SALIVA-BORNE DISEASE CONTROL: ERADICATION.¹

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The following epidemiological research is valuable to the military service because it deals with the saliva-borne infections. These caused the highest disease mortality in the World War, and will be equally devastating in the next if adequate control measures are not instituted.

There will first be discussed, as a background for the research here reported, four epidemiological factors which determine infectious disease prevalence. These are: first, transmission rate; second, healthy carrier rate; third, susceptibility rate; and fourth, the degree of contact. The field observations, the laboratory and statistical research presented here are based on these factors. To the conclusions drawn from this work there will then be applied the three control factors leading to eradication: continuity of control, percentage of transmission blocked, and the evaluation of the various avenues of distribution.

The Transmission Rate.

During the World War there prevailed the greatest facility of transmission for the saliva-borne diseases. At that time our knowledge of the relative importance of the avenues of distribution was limited. Control was attempted chiefly through blocking air-borne, or direct contact, transmission; it was not until the 1918 influenza-pneumonia epidemic that the importance of indirect transmission was recognized and adequate control measures for blocking such transmission devised. In brief, stoppage of distribution had been attempted through blocking the minor avenue only; while the major avenues, those of indirect contact, were unrecognized and uncontrolled.

The necessity of identifying the route, or routes, of transmission is shown in the history of all communicable diseases which have been brought under control. For example, the research of Reed and his colleagues led to the control of yellow fever; the investigations of Vaughan added much to our knowledge of typhoid control. Through such research it was made possible during the late war, to block transmission for both the insect and the intestinal-borne groups of infections. All this research dealt with transmission; as the result we had mosquito and louse control, sanitary supervision of food and water supplies, sewage disposal—all blocking

distribution. In short, the transmission rate is the prime factor; its successful application relegates all other factors to the background.

**The Healthy Carrier Rate.**

For the saliva-borne infections there is a high percentage of carriers among the civil population. Previous to the war the chief avenues of dissemination had not been demonstrated and no successful effort had been made in control; the result was a high healthy carrier rate among the citizenry entering the Army.

With these recruits as a starting point, and in the absence of measures for blocking the major avenues, the Army carrier rate increased with each succeeding month. This increased prevalence of carriers in the enlarged Army is accounted for, not only because there were carriers among recruits as primary sources of infection, but, even more, because those primary sources of transmission were not blocked, which resulted in an accumulative increase of carriers as time passed.

In contrast with this situation in the saliva-borne group of diseases, the healthy typhoid carrier rate in the World War was greatly reduced over that for the Spanish-American War. This reduction resulted from blocking the major avenues—water and milk—of typhoid distribution in cities during a period of about ten years prior to the late war. While this reduction of carriers in civil communities was a favourable influence, it is to be pointed out that typhoid carriers could play but a negligible part in distributing their disease in the Army at that time, because there, as well as in civil life, the major avenues had been for years continuously blocked.

It is, then, not so much the prevalence of carriers, but rather success in blocking the chief routes of transmission, which determines the prevalence of disease. Indeed, in the absence of control of transmission, even a few carriers may provide primary sources for veritable epidemics.

**Susceptibility Rate.**

A considerable percentage of recruits had no acquired immunity to either the virus or other infections; they had not been previously exposed. Unavoidably susceptibles poured into the enlarging army. It was impractical to segregate these from the non-susceptibles; therefore the problem of control of communicable disease had to be attacked from the standpoint of protecting susceptibles.

The susceptibility rate is a minor factor; it becomes important in the protection of troops only when the avenues of spread are wide open. Then the disease runs its course, and a resultant shortage of susceptibles terminates the epidemic. That occurred in the 1918 influenza-pneumonia epidemic; the result was an immunized Army, but at an overwhelming cost.

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1 Carriers, as used in this paper, include not only healthy carriers, but also mild unrecognized cases and convalescents.
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The Army was protected against the insect and intestinal-borne diseases. Had effective measures for the control of transmission of saliva-borne infections been in operation, susceptibility, which is a minor epidemiological factor, would have played little part in the prevalence of influenza-pneumonia.

Crowding or High Numerical Contact.

Massing of troops in training, in manoeuvres, and in battle is essential to military success. This unusual crowding of men, however, facilitates disease transmission only when the routes of distribution are not blocked. During the Civil War the Northern troops were massed in the Tidewater district of Virginia before the attack on Richmond and malaria prevailed to such an extent that the Army was almost incapacitated. In the late war troops were massed in that same general area, yet there was only an insignificant amount of malaria. In the Spanish-American War troops were crowded in camps, and typhoid fever was most devastating; in the World War there was massing with only an occasional typhoid case. The avenues of malaria and typhoid transmission were blocked, thus relegating to the background the factors of massing, susceptibility and carriers.

