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# EMPYEMA

AN EXCERPT FROM

THE MEDICAL DEPARTMENT OF THE UNITED STATES ARMY
IN THE WORLD WAR

PUBLISHED BY AUTHORITY OF THE SURGEON GENERAL

By

LIEUT. COL. EDWARD K. DUNHAM, M. C.

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# FOREWORD.

The name of Edward Kellogg Dunham stands high on the list of distinguished members of the American medical profession who so freely gave of their time and talents to the amelioration of suffering among troops and to the winning of the Great War.

From the Medical Reserve Corps, in which he was commissioned as lieutenant in 1911, Doctor Dunham was called to active duty in January, 1918, as major. He was discharged from the service with this rank in June, 1919, and immediately thereafter was appointed a lieutenant colonel in the Medical Officers' Reserve Corps. He held this rank to the time of his death.

In the performance of his duty in the Army, Colonel Dunham exercised, at all times, the zeal and intelligence which obtained throughout his scientific career. The outstanding feature of his military service was concerned with his work as chairman of the Empyema Commission, appointed by the Surgeon General in the spring of 1918.

This commission was the outgrowth of the Pneumonia Commission, appointed by the Surgeon General during the latter part of 1917. During the second half of the year 1917, pneumonia, in part secondary to measles, in part primary, caused approximately 65 per cent of all deaths in the United States. Prompted by the necessity of devising some means to combat this terrible loss of life, the Surgeon General appointed the Pneumonia Commission for the purpose of studying pneumonia in its clinical, bacteriological, and pathological aspects. The commission was sent to Texas in February, 1918. One of the far-reaching results of the work of this commission was the determination that the *Streptococcus hemolyticus* played the principal rôle as a causative agency in many of the cases of pneumonia, giving rise to an entity which the commission termed "interstitial bronchopneumonia."

Empyema proved to be an important complication of pneumonia, especially in cases of pneumonia associated with the *Streptococcus hemolyticus*. This prompted the Surgeon General to create another commission, later known as the Empyema Commission, to take up the research where the Pneumonia Commission left off, and to study empyema in all its aspects as it occurred in camps in the United States.

Colonel Dunham, as chairman, directed the researches of the Empyema Commission throughout its existence, continuing its work long after it had ceased to exist, his labors in this direction terminating only with his life.

The chief activities of the commission were centered at Camp Lee, Va., but an empyema team or board was organized in each of the base hospitals, where investigations, similar to those carried on at Camp Lee, were conducted. Colonel Dunham personally visited many of the base hospitals in the United States for consultation with the chiefs of surgical and laboratory services.

The preliminary report of the commission was formulated in June, 1918, and published shortly thereafter. In the autumn of that year Colonel Dunham

was officially designated to prepare the history of empyema to form part of the official record of the activities of the Medical Department during the World War. After the war he gave nearly three years of unremitting and devoted labor to the compilation of the valuable data embodied in the manuscript on empyema.

During the years 1920, 1921, and the early part of 1922, while pursuing the study of empyema records in the War Department and the Veterans' Bureau, Colonel Dunham spent much time in Washington, and those of us who came in intimate contact with him then learned to love him. Tireless in the pursuit of information, he always had something new to show in the way of apparatus devised for his study, or something of interest to say on some newly established point. His air of quiet courtesy endeared him to everyone whom he encountered.

To the study of empyema and other important problems having to do with the prevention of disease in our camps, Colonel Dunham brought a mind trained in scientific research and an experience rich in accomplishment. His undergraduate studies in the School of Mines of Columbia University gave him a valuable background of proficiency in the basic sciences of mathematics, chemistry, and physics with which to pursue his study of medicine in the Medical School of Harvard University, from which he was graduated in 1886. While a student in bacteriology in Koch's Laboratory in Berlin he independently discovered the valuable cholera-red reaction, with which his name is associated. On his return to America, Colonel Dunham was engaged for a while in public health work in Boston. From 1898 to 1907 he was professor of pathology in the University and Bellevue Hospital Medical College (New York University). During these years he did much important scientific work. Noteworthy among his accomplishments may be mentioned his pioneer study of the lipoids occurring in glandular organs; his discovery of the sporebearing character of the *Bacillus aerogenes capsulatus*, familiarly known as the gas bacillus of Welch, and his studies of the chemical effects and fermentative power of the meningococcus.

Colonel Dunham, though a tireless student, was not a prolific writer. While this was unfortunate, it was compensated for through his acting as a fountain head of knowledge to a host of scientific workers who drew upon him for information and inspiration.

His work, the record of which is found in this volume, was the culmination of his scientific life. Though he did not live to complete the compilation of the valuable data embodied in the manuscript on empyema, it was so well forward at the time of his death, on April 15, 1922, that what remained could be done by his collaborators in accordance with his plans.

The same affectionate memory of her husband that is responsible for these presentation copies of Colonel Dunham's work on empyema prompted Mrs. Dunham to endow the Dunham lectureship at Harvard University. Book and lectureship, each in its own way, can not fail to carry on inspiration and scientific information in a manner which would have been dear to the heart of the man whose life they so fitly commemorate.

M. W. Ireland,
*Surgeon General, United States Army.*

# PREFACE.

In the first tentative outline of the history of the Medical Department of the United States Army in the World War a complete volume was apportioned to the report of the study of empyema. It was found impracticable, however, to follow this plan, and "Empyema" was given place with other subjects, forming Section I of Part Two, Volume XI, entitled "Surgery."

Acknowledgment is made to Lieut. Franklin A. Stevens, M. C., for the large part he played in the preparation of the empyema manuscript, in association with Colonel Dunham.

The chapter on the surgical treatment of the acute and chronic stages of empyema was prepared by Maj. Evarts A. Graham, M. C. Major Graham was an original and permanent member of the Empyema Commission, Camp Lee, Va., during the World War, and the work in question represents the result of his experimental efforts in the surgical treatment of empyema.

Chapter VIII, the surgical treatment of the refractory empyema cavities, was prepared by Col. William L. Keller, M. C., and is an exposition of his revolutionary surgical work on a series of what had been previously considered almost hopeless cases.

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# SECTION I.

# EMPYEMA.

## INTRODUCTION.

As an introduction to the following study of empyema among the troops of the United States Army on this side of the Atlantic, it is deemed proper to describe the sources of information upon which this study is based.

In the vast majority of instances empyema developed as a complication or incidence in the course of some other affection, and the patient was admitted to hospital treatment because of the primary disease. This primary condition may have been pneumonia, measles, or some other exanthematous disease, tonsillitis, pharyngitis, influenza, or even such a remotely related condition as articular rheumatism, malaria, otitis media, appendicitis, hernia, or a host of others that need not be enumerated.

The fact that empyema is most often a complicating or associated disease has made it impossible to discover all the cases that occurred in the Army; and there must have been some that entirely escaped detection during the whole stay in hospital. It is not possible to estimate the total number of such omissions, but it is certain that they were most numerous among cases that remained, throughout their stay, in the wards of the medical service. Cases admitted to the surgical wards, by transfer from the medical service, were received as empyemata and entered as such upon the records and in the index of diseases. Here omissions in the reports of cases are insignificant in number.

Another aspect of empyema seriously complicated the problem of collecting data. Cases seemingly cured were liable to relapses, not infrequently after a period of apparent good health. It was essential to know about such cases. It was also important to gain information concerning the final disabilities of men who had empyema during their military service, not only while they were in the Army, but after they had returned to civil life. It is obvious that the routine records of the Medical Department of the Army could not supply all of this necessary information. Supplementary data had to be obtained through other than the regularly established military channels. Chapter I is devoted to an account of the manner in which this was attempted, and the way in which the records were assembled for study.

# CHAPTER I.

## THE COLLECTION AND UTILIZATION OF SPECIAL DATA CONCERNING EMPYEMA IN THE ARMY WITHIN THE UNITED STATES.

### THE COLLECTION OF DATA.

*Questionnaire on empyema.*—The receipt of reports indicating a marked increase in the number and severity of cases of empyema in base hospitals, not infrequently subsequent to measles, led to a questionnaire which was issued by the Surgeon General of the Army on February 21, 1918. This questionnaire was designed to secure particulars concerning this disease, the measures that were being taken to limit its occurrence and those that were employed in caring for cases. The letter of instruction accompanying the questionnaire, and the questionnaire, are quoted in full:[1]

FEBRUARY 21, 1918.

From: The Surgeon General, U. S. Army.
To: The Commanding Officer, Base Hospital (through Division Surgeon).
Subject: Questionnaire on empyema.

1. A consolidated report of the chiefs of surgical service, medical service, and pathological service, should be rendered on the inclosed questionnaire at the earliest possible date, to this office, attention Lieut. Col. W. H. Moncrief.

By direction of the Surgeon General.

(Signed.) WM. H. MONCRIEF,
*Lieut. Col., Medical Corps.*

QUESTIONNAIRE CONCERNING EMPYEMA.

1. In the measles cases what prophylactic therapy is applied to the upper air passages (nasal cavities and accessory sinuses)?
2. What measures have been taken to isolate and quarantine empyema patients?
3. Has the X ray been used in diagnosis systematically and repeatedly?
4. What percentage of pneumonias developed empyema? (*a*) Lobar pneumonia; (*b*) pneumonia (broncho- or lobar) following measles?
5. What organisms have been found in pleural fluids in order of their frequency?
6. Have blood cultures been made systematically and repeatedly?
7. What did the blood cultures show?
8. Has the administration of antistreptococcus serum been part of the treatment?
9. If so, what methods of administration have been used?
10. In your opinion has this treatment had any beneficial effect on the progress of the disease?
11. Is immediate operation advisable?
12. Thoracotomy or thoracostomy and costectomy?
13. General or local anesthesia?
14. Do you prefer early aspiration of the chest, followed by operation after the pus has become thick?
15. Has Dakin's or any other solution been used for irrigation in patients operated upon?
16. If so, with what result?
17. Has continuous negative pressure been used post-operatively and with what results?
18. What has been the mortality in empyema? Divide into types if possible.
19. What percentage of empyema cases have been operated upon?
20. What percentage of empyema cases is followed by—
    (*a*) Empyema of opposite side?
    (*b*) Purulent pericarditis?
    (*c*) General peritonitis?
    (*d*) Pneumonia of opposite side?
    (*e*) Sinus involvement.
    (*f*) Meningitis?
21. At autopsy are pockets of pus found, particularly substernal or just internal to and behind the anterior flap of the lung?
22. Furnish other important autopsy findings.

A consideration of the replies to this questionnaire is deferred to the section on epidemiology.

*Circular Letter No. 23.*—While in some instances empyema runs an acute course followed by complete and permanent recovery, there are many cases that are protracted. The cavity fails to diminish in size or to become completely obliterated; improvement is interrupted by relapses, or a narrow and sometimes tortuous sinus is formed. These cases run an indolent course and are very refractory to treatment. Such cases are subject to transfer from one hospital to another, not infrequently with intercalated periods of active or limited duty, during which they are no longer under treatment and consequently escape continuous observation. These cases are, however, of great importance in a study of empyema with a view to deducing methods of treatment likely to avert the occurrence of chronic cases and to reduce the degree of ultimate disability.

In attempting to follow the histories of such cases it was necessary to devise some system which would keep the records of individual cases of empyema in current form in spite of transfers from one hospital to another and which could be continued for an indefinite period of time after discharge from military service. Such a system of records was started in January, 1919, while the hospital records still remained in the organizations where they originated. In the beginning, and in response to Circular Letter No. 23, Surgeon General's Office, dated January 10, 1919,[2] this system was based on the returns received on a special blank form.[3]

CIRCULAR LETTER NO. 23.

WAR DEPARTMENT,
OFFICE OF THE SURGEON GENERAL,
*Washington, January 10, 1919.*

Subject: Requests for abstracts of empyema cases.

1. It is desired to obtain accurate data concerning cases of empyema in the Army which can serve as a basis for a statistical study of this disease for immediate use and for the history of the war. To facilitate this collection of data, blanks are herewith sent, designed for use in preparing abstracts of the clinical course of these cases. These blanks should be invariably used. There will, however, be some cases for which they will prove inadequate. In such cases it will promote the work of compilation if the blanks are used as far as possible with supplementary sheets attached to them.

2. It is requested that the commanding officers of base and general hospitals assign a competent person to fill out these blanks as speedily as is compatible with accuracy. Completed blanks will be promptly sent to the Surgeon General, attention Laboratory Division.

3. In many hospitals the postoperative treatment of empyemata has not been continuously the same; yet many cases have, throughout a certain period, received substantially identical treatment. As the space allotted to postoperative treatment in the blanks will not permit of extended descriptions, it is requested that these descriptions be furnished separately, but that it be made clear on the blank during what period such method was employed in this particular case.

4. All cases in which empyema has been diagnosticated since May 1, 1917, should be included in these abstracts, whether completed or still in hospital.

5. To assist in securing the desired uniformity in the returns, the following explanatory memoranda are furnished to amplify the necessarily concise headings on the blanks:

1. *Serial numbers.*—If this is not on record, scratch "Serial" and give the register number.

2. *Diagnosis on admission.*—If this was pneumonia, so state with location and variety on line below. Note on back of sheet record descriptive of condition of patient; e. g., cyanotic, marked dyspnea, condition severely septic, delirious, etc.

3. *Empyema (pleurisy).*—Give date when fluid was detected in chest, irrespective of its character.

