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SURVIVAL OF BACTERIA ON THE SILVER COMMUNION CUP

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The probably significant role of unhygienically-cleaned eating and drinking utensils in the dissemination of certain of the infectious diseases is a matter of common knowledge. It is not surprising, therefore, that the practice of some Protestant churches with regard to the use of the silver chalice as a common communion cup has been open to considerable, and sometimes bitter, criticism for the past 50 odd years. The lively and perennial interest in the matter, pronounced in lay as well as clerical quarters, was recently accentuated by a reply to a question published in the Journal of the American Medical Association.[1] The matter was brought to our attention by a number of interested persons. Its importance to large lay and clerical groups, coupled with the paucity of appropriate experimental evidence, prompted us to undertake and record the work reported here. It is to be emphasized that we are concerned with neither the theory of the sacrament nor the relative ecclesiastical merits of the various methods of its administration.

To our knowledge the first and perhaps only paper published in a scientific journal on this subject is that of Anders.[2] Relatively lengthy, it is largely discussion with a remarkable scarcity of experimental evidence. The author quotes the report of a Dr. Charles Forbes delivered to the Rochester Pathological Society of April, 1894: "He stated having found in the dregs of the ordinary cup, contamination from both the mouth and clothing; from the former epithelial cells, mucus and various bacteria and spores; from the latter fibrous material. Control experiments showed the unused wine to be practically sterile." Anders himself reported the finding of tubercle bacilli in 2 of 5 specimens of dregs, together with staphylococci, pus and epithelial cells. It is not stated whether these findings were based in part on culture, i.e., that the observed microorganisms were viable, nor is there any indication as to the numbers found. It is also not apparent whether additional specimens were examined with negative results.

Some years late an experimental investigation was carried out by Page and reported in an ecclesiastical magazine,[3] but not in a scientific journal. In all, 23 experiments were carried out. In 20 of these the purificator (a linen cloth used by the officiating clergyman to wipe the rim of the chalice after each individual had drunk) was mailed to the laboratory after use and there dropped into sterile broth and incubated. In 4 cases the rim of the chalice was cultured by dipping in a jar of sterile broth. (In one experiment both purificator and chalice were examined, thus giving a total of 23.) Bacterial growth occurred in every instance and mice and guinea pigs were inoculated (route and numbers of bacteria not specified) with the culture, presumably the mixed culture. Differentiation of the bacteria present was made into the following morphological types: spore-forming bacilli, other bacilli, streptococci, yellow cocci, white and other cocci. In no instance were pure cultures observed. The results may be summarized as follows:

1. Of a total of 18 mice inoculated, 5 died.
2. Of 19 guinea pigs, 8 died.
3. With one possible exception, in no instance did all the animals inoculated in a given experiment die.
4. In the total of 14 experiments in which animal inoculation was carried out, one of more deaths occurred in 8, while none occurred in the remaining 6.
5. The frequency of occurrence of bacterial types was as follows: spore- forming bacilli-17; other bacilli-6; streptococci-1; yellow cocci-6; white and other cocci-10.

In a personal communication, Doctor Page informed one of us (W.B.) that he has since carried out additional experiments in which the rim of the used chalice was pressed deeply into a blood agar plate; profuse growth was present after 5 days' incubation.

Similar, though probably less extensive, experiments have undoubtedly been carried out by others but not reported in other than an informal way. The writers are aware of one such instance and there the results did not differ to a significant degree from those reported by Page. Since such information is not made generally available, it can hardly enter into the present consideration. The general question has been raised in editorial and correspondence columns of medical journals here and in Great Britain but no experimental evidence has been contributed.[4]

In general, then, direct experimental evidence

appears to be deficient, no one, for instance, having attempted quantitative studies on the survival of inoculated bacteria, on the bacteria transmitted from one individual to another by the common use of the silver chalice, or other equally obvious experiments. For reasons that will be discussed later, it is the opinion of the writers that hitherto available evidence is sufficiently open to criticism as to be hardly considered as contributing materially toward answering the question raised.