The operation of the four epidemiological factors, after having had full sway for centuries, can now be so curbed as to circumvent their devastating results. As has been pointed out, among these is one—a prime factor—which, when under control, counterbalances the unfavourable influences of the other three. This is the transmission rate. Block the major avenues of transmission, automatically the healthy carrier is eliminated as a source of infection; the susceptible is protected against the disease; even high numerical mass contact is rendered negligible.

In brief, successful control of disease dissemination through closing the major avenues of transmission is the key which locks the door against invasion by the other three factors.

Civic Co-operation.

This control of the transmission rate had been in operation against the insect and intestinal-borne diseases in civil communities for ten years or more before the war. It had, through these years of effort, greatly reduced the number of healthy carriers of these two groups of diseases; through this control there had come about a gradual reduction in transmission, resulting in fewer and fewer cases as time passed. Such cumulative reduction in cases and sources lead, inevitably, to a cumulative reduction in carriers. That reduced carrier rate benefited the Army, by reducing sources of malaria and typhoid among recruits.

While this lower carrier rate among the incoming groups was important, of greater importance was the fact that this scientific knowledge of control was applied in the Army where disease hazards were so augmented. As a result, the occurrence of these two diseases, as well as of the dysenteries, was insignificant. This chain of events made it possible,
in so far as these two groups of disease were concerned, to recruit a healthy Army, to maintain its health, and to return healthy men to their communities.

It is apparent, then, that the citizenry has a responsibility for the health of its Army, but there is a vast difference between mass protection in typhoid and small group sanitation and individual hygiene as control measures for the saliva-borne diseases. The first is administrative and regulated by law; the second largely a matter of small group practices and individual habits; in one there is centralized, and in the other personal, responsibility.

As the typhoid mortality of a city is now an index of the purity of its water and milk supplies, so the influenza-pneumonia mortality of a community will become an index of its group sanitation and personal hygiene.

**Research.**

The conclusions from the following field observations, and from the statistical and laboratory research here presented will enable, not only the Army, but the communities as well, to control more effectively the saliva-borne diseases. As has been pointed out, the health of a nation influences the health of its Army.

**INDIRECT CONTACT TRANSMISSION.**

**Mess Kits.**

It is believed that our original theory of mess-kit transmission extended to include group sanitation and personal hygiene, supported by statistical studies and confirmed by laboratory research, will enable the military service, in co-operation with the citizenry, to relegate the saliva-borne diseases to the innocuous status now held by the once devastating typhoid and malaria.

In order to check on the transmissibility of influenza-pneumonia through mess-kit wash-water it became necessary to compare the influenza rates of groups using mess kits with those eating from tableware. There was high numerical indirect contact—crowd transmission—among those using mess kits; their hands, as well as their mess gear, became contaminated with the mess-kit wash-water which contained in suspension the mouth organisms of the group. On the contrary, in those groups using tableware, hand contamination by mess-kit wash-water did not occur, for here the dishes were washed collectively in the kitchen.

Our first statistical study, in conjunction with a careful field survey, was made at eleven different camps or posts during the early part of the influenza epidemic; a record of each organization composing these camps was made on the basis of the method of messing. Thus there were two groups, one of which used tableware or mess kits which were boiled, the other ate from mess kits which were washed by the old line method.

At the close of the epidemic a request was made through the commanding officer of each camp for a report of the incidence of influenza
by organizations under his command. The data thus collected were sorted and allotted to the particular group—either the collective or the individual dish-washing group. The rate of infection per 1,000 troops was then determined.

In this epidemiological study there were 66,076 troops; among 33,452 there was collective washing of utensils: while among 32,624 there was individual washing of mess kits: [1] The sick rate from influenza in the former group was 51.1 per 1,000 troops; while in the later it was 252 per 1,000. Thus the facility of transmission by mess-kit wash-water through high numerical indirect contact was substantiated by statistical data. There were five times more influenza cases among men exposed to mess-kit wash-water transmission than among those who ate from the collectively washed tableware.

A second field observation on the methods of washing mess kits, as such methods might influence disease and death-rates, was made at a camp composed of 5,971 men. [2] This survey extended over a period of ten months. The camp was studied in two groups, one of 3,115 men was protected through the use of mess-kit wash-water which was kept over a fire; whereas the other group of 2,856 men was not protected by such means; they used the customary lukewarm wash-water.

In the protected group the water was not always boiling, but its temperature ranged from 76° C. to 100° C., so hot that the men could not use their hands as dish mops. In contrast, the unprotected group washed their mess kits in pans of water which were placed on the ground. The temperature of this water ranged from 38° C. to 50° C., only lukewarm and bearable to the hand.

The observation at this camp was unusual in that both groups used mess kits; yet in one there was protection against high numerical indirect contact transmission; the hand-to-mouth and mess kit-to-mouth distribution of organisms was blocked by the boiling, or nearly boiling, water. There was here a difference in the group sanitation; there should, then, be a difference in their protection against saliva-borne disease transmission which would influence the disease and mortality-rates.

