

Military Medicine and Surgery

A STUDY OF DIPHTHERIA CARRIERS IN A MILITARY CAMP

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Writers on military hygiene have affirmed that diphtheria has never been of serious importance in the Army, for the reason that it is easily controlled. This opinion is not shared by the officers on duty at the Base Hospital, Camp Doniphan, since their experience has demonstrated that, under certain circumstances, an epidemic of the disease is exceedingly difficult to overcome.

During the early months of 1918 the control of diphtheria, with especial reference to the carriers of the disease, was a very serious problem, which for a long time seemed but little influenced by the strenuous efforts of the staff.

As shown in Chart 1, a few cases were constantly present from October, 1917, but it was not until the latter part of January, 1918, that the disease began to show a marked upward tendency. From that time it persisted, despite the most earnest efforts and carefully devised safeguards, for nearly four months.

During the period cited, 461 cases and 686 carriers of diphtheria were observed. In their study, nearly 30,000 cultures were made and examined.

By the greatest of good fortune, the degree of virulence of the responsible organism was slight. Only three deaths occurred, all as the result of myocardial degeneration, and the individuals concerned were already enfeebled as a result of antecedent disease.

The condition, however, was serious militarily, since it compelled the withdrawal, from organizations engaged in intensive training for war, of more than a thousand men. These were separated from their commands for long periods, since the vital question was not how quickly a person might be returned to duty, but how long before it would be safe for his organization to receive him.

The infection was exceedingly tenacious. The means employed for the control of the epidemic, though in many respects more vigorous than those suggested by authorities on the subject, for a long time barely sufficed to maintain an equality between outgoing and incoming cases.

The intramural situation gave most concern. At a time when but few cases were under treatment, it was discovered that more than half of the twenty-six wards contained carriers, among patients and attendants. Though cultures were made of all in such wards, and infected individuals removed, the next search, at an interval of from five to seven days, was sure to reveal at least as many more who harbored the organism.

The epidemic was finally overcome only when available susceptibles had been segregated, or, in the course of military events, had been transferred elsewhere.

STATISTICAL BASIS OF THIS SURVEY

No attempt is made in this paper to discuss the treatment of clinical diphtheria, its complications or results, as that subject has been thoroughly treated by others. We are chiefly interested in the discussion of the diagnosis, treatment, results and control of the carrier condition and the epidemiology of the outbreak in this camp.

The data for this paper were derived from (a) the study of 686 diphtheria carriers and 461 cases of clinical diphtheria; (b) the incidence of *B. diphtheriae* in patients admitted to the head surgery section; (c) the results of operative treatment in 294 diphtheria carriers; and (d) laboratory investigations.

CLASSIFICATION OF CARRIERS

Carriers may be thus classified:

1. Primary carriers: A, transient; B, chronic.
2. Secondary carriers.

A primary carrier is one who has never had clinical diphtheria. In transient carriers the bacilli do not find more than a temporary resting place, the reason being that the nasal passages are normal and the tonsils are quite healthy or have been enucleated. The chronic carrier is one in whom positive cultures are obtained for an indefinite period of time. In some of these individuals the carrier condition is intermittent. Following a series of negative cultures, positive cultures recur at irregular intervals. Reinfection, overgrowth by other bacteria and the fact that the organisms are deep in the crypts and have not manifested themselves on the surface at that examination may be suggested as possible reasons.

The secondary carrier is one who, having recovered from clinical diphtheria, still continues to harbor the germs of the disease.

TABLE 1.—NUMBER OF CULTURES EXAMINED

Year	Month	Positive		Negative	
		No.	Per Cent.	No.	Per Cent.
1917	October.....	10	52.6	9	47.4
	November.....	90	22.9	302	77.1
	December.....	138	7.6	1,084	92.4
1918	January.....	350	9.2	3,462	90.8
	February.....	895	18.9	3,855	81.1
	March.....	1,236	15.3	6,849	84.7
	April.....	1,451	25.1	4,330	74.9
	May.....	456	8.9	4,702	91.1
Total.....		4,626	15.5	25,193	84.5

THE VALUE OF CULTURES

The carrier condition can be determined only by means of cultures. A single negative culture has but little value, as is proved by these figures: Of 294 cases in which tonsillectomy was performed for the relief of the carrier state, cultures taken from the tonsils immediately preceding the operation yielded positive results in 57 per cent. of the cases, and negative results in 43 per cent. Cultures of the tonsils after removal gave positive results in 77.2 per cent. of the cases. The fact that negative cultures were obtained in 22.8 per cent. of individuals in whom the carrier condition had been definitely proved emphasizes the necessity for caution in overestimating the value of a single negative culture. In a number of instances a pure culture of *B. diphtheriae* was obtained from tonsils removed from patients who had not been identified as carriers. But these patients had had the disease from four to fourteen weeks previous to admission and had been released on the required number of negative cultures. As is

well known, negative cultures may be obtained at times from cases that run the course of typical clinical diphtheria.

The value of nasal cultures is not fully appreciated. That a nasal culture is of great importance is well illustrated by the case of a carrier who was under observation for a period of four and one-half months. Cultures from the nose were much more consistently positive than those obtained from the throat. Tests made on several occasions showed that the organism present in the nose was distinctly virulent for guinea-pigs.

These figures illustrate the returns that may be expected in all types of nasal and pharyngeal carriers. Of 700 cultures from the nose and throat, positive returns from the nose were obtained in 26 per cent. of the cases, while those from the throat were positive in 31.7 per cent.