Nevertheless, the opinion appears to be generally held that the use of the silver chalice as a common communion cup is highly undesirable from both the hygienic and aesthetic points of view. We are not concerned with the latter here. This opinion is probably based entirely on analogy with the communal tin cup, the soda fountain and bar drinking glasses, restaurant tableware and dishes, and the experience of the armed services with inadequately washed eating utensils. The very great importance of such fomites in the dissemination of infectious disease has been demonstrated frequently and beyond reasonable doubt by both epidemiological and experimental evidence. Superficially, therefore, it would seem reasonable to include the silver chalice with this group of fomites and on this basis to actively oppose its communal use.

Critical consideration makes it clear, however, that such a judgment may be premature. In this connection three points are to be noted. **First, there has never been, to the writers' knowledge, an epidemic of infectious disease that has been unequivocally traced to the use of the silver chalice.** Even Anders, though passionately opposed to the practice, admitted that "We know of not one bona fide instance of disease contracted from a common communion cup." Such is, of course, strong presumptive evidence to the epidemiologist. It may be pointed out that, as a corollary, a significant role of the silver chalice in the transmission of disease might be expected to be reflected in increased morbidity rates for certain of the infectious diseases, those of the upper respiratory tract in particular, among officiating clergymen. There appears to be no definite evidence available on this point; more or less casual inquiry, however, has indicated that there is at least not an obvious increased prevalence of such disease associated with this occupation.

Secondly, ordained clergymen are highly educated persons whose administration of the sacrament would appear hardly comparable to the activities of the usual soda fountain employee, restaurant dish washer or bar keeper. Most, if not all, are acutely conscious of the hygienic aspects of the sacrament. The usual, though not prescribed, method of administration involves the rotation of the chalice so that successive persons do not drink from the same place, and the wiping of the rim of the chalice both inside and out before the same place is used again, with a purificator of a series of purificators which are freshly laundered and ironed prior to use. The sanitary aspects of the administration of the sacrament are also taken into consideration in more general terms. For example, the Book of Common Prayer of the Protestant Episcopal Church and the Church of England directs, under the head of Communion of the Sick, that "At the time of the distribution of the holy Sacrament, the Minister shall first receive the Communion himself, and after minister unto those who are appointed to communicate with the sick, and last of all to the sick person." Clearly, then, the administration of the sacrament of Communion falls into a rather different category than that of the rinsing of beer mugs or soda fountain glasses in lukewarm water.

Third, the silver chalice does not provide an inert surface on which the survival of bacteria is essentially a matter of resistance to drying as in the case of glass, china, and glazed pottery; rather the metallic surface is actively bactericidal. The bactericidal activity of the heavy metals is well known and of these silver is one of the most active. In the past this phenomenon has been studied at length, particularly by the German workers, in connection with its practical application to the treatment of water by the catadyn process, the preparation of patented materials such as silbersand for use in water filters and the like. It need, not, therefore, be discussed at length here. Suffice it to point out that in a recent publication[5] concerning the self-sterilizing surfaces of silver-containing plastics, it is shown that such surfaces become sterile within one minute after swabbing with a suspension of *Bacterium coli* containing 10^8 cells per cc, the activity being attributable entirely to the presence of the metal. Though it does not follow that the surface of the silver chalice will show such a high degree of activity, owing to inactivation by organic colloids and proteins in particular, it seems not unlikely that

it is bactericidal to an appreciable extent.

Considerations such as these led us to investigate the survival of representative bacteria on the silver chalice, the extent to which bacteria may be transferred from one person to another through its agency, and the numbers of bacteria that may be recovered from its rim under conditions simulating actual use.

EXPERIMENTAL

Bacterial suspensions were prepared in sterile saliva. Sufficient numbers of microorganisms were added to give an obvious though not heavy turbidity. Preliminary experiments indicated that suspensions of this density allowed immediate recovery of 10,000 to 50,000 viable cells by the technic used here. A 200 cc sample of paraffin-stimulated human saliva was taken at the beginning of the experiments and used throughout. It was neutralized to eliminate possible adverse effects of its normal slight acidity, and sterilized by filtration, a process which resulted in the loss of considerable amounts of protein. We have observed that fresh saliva contains around 400 mg % of substances precipitable with phosphotungstic acid, a figure in keeping with those usually given for its protein content, while the neutralized and filtered saliva contained only slightly more than 100 mg % of such substances.