The ratio of cases during the ten months' period in the protected and in the unprotected groups was: For meningitis, 1 to 28; diphtheria, 1 to 2; mumps, 1 to 8; measles, 1 to 17; influenza, 1 to 4; and pneumonia, 1 to 8. In the protected group there were only 259 cases of saliva-borne diseases; while in the unprotected group there were 2,624. This gives an annual rate per 1,000 troops of 177 for the protected and of 1,110 for the unprotected—a ratio of 1 to 6.2. Eighty-five per cent of the cases occurred in the unprotected group.

During the period of the investigation ninety-four per cent of all deaths from saliva-borne infections were either primary or secondary pneumonias. In the protected group there were fourteen pneumonia deaths, but in the unprotected there were eighty-six. There was an annual rate per 1,000
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troops of 5:1 for the protected against 36 for the unprotected, a ratio of 1 to 7. Eighty-eight per cent of the camp mortality occurred in the unprotected group.

THE FIVE-LINK CHAIN.

It has already been indicated that the higher case and mortality-rates in the unprotected units were due to mass indirect contact, to susceptibility, to carriers—especially those of the pneumonia-producing organisms—and, finally, to facility of transmission through warm mess-kit wash-water.

Such transmission may be diagrammed by the following five-link chain of distribution:

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1 2 3 4 5
\| / \| / \| / \|
Hands Hands Oral cavity Mess-kit wash-water Oral cavity
\| / \| / \| / \|
Mess kit Mess kit Mess kit
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The oral cavity, the first link, is the reservoir of the virus infections, in mild unrecognized cases and convalescents, as well as in acute and chronic carriers of potentially dangerous organisms, including streptococci. Organisms found in the oral cavity of any individual are also generally found on his hands and on his eating utensils [3].

Thus the hands and mess kit constitute the second link, a double one, both in fact and in the amount of contagion transmission. The lukewarm mess-kit wash-water, the third link, was the central focus of distribution by indirect mass contact for all the men. The hands and mess kits of susceptibles—constituting the fourth link—passed on, as will be shown, the contamination of the mess-kit wash-water to the oral cavity—the portal of entry of the saliva-borne diseases.

CONFIRMATION BY LABORATORY RESEARCH.

In order to connect these five links of contagion distribution through mess-kit wash-water, it became necessary to demonstrate that connection by the use of a nonpathogenic organism: B. prodigiosus [4]. In this series of experiments there were three groups of ten men each. Five men in each group served as donors (carriers). Their mouths were sprayed before each of six consecutive meals with a suspension of B. prodigiosus. These five men washed their mess gear in one gallon of warm water, after which the five recipients (susceptibles) washed their mess gear in the same water.

It will be noted that here the six successive meals simulated the multiple indirect contact of field conditions. In the field there was at each meal, multiple indirect contact, and this contact was repeated thrice daily.

The bacteriological test for B. prodigiosus in the separate links of the five-link route of transmission is summarized in the table on the following page.
The joining of the five-link chain of multiple indirect contact was established by this laboratory research. Further, these experimental results, in conjunction with statistical research on influenza-pneumonia as influenced by eating-utensil sanitation, confirmed our previously advanced theory of contagion distribution through warm mess-kit water. These results stress the importance of group sanitation as influenced by the use of boiling mess-kit wash-water as a means of maintaining a high standard of crowd sanitation.

Nichols worked with the antiseptic action of soap in dish-water as a barrier against saliva-borne disease distribution [5]. As he and others demonstrated, certain soaps, especially sodium oleate and resinate in clear-water solution of pH 8.5 at room temperature, readily kill pneumococci and streptococci. He likewise shows that if the reaction of soap solution is changed from pH 8.5 to 7 by acids, the antiseptic action is lost, and states further that there is apparently enough acid in some dirty dish-water to change the reaction and to destroy the antiseptic action of the soap. He cites an example in which a soap solution of pH 8.7 was used for washing mess kits. After the washing process the pH reading was 5.8 and there was no antiseptic action on B. influenza, pneumococci, streptococci or on staphylococci.

Weaver concluded from his research that foreign substances interfere markedly with the germicidal activity of soap [6].

During the war large numbers of mess kits or dishes were washed in the same water. There was the resultant addition of food particles, grease, organic acids and salts, all of which not only tend to neutralize the cleansing effect of soap, but, as stated by Nichols, these also destroy the germicidal action.

**TABLEWARE TRANSMISSION.**

The investigation of the distribution of the saliva-borne infections through mess-kit wash-water was extended to the civil communities to include the transmission of these diseases by tableware.