SYSTEM EMPLOYED IN MAKING CULTURES

On the appearance of a clinical case of diphtheria or of a carrier, the regimental surgeon was requested to have all contacts appear at the regimental infirmary at an hour most convenient to the company commander, usually at 1 o'clock or immediately before a formation. When a second or a third case appeared in the same company, cultures were taken from all members of the organization in order to ascertain if carriers were present.

The cultures were taken from the nose and throat and planted on Loeffler's medium, one tube being used for both swabs. Tubes were then collected and returned to the laboratory for incubation and examination. Tubes of the medium, together with sterile swabs, were distributed weekly to each regimental infirmary in order that cultures could be promptly taken in all cases of sore throat. The inoculated tubes were then delivered to the laboratory by the ambulances on their regular rounds. After incubation for from eighteen to twenty-four hours, cultures were smeared and stained with Loeffler's methylene blue.

BACTERIOLOGIC DIAGNOSIS

To aid in establishing uniformity in diagnosis, we adopted Wesbrook's classification of *B. diphtheriae*. Those organisms showing the morphology of Wesbrook's Types A, A¹, B, B¹, C and D were considered as being positive. Those that did not show all the characteristics of these types were further incubated for from four to six hours in order to ascertain if they would assume those characteristics.

In the course of this study it was noted that diphtheroids were found more frequently when cultures made from the nose and throat were planted on the

same tube. In all doubtful cases, when no definite decision could be made, cultures of the nose and throat were inoculated on separate tubes. In these cases it was frequently found that the throat cultures were negative while the nasal ones showed the presence of suspicious organisms.

No attempt was made to carry out virulence tests as a routine measure, since the large number of cases made it impracticable. In cases of doubtful morphology, and in those cases running a persistent positive course, virulence tests were carried out. Twelve cultures obtained from the nose, eleven from rib resection wounds, and nine from the throat were tested for virulence. Of this group of thirty-two cases, eleven cultures from the nose, two from the rib resection wounds, and nine from the throat were virulent for guinea-pigs. In order to conserve animals, the method advocated by Zingher and Soletsky¹ was used. The culture was isolated, transferred to tubes of Loeffler's blood serum, and, after from eighteen to twenty-four hours' incubation, the slant was washed off with sterile salt solution until a uniform dense emulsion was obtained. Of this emul-

sion from 0.1 to 0.2 c.c. was injected intracutaneously into a guinea-pig. At the end of from twenty-four to forty-eight hours an area of redness and induration developed at the site of inoculation which, in most instances, went on to necrosis in those animals showing positive reactions.

LOCALIZATION OF ORGANISMS

Every carrier was given a thorough examination in order to localize the affected area. After thorough cleansing of the mucosa, several cultures were

made from the superior and inferior regions of each nostril and from each tonsil.

A positive culture from the throat does not necessarily imply that the carrier condition is located in this region, as the bacilli may be carried from the nose or nasopharynx by the inspired air or by the secretions. On the other hand, the bacilli may be carried from the throat to the nose by the expired air or the act of sneezing, and from the resulting positive nasal culture one might infer that the nasal passages were involved. No faith should be placed in a single negative culture, especially in those who have previously shown a positive culture. Conversely, the finding of a single positive culture is not sufficient evidence to justify the diagnosis of carrier, as this may be the prelude to an attack of clinical diphtheria that has not yet had time to manifest itself.

FOCI OF INFECTION

Tonsils.—The presence of a favorable soil for bacterial growth is a factor that determines the persistence

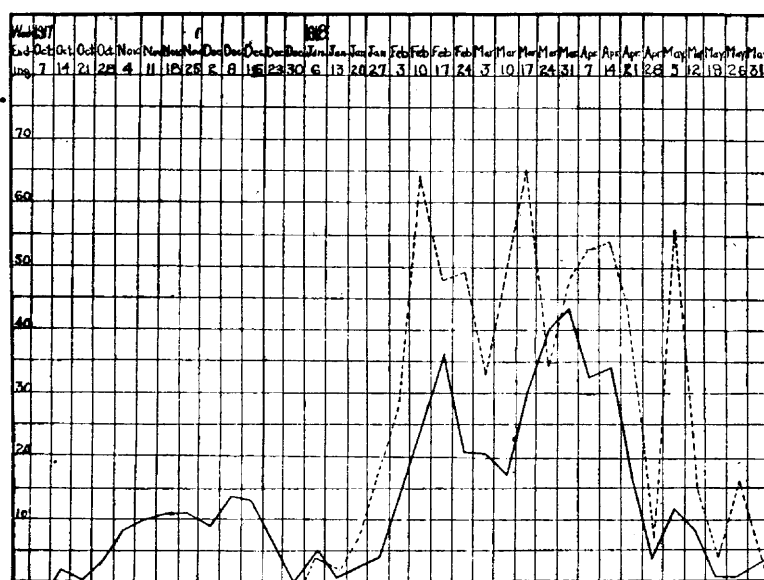


Chart 1.—Weekly occurrence of diphtheria and diphtheria carriers at Camp Doniphan: solid line, cases; broken line, carriers.

1. Zingher and Soletsky: Jour. Infect. Dis., 1915, 17, 456.

of the carrier condition. If necrosis or ulceration of the epithelium covering the tonsils or lining the crypts is present, the bacilli may be found in the tissue beneath the diseased area. The size of the tonsil, per se, is not a factor as a predisposing cause in establishing the carrier condition. The degree to which the tonsil is covered, the extent of surface exposed, lobulation, and the presence of folds or crevices, all have a definite influence on infection of the tonsils by interfering with the evacuation of the crypts. In this study it has been demonstrated repeatedly that acute or chronic pus infections are often associated with diphtheria carrier conditions.