4. *Postoperative treatment.*—See paragraph 3, above.

5. *Secondary operations* refer only to those on the chest.

6. *Thoracic wound closed.*—Give recorded date when the wound or wounds made for the treatment of the empyema were completely healed.

7. *Disposition of patient.*—If in hospital, give number of ward.

8. *Laboratory reports.*—Include blood counts, white and red; determinations of hemoglobin; bacteriological examinations of blood, sputum, and fluids from the pleura or elsewhere.

9. *Memoranda of subsequent temperature.*—The desired information in many cases could be given as follows: "From (date) to (date) daily temperature rose above 100, with maximum to ——— and minimum of ——— for this period."

By direction of the Surgeon General:

C. R. DARNALL,
*Colonel, Medical Corps, U. S. A., Executive Officer.*

Copy to: Commanding officers all general, base and post hospitals, department surgeons.

EMPYEMA CASE ABSTRACT.

(For the Surgeon General of the Army, attention Laboratory Division.)

..... Hospital, at ....., ....., 1919.
Name of patient, ..... Serial Number, .....
Home address, ..... Admitted, ....., 191.....
Diagnosis on admission, ..... following .....
Pneumonia? Date ..... Location, ..... Variety, .....
Empyema (pleurisy). Date, ..... Location, .....
Pneumothorax before operation? Date, ..... Location, .....
Thorax aspirated? (Give dates, character of fluid, amount withdrawn.) .....
.....
.....
First operation: Date, ..... Site, .....
Nature of operation: .....
Fluid evacuated: Character, ..... Amount, .....
Postoperative treatment: .....
.....
.....
Secondary operations? Give dates and nature of operations. .....
.....
.....
Complications? (Give dates, nature of complication, treatment.) .....
.....
.....
Pleurobronchial communication? Date, ..... Treatment, .....
Thoracic wound closed, ....., 191.....
Disposition of patient, ....., 191.....
(In case of death, give autopsy findings on back of sheet, noting particularly any record of pulmonary abscesses.)
X-ray plates? Dates, .....
Laboratory reports: Blood, sputum, pleural and other exudates, with dates.....
.....
.....

| Daily maximum and minimum. | Temperature. | Pulse. | Respiration. |
|---|---|---|---|
| First 5 days in hospital from ....., 191...., to ....., 191....., incl..... | | | |
| | | | |
| | | | |
| | | | |
| Day before 1st operation..... | | | |
| Day of 1st operation..... | | | |
| Day after 1st operation..... | | | |
| 1st normal temp ....., 191..... | | | |

Memoranda of subsequent rises of temperature above 100, with dates: .....
.....
.....

(Use back of sheet if above spaces are inadequate, and for special notes.)

D–420.

When the completed forms were received from any hospital, they were first arranged in chronological order according to the dates of admission to the hospital, consecutively numbered, and then filed according to these numbers. The names of the patients, their home addresses, the dates of admission, the hospitals, and chronological numbers were entered on cards arranged alphabetically by surnames. All later information concerning transfers, operations, etc., was added to these files.

The empyema case abstracts served not only as a beginning of the record in following the progress of the case, but furnished the first data of a continuous clinical history designed to extend beyond the period of military service.

*Follow-up letters.*—At intervals of a few months letters of inquiry were sent to the patients at their home addresses, and the replies entered on the records. One of these letters is reproduced here.

In reply refer to S. G. O..... Mills 100.

WAR DEPARTMENT,
OFFICE OF THE SURGEON GENERAL,
*Washington, Aug. 26, 1920.*

MY DEAR Mr. .....,[4]
*San Francisco, Calif.:*

I am directed by the Surgeon General to inquire about your present health, and whether you have had any recurrence of your empyema or any other trouble of any nature.

Please answer the questions below in the space provided, and send this letter to this office in the inclosed envelope, which requires no postage.

Very sincerely yours,

.....

1. Full name, ..... Home address, .....
   In what military hospital were you treated? .....
   Were you overseas? .....
2. Does your empyema bother you? ..... In what way? .....
   Normal weight? ..... Weight when discharged? ..... Weight now? .....
3. Have you any other trouble? .....
   If so, describe in detail .....
4. Date of discharge from the Army .....
5. What work have you done since your discharge? .....
6. If a doctor is looking after you, give his name and address.....
7. Claim number? .....

These methods helped to maintain contact with patients while they remained in the service, and, still more important, after their discharge, when a change of residence might take place. Otherwise the records of some cases would have been terminated prematurely.

It is obvious that reports rendered by the patients themselves could be of only relative value and chiefly subjective in character. Notwithstanding these limitations, they proved of great importance in following the progress of many cases.

*Physical examinations.*—When it appeared probable that a case had reached a condition in which further change was not to be expected, or when a case was running a very protracted course and remained under medical care or super-

vision, a follow-up letter, coupled with a request for a physical examination, was substituted for the usual inquiry. In the absence of funds available for this purpose it was possible to obtain the desired cooperation only through the courtesy of the physician making the examination, and in nearly every instance this courtesy was cordially extended by the physician to whom the request was sent.

The Bureau of War Risk Insurance of the Treasury Department heartily supported this undertaking as far as was possible, but it was not authorized to order special examinations solely to promote a study of empyema.

The cooperation extended by this bureau was of inestimable value, for many of the physicians caring for these soldiers after their discharge from the Army were medical men selected by this bureau to make the examinations required in fixing the compensation to which the men were entitled.

Copies of the forms used are reproduced here:

In reply refer to S. G. O. .....

WAR DEPARTMENT,
OFFICE OF THE SURGEON GENERAL,
WASHINGTON.[5]

MY DEAR .....

I am directed by the Surgeon General to inquire about your present health and whether you have had any recurrence of your empyema or any other trouble of any nature.

Information concerning the physical condition after their return to civil life of men who have had empyema while in the service is of importance for a better knowledge of this disease and its treatment.

Please answer the questions below in the space provided and send this letter back to this office in the inclosed envelope, which requires no postage.

Very sincerely yours,

.....

1. Full name ..... Home address .....
   In what military hospital were you first treated for empyema?.....
2. Does your empyema now bother you? ..... In what way?.....
3. Have you any other trouble?.....
   If so, describe in detail.....
4. Are you receiving compensation?.....
   What is your claim number?.....
5. Do you report to a doctor from time to time?.....
   If so, give his name and address.....
6. The next time you go for examination, give the inclosed letter, blank and envelope to the doctor.

---

WAR DEPARTMENT.
OFFICE OF THE SURGEON GENERAL,
WASHINGTON.[6]

MY DEAR DOCTOR: In cooperation with the Bureau of War Risk Insurance, the Surgeon General of the Army has requested me to inquire into the present physical condition of men who have had empyema while in military service and now returned to civil life. This information, when connected with the previous histories of these cases, will throw important light on the pathology and treatment of empyema and will be utilized in preparing this section of the Medical History of the War.

I venture to ask the courtesy of your aid in furthering this undertaking by employing the accompanying form when next determining the physical condition of the bearer of this letter.

If there are features of special interest in this case not covered by this form, I beg that you will note them on the back.

When filled out, please mail the form to the Surgeon General of the Army, for which purpose a return envelope is furnished.

There are approximately 5,000 cases of empyema among the troops on this side of the Atlantic and I am confident that you will appreciate the value to our profession of a study of the sequelæ of this disease a year or more after discharge from the hospital where first treated.

Very sincerely yours,

.....

## CASE OF EMPYEMA OF THE THORAX.

Record of examination made by..... On.....192....
Full Name .....Home Address .....
Claim Number..... Age..... Former occupation..... Present occupation.....
First treated for empyema at.....; .....19.....
First operation..... 19.... Thoracotomy? ..... Rib-resection? ..... Site? .....
(Note subsequent operations on back of sheet)
Weight before illness? ..... Present weight? ..... Excessive cough? ..... Excessive sputum? .....
Bloody sputum? ..... Foul sputum? ..... Dyspnoea on exertion? ..... Deafness? .....
Pain on normal respiration? ..... On forced respiration? ..... Location: .....
Precordial pain? ..... Pain on moving arms? ..... Limits of motion: .....
Faintness or dizziness on exertion? ..... Tremor of fingers? .....
Condition of joints? .....
Cyanosis? ..... Swelling of legs? ..... Of feet? ..... Clubbed fingers? .....
Temperature ..... degrees at ..... . M. (afternoon temperature preferred)

| | Observations on Pulse, | Respiration, | Blood pressure |
|---|---|---|---|
| After quiet, in recumbent position, | ..... | ..... | ..... |
| Recumbent, just after 30 seconds stationary run, | ..... | ..... | ..... |
| Recumbent, ..... minutes (2 to 5) later, | ..... | ..... | ..... |

Is thyroid enlarged? ..... Tâche on chest after friction with finger? .....
Liver, level of lower margin? ..... Ascites? .....

HEART: Location of apex beat? ..... Valvular lesions? .....
Location left border of cardiac dullness ..... cm. from mid-line, 5th intercostal space.
Locate murmurs or thrills on Diagram, stating whether systolic or diastolic.

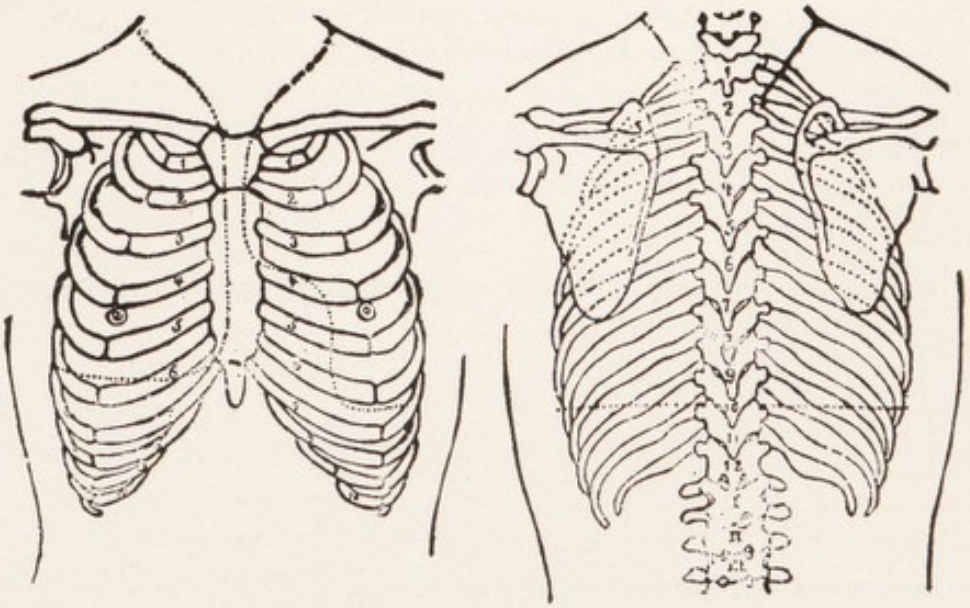
CHEST: Deformity? .....
Curvature of spine? .....
Sinus still open? ..... Does it enter a cavity? ..... Size of cavity? .....
Amount and character of discharge? ..... Character of scars? .....
Is there evidence of pus in the chest? ..... Lung abscess? ..... Tuberculosis? .....
Note physical signs on following Diagrams:

RALES:
*f—fine*
*m—medium*
*c—coarse*
*s—sonorous*
*ck—crackling*

BREATH SOUNDS:
*BF—feeble*
*BE—Bronchial expiration*
*BI—Bronchial inspiration*

PERCUSSION:
DULL—LIGHT SHADING
FLAT—HEAVY SHADING
*T—Tympany*
MARGINAL NOTES FOR OTHER SIGNS, WITH INDICATORS

Locate position and size of scars.



URINE: Specific gravity ..... Albumin ..... Sediment .....

(If more space is required for any data use back of sheet)

FIG. 1.—Blank for physical examination.

Beginning with Circular Letter No. 23, the data obtained in the ways just described will be hereafter collectively referred to as the "Special empyema records."

*Reports of certain special details from empyema centers.*—When the military hospitals were abandoned, the cases of empyema were evacuated to other hospitals. There were seven hospitals which became recognized as centers specially equipped for the care of these cases.[7] They were General Hospital No. 12, at Biltmore, N. C.; Fort McPherson, Ga.; Fort Sam Houston, Tex.; The Letterman General Hospital, San Francisco; Fort Des Moines, Iowa; Fort Sheridan, Ill.; and the Walter Reed General Hospital, Washington, D. C. From three of these centers special monthly reports [8] on the cases under treatment were sent to the Surgeon General, and on completion of the cases a general summary of the history and final condition of each patient was also forwarded. The following blanks upon which this information was transmitted were used:

(To be sent monthly to the Surgeon General, U. S. Army, Washington, D. C. Attention Laboratory Division.)

Case of empyema. Current record. U. S. A. General Hospital No. ..... From ..... ..... to ....., 1919.

Name ..... Serial or Register No. .....

Permanent home address in full .....

Admitted ....., 191.... Overseas case? ..... Transferred from .....

I. Bacteriological data: Numbers of colonies on plate cultures; hemolytic streptococci (H), pneumococci (Pn), total colonies (T):

.....

.....

II. Antiseptic treatment: *a*, Antiseptic used; *b*, strength; *c*, amount; *d*, frequency of application, with dates of beginning, interruptions, changes, and cessation:

.....

.....