If practical means could be devised for reducing the number of cases, and hence the number of sources of infection in the civil population, such reduction would be a great aid to the army—there would be less extracantonment or post-distribution filtering into the Service through recruits. But, as already shown, cases and carriers, as sources of infection, can be reduced only by a reduction in the transmission rate.
As has been established, mess-kit wash-water was the common focus of saliva-borne disease distribution through contaminated hands and mess gear. Was there not, then, a similar mode of indirect distribution through tableware among the general population? The oral cavity is the reservoir for distribution of the saliva-borne diseases; at the same time it is the entrance portal for this group of infections; of all inanimate objects eating utensils come most frequently in contact with the oral cavity and there pick up infection and, if not sterilized, eating utensils pass on that infection to the next user. In the small family gatherings tableware disease distribution is limited to the family; in public eating places the dissemination is in proportion to the size of the group.

Immediately following the influenza-pneumonia epidemic a field investigation was made in two large cities of the influenza rate as affected by the methods of washing dishes [7]. It was our observation that by the machine-washing methods, the water was either very hot or boiling; on the contrary, by the hand methods, the average temperature was only 44.5° C., a temperature which has no sterilization effect on bacteria. Later it will be shown that hand dish washing removes but 78 per cent. of the bacteria; whereas machine washing removes 99.17 per cent.

This survey included 21,411 men and women employed in hotels, restaurants, and in department stores where meals were provided for employees. There were 17,236 who ate from machine-washed dishes, among whom there was a case-rate of 20 per 1,000. There were 4,175 who ate from hand-washed dishes, and among those unprotected persons there was a rate of 103 per 1,000. Machine washing of dishes provided a high standard of group sanitation, minimized mass indirect contact, and, in addition, gave an eighty per cent protection against influenza infection.

A second survey was made on the method of washing tableware as this might influence the influenza rates in public institutions, Federal and State, with a population of 252,186 [8]. In establishments using machine-washed dishes there were 84,748 inmates. Among these there was a case-rate of 108.9 per 1,000. In the institutions using hand-washed dishes there were 167,438 inmates; among these unprotected individuals there was a rate of 324.8 per 1,000. In the protected groups the mortality-rate was 10.4 per 1,000; whereas in the unprotected it was 23 per 1,000.

It will be noted that the chance of influenza infection was three times more, and the chance of dying two times greater, in the unprotected than in the protected groups. Hence it is obvious that in such institutions eating-utensil distribution of influenza is responsible, either directly or indirectly, for a majority of the transmissions and therefore of cases and deaths.

Confirmatory Research.

Our contention that organisms of the saliva-borne infections are in the oral cavity, and that they may be transferred by indirect contact by eating
utensils, is further confirmed by the following laboratory research on tuberculosis, as well as by that on B. prodigiosus already quoted.

Spoons were used as the transferring agent, and guinea-pigs as the test animals to determine the presence or absence of tubercle bacilli [9]. After the spoons were used by open cases of tuberculosis they were washed singly or in pairs, and the wash-water injected into guinea-pigs. Among thirty-one such tests eleven, or thirty-five per cent, of the guinea-pigs died from tuberculosis. These experiments indicate the frequency in open cases of oral-cavity contamination by tubercle bacilli.

In the next series of tests the spoons used by open cases were first hand-washed in hot water by a nurse in the ward. They were then taken to the laboratory, placed singly or in pairs, in large-mouthed bottles, containing fifty cubic centimetres of warm water, and shaken for five minutes. This rinse water was centrifugated and the centrifugate injected into guinea-pigs. Among thirty-six such tests nine, or twenty-five per cent, of the guinea-pigs died from tuberculosis. The results of this series of tests indicate the frequency with which tubercle bacilli may be transferred by tableware from the open case to members of the same messing group, who are exposed to this multiple indirect-contact transmission thrice daily as long as the tableware is not sterilized.

Prior to our original report in 1919 on table utensils as a vehicle of tubercle-bacilli distribution, only 1·5 per cent of the pamphlets publishing advice to consumptives referred to tableware sanitation. A review, however, four years later, of such publications disclosed that all advised either the use of separate dishes, or that tableware be boiled. The adoption of that advice will do much in blocking eating-utensil distribution of tuberculosis, one of the major avenues of transmission. The military service will benefit by this reduction in transmission among the civil population; there will be fewer beds in army hospitals occupied by consumptives and fewer claims paid tuberculous ex-service men.

Floyd and Frothingham confirm our research on tuberculosis transmission in their report on “Table Utensils as Sources of Tuberculosis Infection” [10]. These workers agree with our theory when they state that, “The belief is constantly growing that tuberculosis and probably all of the so-called air-borne diseases are, in the majority of cases, hand-to-mouth, or ingestion infections.”

In their series of investigations they report that twenty-one per cent of the guinea-pigs died from tuberculosis when injected with the wash-water of table utensils used by tuberculous patients, and that two per cent of the animals died when injected with the moppings of washed dishes.

Among their conclusions they make the following statement: “The table utensils used by open cases may harbour tubercle bacilli even after more careful washing than is customary in the average home.”