In order to ascertain the points of localization of *B. diphtheriae* in the tissues, cultures were made from the nose and throat immediately preceding tonsillectomy, and planted on separate tubes of Loeffler's medium. The excised tonsils were received in sterile Petri dishes and delivered to the laboratory. After removal of the surface blood and bacteria by means of sterile salt solution, a sterile swab was inserted deeply in the crypts and then inoculated on Loeffler's medium. From the tonsils found to be infected, almost pure cultures of *B. diphtheriae* were obtained in the vast majority of cases. In most instances the organisms displayed the morphology of Types C and D of Westbrook's classification. About ten or twelve showed his Types B and B¹, while in five or six cases Type A was found.

In two cases studied, Lieutenant Thorne, M.C., demonstrated the presence of *B. diphtheriae* in the submucosa of a tonsil from the surface of which a pure culture had been previously obtained, thus confirming the work of others.

Nose.—The next location, in order of importance and frequency, is the nose. Acute or chronic infection of the accessory sinuses, ulceration or erosion of the septum or soft tissues, and the presence of dry secretions and gross abnormalities interfering with ventilation and drainage all furnish favorable conditions for the lodgment of the bacilli. In the chronic accessory sinus affections, especially those associated with marked atrophic changes, the prognosis is almost hopeless. It was impossible to discover any particular location within the nose that favored the growth of the bacteria. Washings from the sinuses invariably proved negative. The idea that the mucous glands were the definite points where the bacilli thrived was not substantiated. Tissues removed from the various regions of the nasal passages were sectioned and stained for the organism with results that were entirely negative. In spite of several failures to demonstrate the presence of the organisms, their general distribution throughout the nasal passages justifies the belief that, sooner or later, they will be found underneath the diseased mucous membrane and possibly in the ethmoid cells.

Nasopharynx.—The nasopharynx ranks third in order of frequency as a lodging place for *B. diphtheriae*.

This may be attributed to the presence of ulcerative or inflammatory processes, infections of the posterior ethmoid and sphenoid sinuses, and the presence of hypertrophied adenoid tissue. The size of the latter is not of etiologic significance, as a relatively small amount may harbor the bacilli as effectively as a large mass. The same difficulty has been met in finding the organism in the adenoid tissue that was encountered in the case of the nose.

Wounds.—Wounds may carry the bacilli for an extended period of time. An epidemic of wound diphtheria occurred in two wards occupied by patients who had rib resections for empyema. In one of these wards the diphtheria bacillus was first demonstrated in the wound of a head carrier; this occurred about the middle of March. Five more cases had developed by the end of the month, and twenty-eight occurred in April and ten in May, making a total of forty-four cases. In thirty-three of these cases, *B. diphtheriae* was found in the wound alone, while in twelve the organism occurred in both wound and throat. In thirteen cases the presence of a pseudomembrane and other characteristics of a diphtheric wound were noted. With few exceptions the organism was recovered from granulation tissue, while cultures taken from the depth of the wound were usually negative.

The virulence of the organism was proved by intracutaneous injections into guinea-pigs. In one of two cases thus studied, redness and induration at the site of inoculation was produced after twenty-four hours, and at the end of seventy-two hours local necrosis was well marked. The second pig died within seventy-two hours after an intracutaneous injection of 0.2 c.c. of an emulsion of the culture. At the postmortem examination typical lesions of diphtheria were found.

In several instances the organism was recovered from the skin which had covered over the opening into the chest.

Ears.—In a few cases the bacilli were found in the discharge from acute and chronic suppurative processes of the middle ear.

NONOPERATIVE TREATMENT OF THE CARRIER CONDITION

For the cure of the carrier condition many medicinal agents have been advised, such as sprays, applications, gargles, douches and inhalations. Other agents, acting in a purely mechanical manner (such as kaolin), have been proposed. At various times antitoxins, diphtheria vaccine, antibacillary serum, toxins of *B. pyocyaneus*, and cultures of various living bacteria have been recommended and reported on favorably. From experience derived previous to and during this epidemic, we feel that the value of any local treatment is particularly liable to be ineffective because of the fact that the bacilli are found in the depth of the crypts and beneath the epithelium and are, therefore, untouched by the remedial agent.

In nasal carriers the cessation of the carrier state takes place on the disappearance of the accompanying pathologic condition; therefore, efforts must be directed toward the improvement of the underlying condition.

In the most persistent carriers, local measures were without avail. Various kinds of solutions for irrigation, silver salts, dichloramin-T, crystal violet, and oily sprays were given a thorough trial. It was not difficult to obtain negative cultures while the treatment was being carried out, but when this treatment was discontinued the cultures were again returned positive, and, unless the patients were kept under careful control, it was quite easy to draw inaccurate conclusions regarding the effect of local measures. The harm, of course, results in the release of carriers who are still a menace to their comrades. It must not be construed from what has been written that the affected regions, especially the nose, should not be kept clean, since this is one of

the prerequisites for the restoration of the normal functions of the diseased area. At the same time the use of strong irrigating solutions should be carefully governed, for, if used in too great strength, the mucous membrane will be injured to a further degree.

When a wound is involved, it should be dressed frequently in order to keep it as clean and dry as possible, and all granulations should be removed.

