

RESULTS OF PROPHYLACTIC VACCINATION AGAINST
PNEUMONIA AT CAMP WHEELER.*

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INTRODUCTION.

The recently published work of Cecil and Austin (1) on the results of prophylactic inoculation against pneumonia at Camp Upton has furnished considerable evidence that vaccination against Type I, II, and III pneumococci is practical and that it affords satisfactory protection against the pneumonia produced by these types. In view of the widespread prevalence of pneumonia in the American Army, especially in the cantonments, it was obvious that immediate effort should be made toward instituting a more extensive trial of pneumococcus vaccine and, if the results justified it, the establishment of pneumonia vaccination on an efficient and permanent basis.

For the sake of convenience, it might be well to refer briefly to the results obtained by Cecil and Austin at Camp Upton.

From a study of the agglutinins and protective power of the serum of 42 persons vaccinated against pneumococcus, Types I, II, and III, it was demonstrated that a definite immune response could be secured to Types I and II by the dose of vaccine employed. Little evidence of response to Type III could be demonstrated by these methods, but this was of less significance in view of the fact that in animals it is relatively difficult to secure antibodies against this strain even though a considerable degree of active immunity may have been produced in the vaccinated animal. The degree of response to the vaccine appeared to be dependent upon the total dose of each type of pneumococcus ad-

*An official report submitted to the Surgeon General by the Commission appointed to investigate pneumococcus vaccination.

ministered. The greater the dose the greater was the protection elicited, and this remained true whether the vaccine was administered in a single large dose, or in a number of successive small doses. 12,519 men were vaccinated at Camp Upton (40 per cent of the camp strength) most of the men receiving three or four inoculations at intervals of 5 to 7 days. The total dosage was 6 to 9 billion of Types I and II and $4\frac{1}{2}$ to 6 billion of Type III. The local and general reactions were usually mild, but there were quite a few small sterile fluctuating infiltrations at the site of the injection which appeared to be an expression of cutaneous hypersusceptibility. The results of the vaccination were highly satisfactory. The men were under observation for 10 weeks following vaccination, and, during that time, no cases of pneumonia of the three fixed types occurred among the men who had received two or more injections of vaccine. In a control of approximately 20,000 men, there were 26 cases of pneumonia of Types I, II, and III during the same period. The incidence of Pneumococcus Type IV pneumonia and streptococcus pneumonia was much less in the vaccinated troops than among the unvaccinated. The final figures showed only 17 cases of pneumonia of all types occurring among the 12,519 men who received vaccine, whereas, among the unvaccinated troops, during the same period, there was a total of 173 cases of pneumonia of all types. For the 10 weeks during which the men were under observation, the annual pneumonia death rate for vaccinated troops was only 0.83 per 1,000; for the unvaccinated troops it was 12.8.

In spite of the successful results obtained at Camp Upton, there were certain objections to pneumococcus vaccine, which interfered somewhat with its extensive application. In the first place, three injections were necessary in order to obtain a satisfactory protection. This, however, placed a great burden on regimental surgeons, and was distasteful to the men themselves as they had already received the triple typhoid injections and the smallpox vaccination. Another objection to pneumococcus vaccination was the occurrence of the small sterile infiltrations which sometimes followed its use. These infiltrations were never serious, but caused some anxiety and discomfort to the patient. It was a fortunate coincidence, therefore, that just at this time Colonel Eugene R. Whitmore (2), of the Medical Corps, U. S. Army, made his first report on the use of vegetable oil as a vehicle for the suspension of bacterial vaccines. Some work had already been done along this line in France by Le Moignic and Pinoy (3) who had tried suspending triple typhoid vaccine in vegetable oils, and had met with promising results. Achard and Foix (4) also reported favorably on the use of olive oil as a medium for

suspending bacteria. Whitmore applied this principle to a wide variety of vaccines, including the pneumococcus. These vaccines differed in no essential respect from the saline vaccine, except that the dried bacteria were suspended in olive oil instead of in salt solution. More recently Colonel Whitmore has substituted cottonseed oil containing 2 per cent lanolin for olive oil, as it appears to be less irritating to the subcutaneous tissue. Whitmore, Fennel, and Petersen (2) found that the triple typhoid vaccine in oil produced even better agglutination response in the serum than the same vaccine in saline solution. The reaction, both local and general, following the injection of the typhoid lipovaccine was so mild that the three original doses of saline vaccine could be combined into one dose (1 cc.) of the lipovaccine, without producing any unpleasant results. This mild reaction was probably due to the fact that the oily suspension was more slowly absorbed than the saline suspension. The reduction of typhoid vaccination to one injection presented such an obvious advantage over the old method that the Surgeon General shortly afterwards directed that the lipovaccine be substituted for the saline vaccine altogether, and it is now being universally employed throughout the Army.

Following the work with typhoid lipovaccine, experiments were undertaken at the Army Medical School with pneumococcus lipovaccine, and here again, it was found that pneumococcus vaccine in oil produced good immune reactions, and that large doses could be administered without ill effect. It was therefore decided to prepare, in addition to the typhoid lipovaccine, a pneumococcus lipovaccine of Types I, II, and III, and to supply it to the Army for vaccination of volunteers. Some preliminary experiments carried out by us at Camp Wheeler had shown that 10 billion pneumococci of each of the three types could be injected without producing severe reactions.

About September 1, 1918, the writers of this report were appointed by the Surgeon General as a special commission to investigate the value of pneumonia vaccine, and were directed to proceed to Camp Wheeler, Georgia, for the purpose of instituting voluntary vaccination against pneumonia among the troops. There were good reasons for the selection of Camp Wheeler for this experiment. During the 6 months from October 5, 1917, to March 29, 1918, there had been 917

TABLE I.
 Comparison of the Cases of Pneumonia from July 1 to October 1 (Summer Epidemic), with Those from October 1 to December 20, 1918 (Influenza Epidemic).