1 In this connection, attention is invited to Chapters viii to xi of “Tubercle Bacillus Infection, and Tuberculosis in Man and Animals,” by Albert Calmette.
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Taylor reported in detail results of research in three public sanatoria where the dishes were either machine washed or hand washed with soap powder and hot water, and concludes that: "Public health officials should enforce the necessary use of steam or hot water in hotels, restaurants, and soda fountains [11]. These public eating places must to a certain degree be responsible for the dissemination of all the infectious diseases of the air passages and lungs."

HAND AND MACHINE DISH-WASHING METHODS.

That public eating places and the home may be foci of distribution for the saliva-borne infections—due to a low standard of eating utensil sanitation—is indicated by the following research [12].

The average temperature of seventy-two specimens of hand-washing dish-water was but 44.5°C., and the average bacterial count 6,792,500 per cubic centimetre. In contrast to this low temperature which has no sterilizing effect on bacteria, the average temperature of fifty-five specimens of machine-washing dish-water was 91°C., and the bacterial count was but 960 per cubic centimetre. The use of water which was at or near the boiling point, reduced the number of bacteria 99.98 per cent—a reduction comparable to that secured by the purification of our public water supplies in the control of water-borne diseases.

Is there a reduction in the number of bacteria adhering to machine-washed utensils over that of hand-washed corresponding to the reduction in the dish-water counts for the two methods of washing? The average bacterial count of 950 unwashed spoons was 674,500 per spoon. The count for 1,000 spoons after they had been hand washed was 154,000 bacteria per spoon. By this method of dish-washing, then, only 78.82 per cent of the organisms were removed. In contrast, 750 spoons washed by the machine method had an average bacterial count of but 4,790 bacteria per spoon, a removal of 99.17 per cent per spoon.

Dearstyne supports our theory when he states that "Carelessly washed dishes are potential disseminators of infection," and he concludes from relative bacterial counts between machine- and hand-washed utensils that "It is certain that in most restaurants and other public places too little attention is paid to the washing of dishes" [13].

Pathogenic organisms can readily be identified in water used to wash utensils which have been used by patients or by healthy carriers [14]. In the bacteriological examination of thirty-two specimens of wash-water, the *Streptococcus hemolyticus* was isolated from eighty-four per cent of the specimens. In sixteen specimens pneumococci were isolated from sixty-three per cent; in thirty-two specimens *S. viridans* was isolated from sixty-five per cent; and in thirty-one specimens the *B. tuberculosis* was demonstrated in thirty-five per cent of the specimens.

Tableware transmission is a three-link chain; the first link is the oral cavity of the infected person; the second, the tableware, and the third
link is the oral cavity of the susceptible person. The first and third links are moist — a condition which facilitates transfer to and from the intermediate second link.

In brief, in public eating places, as well as in the home, the method of washing dishes by hand without the use of boiling water, results in a high numerical, or mass indirect contact, distribution of the saliva-borne infections. On the other hand, in either the mechanical or hand-washing method, the use of water at, or near, the boiling point, closes this major avenue of indirect transmission of the saliva-borne infections.

HAND TRANSMISSION.

The hands of healthy carriers have long been recognized as the transmitting agent of the intestinal-borne diseases. If the hands become contaminated with the intestinal organisms, there is a far greater chance of hand contamination with the saliva-borne infections.

In order to determine the frequency of hand contamination the hands of cases and carriers were examined for pathogenic organisms [15]. In 340 such examinations the *S. hemolyticus* was isolated in 38 per cent. In 41 tests pneumococci were found in 17 per cent. In 8 the *S. viridans* was isolated in 100 per cent, and in 7 the *B. tuberculosis* was found in 48 per cent. These tests indicate the frequency with which hand contamination occurs among cases and carriers.

INANIMATE OBJECTS AS CONVEYORS OF TRANSMISSION.

From the foregoing research it is concluded that the hands of recognized and of unrecognized cases, convalescents, and of healthy carriers, are contaminated with pathogenic organisms. The hands of these infected persons come in contact with innumerable inanimate objects which are handled by susceptibles. In order to substantiate our theory of indirect contact transmission, the following research was undertaken to ascertain to what extent inanimate objects were contaminated.

The bacteriological investigation of such objects included bedside table-tops, bed posts, door knobs, and the handles of sputum cups [15A]. In sixty-one examinations the *S. hemolyticus* was found in 13 per cent; in fourteen pneumococci were found in 50 per cent; and in forty-five *S. viridans* was found in 26 per cent.

Not only does the contaminated hand deposit organisms on these inanimate objects, but these organisms may be conveyed to other hands. That this actually takes place is shown by the fact that, in these experiments, the gloved hand was wiped over the test object and the contamination adhering to the glove was transferred to the culture media.