Survival experiments. - The bacterial species used were *Chromobacterium prodigiosum*, *Streptococcus pyogenes* (a recently isolated virulent strain) and *Mycobacterium tuberculosis* var. *hominis*. In the case of the first two species a 24-hour culture on agar was suspended and diluted in sterile neutral saliva to a faint turbidity. The tubercle bacilli were emulsified by grinding in a mortar with saliva and similarly diluting the suspension. Just prior to each experiment the chalice was thoroughly washed and polished. Its outside rim was marked off into approximately equal spaces $1^{1/2}$ inches long with a wax pencil. The bacterial suspension was distributed uniformly about the entire outer rim with a cotton swab in a band about 1/2 inch wide. Immediately, and at varying intervals thereafter, the bacteria were removed from a marked area with fresh, wet sterile swabs which were washed off in 2 cc of sterile saline solution. Counts were made on the saline solution by the usual pour plates and also by the spreading of 0.5 cc of the dilutions on the surface of previously poured plates; the latter procedure was used exclusively in the counting of hemolytic streptococci on blood agar.

Counts were remarkably well reproduced considering the crudeness of the swabbing technic. The results of representative experiments with *C. Prodigiosum* and *Str. Pyogenes* are given in table 1. Included in this table is a control experiment in which the streptococci were also spread upon a glass slide. It is readily apparent that the bacteria spread upon the silver surface not only die off rapidly but appreciably more so than those upon the inert glass surface. It may be noted that the polished silver surface was not wet by the bacterial suspension, but small droplets formed so that the majority of the bacterial cells were not in contact with the surface, and a considerable portion of the surface was not in contact with the bacteria. It is of interest, therefore, that even under such adverse circumstances there was evidence of some bactericidal activity. In the case of the tubercle bacilli the time interval was extended to as long as 40 minutes. Guinea pigs were inoculated with 0.1 and 1 cc of the saline solution. They were sacrificed at 6 weeks and in all cases tuberculous infection was apparent and confirmed by autopsy. It was clear, therefore, that an infective dose remained viable over the entire period of observation. The pathology did not suggest quantitative differences in dosage.

TABLE 1.-Survival of Inoculated Bacteria

Time in Minutes	Bacteria per cc					
	C. prodigiosum		*Str. Pyogenes*			
	On Chalice		On Chalice		On Glass Slide	
	Number	%	Number	%	Number	%
0	41,000	100	10,000	100	5,000	100
5	15,300	37	4,500	45	4,000	80
10	<100	< .02	700	7	1,000	20
20	<100	< .02	6	.004	225	4.5

TABLE 2.-Survival and the Effect of Wiping with a Sterile Cloth

Time in Minutes	Bacteria (Str. Pyogenes) per cc			
	Saliva-bacteria		Wine-saliva-bacteria	
	Number	%	Number	%
0-unwiped	9,000	100	10,000	100
0-wiped	840	10	2	< .05
2	280	3	0	< .05
3	12	.12	2	< .05
5	2	< .05	0	< .05
7	4	< .05	0	< .05
10	0	< .05	0	< .05

The effect of wiping.-Since common practice in the administration of the sacrament includes wiping of the chalice rim after use, a series of experiments was carried out to determine the extent to which bacteria present are removed by this means. Bacterial suspensions were prepared as before, and in some instances were made somewhat heavier and diluted with an equal quantity of muscatel wine containing 20% alcohol by volume (a relatively high dilution, for the ratio of wine to water is never less than 5:1, and usually greater). These suspensions were swabbed on and removed from the chalice as previously indicated. Immediately after application the bacterial suspension was wiped off with a sterile linen cloth in a single stroke, with moderate pressure, and the areas cultured immediately and at intervals thereafter.

The results of experiments with *Str. Pyogenes* are given in table 2. It is apparent from these data that wiping reduces the bacterial count by 90% or more, further reduction in numbers taking place with exposure to drying on the silver surface. The experiments in which wine was added to the bacterial suspension approach more closely the conditions of use, and here the immediate reduction in numbers is of the order observed after 5 minutes' exposure in the absence of wine. The suspensions containing wine were also placed in test tubes and in the chalice and cultured at intervals; such suspensions were sterile after 5 minutes. Results such as these indicate that the bactericidal activity of wine is appreciable when Str. Pyogenes is used as the test organism. C. prodigiosum appears to be somewhat more resistant.