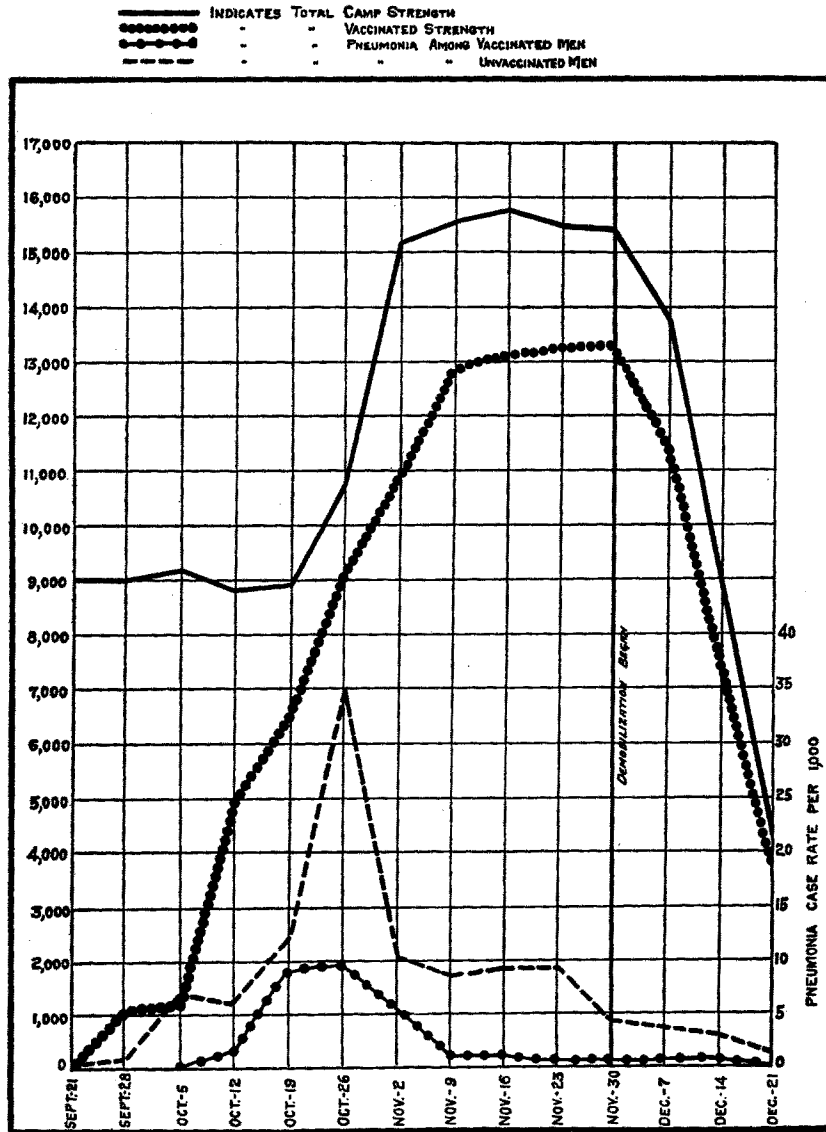
Types.	July 1 to Oct. 1, 1918.			Oct. 1 to Dec. 20, 1918.		
	No. of cases.	No. of deaths.	Mortality, per cent	No. of cases.	No. of deaths.	Mortality, per cent
Pneumococcus, I.....	41	10	24.3	13	4	30.7
“ II.....	21	6	28.6	18	7	38.9
“ III.....	11	2	18.2	39	12	30.7
“ IV.....	96	12	12.5	536	117	21.6
Hemolytic streptococcus.....	1	0	0	10	5	50.0
Non-hemolytic “.....	12	1	8.3	34	2	5.8
Friedländer's bacillus.....	0	0	0	1	1	100
Undetermined.....	34	3	8.9	15	2	13.3
Total.....	216	34	15.7	666	150	22.4

cases of pneumonia at Camp Wheeler, a figure which gave that camp the next highest pneumonia rate of all the camps for that period. Furthermore, in August, 1918, a second epidemic of pneumonia broke out at Camp Wheeler among the negro draft and was the immediate cause of our being sent to that camp.

In Table I it will be seen that for the 3 months, July 1 to October 1, 1918, though it was the hot season, there were 216 cases of pneumonia at Camp Wheeler with 34 deaths. This was nearly all primary pneumonia of the lobar type, and practically all of it of pneumococcus origin. Of the pneumococcus cases, 43.2 per cent were due to the fixed types and 56.8 per cent to Type IV. Nearly half of the pneumonia, therefore, was being caused by the types of pneumococcus against which we proposed to vaccinate.

It soon became apparent, however, that conditions at Camp Wheeler were very different from those which had prevailed at Camp Upton the preceding winter. In the first place, many of the men whom we were to vaccinate at Camp Wheeler were raw recruits of rural origin, a considerable part of them negroes. The men vaccinated at Camp Upton had come chiefly from New York City, were well seasoned at the time of vaccination, and were mostly of the white race. In the second place, the situation at Camp Wheeler was complicated by the influenza epidemic, which, of course, had been absent at Camp Upton.

By referring to Text-fig. 1, it will be seen that on September 21, 1918, the date on which vaccination of troops at Camp Wheeler was initiated, the total strength of the camp was about 9,000 men. The population remained practically unchanged until October 16 when a draft of 1,270 negroes arrived. During the following 2 weeks a large draft of white troops arrived, some from New York State and others from Alabama. By November 2, the population of the camp had increased from 9,000 to something over 15,000, and by November 16, the maximum population, nearly 16,000, was reached. On November 30, demobilization began, and during the next 3 weeks the population was reduced from 15,000 to 4,000 men. The troops who constituted the camp in September and the earlier part of October were practically all seasoned men. We succeeded, as shown by the chart, in getting 75 per cent of the old troops vaccinated before the draft arrived.



TEXT-FIG. 1. Pneumonia at Camp Wheeler from September 21 to December 21, 1918.

The new draft began on October 16 and was completed by November 2. The incoming men were examined by a medical officer as they got out of the train. Any men who were sick were sent at once to the Base Hospital. All the others were marched directly to the vaccinating pavilion, and received at once their pneumococcus vaccine. In this way most of the recruits were vaccinated against pneumonia within 24 hours after arriving at camp. All those who objected to taking the vaccine were passed by.

Technique of Vaccination.

The men were arranged in single file and instructed to roll up the left sleeve. As the troops filed into the vaccinating building, a record of each man's name, age, race, organization, rank, nativity, and duration in service was taken on one of the so called "Sick and wounded cards" (Form 52). On the lower part of the card was stamped the date and dosage of vaccination. After giving the necessary information, the men passed down a narrow aisle and were vaccinated as follows: An enlisted man swabbed the posterior aspect of the left arm half way between the elbow and shoulder with tincture of iodine. A medical officer then injected 1 cc. of pneumococcus vaccine subcutaneously, using a needle of fairly small caliber. Then, in order to prevent the escape of any of the oily suspension, another enlisted man pressed a piece of absorbent cotton against the point of puncture and instructed the man to hold it there for a minute or two.