OPERATIVE TREATMENT OF THE CARRIER CONDITION

Since local applications have proved unreliable in the treatment of the carrier state, it seems to us that operative interference is the only solution of the problem, especially in those cases in which the tonsils can definitely be shown to be the focus of infection. In 77.2 per cent. of carriers, the bacilli were harbored in the tonsils. The majority of the remainder showed the presence of *B. diphtheriae* in the nose.

The tonsils should be removed in every case in which it can be positively demonstrated that they are harboring the organism. The contraindications for tonsillectomy in carriers are those that apply under other circumstances.

The majority of patients with clinical diphtheria remain in the hospital for a period of approximately four weeks before they are returned to their commands. Since, in the average case, the bacilli have disappeared by the end of the third week, this may be taken arbitrarily as the beginning of the carrier stage. Consequently, it is safe to remove the tonsils at this time, provided there are no contraindications.

The reaction in carriers, following operation, does not differ from that found in noncarriers. Occasionally it may be severe enough to arouse suspicion that clinical diphtheria is present. However, unless there has been operative traumatism to the surrounding structures, the limitation of the postoperative exudate to the tonsillar fossae—in contrast to the angry red, edematous throat of diphtheria, in association with the marked prostration—suffices to differentiate the two conditions.

Patients on whom operations were performed had been positive for a period varying from one week to several months. As nearly as could be determined, the proportion of primary to secondary carriers was as 2:1. Of the 294 carriers operated on, 20 per cent. yielded a positive culture from the nose and 57 per cent. from the throat, immediately before operation. Subsequent to operation the following results were obtained:

Ninety-four, or 32 per cent., had no positive returns.

One hundred and thirty-six, or 46.4 per cent., were negative by the end of the first week.

Thirty-eight, or 12.9 per cent., were negative by the end of the second week.

Eleven, or 3.7 per cent., were negative by the end of the third week.

Fourteen, or 4.7 per cent., were negative by the end of from four to eight weeks.

One, or 0.3 per cent., was still positive at the end of four months despite all treatment.

In those cases found to be persistently positive, acute or chronic infections of one or more of the accessory sinuses, septal deformities with erosions, or infected adenoid tissues were present.

The time of clearing, as shown by the 91.3 per cent. who were negative by the end of the second week, corresponds very closely to the time required for healing. As the postoperative exudate disappears and the wound heals and becomes smooth, the lodging places of the bacilli become obliterated. In one carrier with adenoid involvement the bacilli disappeared after the tissue was removed. In the persistent nasal carriers, clearance coincided with improvement in local conditions. On the cessation of the infection in the acute sinus cases, the carrier condition terminated.

In the chronic cases, drainage and constant attention to cleanliness helped, but only after a considerable time. Patients with atrophic rhinitis presented the

greatest difficulty as, even after the most continued and careful treatment, and the return of more than the required number of negatives, there was no assurance that the bacilli had finally disappeared. The advisability of operating on these patients was considered, but the extensive involvement of the nose and accessory sinuses, with the resulting marked disturbances of function and nutrition, all advised against this. In addition, there was no assurance that crusts would not continue to form and thus serve to maintain the original condition. The question naturally arises as to what

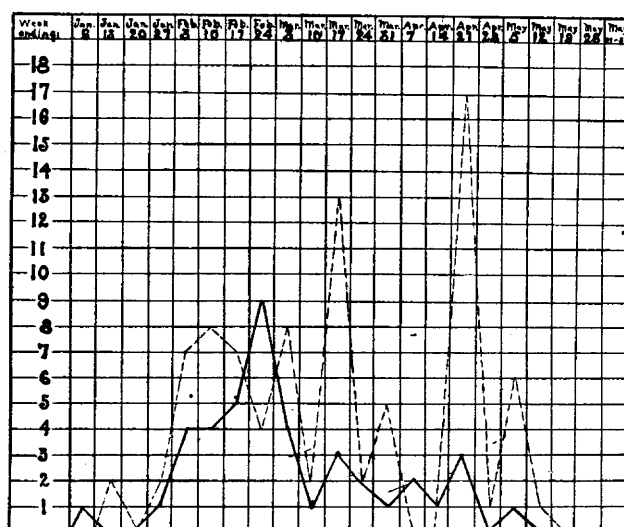


Chart 2.—Occurrence of diphtheria among the base hospital personnel: solid line, cases; broken line, carriers.

should be done with this class of patients. Chronic infection of the accessory sinuses disqualifies for admission into the service. Nevertheless, there are many such cases in the Army at present. It may not be practicable to have the opinion of a specialist on each individual in the service, but, in our opinion, every one connected with a base hospital should have a thorough examination of the nose and throat. Remediable conditions should have early attention. Chronic nasal diseases that offer no hope of early improvement or cure may necessitate discharge from the Army.

The disposition of a chronic nasal carrier with virulent bacilli is a question that will require much consideration. It may be solved partly by employing these patients in diphtheria wards where there are cases of diphtheria in the hospital or camp. What should be done with them at other times is the point to be decided. At present the isolation camp is the only solution. It is impossible to state the length of time during which the carrier condition may persist. To illustrate, one case that occurred in civil practice may be cited. An infant became a carrier at the age of 2 months. The bacilli

continued to be found for 251 days. Virulence tests made shortly before the condition cleared were positive.

CONTRIBUTORY FACTORS IN THE MAINTENANCE AND SPREAD OF THE EPIDEMIC

Measures undertaken for the control of any communicable disease must begin at the source of infection and continue until all danger of infecting others has passed. The following factors may counteract any or all of the defensive measures that have been instituted against an epidemic:

A. Delayed or mistaken diagnosis. This may be seen especially in cases of primary laryngeal diphtheria, which may remain undiagnosed for several days.