III. Measurements of cavity, with dates:

.....

.....

IV. Temperature. Note only temperatures of 100 or over, with dates between which such rises occurred and the maxima:

.....

.....

V. Weights of patient: *a*, Normal weight on entering service; *b*, record of weights while in hospital, with dates:

.....

.....

(For additional notes, or if spaces are inadequate, use back of sheet.)

---

(On completion, to be sent to the Surgeon General, U. S. Army, Washington, D. C. Attention Laboratory Division.)

Case of empyema. Clinical outline. U. S. General Hospital No. ..... 1919.

Name ..... Date of admission .....

Empyema followed: 1, Measles; 2, influenza; 3, pneumonia not preceded by measles or influenza; 4, trauma; 5, other primary disease or idiopathic:

.....

.....

Nature of all operations, with dates and hospitals:

.....

.....

X-ray plates with (without) injection of cavity, with dates and serial numbers of plates:

.....

.....

Description of case on admission and while in hospital with outline of treatment:

.....

.....

Disposition of case, with description of condition on discharge from hospital, or summary of autopsy findings:

.....

.....

(For additional notes, or if spaces are inadequate, use back of sheet.)

*Clinical records transmitted to the Surgeon General.*—After the closing of military hospitals, their clinical records were forwarded to the Surgeon General at Washington,[9] and they then became accessible as a source of information supplementing that obtained through the channels already described. Protocols of autopsies and, in some instances, pathological material secured at necropsy, were sent to the Army Medical Museum. This material also was available for study.

*Publications by Government departments and in current medical journals.*—In many of the military hospitals within the United States, the number of cases of empyema was so large and they presented conditions so unlike those most commonly observed in civil practice that the attention of surgeons of the Medical Reserve Corps was forcibly directed toward developing improved methods of treatment. This led to an intensive study of the disease and to the publication of numerous articles in current medical journals dealing with various aspects of the subject. Groups of medical officers were assigned to duty on empyema teams which comprised a surgeon, an internist, and a member of the laboratory staff.[10] A special empyema commission was placed in the base hospital at Camp Lee [11] where about 140 cases were available for study. The observations and conclusions accruing from these efforts were summarized at intervals so that they were available for study.[12] More specific references to these sources of information will be found in other parts of this study.

*Circular Letter No. 93.*—Cases which were transferred from hospital to hospital were followed by means of monthly lists [13] sent to the Surgeon General from all the military hospitals throughout the country in response to Circular Letter No. 93.[14] These lists contained the names of all patients under treatment at the time, with the dates of the operations. Unfortunately, the addresses of the patients were not included and the hospitals at which the operations were performed were not designated. These omissions often rendered the identification of the cases difficult and at times uncertain, particularly when there were discrepancies in spelling. These lists, however, served as invaluable checks on the accuracy of the data gathered through other means and frequently directed attention to operations that might otherwise have escaped record. They also supplied the first data concerning a number of chronic empyemata received in this country from overseas.

## THE UTILIZATION OF SPECIAL DATA CONCERNING CASES OF EMPYEMA.

The empyema case abstracts gave the initial, detailed information regarding the clinical histories of individual cases. It was necessary to reduce them to some form so that they might be compared with respect to the character of the cases in different parts of the country, and so that groups of cases in particular localities might be studied epidemiologically.

Tally sheets[15] were prepared for this epidemiologic study. One of these is reproduced here to illustrate the data they contained. The numerals placed under the various headings are the chronological numbers assigned the individual cases. These sheets made it possible to detect coincident conditions in a given case by following its number through the various captions under which it might be placed. A study of these sheets shows the prevalence of measles, influenza, pericarditis, etc., among the patients in the base hospitals of the camps.

*Tally sheet, empyema case abstracts, General Hospital No. 6, Fort McPherson, to March 3, 1919.*

A. Abscess, abdominal wall.
do. buttocks.
do. extremities, 194.
do. liver, 201.
do. mediastinum.
do. pulmonary, 24, 46, 47.
do. rectal, 76.
do. thoracic wall.
Adenitis, 46, 47.
Appendicitis, 4, 191, 208.
Arthritis, 37, 57, 58, 54.
B. Blood cultures, neg. 22, 23, 33, 36.
do. posit. 42, 139, 163.
Counts, good.
Balsam of Peru.
Bismuth paste, 14, 108, 109, 111.
C. Chloramine–T.
Castor-oil balsam, 133.
Chloroform.
Cocaine.
Cystitis.
D. Dakin's sol. 13, 18, 19, 20, 22.
Dichloramine–T, 22, 25, 33, 42.
Decortication 1, 2a, 3, 48, 51.
Diphtheria 121. 148, 159, 165.
Delirium.
E. Electric cautery.
Emphysema.
Empyema, double 35.
Embolism.
Endocarditis 42, 43, 87, 101.
Epilepsy.
Erysipelas 152.
Ether.
Expectoration of pus, 203.
F. Foreign body, pleural cavity.
Formaldehyde.
Formalin, intravenous.
G. Gangrene, pulmonary.
German measles 7.
Glucose, intravenous.
G. Gunshot wound, 232, 240, 251, 260.
H. Hemorrhage, intestinal mucosa.
Herpes.
Hemorrhage, punctate 249a.
Hemorrhage, lungs.
I. Influenza 126, 206, 209, 212, 229.
do. bacillus, 25, 34.
Infarction.
Infection.
Infection, mixed, 35, 57, 92, 93.
Intravenous medication.
J. Jaundice.
K.
L. Laryngitis.
Liver.
M. Measles 3, 9, 11, 13, 15, 16.
Meningitis.
Mumps 25, 26, 37, 112, 124.
Mastoiditis 21.
N. Nephritis, 53, 148, 241.
O. Orchitis, 28, 169.
Otitis media, 36, 150, 151.
Osteomyelitis, 111.
P. Pericarditis, 36, 43, 68.
Phlebitis, 150.
Pneumococcus, abscess.
Pneumothorax, 78.
Pharyngitis.
Pleuritis, fibrinous, opp. side 113, 42, 487.
Pleurobron. commun. 190, 206.
Q.
R. Recurrences.
S. Saline irrigation, 250.
Serum, tr., 16, 126.
Scarlet fever.
Suction, 23, 266.
Strept. nonhem.
Sec. opera. 1, 9, 13, 14, 18, 19, 21.
Staphylococcus, 37, 54, 66, 92, 96.
Silver nitrate 6.
Sinusitis.

T. Tuberculosis 5, 34, 46, 47.
Transfusion.
U. Ulcer.
V. Vaccine 22, 126.
Vomiting.
W.
X.
Y.
Z.

Follow-up replies:
Well.
Handicapped.
Reoperated.

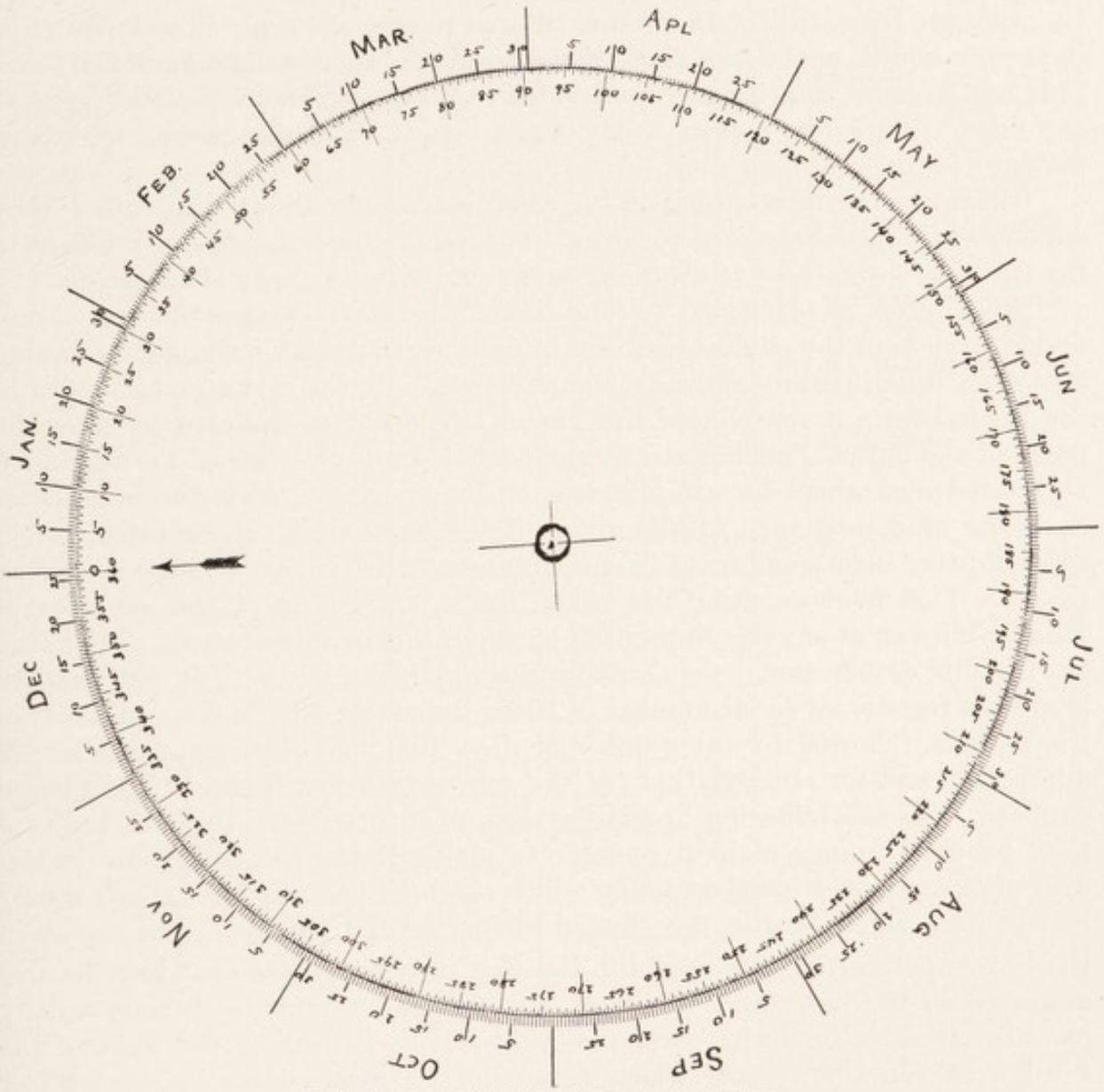



FIG. 2.—Device for determining intervals in histories.

The first step in reducing the data furnished by the empyema case abstracts to a form permitting ready comparison of individual cases was "intervalling" the events in the clinical histories. Starting with the day of admission to the hospital as zero, the number of days that had elapsed when a given event occurred was determined and the corresponding number written over the event on the original record. A mechanical device was invented to facilitate the reckoning of these intervals. This device [a] is shown in Figure 2. The

[a] It was subsequently learned that a similar device, divided to include 365 days for five years and called a "Hemerametre," was employed in the French Army.

degrees of a cardboard protractor were numbered consecutively from 1 to 360 to represent the calendar from January 1 to December 26 (one year, less five days). The centers of the two protractors were pivoted over each other so that the smaller scale revolved upon the larger. By placing the zero of the numbered scale in coincidence with any given date on the calendar scale it was possible to read off at a glance the number of days between that date and any other given date, provided the two were less than a year apart. If the division representing December 26 was passed in using this device, five days were added, or the zero mark of the numbered scale was set back five days. This was because the circles were divided into 360 degrees, while the year has 365 days. For a like reason, a day was added if February 28 was crossed in making readings for leap year.

When the events recorded on the case abstracts had been intervalled, they were entered in abbreviated form on the briefs described. These briefs were the working sheets used in studying and comparing the individual cases.

*Preparation of case briefs.*[16]—The term "case brief" was applied to abbreviated records of the clinical histories of cases of empyema, arranged according to a plan which permitted ready comparisons. A relatively simple history in the briefed form is reproduced in Chart I. The left of the caption gives the name of the patient, his home or permanent address, the date of his admission to the hospital where he was first treated for empyema, and the diagnosis at the time of admission. At the right of the caption is the hospital with a superimposed memorandum of the maximum recorded capacity of the empyema cavity. This memorandum was taken from the reports of the amounts of fluid withdrawn at any one time either by aspiration or at operation. Following the hospital designation is the chronological number of the patient, and beneath it are his register or serial number, a letter indicating the disposition made of the patient, followed by the number of days that had then elapsed after his admission, and an abbreviation for the microorganisms found in the pleural exudate. On the following line is the date of disposition. Beneath the caption, penciled rulings make it possible to pick out any desired square in this area of the cross-sectioned paper on which the brief was written. Each square represents a single day in the clinical history of the patient. The square in the left upper corner was used for the first day after that on which he was admitted to the hospital. The sizes of the page and squares permit a daily record extending somewhat over two years. The margin to the right of the ruled area contains details which could not be inserted in the squares, or memoranda of special interest which might be overlooked unless given this emphasis.

The history chosen as an example may be written out in the following terms:

The patient was admitted to the base hospital, Camp Dodge, Iowa, on March 27, 1918. The diagnosis on admission was influenza with lobar pneumonia in the right lower lobe. Two days later, he developed diphtheria and received 20,000 units of antitoxin. On the eighth day after admission an effusion was detected in the right pleural cavity and 1,200 c. c. of turbid yellow fluid containing hemolytic streptococci were withdrawn by aspiration. The following day 450 c. c. were removed.