This transmission of contamination by inanimate objects forms a five-link chain. The donors of infection are cases—both recognized and unrecognized—convalescents, and healthy carriers. In this group the nose and oral cavity constitute the first link in the chain; their hands the
second, and inanimate objects which they handle the third link; fourth link, hands of the susceptibles who handle these contaminated inanimate objects; while the nose and oral cavity of the susceptibles constitute the fifth link. From the laboratory research here summarized these five links have been definitely connected, so that there is an unbroken chain of indirect transmission of infection from donor to recipient.

The importance of this avenue is apparent when there is massing or crowding, involving high numerical indirect contact as in the army. The larger the group, and the lower their standard of personal hygiene, the greater will be the multiple indirect contact through this five-link chain of distribution; whereas in a similarly large group a high standard of personal hygiene protects against this major avenue of transmission.

The Pneumonia-producing Group of Organisms.

In the army during 1918, of the total number of deaths from infectious disease, approximately ninety-two per cent were due to pneumonia. Evidently, then, efforts must be directed continuously against the transmission of the pneumonia-producing organisms in order to reduce the healthy pneumonia carrier index in the civil community—the source of the army. Type pneumococci are one of the chief causes of mortality as a primary cause of death. During epidemic periods of the virus infections, especially measles, influenza, smallpox and typhus fever, streptococci are responsible for high mortality. Then, as secondary invaders, streptococci are the immediate cause of death.

Our original research on measles mortality brought out two important points relative to the prevention of measles-pneumonia mortality in the army: first, measles was not the cause of death; but rather the complicating involvements, pneumonia, pericarditis, empyema, septicemia—the pneumonia group of organisms—were the cause of death; second, that those who developed pneumonia were healthy carriers of the pneumonia-producing group of organisms on entering the hospital.

We reported the bacteriological findings on thirty-one necropsies, eighteen of which were on patients dead from measles-pneumonia [16]. In these eighteen pneumonia necropsies haemolytic streptococci were isolated in pure culture, or co-existently with pneumococci, with great regularity from the lungs, pleural and pericardial exudates, and from the heart's blood.

In protecting the army from the saliva-borne infections the fact is of basic importance that measles patients who developed pneumonia did not acquire this infection in the hospital; they were healthy carriers of the pneumonia-producing organisms on entrance to the hospital [17].

Throat-swab cultures were taken from 452 measles patients on entering the hospital. In this series of cases it was established that thirty-five per cent of the measles patients were healthy carriers of the S. haemolyticus on entrance to the hospital, and that a third of these developed pneumonia;
on the other hand, of the sixty-five per cent of patients who were non-carriers of \textit{S. haemolyticus} only six per cent developed this complication.

It was evident from our laboratory studies that there were three divisions of patients. First, the non-carriers of \textit{S. haemolyticus} in whom there was but a remote possibility of type pneumonia; second, the light carriers of \textit{S. haemolyticus}, in whom pneumonia might, or might not, develop with an excellent chance of recovery; and third, the heavy carriers in whom pneumonia would inevitably appear and terminate fatally.

Pneumonia as a complication of influenza is now so well understood that no comment is here necessary, except, for the purposes of this paper, to reiterate that it is not the influenza virus, but the pneumonia-producing group of organisms which are the immediate cause of death. Furthermore, in influenza, as in measles, the pneumonia complication is the result of the healthy carrier state.

In our investigation of an epidemic of hæmorrhagic smallpox there were twenty patients, eight of whom were, on admission to the hospital, tonsillar carriers of hæmolytic streptococci [18]. In this group of twenty patients death occurred among \textit{S. haemolyticus} carriers only; six of the eight carriers died. The two who recovered were light carriers; whereas, among those who died, there was an abundance of streptococci in the throat cultures. In all the fatal cases \textit{S. haemolyticus} was isolated, not only from the throat, but also from the blood-stream or from the heart's blood, or from both sources.

We found further incriminating evidence against the healthy carrier of the pneumonia group of organisms in a Russian command of 6,000 men among whom there occurred 245 typhus cases, 49 of which were fatal [19]. In eighty-two per cent of the autopsies there was a well-defined broncho-pneumonia, streptococcal in character. Thus in typhus, as in measles, influenza and smallpox, there was demonstrated a virus infection, as the contributing cause, with pneumonia as the immediate cause of death.

Obviously then, it becomes essential to prevent the healthy pneumonia carrier state in the army, and in its tributary, civil life.

**The Susceptibility of the Healthy Pneumonia Carrier to Virus Infections.**

A reduction in the healthy pneumonia carrier rate signifies more than a corresponding reduction in deaths. Statistical studies of measles and influenza indicated that the pneumonia carrier is more susceptible than the non-carrier to these virus infections.

Our first observation was on measles [20]. Here it was found that while these patients on entering the hospital had a thirty-five per cent \textit{S. haemolyticus} carrier rate, troops in the field had only a six per cent carrier rate. If the carriers and non-carriers were equally susceptible the ratio would then be the same for entering the hospital and for those in the
field. On the contrary, the carrier, in his potentially dangerous state is seven times more susceptible than the non-carrier to measles virus.