B. Ambulatory cases, usually of a mild or nasopharyngeal type. This was illustrated by a case in which a man was admitted to the hospital with the history of an indefinite nasal complaint of nineteen days' duration. A diagnosis of nasal diphtheria was made, which was confirmed by the laboratory. Yet, during the entire period of his illness, the patient had been doing full duty with his regiment.

C. Contiguity. The spread of disease by droplet infection is facilitated by close association in tents, barracks, wards, wash rooms, kitchens and general mess halls.

D. Fomites. Dishes, kitchen utensils, the use of the pipe, drinking cup, canteen, or musical instruments in common, mouth pieces of gas masks, unwashed bed linen, and laundry must all be taken into consideration as distributing agents in an epidemic.

E. Food supply. The milk supply should be investigated, especially when raw milk is being used.

F. Lack of appreciation of the seriousness of the carrier problem on the part of some of the members of the hospital organization, comparatively few of whom have previously had any experience with contagious diseases.

G. Improper methods of taking cultures. Cultures should be taken carefully and not by the "hit or miss" method so often employed. The most reliable results are obtained when cultures are taken from the tonsillar crypts and from the nose. Wound cultures should be made from the granulation tissue before the wound is dressed. Cultures from the nose and throat should be taken immediately before treatment.

H. False conclusions from defective material. Old or contaminated culture mediums may inhibit the growth of the diphtheria bacilli. The use for the Schick test of toxin which has deteriorated in potency may lead to erroneous conclusions as to the presence, in the body fluids, of sufficient antitoxin to protect the individual.

I. Release of patients from quarantine before negative cultures in sufficient number have been obtained, or before the necessary interval of time has elapsed.

J. Disregard of surgical principles in dressing wounds. Particular care should be taken that all gloves and instruments should be thoroughly sterilized for each case.

K. Lack of appreciation of the importance of carrying out quarantine regulations. The fact that the patient is needed by his organization or that there is a shortage of beds in the hospital should not be a sufficient cause for the premature release of a man from quarantine.

L. Undetected carriers. Individuals who have not been found positive by the laboratory, and patients with acute tonsillitis may be discovered to be carriers only when cultures are taken as a routine measure.

The causes for the maintenance or spread of an epidemic of diphtheria may be classified as avoidable and unavoidable. Inexperience, indifference, ignorance and carelessness are factors in the first group. Under unavoidable causes may be included legitimate errors in the diagnosis of atypical cases of diphtheria, clinically mild cases, carriers released after full compliance with the regulations, and, lastly, inadequate laboratory facilities.

CONTROL AND PREVENTION

The methods provided for the control of communicable diseases are so well known that a review would seem unnecessary. When the cases are few, the proposition may be simple; but when there are many to be dealt with and it is essential that company organization and the training of troops shall be maintained, the problem becomes more complex.

A. Centralization of control. For the attainment of efficiency and the accomplishment of results, centralized control is absolutely necessary, as division of responsibility tends toward weakness.

Clinical diphtheria is under the care of the hospital section of medicine. Suspect cases usually appear in the wards pertaining to head surgery. Nose and throat carriers may be found anywhere and are inherited by the latter service. Military or hospital exigencies may require frequent changes in attendants. Patients convalescent from diphtheria must be removed to make room for the acutely ill, and may be transferred to a convalescent camp. Since this may become overcrowded, the patients must in turn be moved to an isolation or quarantine camp. In the meantime, as a result of the conditions cited, cultures may have been overlooked or neglected.

In view of the fact that, in this series of cases, the laboratory passed on all cultures submitted and was therefore cognizant of the status, from a bacteriologic standpoint, of all cases of diphtheria, the following system was adopted for the control of the epidemic: Whenever a new positive culture was found, a record was made of the name, rank, organization, date of primary culture, and whether the patient was a case or carrier. The results of all subsequent cultures were added to this record. After three negative cultures had been obtained at three-day intervals, the chief of service was notified that the patient could be released from quarantine. In cases in which the positive returns persisted for a period of three weeks or longer, the matter was brought to the attention of the chief of the nose and throat service for further investigation.

B. Disposal of patients. Undoubted clinical cases of diphtheria were sent directly to the diphtheria wards by the receiving officer. All patients who were sent to the head surgery section were examined in the outpatient room before being admitted to the wards. Owing to the large number of acute inflammatory throat conditions admitted at this season, it was considered advisable to make cultures of every patient admitted to this service. Suspicious cases were isolated in private rooms. Separate wards were set aside for the reception of carriers. Known carriers from the camp or other wards were received there directly.

On account of the necessity of awaiting the laboratory report on cultures, the disposal of patients presented a problem. To meet this contingency, the following plan was evolved in conference with the commanding officer, the chief of the section of head surgery, and the chief of the laboratory: Five pyramidal tents, each having a capacity of four beds, were erected in the rear of the head surgery wards. All patients admitted to the service other than by transfer from other wards were examined, cultures were taken, and the patients were treated and then sent to the observation tents. On the return of the culture findings, patients with negative cultures were transferred to the clean wards, while those with positive cultures were

sent to the carrier or diphtheria wards, according to the laboratory findings. Since the information furnished from the return of a single negative culture was found to be insufficient, the patients who had been sent to the clean wards were isolated in cubicles and further cultures were taken. If found negative on the second culture, they were allowed the freedom of the wards, but if found positive they were transferred to a carrier ward. All patients presenting symptoms suggestive of clinical diphtheria, even though the cultures were negative, were kept isolated in the observation tents or, if quite ill, in private rooms in wards until a definite diagnosis was made.