On the 21st day, April 17, resection of the eighth rib in the right postaxillary line was done and 1,000 c. c. of creamy yellow pus were evacuated. Simple drainage, with daily dressings, constituted the postoperative treatment for the following six weeks. At this time he had been in the hospital 63 days. Carrel-Dakin antisepsis was then instituted and continued for 11 days, after

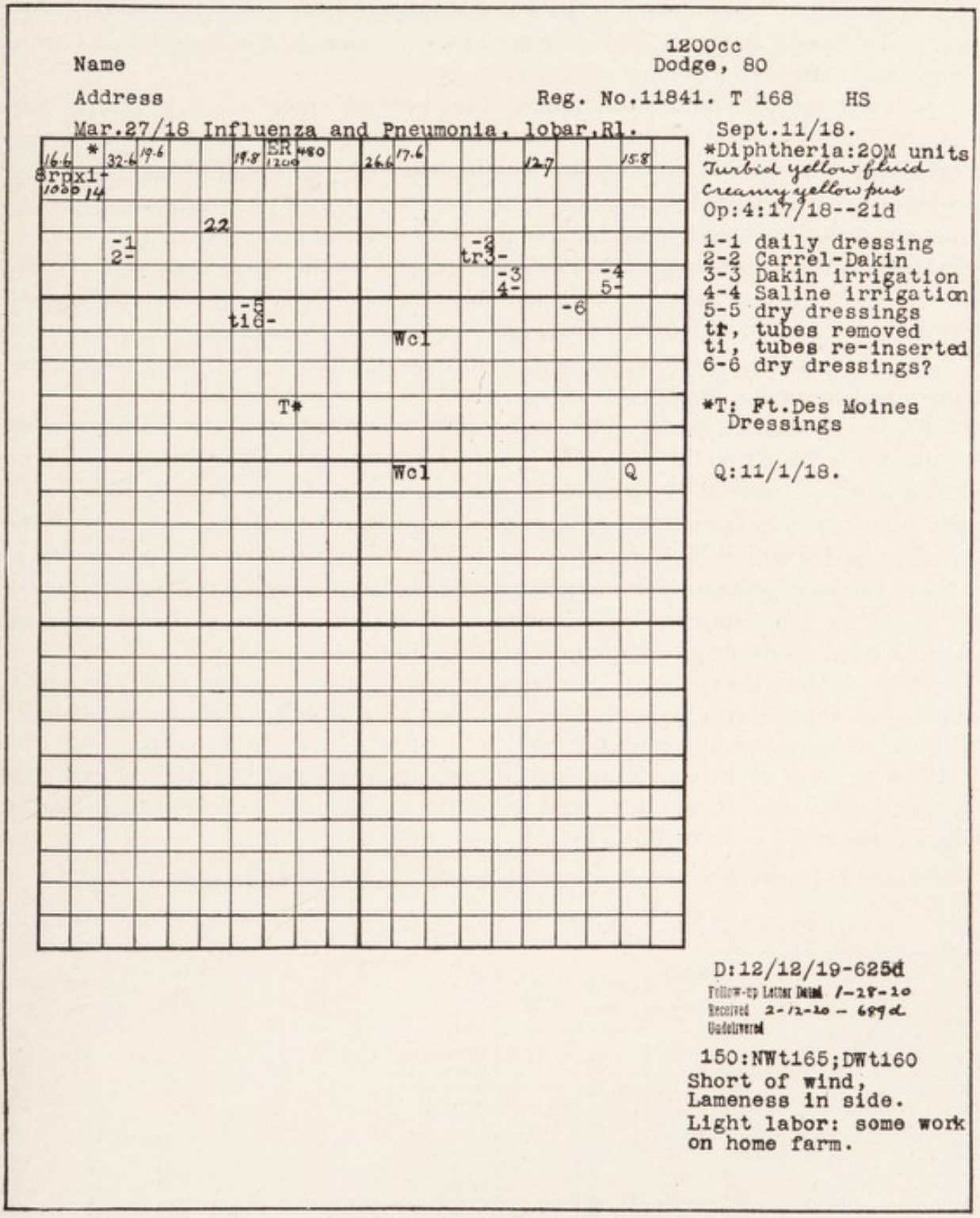



CHART I.—Final condensed brief of case.

which the tubes were removed and the application of Dakin solution limited to a single daily irrigation. It is obvious that at the end of this period progress was not wholly satisfactory because a tube was reinserted on the one hundred and seventh day to secure greater freedom of drainage, but there is no evidence that other treatment beyond simple dressings was employed. Ten days later

the tube was again removed and the cavity was allowed to close 132 days after the patient was admitted to the hospital. The closure was not permanent.

On September 11, the one hundred and sixty-eighth day, the patient was transferred to Fort Des Moines, where dressings of the thoracic wound were continued until final closure on the two hundred and twelfth day, and one week later he was sent to quarters. He was discharged from the Army on December 12, 1919, which was 625 days after his admission to the hospital at Camp Dodge and 406 days after his return to duty.

In response to a letter of inquiry, this patient reported on February 12, 1920, two months after he had received his discharge from the Army, that his weight was 150 pounds, his normal weight was 165 pounds, and his weight at the time of discharge 160 pounds, that he was "short of wind, experienced lameness in his side, and was doing light work on the home farm."

When, as in this case, there are records of leucocyte counts, they were entered with a pen in red ink in the squares corresponding to the days of observation, the figures being thousands and fractions of thousands.

In the event of death, notes of the autopsy findings, when available, were transcribed upon the briefs.

Since the salient features of each case were noted on the right margin of the page, the briefs could be easily grouped according to similarities or divergencies in the course of the disease or the character of treatment. This flexibility of the system facilitated greatly the comparative study of the large number of cases for which histories were available. Furthermore, the preparation of these briefs called attention to gaps in the histories which it was often possible to fill by searching for the missing information. Cases with exceptional features were rendered prominent by this method of recording.

It is obvious that these briefs were not only useful in the way just mentioned, but that they also served as an index to the more voluminous records from which they were prepared.

The number of briefs, follow-up letters, and autopsy records for cases of empyema admitted during 1917 and 1918 for which data were collected in the manner described is shown in Table I.

TABLE 1.—*Summary of cases included in the special empyema records for 1917 and 1918.*

| Camps. | Survived. | | Died. | | Camps. | Survived. | | Died. | |
|---|---|---|---|---|---|---|---|---|---|
| | Briefs. | Follow-up letters. | Briefs. | Autopsies. | | Briefs. | Follow-up letters. | Briefs. | Autopsies. |
| Beauregard | 68 | 53 | 28 | 0 | MacArthur | 19 | 12 | 2 | 0 |
| Bowie | 144 | 79 | 77 | 48 | McClellan | 41 | 29 | 2 | 2 |
| Cody | 107 | 51 | 32 | 9 | Meade | 60 | 50 | 28 | 9 |
| Custer | 155 | 92 | 63 | 32 | Merritt | 64 | 48 | 68 | 26 |
| Devens | 77 | 54 | 21 | 21 | Mills | 86 | 47 | 33 | 0 |
| Dix | 71 | 55 | 19 | 3 | Pike | 188 | 159 | 90 | 57 |
| Dodge | 126 | 77 | 216 | 177 | Sevier | 34 | 26 | 18 | 16 |
| Eustis | 8 | 0 | 1 | 1 | Shelby | 40 | 24 | 8 | 6 |
| Fremont | 17 | 9 | 0 | 0 | Sherman | 87 | 67 | 89 | 54 |
| Grant | 121 | 74 | 29 | 19 | Stuart | 33 | 22 | 6 | 0 |
| Greene | 67 | 52 | 36 | 24 | Travis | 134 | 107 | 29 | 8 |
| Gordon | 119 | 58 | 32 | 12 | Upton | 54 | 12 | 24 | 2 |
| Hancock | 40 | 26 | 9 | 2 | Wadsworth | 28 | 19 | 17 | 11 |
| Humphreys | 17 | 0 | 8 | 0 | Wheeler | 80 | 38 | 49 | 19 |
| Jackson | 14 | 0 | 2 | 0 | | 2,356 | 1,496 | 1,096 | 600 |
| Johnston | 23 | 18 | 6 | 0 | General and debarkation hospitals | 426 | 291 | 91 | 20 |
| Kearny | 6 | 5 | 18 | 18 | Forts and miscellaneous | 157 | 78 | 73 | 16 |
| Lee | 146 | 101 | 24 | 18 | | 2,939 | 1,865 | 1,260 | 636 |
| Lewis | 70 | 25 | 7 | 6 | | | | | |
| Logan | 31 | 19 | 7 | 0 | | | | | |

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(1) Questionnaire of February 21, 1918, S. G. O. (Sent to all base hospitals.) On file, Record Room, S. G. O., 710 (Empyema).
(2) Circular Letter No. 23 (D–386) January 10, 1919. On file, Historical Division, S. G. O., Empyema.
(3) Empyema case abstracts Form D–420. On file, Record Room, S. G. O., 710 (Empyema).
(4) Letter from the Surgeon General, U. S. Army, to Charles A. Ramsher, August 26, 1920. Subject: Inquiry regarding health. On file, Record Room, S. G. O., 710 (Empyema, Mills 100).
(5) Letter from the Surgeon General, U. S. Army, to discharged empyema patients (various dates). Subject: Present health. On file, Record Room, S. G. O., 710 (Empyema).
(6) Letter from the Surgeon General, U. S. Army, to Examining physician (various dates). Subject: Report on empyema cases. On file, Record Room, S. G. O., 710 (Empyema).
(7) Annual Report of the Surgeon General, U. S. Army, 1919, Vol. 11, 1092.
(8) Monthly reports, empyema cases. On file, Record Room, S. G. O., 710 (Empyema).
(9) Clinical records. On file, Medical Records Section, A. G. O., Retained Hospital Files under name individual hospital.
(10) Letter from the Sugeon General, U. S. Army, to Commanding Officers of all Hospitals, April 13, 1918. Subject: Empyema. On file, Record Room, S. G. O., 710 (Empyema).
(11) Report from Major Allen B. Kanavel, M. C., to the Surgeon General, U. S. Army, April 25, 1918. Subject: Empyema Commission. On file, Record Room, S. G. O., 710 (Empyema).
(12) Empyema Commission reports from Camp Lee. On file, Record Room, S. G. O., 710 (Empyema, Camp Lee) (c).
(13) Monthly lists, response to Cir. Letter No. 93. On file, Record Room, S. G. O., 710 (Empyema).
(14) Circular Letter No. 93, W. D., S. G. O., to All Military Hospitals, February 14, 1919. Subject: Empyema. On file, Record Room, S. G. O., Document file.
(15) Tally sheets. On file, Record Room, S. G. O., 710 (Empyema).
(16) Briefs of empyema reports. On file, Division of Surgery, S. G. O., Empyema.

## CHAPTER II.

# EPIDEMIOLOGY.

### STUDY OF THE COMBINED DATA FROM TWENTY-THREE CAMPS.

The records obtained in the manner described in the preceding chapter show that cases of empyema occurred in camps in all parts of the United States. The incidence of these cases falls into two main groups. The first comprises those occurring in the fall of 1917, soon after the camps were established, and during the early months of 1918. The second period of high incidence began in the late summer and fall of 1918 and extended in some instances into the early months of 1919. Between these two groups of high incidence, the cases in a given camp were either very small in number or a period of one to three months elapsed in which no new cases were reported.

The reports received from 23 base hospitals are sufficiently full to give a clear picture of the incidence of empyema in the respective camps. These data are depicted by diagrams in Figure 3. An enlargement of the diagram for the first camp, Camp Devens, appears in the lower left corner, and will serve to explain the plan used in preparing those of all the camps. Two fine vertical lines separate the months of 1918 from those of the preceding and following years; and the black columns indicate the incidence of empyema as the ratio per thousand men in the camps for the respective months.

Since these ratios differed very widely, they could not be represented conveniently in their simple arithmetical relations. For example, at Camp Devens, there were two cases of empyema reported for August, 1918.[1] As the strength for that month was 40,048,[2] the empyema ratio per thousand was therefore 0.050. The next month, with the advent of influenza, the number of reported cases of empyema rose to 52,[1] giving a ratio of 1.148 per thousand men, the strength of the camp for that month being 45,308.[2] In October the ratio fell to 0.049, almost identical with that of August. It will be observed from these figures that the ratio for September rose to approximately 23 times that for the adjacent months. To have given the column for September this relative height on a simple arithmetical scale would have carried it beyond the confines of the map. For the presentation of such widely divergent figures in a compact form, it was necessary to employ a scale which would compress the large quantities into small compass and yet preserve the relation accurately. A logarithmic scale, fulfilling these conditions admirably, was employed in preparing the diagrams upon the map. To simplify the reading of the diagrams, horizontal lines were drawn to give the heights of the columns. These horizontal lines correspond to the ratios 0.1 and 1 per thousand men, respectively. On the enlarged diagram the ratios of 0.05 and 0. 5 are also given to show the diminishing increment by which the columns lengthen as the numbers they represent increase.

The use of the logarithmic scale proved so valuable in the studies for this chapter that a diagram is introduced here in explanation of its advantages.