Transfer of bacteria.-Using *C. prodigiosum* as the test organism, a series of experiments was undertaken to determine to what extent transfer of bacteria from one person to another through the medium of the chalice can take place. Heavy suspensions of 24-hour agar slant cultures were prepared in saline solution and used as a mouth wash by Subject A. An unstimulated saliva sample was taken immediately. The chalice was filled with wine diluted with an equal volume of water. Subject A drank a small amount of wine from the chalice in two places, making a special effort to spread and leave as much saliva on the rim as possible. One of these places was swabbed immediately and 1 cc of the wine in the chalice taken for culture. Subject B then drank from the cup at the other place touched by Subject A and an unstimulated saliva sample was taken from B and cultured. In preliminary experiments this procedure was altered by wiping the chalice rim with a sterile linen cloth after contact with Subject A.

The results of representative experiments are

TABLE 3.-Transfer of Bacteria by Common Use of the Chalice

Specimen	Bacteria (C. Prodigiosum) per cc			
	Unwiped		Wiped	
	Number	%	Number	%
Saliva A	400,000,000	100	300,000,000	100
Cup-unwiped	180,000	.45	6,000	.002
Cup-wiped			300	.0001
Wine	<200	< .00005	200	.00007
Saliva B	4,000	.001	<100	< .00003

summarized in table 3. The data are taken from experiments in which Subject B's contact with the chalice immediately followed that of Subject A, since in preliminary experiments bacteria could not be recovered from the chalice, wine or Subject B after a 5-minute interval. It is evident from the data of table 3 that a remarkably small proportion of the bacteria present in Saliva A can be recovered from the chalice and from the wine. Assuming that no bacteria were killed in the short intervening time, the numbers found would indicate that about 0.01 cc of saliva was left on the cup. The high efficiency of wiping is again apparent, no bacteria being found in Saliva B in the lowest dilution cultured when the chalice was wiped. Control cultures of Saliva B before each experiment were always negative.

Contamination with normal flora.-In the immediately preceding experiments, few bacteria other than *C. prodigiosum* were observed. This is probably attributable to the rinsing action of the bacterial suspension and wine drunk as well as to the use of nutrient agar and incubation of the plates at room temperature. An additional series of experiments, therefore, was carried out to allow an approximation of contamination by oral flora. The wine was diluted in the proportion of 3 parts of wine to 1 of water and about 50 cc poured into the chalice. Four persons drank from it, each from a different side. The entire rim was swabbed immediately and cultures made, as indicated earlier, on aerobic blood agar plates. The individuals participating in these experiments probably had, on the whole, somewhat cleaner mouths than one might expect to find in the average person in an ordinary congregation, but, since oral cleanliness is determined largely by the condition of the teeth rather than of the saliva, this factor is probably of little importance for our purposes.

In the first experiments no instruction was given, each person drinking in his own way. Three successive experiments were carried out in this manner and in all of them no bacteria of any kind could be recovered. In other experiments, therefore, the persons drinking were instructed to leave as much saliva as possible on the chalice. Under these conditions appreciable though small numbers of bacteria were recovered. In additional experiments the rim of the chalice was wiped immediately after drinking and before swabbing. In no case was a greater time allowed to elapse than necessary for the manipulations.

Of the data given in table 4, that part indicated by "no instruction" is the only experiment out of a total of four in which bacteria were recovered under these circumstances. It is apparent that only small numbers of bacteria representing the normal oral flora can be recovered from the chalice under conditions simulating actual use. It is highly probably that the recovered bacteria were of oral origin; the proportion of alpha streptococci is what would be expected.