From the middle of February to the latter part of May, 680 patients were sent from the receiving office to the head surgery section for all causes. Of this number 127 were found to be either diphtheria carriers or cases: of these, fourteen patients were sent at once to the diphtheria wards; sixty-one patients were sent from the observation tents to the diphtheria wards at a varying number of hours after admission; thirty-two patients were sent to the carrier wards. Twenty patients who were negative on the first culture and who had been isolated in clean wards gave positive returns on the second culture. The extent of the epidemic may be readily appreciated when it is noted that 18.6 per cent. of all cases that passed through the head surgery section were either carriers or cases of diphtheria.

Routine cultures were taken, at five to seven day intervals, of the personnel and patients. The system of cubicle isolation and the establishment of carrier wards was soon extended to the other wards of the hospital.

C. Masks. The protection afforded by masks may be real or imaginary. The simple gauze bandage is the poorest of all, since when worn by patients it may be found in any position between the chin and the forehead. The mouth and nose are rarely covered at the same time. The combined head and face (helmet) mask, if made of a material with a close mesh, is the most efficient and may be worn for some time with comparatively little discomfort. The thick gauze surgical mask which fits the mouth and nose closely is uncomfortable for continuous wear and, owing to the condensation of moisture on it, becomes unsightly. A mask that was found suitable for clinic work and ward visits was made of a copper wire frame covered with several layers of gauze held in place by small strips of adhesive plaster or by basting thread. It was similar in appearance to an anesthetic mask. The frame was bent to fit the nose and mouth closely. Tapes or paper

clips that held a rubber band were attached to the sides of the mask, and by the slipping of these bands over the ears the mask was securely held in place. Its chief advantages consisted in the rapidity with which it could be adjusted or removed, and the absence of the discomfort that is found with all close-fitting masks. Conversation was not interfered with, which was also advantageous when clinical instruction was being given.

Despite regulations regarding the wearing of masks, it is very difficult to obtain complete observance with ambulatory patients and even with attendants. Sharp disciplinary measures are necessary to enforce compliance with the rules.

D. The Schick test. There is very little doubt that the Schick reaction, by determining the susceptibility of individuals to diphtheria, is of great value as an aid in controlling the spread of the disease. Of 1,035 Schick tests performed, eighty-eight (8.5 per cent.) were positive, while 947 (91.5 per cent.) were negative. Of the eighty-eight persons who yielded a positive

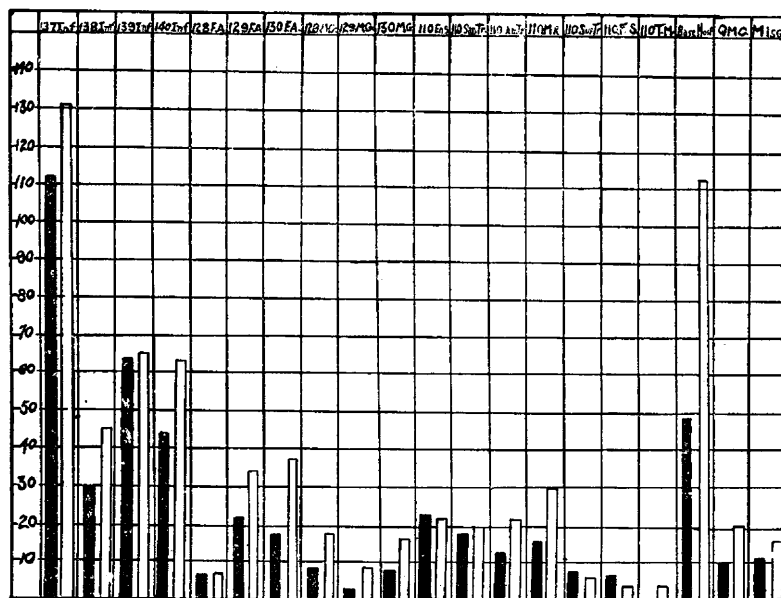
reaction, fifteen developed diphtheria, while among those who showed a negative reaction only three contracted the disease. All carriers tested gave a negative Schick.

Faulty results will be obtained if the toxin used is not of the proper potency. This was demonstrated in the case of the three men who developed diphtheria after a negative Schick, for, on further investigation, it was found that this particular lot of toxin had deteriorated.

E. Toxin-antitoxin. That diphtheria antitoxin confers but a transient immunity is well known. This fact is further corroborated by our own observation of a group of men, a number of whom manifested a positive Schick reaction within from three to four weeks after the administration of immunizing doses of antitoxin.

Within the past four months fifty-eight Schick-positive individuals have been injected with three doses of a toxin-antitoxin mixture prepared by the New York Board of Health. As these men have been transferred from this station we have been unable to carry out further tests in order to ascertain whether or not they have developed an active immunity.

We appreciate the fact that the injection of toxin-antitoxin will not give rise to immunity until after three or four months and is, therefore, of but little value in an epidemic. We are aware, moreover, that the administration of immunizing doses of antitoxin to susceptible individuals during the epidemic, though they protect the patients for the time being, may, on the other hand, so sensitize them as to make further



introduction of serum dangerous, since it may give rise to anaphylactic shock. Nevertheless, these measures are of decided value and should be employed.