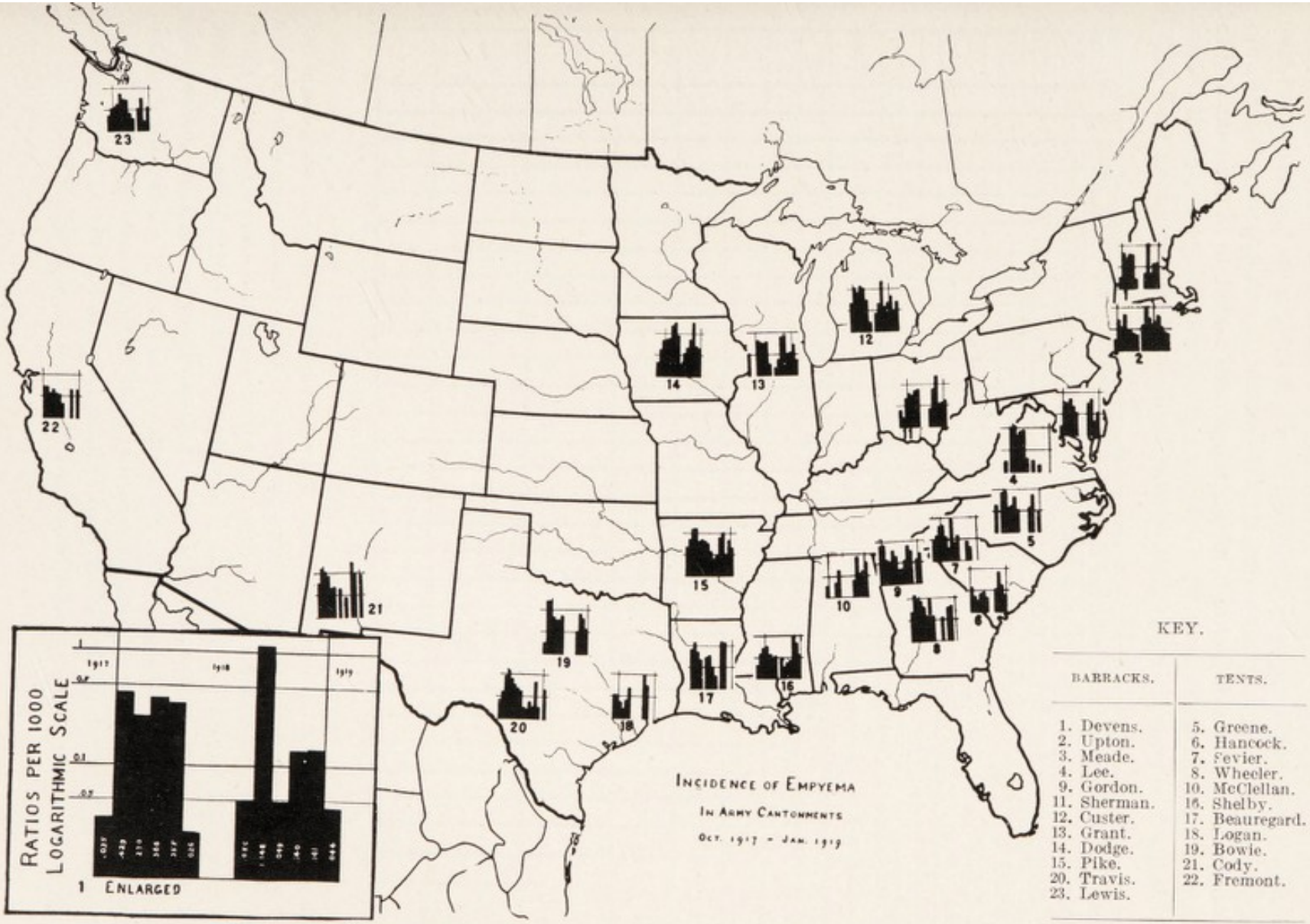


FIG. 3.—Incidence of empyema in Army camps and cantonments from October, 1917, to January, 1919, inclusive.

In Figure 4 a series of columns, representing successive numbers from 2 to 30, are shown in close contact with each other. Four of these columns are marked with the numbers they represent, 2, 4, 8, and 16. Column 4 is twice the height of column 2 and half the height of column 16. Doubling the height of a column squares the number it represents. If the column 2 were superposed on 4, the combined height would equal 8, but if the 2 were added to 8, the sum of the two would reach the level of 16. Adding any column furnishes a total height which, on this scale, is equivalent to the product of the numbers they indi-

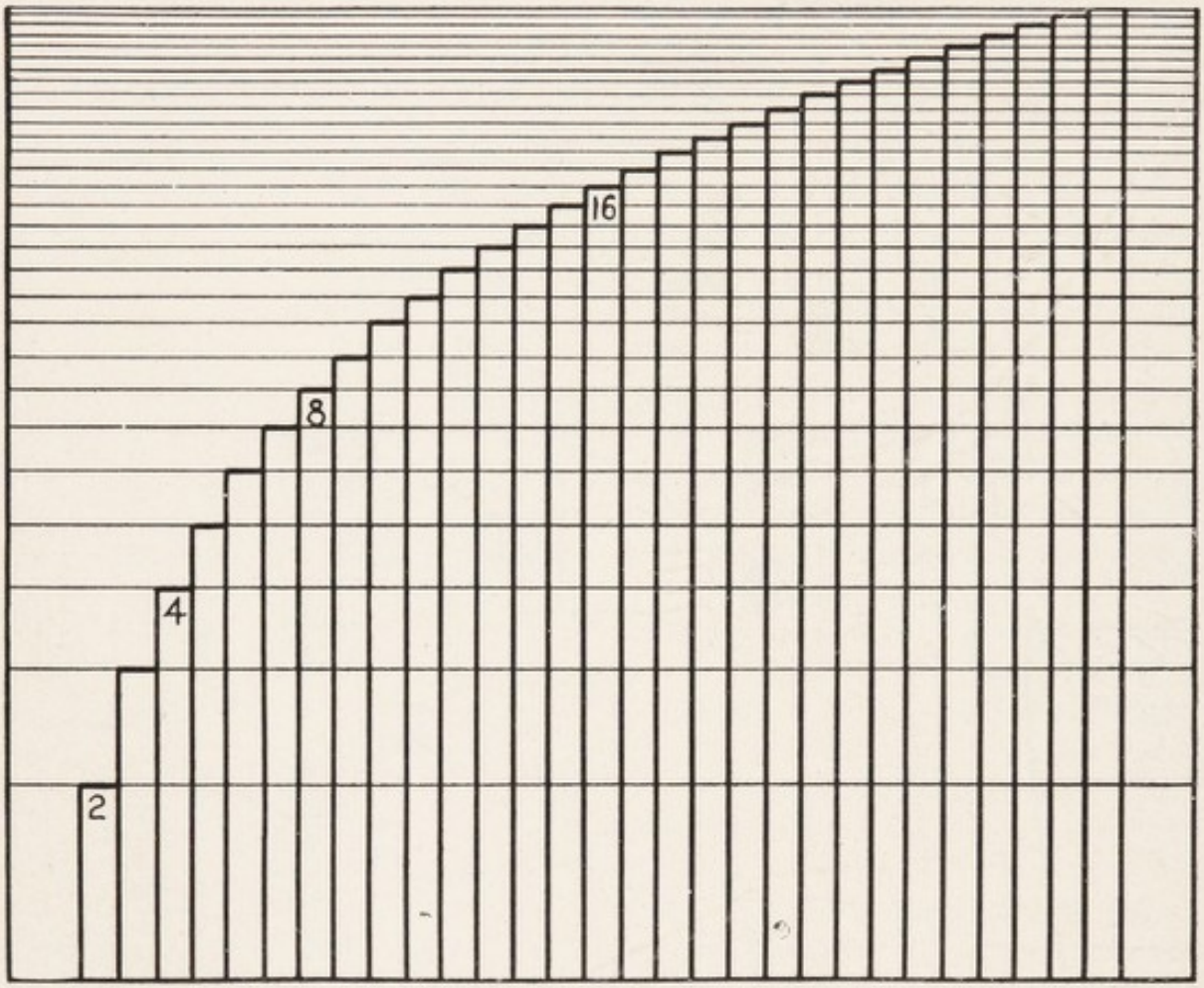


FIG. 4.—Diagram of logarithmic scale.

vidually represent. It follows that, if two lines charted upon this scale are parallel, the quantities they represent are in the same ratio to each other at any two points on the same vertical line, since the constant distance between them represents the quotient resulting from dividing one by the other. If they converge, this ratio approaches unity. If they diverge, the ratio correspondingly departs from unity. The value of the properties of the logarithmic scale will become evident when the incidence of empyema in relation to other diseases is studied in the individual camps, since it reveals at a glance the constancy of variations in the ratios for the figures plotted.

Referring again to Figure 3, it will be noted that, in general, those camps in which the men were lodged in tents fared better than those providing frame barracks for the men. This is especially true in the earlier groups of cases which occurred in the later months of 1917 and early in 1918. Camp Logan, No. 18 (tents), compares favorably with Camp Travis, No. 20 (barracks), Camp McClellan, No. 10 (tents), with Camp Gordon, No. 9 (barracks). On the other hand, Camp Bowie, No. 19 (tents), shows a higher incidence during November and December, 1917, than Camp Travis, though the termination of this outbreak was as abrupt as and coincident with that at Camp Logan. Again, Camp Sevier, No. 7, and Camp Wheeler, No. 8 (both tents), show no very marked contrast to Camp Gordon, No. 9 (barracks).

The mode of housing the men was only one of the differences between the tent camps and those with barracks, as the men brought to each class of camp were drawn from somewhat different sources. Those in barracks were drafted men, constituting the National Army,[3] while the National Guard, which consisted in part of men having at least some previous conception of military life, was brought together in the camps provided with tents.[4] That previous military life, so far as this went, did not very materially protect men from empyema is shown by the figures, and their experience in caring for themselves under Army conditions, played no important part in the incidence of empyema. While camps in which the incidence was smallest are among those in which tents were used and the men more experienced, the contrast between these camps and the others is not sufficient to be stressed. The average incidence per month for December, 1917, January, February, and March, 1918, in tent camps was 0.397; in those with barracks, 0.555 per thousand men in the commands; or, expressed in percentages, monthly ratio in tents, 41.7 per cent; in barracks, 58.3 per cent.

During the period of high incidence in the autumn of 1918, these differences appear less striking. The figures for September, October, and November, 1918, confirm this impression, the average monthly ratio of incidence being 0.447 for the 11 tent camps and 0.482 for the 12 others—47 per cent and 53 per cent, respectively. No appreciable difference existed in the camp populations at this time.

In the current literature there is frequent reference to an association of empyema with measles during the early period, and with influenza in the later epidemic. The relations between the incidence of these diseases and other respiratory infections to that of empyema will be illustrated presently by charts for individual camps, but first it will be well to learn what light can be thrown upon the relation of empyema to measles by a collective study of the available statistics bearing upon this particular question. In the Office of the Surgeon General, United States Army, the admissions for measles to the military hospitals have been tabulated for each month from September, 1917, to December, 1919.[5] From these data and from special empyema records[6] Table 2 has been prepared to show the comparative incidence of measles and of empyema.

TABLE 2.[a]—*Incidence of measles, empyema, and pneumonia and empyema following measles.*

| Camps. | 1917 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | October. | | | | November. | | | | December. | | | |
| | Measles. | Measles—pneumonia. | Empyema. | Measles—empyema. | Measles. | Measles—pneumonia. | Empyema. | Measles—empyema. | Measles. | Measles—pneumonia. | Empyema. | Measles—empyema. |
| Devens | 2 | 0 | 0 | 0 | 33 | 0 | 0 | 0 | 165 | 1 | 1 | 1 |
| Upton | 1 | 0 | 0 | 0 | 6 | 1 | 0 | 0 | 37 | 6 | 1 | 0 |
| Meade | 6 | 1 | 0 | 0 | 49 | 0 | 0 | 0 | 112 | 1 | 1 | 1 |
| Lee | 1 | 0 | 1 | 0 | 211 | 4 | 0 | 0 | 222 | 14 | 34 | 9 |
| Greene | 56 | 1 | 3 | 0 | 125 | 1 | 0 | 0 | 444 | 6 | 20 | 10 |
| Hancock | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 8 | 0 | 0 | 0 |
| Sevier | 307 | 24 | 2 | 1 | 2,295 | 229 | 4 | 1 | 126 | 24 | 12 | 3 |
| Wheeler | 500 | 22 | 5 | 1 | 2,335 | 86 | 35 | 11 | 90 | 8 | 44 | 2 |
| Gordon | 61 | 0 | 0 | 0 | 197 | 2 | 0 | 0 | 498 | 27 | 22 | 14 |
| McClellan | 39 | 0 | 0 | 0 | 57 | 2 | 0 | 0 | 118 | 2 | 1 | 0 |
| Sherman | 10 | 0 | 2 | 0 | 46 | 0 | 1 | 0 | 149 | 0 | 8 | 0 |
| Custer | 25 | 0 | 0 | 0 | 112 | 0 | 0 | 0 | 180 | 1 | 5 | 3 |
| Grant | 4 | 0 | 3 | 0 | 13 | 0 | 0 | 0 | 139 | 2 | 0 | 0 |
| Dodge | 22 | 1 | 1 | 0 | 82 | 2 | 4 | 0 | 255 | 4 | 9 | 3 |
| Pike | 974 | 36 | 5 | 2 | 1,862 | 81 | 14 | 5 | 1,295 | 93 | 47 | 24 |
| Shelby | 118 | 3 | 1 | 0 | 1,173 | 36 | 4 | 3 | 277 | 15 | 7 | 2 |
| Beauregard | 149 | 6 | 0 | 0 | 1,566 | 130 | 11 | 5 | 130 | 20 | 27 | 4 |
| Logan | 12 | 0 | 0 | 0 | 23 | 1 | 4 | 0 | 195 | 2 | 4 | 1 |
| Bowie | 282 | 11 | 1 | 0 | 2,925 | 238 | 76 | 42 | 143 | 35 | 71 | 13 |
| Travis | 31 | 3 | 0 | 0 | 2,608 | 63 | 6 | 5 | 1,382 | 53 | 30 | 10 |
| Cody | 14 | 1 | 0 | 0 | 153 | 11 | 7 | 0 | 155 | 14 | 39 | 6 |
| Fremont | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lewis | 12 | 0 | 0 | 0 | 41 | 0 | 2 | 0 | 82 | 1 | 4 | 0 |
| Total | 2,626 | 109 | 24 | 4 | 15,914 | 887 | 168 | 72 | 6,202 | 329 | 387 | 106 |