TABLE 4.-Contamination with Normal Oral Flora

Specimen		Total Bacterial Count (Blood Agar)
"Sloppy"	Unwiped	300 (# alpha streptococci)
	Wiped	50 (# alpha streptococci)
No instructions	Unwiped	150 (# alpha streptococci)
	Wiped	None (less than 10)

DISCUSSION

From both epidemiological considerations and the available experimental evidence, it seems probable that the silver chalice, used as a common communion cup, is not an important vector of infectious disease. Though the early work of Anders2 is too fragmentary to have great significance, that of Page3 is considerably more detailed. In the latter experiments, however, it was not established that the source of the bacteria found was the mouths of the communicants. The general distribution of types of microorganisms observed is not characteristic of the oral flora in which alpha and gamma streptococci predominate. Rather, it closely resembles the flora observed on an agar plate which has been exposed to the air for some time and then incubated, as in experiments carried out in beginning courses in bacteriology.[6]

The spore-forming bacilli are almost certainly from air and dust, and the frequent finding of these forms, i.e., in 17 or 23 specimens, indicates the extent to which such contamination probably occurred. Similarly, the cocci may have been of this origin also or may have come from the skin in handling the specimens; the relative predominance of the non-pigmented variety strongly suggests such contamination. Non-spore-forming bacilli are like-

wise ubiquitous, but in fact constitute only a small part of the oral flora. Streptococci are also not confined to the mouth and upper respiratory tract; contamination of the hands from this source or with enterococci, for example, may readily occur. In general, then, no type of bacterium was observed which was necessarily, or perhaps even probably, of oral origin, and those observed most frequently were almost certainly contaminants from air and dust. The results of inoculation of experimental animals, presumably with mixed cultures, indicate only the low order of virulence associated with nonpathogens and thus reinforce the inference that many, if not all, represented contamination of other than oral origin. It is, of course, well known that many of the saprophytic bacteria (for example, *Bacillus subtilis, Bacillus mesentericus and Bacillus megatherium*) will produce death of experimental animals on parenteral inoculation. Conversely, highly virulent forms are not necessarily infective by mouth, as in the case of the tetanus and gaseous gangrene bacilli. It is not clear, therefore, how this work contributes toward answering the question of the relative importance of the silver chalice in the dissemination of infectious disease.

The experimental evidence reported here is of three general kinds. The experiments in which the survival of *C. prodigiosum* and *Str. Pyogenes* spread upon the silver surface was studied indicated that the numbers of recoverable bacteria were rapidly reduced. Though drying undoubtedly contributes to this reduction, the polished silver surface appears to exert a definite and appreciable bactericidal effect. As indicated earlier, it is somewhat surprising that this effect is of sufficient magnitude to be detected under the adverse circumstance of failure to wet the silver surface. It is reasonable to suppose that a similar reduction in numbers would occur when bacteria are transferred to the chalice rim in drinking and such a reduction was, in fact, observed. Though the necessary manipulations were carried out as rapidly as possible, this effect may have contributed to the small numbers of bacteria recovered from the used chalice. A sufficient number of tubercle bacilli, however, survived from the relatively heavy inoculum, even after a period of 40 minutes' exposure, to produce infection in guinea pigs. The result is not surprising, of course, in view of the marked resistance of these organisms to drying and chemical agents. The inoculum was undoubtedly very much heavier than could be obtained with naturally infected saliva and here, as throughout these experiments, the probability of survival was heavily weighted in favor of the bacteria.

Even though here less thoroughly done than by most officiating clergymen, the efficiency of wiping, in reducing the numbers of bacteria present, is notable. In our experiments the reduction was never less than 80% and usually over 90%. The process is not, of course, comparable to the use of a dish towel in public eating establishments.

The experiments on the transmission of the test organism, *C. prodigiosum*, from one person to another through the medium of the chalice may be noted. While many similar experiments have been carried out, in relatively few instances have quantitative studies been made; in others, the results have been recorded simply as positive or negative cultures. In these experiments the enumeration indicated that only 0.001% of the bacteria present in the saliva of the first individual may be found in the saliva of the second, and then only when considerable conscious effort was made to transfer as many as possible, and when the cup was not wiped. It is not unlikely that the figure for the second saliva is high; many of the bacteria deposited on the chalice rim may remain on the lips of the recipient to contaminate to an appreciable extent the saliva sample taken for examination. **However, in no instance in which the rim of the chalice was wiped, including others for which data are not given here, were we able to detect transfer of the test organism in the lowest dilution made.**