In addition to the pneumococcus vaccine 2,226 recruits received an injection of influenza vaccine (1 billion influenza bacilli) in the right arm. The results of the vaccination against influenza will be considered in a separate report. The reaction produced by influenza vaccine was almost always very mild. After the men had received the vaccine, they were marched to their quarters and given complete rest for 24 hours.

By referring again to Text-fig. 1, it will be observed that the recruits were vaccinated almost as rapidly as they came to camp and that by November 9, 13,000 men in all had received pneumococcus vaccine, about 80 per cent of the camp strength. In other words, from October 19 to December 20, a period of 2 months, 75 to 80 per

cent of the entire population of the camp consisted of men who had been vaccinated against pneumonia.

Table II indicates the number of men vaccinated and classified according to whether they were white or negro, recruits or seasoned men. We arbitrarily defined the term "recruit" to mean any man who had been in the service 1 month or less. Table II shows that altogether 3,832 white recruits (80 per cent of the total number) and 1,230 negro recruits (86 per cent of the total number) received the pneumococcus vaccine, making a grand total of 5,062 recruits who were inoculated. Of the seasoned men, 6,687 white troops (75 per

TABLE II.
Data on Pneumococcus Vaccination.

Race.	No. vaccinated.			Approximate No. unvaccinated.		
	Recruits.*	Seasoned men.	Total.	Recruits.	Seasoned men.	Total.
White.....	3,832	6,687	10,519	919	2,156	3,075
Negro.....	1,230	1,711	2,941	194	146	340
Total.....	5,062	8,398	13,460 (80% of camp strength).	1,113	2,302	3,415 (20% of camp strength).

* All men in service for 1 month or less were classified as recruits.

cent) and 1,711 negro troops (92 per cent), a total of 8,398, were inoculated against pneumonia. Altogether, 10,519 white men and 2,941 negroes were vaccinated with the pneumococcus lipovaccine, making a grand total of 13,460 men, or 80 per cent of the entire camp strength.

For the purposes of control, it would have been more desirable to have vaccinated only half of the camp; that is, only half of each organization. As this method, however, was not feasible, and in consideration of the serious influenza epidemic, it was decided to vaccinate as large a percentage of the camp as possible with the hope of reducing the pneumonia rate to a minimum.

Character of Reactions to Pneumococcus Lipovaccine.

Local Reaction.—Pneumococcus lipovaccine produces a mild local reaction, which is distinctly less marked than that caused by triple typhoid lipovaccine, though the former contains more than three times as many bacteria as the latter. That the lipovaccine is much less irritating than the saline vaccine is evidenced by the fact that while the saline preparation often produces a sterile fluctuating infiltration at the site of injection, only five such reactions (Table III) were observed among the 13,000 men vaccinated with lipovaccine at Camp Wheeler. This figure is in strong contrast to the 152 infiltrations encountered in the Camp Upton experiment. This type of local reaction is never serious, but causes some concern and discomfort to the patient, and its frequent occurrence would certainly militate against the general use of pneumococcus vaccine. In our opinion, the elimination of these infiltrations marks one of the most important advances in prophylactic pneumococcus vaccination.

Doses of pneumococcus lipovaccine three times as large as the dose finally decided upon were administered to volunteers at Camp Wheeler without any serious local or general reaction. It is almost incredible that such huge numbers of pathogenic bacteria (90 billion) can be injected beneath the skin with so little untoward effect.

Constitutional Reaction.—Like the local reaction, the constitutional reaction to pneumococcus lipovaccine is usually insignificant. In many cases it is entirely absent. Of the 13,460 men who received the vaccine at Camp Wheeler, only 104 (0.7 per cent) were sufficiently affected to be admitted to the Base Hospital (Table III). It is especially interesting to note that while 5,062 recruits and 8,398 seasoned men were inoculated, 101 of the admissions to the hospital were recruits, and only 3 were seasoned men, a fact which would indicate that practically 100 per cent of men in good physical condition can take the vaccine without any particular discomfort.

It is also important to note that 80 of the 104 admissions were among the 2,226 recruits (44 per cent) who received the pneumococcus and influenza vaccine simultaneously; only 24 occurred among the 2,836 recruits (56 per cent) who received pneumococcus vaccine alone.

The negroes seemed more susceptible to the pneumococcus toxin than whites; 65 per cent of the hospital admissions were negroes,

TABLE III.
Hospital Admissions for Pneumococcus Vaccine Reactions.

Severe local reactions.....			5 cases.
General reactions.			
	Recruits.	Seasoned men.	Total.
White.....	34	2	36
Negro.....	67	1	68
Total.....	101	3	104
Day of admission.			
Day of vaccination.....			9 cases.
“ after “			48 “
2 days after “			23 “
3 “ “ “			13 “
4 “ “ “			5 “
5 “ “ “			6 “
Total.....			104 “
Symptoms.			
Headache.....		88 cases (84 per cent).	
Backache.....		37 “ (35 “ “).	
General muscular aching.....		39 “ (38 “ “).	
Malaise.....		22 “ (21 “ “).	
Chill.....		21 “ (20 “ “).	
Pain in chest.....		18 “ (17 “ “).	
Cough.....		13 “ (12 “ “).	
Sore throat.....		11 “ (10 “ “).	
Nausea.....		2 “	
Anorexia.....		1 “	
Nosebleed.....		1 “	
Length of time in hospital.			
1 day.....			7 cases.
2 days.....			30 “
3 “			22 “
4 “			13 “
5 “			9 “
More than 5 days.....			23 “
Total.....			104 “
Fever cases.			
Temperature.			
^{°F.}			
98- 99.....			12 cases.
99-100.....			14 “
100-101.....			15 “
101-102.....			23 “
102-103.....			17 “
103+.....			23 “
Total.....			104 “
History of pneumonia.....			13 cases.

though they constituted only 21.8 per cent of the total number of men vaccinated. Only 13 of the hospital admissions gave a previous history of pneumonia.

Most of the men with sharp reactions reported to the hospital within 48 hours after receiving the inoculation, but there were a small number who did not appear until the 4th or even the 5th day after injection. Apparently the slower absorption of the oily emulsion sometimes causes a delayed reaction. These men were in no instance seriously ill, though some of them were quite uncomfortable.