F. Hospital rules for the control of the epidemic. To supplement or amplify the rules concerning communicable diseases as prescribed by the Office of the Surgeon-General, the following additional rules were promulgated as occasion demanded

1. Cultures will be taken from the nose and throat of all patients, ward attendants, and detachment personnel other than those employed in the wards, every seven days.

2. The receiving officer or officer of the day will have cultures taken from the nose and throat of all patients admitted to the hospital and will note that fact on the admission slip. If patients are too ill to have cultures taken in the receiving ward, cultures will be promptly taken by the ward officer.

3. It is directed that cultures from new cases entering the hospital be designated by writing across the request blank, "Field case," "For diagnosis," "Carrier" or "Release," as the case may be.

4. Masks will be worn by all members of the staff in all wards and by the patients in the diphtheria and carrier wards. The nose must be kept covered as well as the mouth.

5. Except in emergency, new personnel must show a negative culture and a negative Schick test before assignment to ward duty.

6. Nurses who are infected (patients and carriers) will be isolated in separate wards. Carriers will remain on duty but will be assigned to diphtheria wards only.

7. No contact will be permitted between patients from different wards. To insure this at meal times, all patients will be messed in their wards and no meals will be served in the mess hall.

8. Articles used in serving food (dishes, knives, forks, etc.) will be cleansed in the wards and then sent to the kitchen to be sterilized by boiling.

9. Visiting in carrier wards is forbidden.

10. Symptoms of sore throat in any member of the hospital organization will be immediately reported to the next higher authority. Cultures will be made at once and the individual isolated until the result is known.

11. Patients in clean wards who are found to be positive are to be transferred to carrier wards at once, and cultures are to be made of patients remaining in the clean wards.

12. Cultures of carriers are to be made daily until a negative is secured. Thereafter they are to be made every third day.

13. New patients in clean wards are to be isolated in cubicles and will not be allowed the freedom of the ward or latrine. A culture will be taken on the day of admission and on the following day.

14. Cases and carriers will not be released until notification of release from quarantine is received from the laboratory.

15. Cultures will be taken of patients received in the ward, by transfer from another ward, and these patients will be isolated until the results of the cultures are reported from the laboratory, unless cultures have been taken within three days prior to transfer.

16. All medical officers, nurses and enlisted attendants are to have a Schick test, and when this is found positive, toxin-antitoxin is to be administered for the purpose of immunization.

17. After discharge from the hospital, carriers and patients are to report once a week for culture of nose and throat for such a time as is deemed advisable.

EPIDEMIOLOGIC STUDY OF DIPHTHERIA

Chronologic Occurrence of Diphtheria.—That diphtheria is a disease of winter is well shown in Chart 1, since its incidence is much higher during the coldest months. Unfortunately, no differentiation was made between the cultures obtained from clinical cases and from carriers prior to January, 1918, but after that date all cultures submitted to the laboratory were des-

ignated as from clinical cases or otherwise. Almost perfect parallelism is seen to exist in this chart between the number of carriers and clinical cases. The great increase in the number of carriers over cases for the week ending May 5 was especially notable in the three organizations in which the greatest number of clinical cases for that week developed.

Occurrence of Diphtheria Among Hospital Personnel.—Examination of Chart 2, showing the occurrence of diphtheria and carriers among the hospital personnel, does not reveal the close parallelism that is seen to exist in Chart 1, since the number of carriers greatly exceeds the number of cases, except during the onset of the hospital epidemic, which occurred during the month of February. This is explained by the fact that the hospital attendants who were susceptible to diphtheria contracted the disease during the early part of the epidemic while, later, the constant exposure of those who were immune increased the proportion of carriers. It is of interest to note that a decided increase in the number of cases of diphtheria in the camp is followed, within a few days, by a similar increase in the number of cases among the hospital personnel. This may be noted by contrasting Charts 1 and 2 for the weeks ending February 17 and 24, March 31, and April 7, 14 and 21. This may naturally be attributed to the fact that the members of the base hospital received their infection from the patients admitted from the camp, and, since a period of incubation must elapse from the time of exposure to the time of the manifestation of the disease, the apex of the curve in Chart 2 would necessarily lag behind that of Chart 1.

Another source of infection, aside from the camp cases, was found within the hospital itself. On examination, the fact was revealed that approximately twenty carriers and patients were working in the detachment and hospital messes as cooks or cooks' police. Since the ambulatory patients from all clean wards congregated here for their meals, they were naturally subject to exposure to diphtheria. Corroborative evidence that this was a source of infection was adduced by the fact that the highest incidence of carriers and cases occurred in Hospital Barracks A and B, where most of the kitchen force was quartered.

Occurrence by Organizations.—On examination of Table 2 we find that organizations coming from rural communities have distinctly higher incidences of diphtheria than those coming from the cities. Thus a comparison of the four regiments of infantry, all having approximately the same strength and living under the same conditions, reveals the fact that the 137th and 139th infantries, coming from rural communities, have a higher percentage of cases and carriers than the 138th and 140th, coming from St. Louis and Kansas City, respectively. The same distinct difference may be seen to exist among the regiments of artillery, which were of like strength and lived adjacent to each other under similar conditions.

An apparent discrepancy in this statement may be found in the percentage of carriers and cases occurring among the base hospital personnel, which had a strength of approximately 500. This fact may be attributed, as has been mentioned in the discussion of Charts 1 and 2, to their continual exposure to the disease.

It is of more than passing interest to note that, in the study of empyema made during the past winter, those organizations that exhibited a high morbidity for

empyema showed, in this survey, a high incidence of diphtheria. From these facts one must conclude that, as has already been shown by others, a man from a rural community is not as great an asset to his organization in the early part of his military career as is an urban individual.

