davis	1	48		
Anderson	1	77		
Lundy	1	72		
Pease	1	51		
Johnston	1	89		
Hubert	3	67	80	57
Smick	1	44		
McConnell	4	61.2	69	50

Table VI shows a marked increase in the "average percentage reduction" value when scrubbing is continued for a ten-minute period. Furthermore, the variation in the figures for different individuals is less than for any other time period.

TABLE VI

Data Obtained for Ten Minutes of Mechanical Cleansing

SUBJECT	NUMBER OF TEN MINUTE SCRUBS	PER CENT REDUCTION	MAX. & MIN. PER CENT REDUCTION	
Anderson	1	85		
Fearl	1	55		
Neilson	1	86		
McConnell	3	67	77	58
Smick	4	50	62	38
Wynia	1	71		
Youmanns	1	66		
Aumann	1	77		

It would appear from Table VII that the percentage reduction following twelve minutes of scrubbing is no greater than that following ten minutes. Although an insufficient number of subjects were studied to justify any broad assumptions, this table suggests that there is maximum time of mechanical cleansing beyond which very little will be accomplished.

TABLE VII

Data Obtained for Twelve Minutes of Mechanical Cleansing

SUBJECT	NUMBER OF TWELVE MINUTE SCRUBS	PER CENT REDUCTION
Aumann	1	85
McConnell	1	60
Smick	1	71

Table VIII demonstrated the constancy of results obtained by the same subject in a given procedure repeated several times and the individual variations among subjects using identical technics. In presenting this information it shows that the difference in per cent reduction figures obtained from the same individual in different trials is too great to permit the attachment of much significance

to the results of a single test. It also exhibits the fact that neither the variations of percentage reduction for the same subject in different tests, nor those occurring among different individuals in the same test, bear any relation to the actual number of organisms on the hand at the time of beginning test.

Two types of averages are used in Table VIII. One is the average of the "per cent reductions" obtained from a number of tests on the same subject, the other is the average of the figures obtained from one test on each of a number of subjects. The first can be called individual averages, the second the group averages. Comparing the individual averages in Table I, calculated from the results of a maximum of six tests only, it is apparent that the figures for the six subjects vary over a narrow range. It suggests that if averages were obtained from a very large number of tests individual differences would become insignificant.

(TABLE VIII) here

Table IX suggests, as did also Table VIII, that the average of the results of a simultaneous test on seven subjects falls near the middle of the range of the individual results.

Table VIII

DATA OBTAINED ON SUBJECTS FOR FOUR MINUTES OF MECHANICAL CLEANSING

jects	Test No.	Total Count first basin Millions	Total Count second basin Millions	Difference Millions	Percentage reduction	Average per cent reduction
	1	4.05	2.23	1.82	45	
	2	12.71	8.65	4.06	32	
	3	3.71	3.05	.66	18	
.S.	4	4.59	2.88	.71	38	
	5	4.99	2.79	2.20	44	
	6	10.02	4.98	5.04	50	37
	1	7.32	3.83	3.49	47	
	2	7.54	4.65	2.89	38	
	3	6.49	4.23	2.26	34	
S.	4	6.53	4.55	1.98	30	
	5	8.17	2.83	5.34	65	
	6	5.13	3.15	1.98	38	42
	1	.36	.21	.15	42	
	2	.11	.04	.69	59	
W.	3	.40	.18	.22	54	
	4	1.50	.32	1.17	78	
	5	2.07	.90	1.17	56	57
	1	1.70	.94	.75	44	
	2	.25	.14	.10	42	
A.	3	1.26	.61	.65	50	
	4	12.24	2.52	9.72	69	51
	1	.18	.11	.66	38	
	2	1.89	1.38	.51	27	
.	3	4.10	2.21	1.89	46	
	4	.73	.59	.15	20	
	5	.70	.51	.19	55	37
	1	3.47	1.93	1.54	44	
	2	2.70	1.26	1.44	53	
	3	2.79	.81	1.98	71	
.	4	2.16	1.39	.77	36	
	5	3.83	2.79	1.04	27	
	6	.95	.76	.18	19	41

TABLE IX

SUBJECT	PER CENT REDUCTION DUE TO FOUR MINUTES SCRUBBING
A.O.	58
D.J.	53
B.P.	28
W.W.	29
L.M.	47
H.V.	45
A.C.	35
Average for all subjects	42

In Table X the real test of the method which is being proposed appears by calculating the effect produced upon the average percentage reduction figures by altering the time of application of the degerming process.

TABLE X

AVERAGE PERCENTAGE REDUCTION GIVEN BY DIFFERENT PERIODS OF MECHANICAL CLEANSING

	Average percentage reduction for various minutes of scrubbing (individual scrubs vary from 2-10 individual tests)						
Minutes	2	3	4	5	8	10	12
W.E.S.	4	5	42	58	44	50	71
H.J.S.	-	-	43	61	-	79	-
F.W.	5	18	57	62	76	71	-
K.A.	-	-	51	60	57	77	85
H.H.	0	0	27	74	72	-	-
G.M.	0	10	33	48	61	67	60

Table XI shows a trend similar to Table X. That is, there is a definite progressive increase of "percentage reduction" proportionate to increases in time of scrubbing. These figures represent an average of single tests on all or part of a group of six subjects. It may be concluded that the method of "mechanical cleansing" results in a definite ratio between the length of a process and the "Average percentage reduction". It should be noted however, that large variations in the results in a procedure so difficult to standardize may be significant.