The symptom most often complained of was headache. Backache and general muscular aching were also very common. The symptoms described were headache (84 per cent), backache (35 per cent), general muscular aching (38 per cent), general malaise (21 per cent), chill (20 per cent), pain in chest (18 per cent), cough (12 per cent). A rise in temperature was noted in 89 per cent of the hospital admissions, but this was usually not marked. In 64 cases the temperature never rose above 102° F., and in most cases it was normal 24 or 48 hours after admission. As a rule, these patients remained in the hospital only 2 or 3 days. They rarely stayed longer than 5 days.

Method of Keeping Records.

In order to keep a careful record of all cases of pneumonia that developed in camp subsequent to vaccination, the vaccination register cards were filed (1) according to organization; (2) carbon copies were filed alphabetically; (3) a special file was prepared from the soldiers' identification numbers. Whenever a case of pneumonia was reported, a search was made for the patient's name in all three files. In addition to searching the file, the patient himself was carefully questioned as to whether or not he had received the pneumonia vaccine. By this method of procedure, the percentage of error in our results was probably reduced to a very low figure.

Sputum Examination.

Realizing from the outset the great importance of accurate bacteriological study on all cases of pneumonia, we made arrangements for a large supply of white mice and were able to maintain this supply

throughout the entire experiment. In this way practically every sputum examined was tested by the mouse method. In a series of 690 cases of pneumonia, there were only 17 cases in which the sputum was not examined. It had been our original intention to check every sputum, either by examination of a second specimen or by having two independent observers make examinations on the same specimen. During the height of the influenza epidemic, however, it was found impossible to maintain this method of control on every case. Of the 673 cases of pneumonia in which a sputum analysis was made, 368 were controlled by a second examination or by a second observer. The second examination was not always made on a specimen of sputum, however. In some instances it was a positive blood culture, an empyema exudate, or cultures taken directly from the lung at autopsy. In the majority of instances, the two examinations were consistent, and often where the findings were inconsistent, there was good reason to believe that we were dealing with a mixed infection. In the final classification of pneumonia cases, however, we have tried to avoid a group of mixed infections and, in some cases where two or more organisms have been found, have classified them according to the virulence of the types. For example, in a number of cases, Type IV pneumococcus was found in association with one of the fixed types of pneumococcus, and such cases were always classified as fixed types.

Results of Vaccination.

The results of vaccination against pneumonia, as shown by the incidence of pneumonia in vaccinated and unvaccinated troops, are indicated in Tables I, IV, and VI. In Table I the classification of all cases of pneumonia occurring at Camp Wheeler between July 1 and October 1, 1918, is compared with a classification of all the cases of pneumonia occurring at this camp from October 1 to December 20, 1918. From these figures it will be observed (1) that the incidence of pneumonia for the 3 months July 1 to October 1 was comparatively high, in view of the season of the year; (2) that there were three times as many cases of pneumonia during the following 3 months (October 1 to December 20) due to the influenza epidemic; (3) that pneumonia

TABLE IV.
Cases of Pneumonia at Camp Wheeler from September 21 to December 20, 1918 (Period of Experiment). Number of Men Vaccinated against Pneumonia, 13,460 (about 90 Per Cent of Strength of Camp).

Types.	Vaccinated.			Unvaccinated.		
	No. of cases.	No. of deaths.	Mortality. per cent	No. of cases.	No. of deaths.	Mortality. per cent
Pneumococcus, I.....	7	2	28.5	6	2	33.3
" II.....	3*	1	33.3	16†	6	37.5
" III.....	22	7	31.8	20	6	30.0
" IV.....	298	63	21.1	256	55	21.4
Hemolytic streptococcus.....	5	3	60.0	5	2	40.0
Non-hemolytic ".....	21	2	9.5	13	0	0
Friedländer's bacillus.....	0	0	0	1	1	100
Undetermined.....	7	1	14.2	10	1	10.0
Total.....	363	79	21.7	327	73	22.3

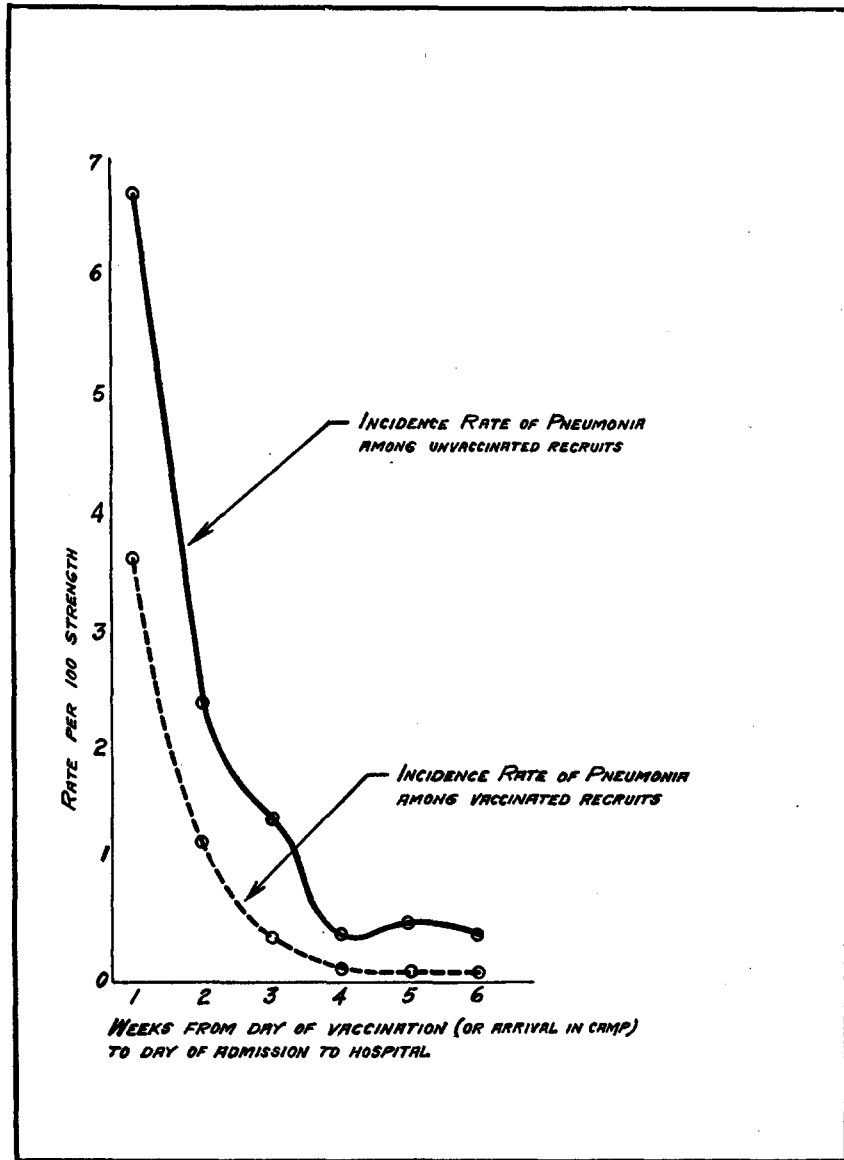
* These three cases were all atypical Type II.