Finally, the small numbers of bacteria recovered from the used chalice is a curious finding in view of the large numbers known to occur in saliva. Observations made by one of us (E. S. H.) in another connection showed that in 43 samples of saliva cultured on blood agar, the total bacterial counts varied from 43 million to 5,500 million per cc, with an average of 750 million. Of these specimens, 11 contained beta hemolytic streptococci in numbers varying from 200,000 to 500,000, with an average of 380,000 per cc. Nevertheless, as indicated previously, in a number of experiments we were unable to recover any bacteria at all from the used chalice and in others only very small numbers were found. These observations are, however, in keeping with the negligible degree of contamination encountered in all the experiments reported here,

including those on the transfer of bacteria. It is highly probable that the rinsing effect of drinking, the flow of liquid from the chalice to the mouth, rather than vice versa, and some bactericidal activity of the silver surface and wine during the short but unavoidable delay in removal for culture all contribute to the observed results.

It is apparent that the evidence reported here is, with the exception of a single experiment with the tubercle bacillus, limited to the saprophytic bacillus, *C. prodigiosum*, and a single virulent strain of *Str. Pyogenes*. It is not unreasonable, however, to generalize to a limited extent from the results obtained. *C. prodigiosum* has no less resistance than the enteric forms, such as the typhoid and dysentery bacilli, and similarly, *Str. Pyogenes* may be regarded as representative of the pathogens of the upper respiratory tract, such as the pneumococcus, meningococcus and diphtheria bacillus. Unfortunately, in the case of the viruses, such as the influenza virus, and the spirochetes, such as those of syphilis and Vincent's angina, quantitative studies were not possible and qualitative studies were not undertaken because of the questionable value of negative results. In general, however, the resistance of the viruses appears to be not greatly different from that of the usual pathogenic bacteria[7] and the spirochetes are unusually susceptible to the effects of drying. It would seem, therefore, that the omission of these classes of infectious agents is not too serious for it is unlikely that in general they would survive significantly longer than the test organisms.

The significance of the chalice in the spread of infectious disease is, of course, dependent upon the transmission of an infective dose. While such a dose for man is not susceptible to the usual experimental study, ancillary evidence allows some rough approximations. For example, relatively large number of diphtheria bacilli are probably required to produce the disease in the average adult; in those diseases in which the virulence of the parasite and resistance of the host are nearly balanced, as in the case of the pneumococcus, from the immediate point of view infection is frequently endogenous because of the importance of predisposing factors.

Such diseases would probably be difficult to transmit by means of the chalice. In this connection the significance of the results of the experiment with tubercle bacilli is not clear because of lack of quantitative data on their survival, and the question of the numbers constituting an infective dose. This is a matter of particular interest in view of a recent report[8] on extra-familial contacts in pulmonary tuberculosis, in which the common use of the chalice was one of a number of possible channels of transmission. The evidence, however, did not specifically implicate the chalice and the authors, as indicated by the following statement did not regard it as of primary importance: "The question of the use of the common communion cup is a 'moot' one. It is reasonable to suppose that droplet infection through the contact at choir practice and social functions might well be sufficient to result in active disease in susceptible individuals such as girls of this age group."

In those diseases which are highly contagious and spread rapidly through the host population, however, it is probable that only a small, possibly a very small, number of bacteria constitute an infective dose. Such is probably the case in the streptococcus infections of the upper respiratory tract in their various clinical forms, i.e., scarlet fever, septic sore throat, etc.

To assay the implications of the present evidence let us take a hypothetical example defined by the following assumptions:

1. The bacterium is so highly virulent and the general level of host resistance so low that a single microorganism by mouth will produce the disease in one half the susceptibles so exposed.

2. The experimental evidence presented here is a reasonably accurate approximation of the behavior of that microorganism on the silver chalice.

3. An individual carrying these bacteria, yet well enough to attend and participate in a church service, has 1,000,000 bacteria per cc of saliva (there is little information on numbers of causative microorganisms present in *saliva* in disease; considering the virulence postulated above, this is probably much too high a number).