TABLE XI

AVERAGE "PER CENT REDUCTION" SHOWN BY A GROUP OF SIX SUBJECTS AFTER SCRUBBING FOR VARIOUS TIME PERIODS

Minutes of scrubbing	2	4	8	10
Per cent reduction (average of six subjects)	7	47	50	67

It may be accepted without dispute that treatment of hands with a disinfectant of known germicidal potency, after a period of mechanical cleansing will further reduce the number of live organisms on the hands, and the amount of this further

reduction will have some relation to the germicidal power of the disinfectant. Table XII shows the effect of a number of such treatments on the individual average per cent reduction figures obtained from two subjects by our method. The figures in parentheses give the number of tests from which the averages were calculated. In each test, following the use of a chemical substance, the hands were rinsed briefly, without rubbing, in running water before the final standard one-minute scrub. This eliminated any effect that introducing traces of growth-inhibiting disinfectants into the wash water may have made on the count.

The results of these tests again reflect the validity of the proposed technic of measurement in that they correlate roughly with the well-known efficiencies of the various disinfectants. Seventy per cent alcohol, for example, is distinctly superior in germ removing power to 1-2000 $Hg\ CI_2$ since, in spite of the greater germicidal potency of the latter, its poor penetrating power and its tendency to combine with albuminous matter make it a relatively inefficient skin disinfectant. Cyanide of mercury shows a comparable efficiency. It is interesting to note that the method seems to show a lower efficiency for mercury bichloride followed by alcohol than for alcohol alone. This result seems not unreasonable. It is easy to believe that bichloride could produce a film of

coagulated albumen which would somewhat protect the bacteria of the underlying skin from the action of the alcohol. The high germicidal potency and penetrating power of tincture of iodine is reflected in the results with both half and full strength of this drug.

TABLE XII

THE EFFECT OF "AVERAGE PER CENT REDUCTION" FIGURES OF FOUR MINUTE MECHANICAL CLEANSING FOLLOWED BY CHEMICAL DISINFECTION

SUBJECT	CHEMICAL DISINFECTION USED				
	No Disinfectant	Rinsing one min. in 70% ethyl alcohol	Rinsing one min. in 1-2000 aq.H_gCI_2	Rinsing with 3½% iodine followed by Sod. thiosulphate	Covering with Tr. Iodine followed by U.S.P. alcohol one min.
W.E.S.	42.5%(8)	79.7%(4)	65.3%(3)	94.5%(2)	99.9%(4)
McC.		90.6%(6)	60.3%(3)	96.2%(4)	99.9%(4)

SUMMARY

In the foregoing thesis the efficiency of a surgical preparation method was proposed and subjected to a series of experimental tests. It was found that this method bears a direct ratio to the quantitative germ-removing or germ-killing effect, and that this effect could be measured by calculating the number of bacteria in a random sample of the germ population of the hands at the beginning and again at the end of the process. A standard method of taking these samples and making bacterial counts was developed. From the counts a factor called "average percentage reduction" was calculated. This factor was found to be roughly constant in its relationship to the known efficiency of the cleansing process.

In a series of 230 test scrubs ranging from two to twelve minutes, it was found that the maximum removal range was in the six- to ten-minute level. The results in the two-and three-minute series of scrubbings were inconstant in many instances. Ten to twelve minutes of hand scrubbing are very irritating to the skin, with no appreciable increase in

the bacteria removed by the increased time of scrubbing. Total removal of bacteria from the skin is impossible by hand scrubbing. Using the same method of quantitatively measuring the number of bacteria removed per unit time, it was decided to test the value of several antiseptics which could possible be used in conjunction with the soap and water scrub. The scrubbing portion consisted of four-minute scrub with brush, soap and water, followed by a one-minute rinse in the antispetic being tested, and concluded with a three-minute rinse under tap water.

Antispetics tested were: mercuric chloride, 1:2000; 70% ethyl alcohol; 1:000 mercuric cyanide; 3½% tincture of iodine plus 70% alcohol saturated with sodium hyposulphite. It was found that the iodine combination was the most effective, both as a disinfectant and as a skin irritant. Alcohol 70% was found to be the next most effective, probably due to its cleansing properties as well as its antiseptic property.

CONCLUSIONS

From the experimental work performed the following conclusions are drawn:

1. That a method for measuring the removable bacteria per unit time was devised and proved.
2. In a series of 230 test scrubs ranging from two to twelve minutes, it was found that the maximum removal range was in the six to ten minute level.
3. Two to three minutes of scrubbing in many instances is inaccurate.
4. Ten-to twelve-minute periods of hand scrubbing are very irritating to the skin, with no marked increase in the bacteria removed by increasing the time of scrubbing.
5. The total removal of bacterial flora from the skin is impossible by hand scrubbing or disinfection.

6. The efficiency in removing or reducing the bacteria present following mechanical soap cleansing is definitely increased by the application of an antiseptic.
7. Seventy per cent ethyl alcohol is an effective antiseptic agent and simultaneously is only a very low-grade irritant to the human skin.
8. Tincture of iodine, three and one-half per cent or seven per cent are the most effective antiseptic agents, but also the most irritating to the human skin.

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