† Of these sixteen cases ten were typical Type II, and six were atypical Type II.

of Types I, II, and III constituted 43.2 per cent of all the pneumococcus cases in the period from July 1 to October 1, while in the period from October 1 to December 20, Type I, II, and III pneumococci caused only 11.5 per cent of all the pneumococcus pneumonia; (4) that the mortality rate for all cases was 15.7 per cent during the summer months and 22.4 per cent during the influenza epidemic.

Table IV shows the relative incidence of pneumonia among vaccinated and unvaccinated troops during the period of the experiment, September 21 to December 20, 1918. In comparing these figures it should be borne in mind that during most of this period 80 per cent of the men were vaccinated against pneumonia. Examination of Table IV shows that, during these 3 months, there were 32 cases of pneumonia of Types I, II, and III among vaccinated men and 42 cases of pneumonia of these types among the unvaccinated; there were 298 Type IV pneumonia cases among the vaccinated men, as compared with 256 Type IV cases among the unvaccinated. In other words, 9.6 per cent of the pneumococcus cases were caused by fixed types of pneumococcus in the vaccinated group and 14 per cent were caused by the same types among the unvaccinated. Altogether, there were 363 cases of pneumonia during this period among vaccinated men and 327 among the unvaccinated. The incidence of pneumonia was about the same in the two groups, though the vaccinated group represented 80 per cent of the camp strength. The mortality rate in the vaccinated series, 21.7 per cent, was slightly lower than that for the unvaccinated series, 22.3 per cent.

These figures are not altogether encouraging, but a more careful analysis shows that other factors have to be considered before any just estimate of the value of the vaccine can be arrived at. In the first place, Text-fig. 1 shows clearly that the weekly incidence rate of pneumonia was conspicuously lower among the vaccinated than among the unvaccinated troops. It will be observed that the scope of the two rate curves is about the same between October 12 and 19, the time at which the influenza epidemic began to make itself felt at Camp Wheeler. The following week, as the vaccinated men began to develop protection, the rate for the vaccinated ceased to increase, then rapidly declined. Had these men remained unvaccinated, the pneumonia rate for this particular group would almost certainly have



TEXT-FIG. 2. Comparison of the pneumonia case rate (all types) among vaccinated and unvaccinated recruits.

reached a high peak by October 26 as did that for the unvaccinated group.

Text-fig. 2 shows that a large percentage of pneumonia cases occurring among the troops at Camp Wheeler developed among the recruits, whether vaccinated or unvaccinated, during the first 2 weeks of their residence in camp.

Colonel Whitmore in his recent Harvey lecture (5) reports some experiments with pneumococcus lipovaccine which show that immunity

TABLE V.

Showing Development of Protective Bodies against Pneumococcus Type I in Human Serum Following Injection of 1 Cc. of Pneumococcus Lipo-Vaccine.

Date.	Control.		Nov. 17	Nov. 18	Nov. 19	Nov. 20	Nov. 21	Nov. 22	Nov. 23	Nov. 25	Nov. 26	Nov. 28	Nov. 29	Dec. 1	Dec. 4	Dec. 20
			Before.	1	2	3	4	5	7	8	10	11	13	16	32	
0.000001 cc.....	30	30	30	36	36	36	30	24	24	36	S.	S.	S.	S.	S.	S.
0.00001 cc.....	30	36	30	24	30	24	30	30	30	36	48	"	"	"	"	"
0.0001 cc.....	30	X.	22	24	22	24	24	30	30*	30	30	30	30	30	"	24
0.001 cc.....	30	"	22	22	22*	24*	15	15	X.	24	36	30	22	30	22	30
0.01 cc.....	22	"	X.	22	X.	X.	22*	15	"	X.	10	30*	15	24	22	15
0.1 cc.....	X.	"	"	X.	"	"	X.	15	"	"	X.	X.	15	15	22	15

Private G. vaccinated November 18, 1918, 4 p.m. Vaccine 2 mg. per cc.

Protection test December 21, 1918. 0.2 cc. of serum + multiple of minimum lethal dose of Pneumococcus Type I broth culture injected intraperitoneally into mice. Time of death noted in hours. Pneumococci found in all peritoneal exudates.

X. indicates no test; S. survival; * 0.1 cc. of serum.

Vaccine contained 0.83 mg. (about 10 billion) of each of the three fixed types, I, II, and III, pneumococcus.

against the pneumococcus does not begin to develop until the 8th day after injection of the vaccine. From that time on the immunity curve rises steadily and continues to rise for some time thereafter. Table V shows the results obtained in one of Colonel Whitmore's experiments.¹ The serum was tested before vaccination and found to have no protective power value for mice. The individual was vaccinated on November 18, and his blood taken on successive days

¹ Colonel Whitmore has kindly permitted us to publish this table.

for the purpose of studying the development of protective bodies. It will be seen from the table that there were no survivals among the mice until the 8th day after vaccination, and that from that time on the percentage of survivals increased from day to day.

With this consideration in mind, we have prepared a revised table of pneumonia cases occurring among the vaccinated men (Table VI). In this table all cases of pneumonia developing within 1 week after vaccination have been excluded. When this alteration is made, there remain only two cases of Type I pneumonia, one case of Type II (and that an atypical Type II), and five cases of Type III develop-

TABLE VI.