A further proof of this susceptibility of the healthy carrier to the virus infections was drawn from public institutions. A comparison was made of the case-fatality rates between groups protected against transmission and others not so protected [21]. If the carriers and non-carriers were equally susceptible to influenza, the ratio of influenza cases and the ratio of mortality from pneumonia per 1,000 inmates for the two groups would be the same. On the contrary, while the ratio for influenza in the protected and in the unprotected groups was 1 to 3, the ratio of pneumonia deaths per 1,000 in these two groups was 1 to 2:2. In other words the case fatality rate among the protected was 94:2; whereas among those not protected it was only 70:4. These rates show that there was a larger proportion of pneumonia carriers to non-carriers infected with influenza in the protected than in the unprotected group. Among the protected the restricted distribution of influenza limited infection chiefly to carriers, due to their high susceptibility. In the unprotected groups the facility of distribution resulted in influenza infection, not only in carriers, but spreading among the less susceptible non-carriers. Hence there were more influenza cases among the unprotected, but as it is the carrier who develops fatal complications, this group had a lower case-fatality rate.

A third statistical survey was made, on the pneumococcus carrier susceptibility factor as it affected the influenza-pneumonia case-fatality rate in our army at home in 1918. The rates for several periods of the 1918 epidemic as compiled from the 1919 Annual Report of the Surgeon General of the Army are as follows:

<table>
<thead>
<tr>
<th>Period</th>
<th>Ratio of pneumonia deaths per 1,000 influenza cases</th>
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</thead>
<tbody>
<tr>
<td>September and October</td>
<td>54 deaths per 1,000 influenza cases</td>
</tr>
<tr>
<td>November</td>
<td>23</td>
</tr>
<tr>
<td>December</td>
<td>14</td>
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</table>

Here again it can be pointed out that influenza does not kill, but that pneumonia does. The high case-fatality rate for the first period, and the decreasing rates for the succeeding periods of the epidemic are indicative of the greater susceptibility of the pneumonia carrier than of the non-carrier to influenza virus. On the basis of the rates here presented, the healthy carrier appears to be at least four times more susceptible than the non-carrier or than the light carrier.

An epidemic comes to a close because there is a lack of susceptibles; furthermore, it is evident that among those attacked the ratio of carriers to non-carriers is high during the first part of an epidemic, and that the non-carriers—being less susceptible—are attacked late in the epidemic, when there is a widespread distribution of highly infectious doses of the virus.

From the viewpoint of the statistician an influenza death is a death from influenza; from the viewpoint of the epidemiologist a death from influenza is a death from pneumonia. This distinction carries implications;
for there are several steps leading to pneumonia mortality during an influenza or other virus epidemic; moreover, each step in that series is contributory to its successor.

The primary cause of this mortality is the pneumonia-carrier state; the intermediate cause, influenza infection, and the immediate cause of death pneumonia infection. Antecedent to all these is a basic cause—remote in origin—the pneumonia transmission rate. This is the heart of the problem; on it depends the pneumonia-carrier index; this in turn determines the virus disease incidence and the pneumonia mortality. The five culminative steps leading to mortality may be represented as follows: pneumonia transmission rate, pneumonia carrier index, virus disease incidence, pneumonia complications, death-rate.

Inasmuch as each step contributes to its successor, it may be concluded that preventive measures against pneumonia complications—and to a less degree against virus disease incidence—used as emergency measures during an epidemic will be ineffective. Morbidity and mortality must be attacked at their source-transmission; there the major avenues must be blocked—and continuously. This alone will prevent a piling up of pneumonia carriers during inter-epidemic periods.

**Discussion.**

As has been pointed out, the imperceptible workings of the four epidemiological factors can best be influenced through the first or key factor, transmission; further, it is difficult to identify all carriers; it is impossible to segregate the susceptibles, and impractical to avoid contact.

Consequently, for saliva-borne disease control the transmission rate must be reduced, i.e., the route or routes of distribution must be determined and practical means devised for blocking them.

When this research was undertaken the aim in working with the epidemiological factors was merely temporary control by blocking transmission during epidemic periods; we extended our studies of transmission, however, to include control leading to eradication.

There are three control factors leading to eradication:

1. Continuity of control; there must be control of distribution throughout inter-epidemic periods as well as during epidemics.

2. Percentage of transmission blocked: if there is but a single avenue of dissemination, as in malaria, more than fifty per cent of the transmission must be continuously blocked.

3. Evaluation of the various avenues of transmission; if there are two or more avenues of distribution their relative importance must be determined; then the major avenue or avenues continuously blocked to an extent of more than fifty per cent of the total transmission.