| Camps. | 1918 | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | January. | | | | February. | | | | March. | | | | April. | | | | May. | | | |
| | Measles. | Measles—pneumonia. | Empyema. | Measles—empyema. | Measles. | Measles—pneumonia. | Empyema. | Measles—empyema. | Measles. | Measles—pneumonia. | Empyema. | Measles—empyema. | Measles. | Measles—pneumonia. | Empyema. | Measles—empyema. | Measles. | Measles—pneumonia. | Empyema. | Measles—empyema. |
| Devens | 237 | 8 | 12 | 3 | 48 | 1 | 7 | 3 | 43 | 1 | 11 | 0 | 24 | 0 | 11 | 0 | 81 | 5 | 1 | 0 |
| Upton | 17 | 2 | 7 | 0 | 7 | 0 | 4 | 0 | 32 | 2 | 16 | 0 | 57 | 4 | 4 | 0 | 15 | 2 | 1 | 0 |
| Meade | 70 | 5 | 11 | 1 | 59 | 4 | 10 | 1 | 31 | 0 | 16 | 2 | 27 | 2 | 6 | 0 | 25 | 1 | 4 | 0 |
| Lee | 172 | 13 | 43 | 11 | 72 | 6 | 16 | 1 | 16 | 0 | 23 | 0 | 22 | 0 | 27 | 1 | 58 | 2 | 2 | 0 |
| Greene | 563 | 10 | 33 | 18 | 103 | 2 | 6 | 1 | 120 | 4 | 7 | 0 | 45 | 1 | 10 | 1 | 10 | 0 | 2 | 0 |
| Hancock | 34 | 2 | 4 | 0 | 78 | 1 | 2 | 0 | 44 | 0 | 1 | 0 | 12 | 1 | 2 | 0 | 2 | 0 | 1 | 0 |
| Sevier | 28 | 2 | 12 | 0 | 24 | 0 | 4 | 0 | 6 | 1 | 1 | 0 | 48 | 5 | 10 | 0 | 32 | 1 | 1 | 0 |
| Wheeler | 15 | 0 | 16 | 1 | 4 | 0 | 10 | 0 | 2 | 0 | 3 | 0 | 6 | 0 | 18 | 0 | 7 | 0 | 3 | 0 |
| Gordon | 248 | 18 | 21 | 13 | 12 | 0 | 4 | 1 | 47 | 0 | 4 | 0 | 106 | 11 | 12 | 0 | 194 | 11 | 6 | 0 |
| McClellan | 164 | 4 | 0 | 0 | 73 | 0 | 0 | 0 | 36 | 0 | 1 | 0 | 7 | 0 | 4 | 0 | 6 | 0 | 0 | 0 |
| Sherman | 593 | 5 | 12 | 5 | 258 | 3 | 10 | 5 | 59 | 2 | 13 | 1 | 33 | 2 | 18 | 0 | 50 | 0 | 0 | 0 |
| Custer | 201 | 1 | 27 | 8 | 59 | 0 | 15 | 13 | 15 | 1 | 25 | 0 | 28 | 2 | 26 | 1 | 24 | 0 | 9 | 3 |
| Grant | 384 | 7 | 12 | 4 | 82 | 0 | 8 | 2 | 46 | 0 | 9 | 0 | 65 | 0 | 10 | 1 | 60 | 0 | 1 | 0 |
| Dodge | 252 | 0 | 12 | 2 | 119 | 1 | 13 | 0 | 407 | 2 | 64 | 4 | 154 | 12 | 69 | 9 | 65 | 3 | 23 | 3 |
| Pike | 233 | 29 | 43 | 13 | 44 | 1 | 12 | 2 | 77 | 4 | 14 | 2 | 96 | 2 | 11 | 0 | 94 | 5 | 12 | 0 |
| Shelby | 14 | 0 | 8 | 0 | 3 | 0 | 3 | 0 | 4 | 0 | 2 | 0 | 8 | 0 | 3 | 0 | 8 | 0 | 0 | 0 |
| Beauregard | 7 | 2 | 13 | 0 | 4 | 0 | 5 | 0 | 3 | 1 | 0 | 0 | 4 | 0 | 6 | 0 | 3 | 0 | 7 | 0 |
| Logan | 153 | 10 | 2 | 0 | 130 | 8 | 1 | 1 | 26 | 0 | 2 | 0 | 39 | 1 | 8 | 0 | 10 | 0 | 0 | 0 |
| Bowie | 8 | 0 | 13 | 0 | 5 | 0 | 10 | 0 | 2 | 0 | 10 | 0 | 0 | 0 | 14 | 0 | 2 | 0 | 0 | 0 |
| Travis | 44 | 2 | 52 | 0 | 32 | 1 | 19 | 1 | 193 | 5 | 11 | 0 | 88 | 2 | 7 | 0 | 83 | 0 | 7 | 0 |
| Cody | 35 | 1 | 30 | 2 | 10 | 0 | 18 | 0 | 3 | 0 | 5 | 0 | 2 | 0 | 5 | 0 | 1 | 0 | 0 | 0 |
| Fremont | 24 | 1 | 0 | 0 | 24 | 0 | 3 | 2 | 46 | 0 | 2 | 0 | 39 | 0 | 2 | 0 | 56 | 0 | 3 | 0 |
| Lewis | 30 | 1 | 5 | 0 | 138 | 10 | 6 | 3 | 131 | 1 | 15 | 1 | 29 | 0 | 9 | 0 | 33 | 0 | 11 | 4 |
| Total | 3,536 | 123 | 388 | 81 | 1,388 | 38 | 185 | 36 | 1,389 | 24 | 255 | 10 | 939 | 45 | 292 | 13 | 920 | 30 | 94 | 10 |

[a] Sources of information: 1. Reports of sick and wounded made to the Office of the Surgeon General. 2. Special empyema reports made to the Office of the Surgeon General.

An inspection of this table shows that in any given camp the admissions for measles bear no exact relation to the incidence of empyema. Neither does the number of recorded postmeasles empyemata vary with much precision in conformity to the variations in the number of admissions for measles nor conform to those of measles complicated with pneumonia. Though these numbers usually increase or decrease at the same time, the extent of the upward or downward excursions taken by each is often markedly different, and in many instances they are in the opposite directions.

Turning to the totals for each month, in order to eliminate as far as possible fortuitous discrepancies likely to occur in single localities, a progressive increase in the number of empyemata as compared with the number of measles cases is revealed. Starting in October, the empyemata are less than 1 per cent of the measles, but by April the ratio has risen to over 30 per cent. If the series were carried further through the year there would come a time when the number of empyemata exceeded the total number of measles cases. At the time of highest incidence of measles, the total for empyemata was 1.5 per cent of the measles and the recorded postmeasles empyemata 0.46 per cent. The largest number of postmeasles cases was in December and the highest rate in February.

It is clearly evident from these tabulated figures that measles plays no direct part in determining the incidence of empyema in the sense that the latter is a natural sequela of measles. That it may be a contributing cause when other conditions prevail can not be either established or disproved by a simple array of figures such as these, but is suggested by the fact that in many instances the postmeasles cases increase in number with an increase of measles. Whether these fluctuations exceed the probabilities deducible from the doctrine of chance can not be stated. There is no relationship so clearly revealed by this table that it can be stated in simple terms.

By referring to Table 3, it will be seen that a tabulation of influenza and empyema cases reveals no obvious and simple relationship between the two. Since the proportion of cases followed by empyema is too small for such a conclusion, empyema can not be regarded as one of the natural sequelæ of influenza in the sense that infection of the pleura leading to suppuration is a definite part of its pathology. One is forced to search elsewhere for more satisfactory causes predisposing to the development of empyema.

Bacteriological examinations of empyema fluids revealed the presence of organisms commonly associated with suppurative or at least exudative inflammations in other regions in substantially all cases. The organisms most usually found are pneumococci, streptococci, and staphylococci. More rarely the influenza or tubercle bacillus, or bacillus mucosus capsulatus were encountered. There were many instances in which two or three bacteria were found in the fluids obtained at the first diagnostic aspiration.

TABLE 3.[a]—*Incidence of influenza and of empyema. Absolute numbers.*

[NOTE.—The number of cases definitely recorded as being postinfluenzal are given in parentheses.]

| Camps. | 1918. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | August. | | September. | | October. | | November. | | December. | |
| | Influenza. | Empyema. | Influenza. | Empyema. | Influenza. | Empyema. | Influenza. | Empyema. | Influenza. | Empyema. |
| Devens | 26 | 2 | 9,329 | 52 (27) | 1,040 | 2 (2) | 32 | 6 (2) | 121 | 4 (3) |
| Upton | 24 | 0 | 3,033 | 5 (3) | 2,226 | 13 (4) | 523 | 5 (2) | 124 | 3 |
| Meade | 50 | 0 | 7,465 | 11 (11) | 5,929 | 22 (13) | 199 | 2 | 95 | 4 |
| Lee | 24 | 0 | 7,148 | 1 (1) | 5,372 | 0 | 185 | 0 | 628 | 0 |
| Greene | 18 | 0 | 228 | 2 (1) | 3,998 | 15 (10) | 102 | 0 | 75 | 1 (1) |
| Hancock | 46 | 0 | 1,296 | 4 (3) | 6,813 | 25 (24) | 206 | 6 | 118 | 2 (2) |
| Sevier | 17 | 0 | 2,211 | 2 (2) | 3,673 | 1 (1) | 156 | 0 | 105 | 0 |
| Wheeler | 155 | 3 (1) | 142 | 0 | 389 | 5 (1) | 108 | 6 (3) | 26 | 0 |
| Gordon | 267 | 6 | 745 | 25 (17) | 151 | 12 (3) | 11 | 0 | 4 | 2 |
| McClellan | 12 | 0 | 170 | 1 (1) | 5,204 | 20 (11) | 294 | 3 | 76 | 3 (1) |
| Sherman | 22 | 2 | 1,725 | 22 (9) | 4,620 | 73 (38) | 53 | 4 | 27 | 2 |
| Custer | 17 | 2 | 1,089 | 8 (4) | 6,551 | 76 (56) | 68 | 5 (2) | 7 | 7 (1) |
| Grant | 8 | 2 | 5,798 | 29 (36) | 3,284 | 50 (39) | 100 | 4 (4) | 149 | 5 (1) |
| Dodge | 39 | 8 (2) | 757 | 15 (9) | 9,734 | 105 (96) | 492 | 8 (1) | 317 | 4 (1) |
| Pike | 77 | 4 | 6,560 | 34 (19) | 5,717 | 55 (31) | 200 | 4 | 95 | 11 (2) |
| Shelby | 260 | 2 | 679 | 1 (1) | 1,730 | 7 (6) | 315 | 5 (5) | 94 | 1 |
| Beauregard | 26 | 0 | 3,520 | 11 (8) | 2,356 | 13 (9) | 98 | 0 | 24 | 0 |
| Logan | 97 | 0 | 2,238 | 10 (9) | 2,018 | 5 (2) | 220 | 0 | 180 | 0 |
| Bowie | 6 | 0 | 766 | 1 | 3,325 | 12 (8) | 136 | 4 | 39 | 1 |
| Travis | 230 | 2 | 301 | 1 | 10,194 | 20 (17) | 570 | 1 (1) | 953 | 0 |
| Cody | 25 | 1 (1) | 16 | 0 | 2,178 | 17 (17) | 525 | 9 (7) | 28 | 0 |
| Fremont | 3 | 0 | 9 | 0 | 526 | 2 | 16 | 0 | 8 | 1 |
| Lewis | 401 | 0 | 582 | 4 (1) | 3,029 | 12 (10) | 657 | 1 (1) | 160 | 4 (1) |
| Total | 1,850 | 34 | 55,807 | 239 | 90,057 | 562 | 5,266 | 73 | 3,453 | 55 |

[a] Sources of information: 1. Reports of sick and wounded made to the Office of the Surgeon General. 2. Special empyema reports made to the Office of the Surgeon General.

A natural inquiry would be the relative frequency with which these groups of organisms occurred in relation to the total numbers of empyema cases at intervals during the epidemic. Table 4 gives by months the total number of empyema cases recorded for the 23 camps included in the map, the number of positive bacteriological reports, and those reports which showed streptococci and pneumococci.[7] Since it is not easy to comprehend the significance of this table, these data have been plotted as shown in Chart II.