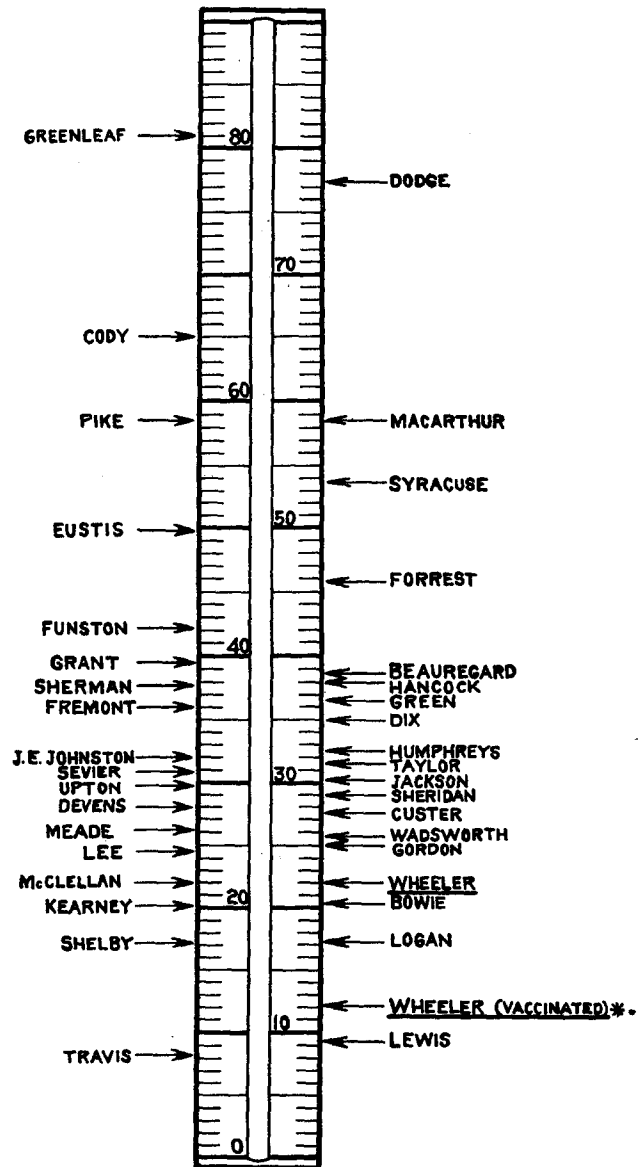
*Revised Table of Incidence of Pneumonia among Vaccinated Men from September 21 to December 20, 1918.**

Types.	No. of cases.	No. of deaths.	Mortality.
			<i>per cent</i>
Pneumococcus, I.....	2	0	0
“ II.....	1†	0	0
“ III.....	5	1	20
“ IV.....	124	14	11.2
Hemolytic streptococcus.....	4	2	50.0
Non-hemolytic “.....	14	1	14.2
Undetermined.....	5	1	20.0
Total.....	155	19	12.2

* In this table all cases of pneumonia developing within 1 week after inoculation have been excluded.

† This case was an atypical Type II.

ing among vaccinated men during the period of the experiment. That there were five Type III cases in this group is not so surprising when we recall the difficulty one has in immunizing animals against Type III pneumococcus. The most important and significant point, however, in connection with these eight cases of pneumonia is the fact that all eight cases followed severe attacks of influenza. Only one of the eight cases died, and this was one of the Type III group. If all pneumonia patients developing within a week after vaccination are excluded from the Type IV group of vaccinated pneumonia cases, the figure is reduced from 208 to 124 cases. 103 of the 124 cases were



TEXT-FIG. 3. Mortality rate per 100 cases of pneumonia in Army camps from September 21 to December 20, 1918.

* Rate for 155 cases of pneumonia that developed among vaccinated men 1 week or more after vaccination.

instances of secondary pneumonia and only 21 primary. There were 14 deaths among the 103 secondary pneumonia cases and no deaths in the series of 21 primary pneumonia cases.

The mortality rate for the 155 cases of pneumonia of all types that developed 1 week or later following vaccination was only 12.2 per cent. When this figure is compared with the pneumonia mortality rate for the various camps during the same period (Text-fig. 3), it will be seen that the rate for vaccinated pneumonias at Camp Wheeler was one of the lowest of any of the camps. The mortality rates for other camps were calculated from the Surgeon General's "Weekly sick report," and are accurate only in as far as the figures on incidence of pneumonia and deaths from pneumonia in the respective camps are accurate.

Pneumonia among Recruits.

The influenza epidemic made its first appearance at Camp Wheeler on September 30 when about 40 cases were admitted to the hospital from the Camp Stockade for General Prisoners. These men, the first to import the infection, were negro draft evaders from rural parts of Georgia who had failed to report at the time of the last draft, September 1, and who had since been rounded up as general prisoners. As soon as these draft evaders, who numbered about 150, had been mustered into service, those not in the hospital with influenza were transferred gradually to the negro companies of the Receiving Camp. Influenza was transferred to this organization with them and reached a maximum daily admission rate of 69 cases on October 4.

On October 16, 17, and 18, 1,270 negro recruits arrived in camp from rural sections of Georgia. 1,113 of these men were vaccinated for pneumonia within 24 hours after arrival. Between October 23 and 27, 4,751 white recruits arrived, approximately 3,500 from western New York State, the remainder from rural sections of Alabama. 3,382 of these men were immediately vaccinated.

During their 1st week in camp 419 negro recruits, 33 per cent of their command, developed influenza. Of these, 72 cases, or 17.2 per cent, were followed by pneumonia. These men arrived at Camp Wheeler already exposed to or infected with influenza, and were an

especially susceptible group since the epidemic had not at that time generally reached the rural counties of Georgia. 533 of the white recruits, 11.2 per cent of their strength, developed influenza during their 1st week in camp, followed by 89 cases of pneumonia, a rate of 16.7 per cent. It therefore appears that this particular group of negroes was much more susceptible to influenza than the whites; but when they had once become infected, the chances of developing pneumonia were about the same. The white recruits from New York State came from a section already generally infected with influenza.

Text-fig. 2 aims to show the relative incidence (by week) of pneumonia among vaccinated and unvaccinated recruits immediately following their arrival in camp. The bacteriological types have been left out of consideration, *Pneumococcus* Type IV and other organisms being included with the three types which compose the vaccine. The curves express a rate which in either case is very high for the 1st week, due to the fact that practically all of the group of recruits arrived in camp already exposed to or infected with influenza. 6.7 per cent of the unvaccinated and 3.6 per cent of the vaccinated recruits developed pneumonia within 1 week after arrival in camp. The rates for the 1st week would doubtless have been more nearly the same had it not been for the fact that those already infected with influenza were not vaccinated. As immunity does not develop until after the 8th day, it is reasonable to expect the incidence among the vaccinated to remain high during the 1st week and even during the 2nd week, as the latter group was being infected with influenza at the same time that the lipovaccine was building up resistance against pneumonia.