From a practical point of view it is impossible to control permanently, or even temporarily, any epidemic except through the checking of transmission between the group of unrecognized cases, convalescents, and healthy carriers, and the susceptibles with whom they come in contact.
There is, then, a vast difference between temporary measures, quarantine of patients, isolation of carriers, segregation of susceptibles, avoidance of contact, and the continuous blocking of transmission during inter-epidemic periods.

During an influenza or measles epidemic every effort is made, by avoidance of crowds, quarantine, etc., to control the spread of the disease. These temporary measures are helpful, but ineffective in that they can be neither continuous nor permanent. During the epidemic there is a high distribution and contact rate, and a high sick rate with a resultant reduction in the susceptibility rate. Lack of susceptible contacts draws the epidemic to a close. Such temporary measures as had been taken are then allowed to lapse; as time passes there emerges another group of susceptibles, and again an epidemic arises to be terminated in its turn by lack of susceptible contacts.

Measures which will control an epidemic by blocking transmission between healthy carriers and susceptibles, will, if continuously applied, prevent entirely, or mitigate the severity of, future epidemics. We have had repeated epidemics of influenza and measles; there is still a high mortality from tuberculosis and pneumonia. The difficulty has been that we have had no measures for blocking the chief avenues of distribution which would protect all the people all the time. The result has been repeated epidemics of the saliva-borne diseases.

Who knew whether or not the pasteurization of milk would reduce infant mortality until the theory was put to the test? There is no difference fundamentally in the prevention of pneumonia among adults and cholera infantum among infants. In both instances the control measures must be continuous. Who knew that mosquito control would eradicate yellow fever from North America? Finley advanced the theory, Reed proved it, and the control of this disease—through blocking transmission—has limited it to a few scattered foci. We no longer burn villages as an epidemic expediency, but control distribution by continuously blocking distribution. We do not purify our public water and milk supplies merely during typhoid outbreaks. It has been the unceasing blocking of distribution through those major avenues which after years has resulted in a cumulative reduction in typhoid mortality.

This success in the control of these infectious diseases has been based on the first, or prime, epidemiological factor; discovery of the main avenue, or avenues, of transmission, followed by the continuous blocking of these avenues.

A similar method of approach towards control of the saliva-borne diseases has been followed in the research here reported. Through field observations on the method of washing mess kits during the early part of the war it appeared that there was a possibility of transmission through this multiple indirect avenue of distribution. There was a striking similarity in the transfer of organisms from the oral cavity of one soldier to that of
another, and in the transfer of a culture from one test tube to another in the laboratory.

On the basis of the theory of mess-kit wash-water distribution of the saliva-borne diseases, a statistical study of the 1918 influenza-pneumonia epidemic indicated that the warm water was responsible either directly, or indirectly, for about eighty per cent of the influenza incidence in the large groups under observation. The immediate transmission from man to man was through the contaminated mess kits and hands; in addition, there was more extended transmission through the distribution of hand contamination through inanimate objects commonly handled by the group.

While the last mentioned study covered only the time of the influenza epidemic we have presented additional statistical data covering the much longer period of ten months. Here we have an observation extended to include the other saliva-borne infections, and here, as in influenza, the warm mess-gear wash-water is shown to be the central focus of distribution, with the hands and mess gear the major avenues of transmission.

The statistical evidence that the warm mess-kit wash-water was the chief focus of distribution, and the hands and mess gear the major avenues of dissemination is confirmed by the laboratory research on the five-link chain of transmission. The links through many laboratory tests were united into a complete chain.

The influenza rate as based on the method of washing table utensils in public institutions showed that seventy-five per cent of the total disease occurred in those institutions where the hand-washing method was employed. Eating-utensil distribution would then appear to be the major avenue of influenza transmission in these institutions. Among civilian groups carelessly washed table utensils appear to be responsible for two-thirds of the influenza incidence. Thus table utensils are directly, as well as indirectly, one of the chief avenues of distribution.

The facility of distribution through tableware has been fully supported by the laboratory investigations here reported, especially those dealing with the transmission of tuberculosis. The isolation of pathogenic organisms from the hands of patients, and from healthy carriers, as well as from inanimate objects, clearly indicates the importance of hand-to-mouth transmission in the army and in the civil population. From the data here presented the conclusion may be drawn that there are two major avenues of saliva-borne disease distribution. These are through contaminated hand-to-mouth and eating-utensil-to-mouth transmission.

It has been pointed out in this research that in the mechanics of control leading to eradication the major avenue, or avenues, must be identified, so that fifty per cent or more of the distribution may be blocked. The research here presented supports the theory of multiple indirect transmission through hands and eating utensils. That these are the major avenues of distribution makes it possible to eliminate more than fifty per cent of the
transmission by the adoption of higher standards of group sanitation and personal hygiene. Thus there is established a control leading to eradication—a control which means a cumulative reduction in cases and carriers in each successive cycle of transmission.

BIBLIOGRAPHY.


[15] Ibid.

[15A] Ibid.