TABLE 4.[a]—*Comparison of the microorganisms in pleural exudates.*

| | Empyema. | Positive reports. | Positive reports—Percentage. | Streptococcus group | Streptococcus—Percentage of total. | Streptococcus—Percentage positive reports. | Pneumococcus. | Pneumococcus—Percentage of total. | Pneumococcus—Percentage positive reports. |
|---|---|---|---|---|---|---|---|---|---|
| 1917. | | | | | | | | | |
| October | 24 | 10 | 41.6 | 4 | 16.6 | 40.0 | 6 | 25.0 | 60.0 |
| November | 168 | 68 | 40.5 | 25 | 14.9 | 36.7 | 43 | 25.6 | 63.3 |
| December | 387 | 202 | 52.2 | 116 | 30.0 | 57.4 | 86 | 22.2 | 42.6 |
| 1918. | | | | | | | | | |
| January | 388 | 254 | 65.4 | 179 | 46.1 | 70.5 | 75 | 19.3 | 29.5 |
| February | 186 | 137 | 73.6 | 102 | 54.8 | 74.4 | 35 | 18.8 | 25.6 |
| March | 255 | 193 | 76.1 | 179 | 70.6 | 92.7 | 14 | 5.5 | 7.3 |
| April | 292 | 228 | 78.1 | 191 | 65.4 | 83.8 | 37 | 12.7 | 16.2 |
| May | 94 | 67 | 71.3 | 56 | 59.4 | 83.6 | 11 | 11.5 | 16.4 |
| June | 29 | 27 | 93.0 | 18 | 62.0 | 66.7 | 9 | 31.0 | 33.3 |
| July | 22 | 19 | 86.3 | 11 | 50.0 | 57.8 | 8 | 36.3 | 42.2 |
| August | 34 | 26 | 76.4 | 13 | 38.2 | 50.0 | 13 | 38.2 | 50.0 |
| September | 239 | 190 | 79.5 | 108 | 45.2 | 56.8 | 82 | 34.3 | 43.2 |
| October | 562 | 423 | 75.3 | 243 | 43.3 | 44.3 | 180 | 32.0 | 55.7 |
| November | 73 | 54 | 74.0 | 40 | 54.8 | 74.1 | 14 | 19.2 | 25.9 |
| December | 55 | 36 | 65.5 | 28 | 51.0 | 77.8 | 8 | 14.5 | 22.2 |
| | 2,808 | 1,934 | 68.8 | 1,313 | 46.7 | 67.9 | 621 | 23.0 | 32.1 |

[a] Source of information: Special empyema reports made to the Office of the Surgeon General.

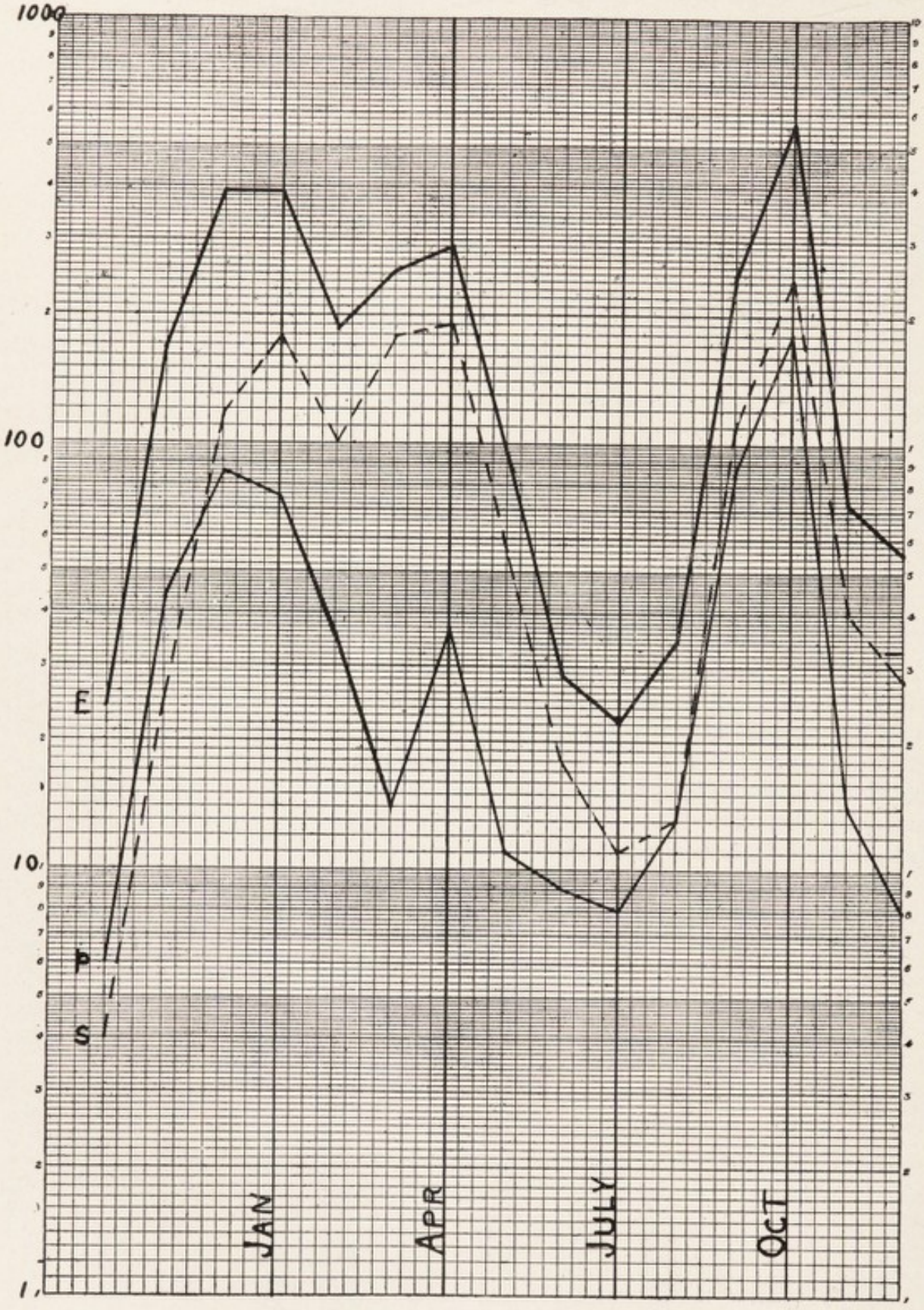


CHART II.—Empyema in Army camps and cantonments with pneumococci and streptococci isolated from the exudates. Absolute numbers on a logarithmic scale.

Chart II brings out a very striking parallelism between the cases of streptococcus empyema and the total number of empyema cases. The pneumococcus cases pursue a more independent course. As a matter of fact, between November, 1917, and April, 1918, the majority of the empyemata were the result of streptococcus infection. After this, there is a marked recession until August, when the percentage of streptococcus cases again increases. In contrast to this, the pneumococcus curve recedes after November, 1917, with a sudden decrease in

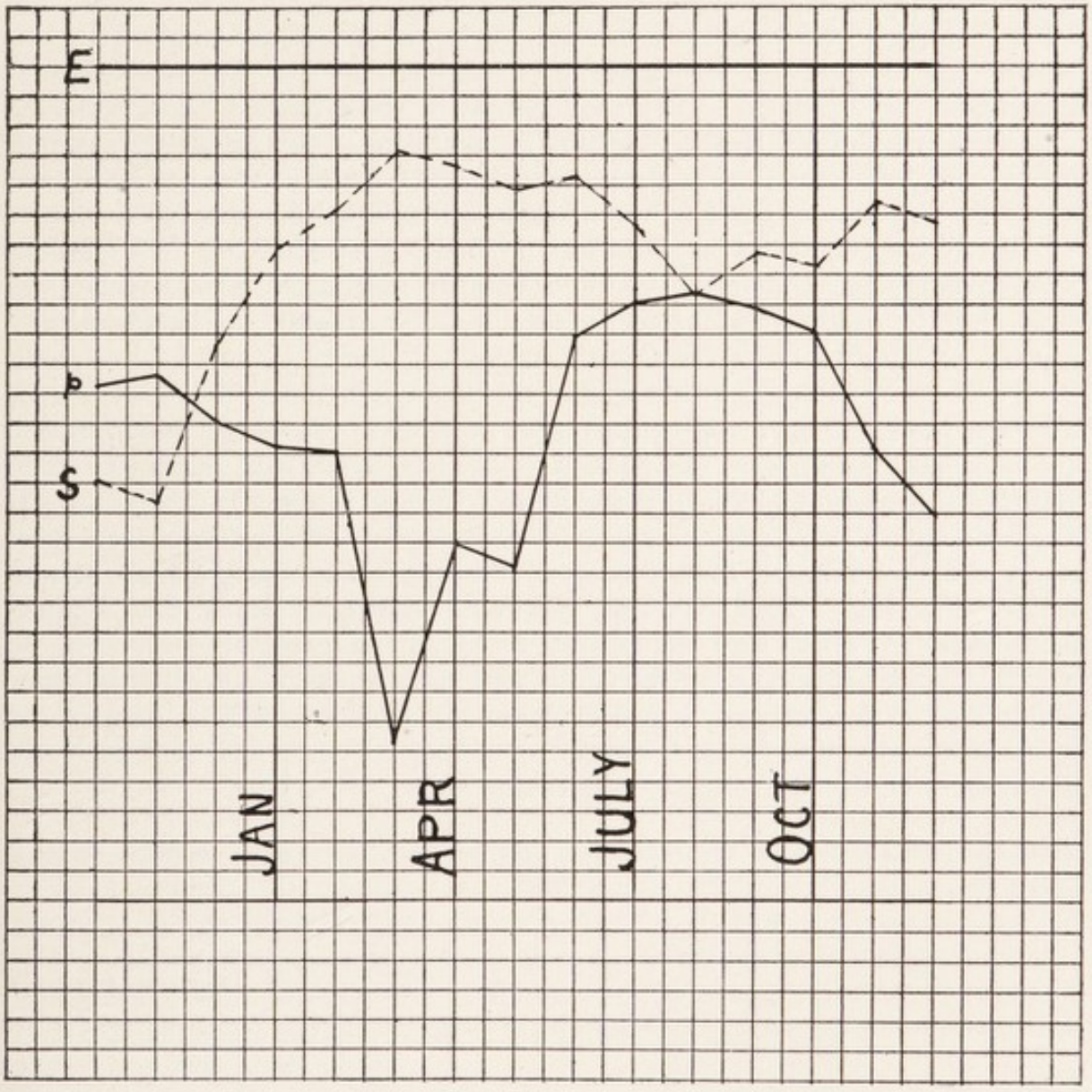


CHART III.—Arithmetical chart further illustrating Chart II.

March. After April the number of pneumococcus infections increases, and from June until October pneumococci play a more prominent part than at any previous time. After this there is a rapid decline in the proportion of cases associated with this organism. The relations just described are better illustrated in Chart III, where the empyema curve, shown in Chart II, is represented by a straight line and the distances between it and the streptococcus and pneumococcus empyemata are plotted to form simple arithmetical curves. The abrupt rise shown by the pneumococcus curve during April coincides with an

outbreak of influenza in the camps at that time just as the still greater rise in September and October coincides with the pandemic of that disease.

To pursue the thread of this inquiry, it is necessary to discover the sources of those organisms which have been shown to be most frequently associated with empyema. The pneumococcus is present in the lungs in the vast majority of cases of lobar pneumonia, as well as those not conforming strictly to the typical forms of lobar pneumonia. The streptococcus is also known to be present in many varieties of pneumonia, but particularly in the bronchial types. In either case the portal of entry is through the upper respiratory tract. It is well known that streptococci frequently find lodgment in the throat and induce pharyngitis, or tonsillitis. They may persist in these parts without inducing noticeable symptoms. Healthy carriers of organisms of this group are not very uncommon, particularly when people are thrown together in close association. There are abundant reports in the literature demonstrating this fact.

These considerations suggest the importance of studying the relations between empyema and infections of the upper respiratory tract. Infections which fail to produce symptoms could be detected only by bacteriological surveys, which were not systematically made.

Table 5 contains the total respiratory diseases, including influenza, for the 23 selected camps lying in different parts of the United States. Pneumonia and empyema also are given. The percentages of empyema with respect to other respiratory diseases and to pneumonia are found in the last two columns. It is apparent from these percentages that the incidence of empyema bears a more nearly constant relation to infections of the upper air passages than to pulmonary infections. This does not, however, necessarily imply that a pneumonia does not enter into the history of individual cases of empyema. In fact, this is almost invariably the case. But the deduction suggested by these calculations is that whether a given pneumonia is or is not to be complicated by empyema depends to some extent upon the existence and character of a preceding infection of the upper respiratory tract.