It is noteworthy that the weekly pneumonia rate among the vaccinated recruits remained consistently only about one-half of that for the unvaccinated. 72 unvaccinated recruits developed pneumonia during the week following vaccination, 6.7 per cent of their strength; 180 vaccinated recruits, 3.6 per cent of their strength. 53 unvaccinated recruits developed pneumonia after the 1st week, 4.9 per cent of their strength; 108 vaccinated recruits, 2.2 per cent of their strength. Furthermore, there is certainly no evidence to show that the administration of pneumococcus vaccine has in any way predisposed to an attack of pneumonia. Had such been the case the inci-

dence rate for the 1st week among the vaccinated would doubtless have exceeded that for the unvaccinated. As it was, the former was considerably inferior to the latter.

Pneumonia among Recruits Compared with Pneumonia among Seasoned Men.

Table VII shows that in recruits pneumonia secondary to influenza has proved more fatal than primary pneumonia, the death rate being 25.3 per cent for the former, 13.8 per cent for the latter. Moreover,

TABLE VII.

Mortality Rates for a Series of 412 Cases of Pneumonia among Recruits. Primary Pneumonia and Pneumonia Secondary to Influenza.

Classification of recruits.	Primary.			Secondary.			
	No. of cases.	No. of deaths.	Mortality. <i>per cent</i>	No. of cases.	No. of deaths.	Mortality. <i>per cent</i>	
White. {	Vaccinated.....	6	1	16.7	142	36	25.3
	Unvaccinated.....	1	0	0.0	58	15	25.8
Negro. {	Vaccinated.....	17	1	5.9	123	32	26.0
	Unvaccinated.....	5	2	40.0	60	14	23.3
Total. {	Vaccinated.....	23	2	11.5	265	68	25.7
	Unvaccinated.....	6	2	33.3	118	29	24.6
Grand total.....	29	4	13.8	383	97	25.3	

in primary pneumonia it will be observed that the death rate for vaccinated cases is only one-third that for unvaccinated cases, 11.5 and 33.3 per cent respectively; whereas in secondary pneumonia the death rate is practically the same in the vaccinated and unvaccinated groups.

The seasoned men (Table VIII) show a somewhat higher death rate for pneumonia secondary to influenza than for primary pneumonia. Again, however, a marked contrast is observed in the mortality rate of primary pneumonia in vaccinated and unvaccinated men, the rate in unvaccinated (31.2 per cent) being twice that of the vaccinated (15.8 per cent). And again the death rate in secondary pneumonia

TABLE VIII.

*Mortality Rate for a Series of 168 Cases of Pneumonia among Seasoned Troops.
Primary Pneumonia and Pneumonia Secondary to Influenza.*

Classification of seasoned men.	Primary.			Secondary.			
	No. of cases.	No. of deaths.	Mortality.	No. of cases.	No. of deaths.	Mortality.	
			<i>per cent</i>			<i>per cent</i>	
White. {	Vaccinated.....	5	1	20.0	29	5	17.3
	Unvaccinated.....	3	1	33.3	74	16	21.6
Negro. {	Vaccinated.....	14	2	14.3	13	1	7.9
	Unvaccinated.....	13	4	30.7	17	1	5.9
Total. {	Vaccinated.....	19	3	15.8	42	6	14.3
	Unvaccinated.....	16	5	31.2	91	17	18.7
Grand total.....	35	8	22.9	133	23	17.3	

TABLE IX.

Pneumonia Rate per 1,000 for Recruits and Seasoned Men during the 3 Months of the Investigation.

Classification of men.	Absolute No. of men.	Absolute No. of cases of pneumonia.	Incidence per 1,000 men.	
Recruits.				
White. {	Vaccinated.....	3,832	148	38.7
	Unvaccinated.....	919	59	64.0
Negro. {	Vaccinated.....	1,113	140	125.0
	Unvaccinated.....	157	65	413.0
Total vaccinated recruits.....	4,945	288	58.2	
“ unvaccinated “	1,076	124	115.2	
Seasoned men.				
White. {	Vaccinated.....	6,570	34	5.2
	Unvaccinated.....	1,919	77	40.0
Negro. {	Vaccinated.....	1,828	27	14.8
	Unvaccinated.....	383	30	78.4
Total vaccinated seasoned men.....	8,398	61	7.2	
“ unvaccinated “ “	2,302	107	46.4	

differs very little for the vaccinated and unvaccinated series. It would appear, therefore, from Tables VII and VIII that the death rate in primary pneumonia is favorably influenced by pneumococcus vaccination, but is slightly, if at all, affected by it in pneumonia secondary to influenza. The series of primary cases, however, in both recruits and seasoned men is too small to allow of definite conclusion.

Table IX is a comparison of the pneumonia rate per 1,000 men in recruits and seasoned men during the period of the experiment. It was hardly possible to determine the annual pneumonia incidence rate for each group, as the various organizations composing a group were vaccinated at different times. Table IX shows: (1) that the pneumonia rate was considerably higher among negro troops than among white troops, and that this difference was quite marked, whether the men were recruits or seasoned men; (2) that the pneumonia rate for any particular group, white or negro, recruits or seasoned men, was markedly lower for the vaccinated part of the group than for the unvaccinated part. This difference was most marked in the case of seasoned white men where the pneumonia rate for unvaccinated men was nearly seven times that for the vaccinated men.

DISCUSSION.

It is necessary to emphasize again the fact that conditions at Camp Wheeler were not nearly so favorable for a test of pneumococcus vaccine as they had been at Camp Upton. The high incidence of pneumonia among recruits at Camp Wheeler shows how much more susceptible they are to pneumonia than seasoned men such as were vaccinated at Camp Upton. In other words, the natural immunity of recruits is much lower than that of seasoned troops, and this is particularly true of rural men, such as composed the Camp Wheeler draft. The Camp Upton division was composed chiefly of New York City men.

A combination of influenza vaccination with pneumococcus vaccination in 2,226 men was another complicating factor at Camp Wheeler, but there is no evidence that the simultaneous injection of the two interfered in any way with the effectiveness of the pneumococcus vaccine.