4. One half of the congregation is so affected, the other half consisting of susceptibles.

5. The individuals drink in random order and therefore only half the susceptibles will, on the average, drink from a place previously drunk from by an infected person. The bacteria deposited by the first individual are assumed to have died by the time the third individual drinks, i.e., contamination does not accumulate.

Under these circumstances the course of events

may be visualized as follows: a. the infected person drinks, depositing 10,000 bacteria on the chalice (from the highest value in table 3); b. the clergyman wipes the chalice, removing 90% of the bacteria, leaving 1,000 remaining; c. the chalice is rotated, 2 minutes elapsing before a second person drinks at this same place; at the end of this time only 0.5 bacteria remain viable (a high value taken from the saliva-wine-bacteria series of table 2); d. the susceptible drinks, removing 2% or 0.01 of these bacteria (an estimate based on table 3 in which this value is probably too high as indicated in the earlier discussion). Only half of the susceptibles will be exposed, the other half having drunk from places where other susceptibles had drunk, and thus 1.0 susceptible per 200 will receive a single bacterium, the other 199 none. Of the exposed susceptibles, only half become infected since one bacterium was postulated as the median infecting dose. Since the susceptibles make up only one half of the congregation, of a group of 400 communicants, 1 may contract the disease by this means.

This value represents the highest that can be derived from the data presented here. It will be recalled that throughout this work the experimental technics have been strongly biased in favor of bacterial survival, and in this example of exaggerated infectivity and prevalence only the highest values are taken. The significance of this incidence of new infections may be illustrated by comparing it with the age specific death rates for all causes of death. Since it is approximately the same as the rate for the 35-44 age group (3.2 per 1,000 in 1940), **it would appear somewhat more dangerous to attain the age of 35 than to receive communion from the silver chalice once a year.**

The question, however, is not one of whether it is *possible* to transmit infectious disease through the agency of the chalice-as Anders pointed out in the unanswerable remark: "But who will say that many an innocent person may not have acquired disease from the common communion cup?"-but rather is one of the relative importance of the chalice. This is readily apparent from further consideration of the above hypothetical example. If a population, consisting of half susceptibles and half persons infected with such a highly virulent bacterium, is confined in a closed room for one hour, the disease will appear in the susceptibles in epidemic form with very many more cases than can be accounted for on the basis of chalice transmission. Clearly, then, other modes of transmission, notably airborne infection, are of much greater importance and the relatively insignificant role of the chalice becomes apparent. In the opinion of the writers, therefore, the silver chalice, used as a common communion cup, plays only a minor part in the dissemination of infectious disease.

SUMMARY

Evidence is presented which indicates that bacteria swabbed on the polished surface of the silver chalice die off rapidly. Experiments on the transmission of test organisms from one person to another by common use of the chalice showed that approximately 0.001% of the organisms are transferred even under the most favorable conditions; when conditions approximated those of actual use, no transmission could be detected. Only small numbers of bacteria from the normal mouth could be recovered from the chalice immediately after its use by 4 persons. **It is concluded that in practice the silver communion cup is not an important vector of infectious disease.**

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1. J.A.M.A. 112: 2555, 1939.

2. Anders, H. S.: J.A.M.A. 29: 789-794, 1897.

3. Page, C. G.: The Common Cup, The Churchman, June 27, 1925.

4. See, for example, Editorial, J.A.M.A. 23: 731, 1894; Anders, H. S.: J.A.M.A. 28: 662, 1897; ibid. 35: 1291, 1900. The last is in reply to an article in the Lancet. The authors are grateful to Dr. Edwin P. Jordan for calling their attention to these communications.

5. Goetz, A., Tracy, R. and Goetz, S.: Science 95: 537-538, 1942.

6. For a recent study of bacteria in air and dust with special reference to pathogenic forms see Ostertag, H.: Ztschr. F. Hyg. u. Infektionskr, 123: 698-708, 1942.

7. Cf. Gordon, F. B.: Chapter 37 in Jordan E. O. and Burrows, W.: Textbook of Bacteriology. W. B. Saunders Company, Philadelphia. 13th Ed., 1941.

8. Twinan, C. W. and Pope, A. S.: Amer. J. Pub. Health, 32: 1215-1218, 1942.

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