CONCLUSIONS

1. A single negative culture is only of relative value, as is shown by the fact that preoperative cultures, taken from tonsils that later proved positive for diphtheria, were negative in 22.8 per cent. of the cases.
2. The importance of nasal cultures is shown by the fact that in routine cultures taken from carriers, 26 per cent. were positive from the nose.
3. Cultures from chronic carriers should be tested for virulence.
4. The carrier state is maintained by some underlying pathologic condition of the affected tissues.
5. In the great majority of cases the carriers harbor the bacilli in the tonsils; a few carry the germs in the nose only; a small group maintains the infection in both nose and tonsils.
6. Conclusions based on the results of local treatment should be founded on careful and prolonged bacteriologic study. Cultures should be taken immediately before treatment, or, if local treatment is being

TABLE 2.—OCCURRENCE OF DIPHTHERIA BY ORGANIZATIONS

Organization	Source	Carriers Per Cent.	Cases Per Cent.
137th Infantry.....	Rural.....	19.1	24.2
138th Infantry.....	Urban.....	6.7	6.6
139th Infantry.....	Rural.....	9.7	13.9
140th Infantry.....	Rural and urban.....	9.2	9.3
128th Field Artillery.....	Urban.....	1.3	1.8
129th Field Artillery.....	Rural and urban.....	5.1	4.6
130th Field Artillery.....	Rural.....	5.3	3.9
128th Machine Gun Battalion.....	Rural.....	2.7	1.8
129th Machine Gun Battalion.....	Rural.....	1.3	0.4
130th Machine Gun Battalion.....	Rural.....	2.3	1.7
110th Engineers.....	Rural and urban.....	3.6	4.9
110th Sanitary Train.....	Rural.....	3.0	3.6
110th Ammunition Train.....	Rural and urban.....	3.0	2.5
110th Military Police.....	Rural.....	4.3	3.2
110th Supply Train.....	Urban.....	1.0	1.1
110th Field Signal Battalion.....	Rural.....	0.4	1.3
110th Trench Mortar Battalion.....	Rural.....	0.4	0.0
Base Hospital.....	Rural and urban.....	16.7	10.6
Quartermaster.....	Rural and urban.....	3.2	2.1
Miscellaneous.....	Rural and urban.....	2.3	2.2

administered, this should be suspended for a number of days before cultures are taken. The results of local treatment are problematical, since the organisms are situated deeply in the tissues.

7. In persistent carriers in whom the focus of infection is the tonsil, enucleation offers the only certain procedure for terminating the carrier state.

8. The most persistent nasal carriers are those in whom chronic inflammatory or atrophic processes are found. It is almost impossible, in view of the varying culture returns, to state when the condition has finally cleared.

9. Centralization of authority is necessary for the control of an epidemic of diphtheria and diphtheria carriers in camp. Release of patients from quarantine should be under the supervision of the laboratory.

10. During an epidemic, patients should not be admitted to a clean ward unless they have had at least two successive negative cultures from the nose and throat.

11. Improperly constructed and improperly worn masks give a sense of false security.

12. The hospital personnel should be given a Schick test, and those giving a positive reaction should be immunized with toxin-antitoxin mixture.

13. Toxin for the Schick test should be prepared fresh, and no diluted toxin should be used after twenty-four hours. The undiluted toxin should be kept in the dark and in a refrigerator.

14. Intermittent chronic carriers should be employed as attendants in diphtheria wards or in quarantine camps. They should be separated from the hospital personnel and from their organizations.

15. Diphtheria patients may be discharged from the hospital after they have had at least three negative cultures at three-day intervals. Chronic carriers should not be discharged until cultures taken over a long period of time prove consistently negative.

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THE PROTECTIVE QUALITIES OF THE GAUZE FACE MASK

EXPERIMENTAL STUDIES

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The use of the face mask by surgeons and their assistants to protect clean operative fields which they otherwise would spray with their own mouth organisms at every cough or sneeze is an old and well established procedure. The utilization of the face mask to protect the wearer from droplet infection in the presence of those ill with acute infectious diseases is likewise now a well established custom owing in large part to the careful studies at the Durand Hospital in Chicago. Weaver¹ has shown its efficacy when used in this institution in protecting attendants on infectious disease cases both from contracting these diseases and from becoming carriers of them. Capps² has published statistics tending to confirm the work of Weaver and has proposed a new adaptation for the face mask, the essential idea being to use this mask to protect patients from cross-infection in the ambulances, and in the admission rooms and wards of the hospital. The clinical results of this adaptation of the face mask were described by Capps³ recently.

The work described in this paper was carried out for several reasons. The masks used at this hospital have come from several different sources. Masks found in use in the various wards on the same day showed extreme variation in the number of layers of gauze. Some were made with only three layers, and were obviously too thin. Others were made with eight layers, and these were quite hard to breathe through; also they were very warm and uncomfortable. The gauze of which the masks were made varied in quality,

1. Weaver, G. H.: The Value of the Face Mask and Other Measures, *THE JOURNAL A. M. A.*, Jan. 12, 1918, p. 26.

2. Capps, J. A.: A New Adaptation of the Face Mask in Control of Contagious Diseases, *THE JOURNAL A. M. A.*, March 30, 1918, p. 910.

3. Capps, J. A.: Measures for the Prevention and Control of Respiratory Infections in Military Camps, *THE JOURNAL A. M. A.*, Aug. 10, 1918, p. 448.