The influenza epidemic was, of course, the greatest disturbing element in the Camp Wheeler experiment. The type of influenza which has been recently prevalent certainly causes a marked reduction in the patient's resistance to pneumonia. It is possible that a vaccine which, under ordinary circumstances, would have given complete protection against primary lobar pneumonia would fail completely during an epidemic of such virulence as the recent influenza epidemic. Furthermore, it is reasonable to suppose that with the resisting power of the lungs at such a low ebb, even had pneumococcus infection with Types I, II, and III been prevented by means of a vaccine, some other type of pneumonia would have developed in its place. It will be recalled that at the onset of the influenza epidemic at Camp Wheeler, the proportion of Type IV pneumonia cases greatly increased even among the unvaccinated men. This may have been due to the fact that, from that time on, pneumonia at Camp Wheeler ceased almost entirely to be a primary disease, and became a complication of influenza. Under such circumstances infection by whatever virulent organism that happened to be in the mouth would have occurred, and as the Type IV pneumococcus is the type so frequently present in the normal mouth, it would naturally play a prominent part in the etiology of secondary pneumonia.

The epidemic at Camp Wheeler was about over December 1, and the effect of vaccination against pneumonia under more normal conditions could have been observed had not demobilization occurred at this time.

It is apparent that any sort of vaccination against pneumonia must, of necessity, be put to a very crucial test. Typhoid fever, for example, is a primary infection, and the typhoid bacillus rarely finds its way into the alimentary canal of healthy men. The pneumococcus, on the contrary, is frequently found in the healthy mouth and the host is therefore constantly exposed to infection at some moment when his resistance is at a low point. Moreover, pneumonia, in many of the camps at least, has been largely a secondary infection, overtaking a patient when the natural resistance has been lowered to such a degree that pulmonary infection of some kind is almost inevitable. In cases of this kind the problem is to reduce the chances of the patient's becoming infected with a highly virulent organism, so that if pneumonia does develop, the disease will run a mild course.

The present study has not been altogether satisfactory, but it has served to bring out certain points with a fair degree of definiteness. Though 80 per cent of the population at Camp Wheeler were vaccinated, almost as many cases of pneumonia developed among the unvaccinated one-fifth as occurred among the vaccinated four-fifths. If we reckon from 1 week after vaccination, the time when the individual's immunity begins to develop, only 8 cases of Type I, II, and III pneumonia occurred among the vaccinated men, and all these were secondary to severe attacks of influenza. By using the same standard, 124 cases of Type IV pneumonia developed among the vaccinated troops, and 103 of these were also secondary to influenza. Furthermore, it has been demonstrated that the weekly incidence of pneumonia (all types) among both recruits and seasoned men has been more than twice as great among the unvaccinated as among the vaccinated.

These investigations also show that the most striking results of pneumococcus vaccination are obtained with well seasoned men, where the pneumonia incidence rate per 1,000 men was only 7.2 per cent for vaccinated men and 46.4 per cent, almost seven times as great, for unvaccinated men. These findings are in complete accord with those at Camp Upton last winter where only seasoned troops were vaccinated and where the pneumonia incidence rate was ten times as great for unvaccinated men as for vaccinated. We are inclined to believe that the best time to vaccinate recruits would be 2 or 3 weeks before they come to camp.

The large number of cases of Type IV pneumonia in the present epidemic strongly emphasizes the need of a Type IV pneumococcus vaccine. Before an efficacious Type IV vaccine can be obtained, however, much careful study of the biological characteristics of this group will be necessary.

With the cessation of the war, the question naturally arises: How much use can be made of pneumococcus vaccine in civil life? Vital statistics show that pneumonia now kills more people in the United States than any other infectious disease, and the rate seems to be increasing slowly every year. Furthermore, a majority of the pneumonias seen in civilian adults is of the primary lobar type, which is the type of pneumonia most amenable to prophylactic vaccination.

If methods can be devised for still further reducing the toxicity of pneumococcus vaccine, and if active educational propaganda are instituted in its behalf, there is no reason why vaccination against pneumonia should not find a large field of usefulness in civilian as well as in Army life.

SUMMARY.

1. 13,460 men, or about 80 per cent of the entire camp strength, were vaccinated against pneumonia with pneumococcus lipovaccine.

2. The dosage employed in all cases was 1 cc. of the lipovaccine containing approximately 10 billion each of Pneumococcus Types I, II, and III.

3. Both the local and general reactions produced by the vaccine were usually mild. Only 0.7 per cent of those who received the vaccine were sufficiently affected to need hospital care. None of these was seriously ill, and a majority of them returned to duty on the 2nd or 3rd day after admission.

4. Most of the troops inoculated were under observation for 2 or 3 months after vaccination. During this period there were 32 cases of Pneumococcus Type I, II, and III pneumonia among the vaccinated four-fifths of camp, and 42 cases of pneumonia of these types among the unvaccinated one-fifth of camp. If, however, all cases of pneumonia that developed within 1 week after vaccination are excluded from the vaccinated group, there remain only 8 cases of pneumonia produced by fixed types, and these were all secondary to severe attacks of influenza. This exclusion is justified by the fact that protective bodies do not begin to appear in the serum until the 8th day after injection of pneumococcus lipovaccine.

5. There is no evidence whatever that pneumococcus vaccine predisposes the individual even temporarily toward either pneumococcus or streptococcus pneumonia.

6. The weekly incidence rate for pneumonia (all types) among the vaccinated troops was conspicuously lower than that for the unvaccinated troops.

7. The pneumonia incidence rate per 1,000 men during the period of the experiment was twice as high for unvaccinated recruits as for vaccinated recruits, and nearly seven times as high for unvaccinated seasoned men as for vaccinated seasoned men.

8. Influenza causes a marked reduction in resistance to pneumonia even among vaccinated men. Of the 155 cases of pneumonia (all types) developing 1 week or more after vaccination, 133 were secondary to influenza.

9. The death rate for 155 cases of pneumonia (all types) that developed among vaccinated men 1 week or more after vaccination was only 12.2 per cent, whereas the death rate for 327 cases of all types that occurred among unvaccinated troops was 22.3 per cent. The death rate for primary pneumonia among vaccinated troops was 11.9 per cent. Among unvaccinated, it was 31.8 per cent, almost three times as great. On the other hand, the mortality rate in pneumonia secondary to influenza is about the same for the vaccinated and unvaccinated groups.

10. In conclusion, it must be admitted that the results of pneumococcus vaccination at Camp Wheeler have not been so striking as those obtained at Camp Upton in 1918, largely on account of the influenza epidemic; but, although influenza obscured to some extent the effect of pneumococcus vaccination at Camp Wheeler, the results are sufficiently encouraging to justify its further application in civil as well as in military life.

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