TABLE 5.[a]—*Relations between pneumonia and other respiratory diseases and empyema, 23 Army camps.*

| | Pneumonia. | Other respiratory diseases. | Empyema. | Per cent of pneumonia. | Per cent of other respiratory diseases. |
|---|---|---|---|---|---|
| 1917. | | | | | |
| October | 533 | 4,855 | 24 | 4.5 | 0.49 |
| November | 1,620 | 14,827 | 168 | 10 | 1.12 |
| December | 1,926 | 24,567 | 387 | 20.1 | 1.57 |
| 1918. | | | | | |
| January | 2,026 | 26,825 | 388 | 19.15 | 1.67 |
| February | 1,228 | 16,960 | 186 | 15.14 | 1.1 |
| March | 1,284 | 22,112 | 255 | 19.86 | 1.15 |
| April | 1,565 | 32,311 | 292 | 18.6 | .9 |
| May | 799 | 11,593 | 94 | 11.76 | .81 |
| June | 525 | 6,233 | 29 | 5.52 | .46 |
| July | 475 | 6,156 | 22 | 4.63 | .36 |
| August | 851 | 7,478 | 34 | 4 | .45 |
| September | 2,997 | 65,048 | 239 | 7.98 | .37 |
| October | 6,077 | 99,673 | 562 | 9.25 | .56 |
| November | 1,207 | 10,301 | 73 | 6.05 | .71 |
| December | 776 | 11,983 | 55 | 7.1 | .47 |

[a] Sources of information: 1 Reports of sick and wounded made to the Office of the Surgeon General. 2. Special empyema reports made to the Office of the Surgeon General.

If the above deduction were supported by a more detailed study, it would have an important bearing on the preventive measures likely to reduce the occurrence of empyema and would tend to avert the very serious disabilities following this disease.

### STUDY OF DATA FROM EACH OF TWENTY-THREE CAMPS.

Because combined statistics such as the foregoing give totals only, and these may mask individual departures from the average that may be of importance, it is desirable to study separately each of the camps contributing to these totals. The following pages are devoted to this study.

In the tables and graphic charts included in this section, the data concerning pneumonia and common respiratory diseases have been obtained from monthly reports of sick and wounded to the Office of the Surgeon General, United States Army. The data concerning the incidence of empyema and the associated bacteria are derived from the special empyema records described in Chapter I of this section. They also are expressed in monthly ratios per thousand men, but the absolute numbers are given in addition so that the number of cases upon which those ratios are based and the incompleteness of the bacteriological data may be seen. Where information supplementing that contained in the special empyema records was available, it has been used. Such information was sometimes furnished by replies to the questionnaire concerning empyema which was sent to military hospitals by the Surgeon General on February 21, 1919.[8] It has not always been possible, however, to compare accurately the data in these replies with those in the special empyema records. There are two reasons for this. First, the replies were frequently in percentages rather than in absolute numbers. Second, cases which had not developed empyema at the time the replies were prepared could be included, but empyema cases included in the special empyema records were always referred to the date of admission for the primary disease irrespective of the interval between that date and the development or recognition of the empyema. Since the dates of transmission of the replies are the only dates given, it has been impossible, particularly when empyema cases were numerous, to know just what cases were common to both sources of information. The replies relate only to those which occurred in the fall of 1917 and the early months of 1918.

For additional facts regarding cases, particularly in the later months of 1918, valuable information has been obtained from reports published in current medical journals. Where these were available and contained statistical data, they have been freely used.

There is at least one known element of incompleteness in the data contained in the special empyema records, which it has been impracticable to avoid. This arises from the fact that empyema is a secondary or complicating disease in substantially all instances. Unless a given case was transferred from the medical to the surgical service of a hospital, the occurrence of empyema was likely to be noted only as an incident in the clinical history and this, when filed, was indexed under the primary disease for which the case was admitted to the hospital. If, however, the case was transferred to the surgical service for the treatment of empyema, it would there be classed as such and so indexed in the files.

It follows from this that the special empyema records probably include substantially all cases coming to operation and transferred to surgical wards but probably do not include many cases which were never transferred. Empyemata, first recognized at autopsy, have undoubtedly been frequently omitted. Clinically unrecognized cases on which no post-mortem was held would, of course, remain unknown. There can be no doubt of the actual existence of such cases but their number can not be estimated.

In grouping the bacteriological findings into three broad classes—pneumococcus, streptococcus, and staphylococcus—some liberty has been taken which may have served to exaggerate to a slight extent the number of cases associated with streptococci. Some—probably many—of the bacteriological reports [9] were based on the microscopical examination of a stained streak or smear of the exudate without the preparation of cultures. This resulted in such inconclusive diagnoses as "diplococci" or "Gram-positive" cocci, or diplococci. These might actually have been pneumococci or streptococci, or even, in some instances, staphylococci. They have been placed in the streptococcus group. The justification here advanced for this is that in many cases—in probably the majority—certain streptococci, particularly hemolytic streptococci, fail to appear in chains when a pleural exudate is examined morphologically soon after withdrawal from the chest. They appear as diplococci, with the adjacent sides slightly flattened. Sometimes two to four such diplococci will be in juxtaposition, but this often appears to be fortuitous, and a positive diagnosis of streptococcus would be deemed hazardous. Their appearance differs considerably from that of the capsulated, lanceolate, diplococcus forms constituting the classical picture for the pneumococcus. It appears highly probable that the term "diplococcus" was used to describe the organism as being safer than to venture upon a more specific designation in the absence of appearances clearly indicating that they were pneumococci. However this may be, the instances of such inconclusive diagnoses are not numerous, and to include all among the streptococci, where doubtless the majority of them actually belong, can not seriously affect the statistics.

The pneumococci obtained from pleural exudates have been typed so rarely that no useful purpose would be served by attempting to classify the findings in this respect in the tables given in this chapter.

In view of all the foregoing considerations, it has appeared most instructive for present purposes to classify the bacteriological findings into the three broad groups adopted, trusting that the mass of the statistics would minimize incidental inaccuracies.

Finally, it should be stated that the empyemata included in these tables and charts are those originating in the respective camps. Transferred cases are excluded because they throw no light upon epidemiological questions.

The charts give in graphic form the relations between the ratios per thousand men contained in the tables. These data have been plotted on paper ruled for the logarithms of the actual figures. This logarithmic scale has been used because a comparison of the curves so plotted is particularly instructive. If any portions of two curves are parallel, it shows that the figures represented by those portions are in the same ratio to each other, and the vertical distance between the curves gives that ratio. For example,

the chart for Camp Devens shows a much closer parallelism between the curves "E" and "R" than that between "E" and "P," showing that in this camp there was a more uniform relation between the incidence of empyema and infections of the upper respiratory tract than between empyema and the pneumonias. The actual figures are given by the small numerals at the side of the chart. These are arranged in four similar banks, each bank being 10 times that of the one immediately below. As used, the first bank represents hundredths (i. e., ratios of 0.01 to 0.09 per thousand men), the second bank tenths (0.1 to 0.9 per thousand men), the third bank units (1 to 91), and the fourth tens (10 to 99). Occasionally the figures are greater than 100, and therefore the curve runs off the ruled portion of the chart. In such instances this part of the curve has been calculated to conform to the scale. The curve marked "R" represents the total respiratory diseases less the pneumonias. It includes, therefore, all forms of influenza and common respiratory diseases, such as tonsillitis, pharyngitis, laryngitis, and bronchitis, if of sufficient severity to entail admission to the hospital. The pneumonias (lobar and bronchopneumonia) are represented by the curve "P." The monthly ratios per thousand have been used for convenience in plotting. Had the annual rates been used, the curves would have exceeded the bounds of any available paper. This method does not in any way change the character of the curve and is in exact accord with the mode of calculating the ratios given for empyema and associated bacteria.

## CAMP DEVENS.

Camp Devens, Mass., was situated on the outskirts of Ayer, a town of about 3,000 inhabitants, 30 miles from Boston. [10]

Drafted men from New England and part of New York were assembled here. [10] The urbanity for the whole territory was 63.7 per cent. [10]

Frame barracks were used as quarters for the troops. [10] The strength of the command reached 28,000 men by December, 1917, all white. [10] The first contingent of 2,184 men arrived between September 5 and 10. [10]

Infectious diseases were of low incidence in the fall of 1917, measles being largest in number, reaching a total of 201 cases for the last four months of that year. [11] They were most numerous in the quarters most crowded, but were of mild type and generally uncomplicated, only one case of lobar pneumonia being reported. This occurred in December, when the incidence of measles was at the highest point for that year, 166 cases being admitted to the hospital. The following month the admissions rose to 245, but fell to 49 the next month and never exceeded 88 in any subsequent month. [11]

From the start the camp was always overcrowded. [10] The accommodations were designed for approximately 35,000 troops, but the number often exceeded this, reaching at one time 45,000 (September, 1918). [10] Despite this congestion the admissions for infectious diseases were relatively few. This may be owing to the high proportion of men from urban homes. The comparatively small influx of troops from distant parts of the country may have had some influence also.

According to the special empyema records, the first case to develop empyema was admitted to the hospital December 29, 1917, for measles. [12] Lobar pneumonia developed in the left upper lobe on the twenty-second day

after admission, and empyema on the left side was noted four days later. The empyema was treated by thoracotomy and drainage on the day it was recognized. Streptococci were found in the discharge. This case was further complicated by abscesses about the rectum, in the sacral and gluteal regions, in the rectus abdominis, and in the left shoulder, apparently involving the joint. Death occurred March 4, 1918, 65 days after admission to the hospital. The post-mortem revealed a septic infarct in the upper lobe of the right lung, with acute fibrinous pleuritis on that side. On the left side there was an undrained pocket containing 200 c. c. of pus in the lateral upper portion of the pleura, in addition to the drained cavity below. Smears from the right rectus sheath contained streptococci.

In addition to the foregoing, there were four cases of empyema following true measles and one following rubella.[12] These all occurred prior to March, 1918, and were associated with streptococci. Two died, 12 and 52 days after admission. The remaining three were returned to duty after 44, 113, and 151 days in the hospital. It is worthy of note that two of these five cases suffered from acute follicular tonsillitis within a short time after admission. It is also noteworthy that five other cases not associated with measles were admitted to the hospital for acute infections of the throat prior to May, 1918—three for follicular tonsillitis and two for pharyngitis. The pleural exudates in all these cases, with a single exception lacking a record of any bacteriological examination, contained streptococci.

With the advent of epidemic influenza, the number of cases of empyema increased rapidly. In all, 41 cases are associated with this disease in the special empyema records, with 8 deaths.[12] The presence of streptococcus is less marked in this period than in the earlier period of high incidence, in the fall of 1917 and early in 1918.

The figures given above and in the tabulation to follow do not correspond precisely to those obtained through other sources.

In the reply dated February 27, 1918, to the questionnaire of February 21, 24 cases of empyema were reported, among which 11 died.[9] The special empyema reports include only 11 cases, with 1 death, prior to February 27. This is such a serious discrepancy that an inquiry into the reasons for its occurrence is important.

When the request for data concerning empyema was sent, on January 10, 1919, to military hospitals throughout the country, it could be complied with only by consulting the records preserved in the hospitals.[13] Many cases of empyema would inevitably be overlooked in searching these records.

Examining the above discrepancy, it appears that 12 of the 24 cases referred to in the reply were not operated, and that 11 of the 12 were fatal. On the other hand, all of the cases appearing in the special empyema reports were operated. If the unoperated cases just referred to are added to these, the total reaches 23, or only 1 less than the total given in the reply, but with a mortality of 12, instead of the 11 therein noted. The discrepancy becomes reduced to 1 case less, and 1 death more in the special empyema report as amended with data included in the reply to the questionnaire and collected by those themselves familiar with the cases while in the hospital wards. The additional death had not taken place at the time the reply was sent.

It will not be possible to detect such discrepancies as the foregoing in many of the reports from hospitals, for the data given in the replies to the questionnaire of February 21 are often expressed in percentages, without the absolute numbers upon which those percentages are based being stated. But it is well to bear in mind that cases of empyema not admitted to the surgical wards, either by reason of recovery without operation or because of death, are liable to escape classification as empyema and in consequence fail to be included in the special empyema reports. The data concerning incidence and other questions of epidemiological importance furnished by these records must be regarded as minimal rather than actual.

Returning to the data furnished in the reply: In 23 of the 24 cases, a bacteriological examination of the pleural fluid was made. In 15, or 70 per cent, streptococcus alone was found; in five, pneumococcus, and in the remaining two, staphylococcus associated in one instance with streptococcus. Two of the cases followed pneumonia secondary to some other disease (presumably measles). This would be approximately 8 per cent of the total number of empyema cases.

Another source of information concerning empyema at Camp Devens in the earlier period is furnished in an article by [14] a member of the local empyema team, created to study this disease in the base hospital, Camp Devens. The period covered is from September 27, 1917, to May 31, 1918, or 35 weeks, beginning at a time when the camp contained approximately 18,000 men.

There were 77 cases of empyema, of which 14 were preceded by measles, constituting 18.2 per cent of the whole number of empyema cases considered. The number of measles cases was 588, so that those which developed empyema were a trifle less than 2.4 per cent. The measles cases developing pneumonia were 41, or 7 per cent of all the measles cases, and of these, 34 per cent were complicated by empyema. This is a much higher proportion than that for primary pneumonia, which is given as 15 per cent. The bacteriological examinations of the postmeasles cases are not separated from those having other histories. The most frequent organism found in all 77 cases of empyema was a streptococcus alone in 53 per cent of the cases. Next most frequent was pneumococcus alone in 27 per cent, and the two in association amounted to 17 per cent. If the streptococcus is given precedence and this last figure added to the 53 per cent in which this organism occurred without admixture, the total number of cases in which the streptococcus was found amounted to 70 per cent, exactly agreeing with the figure reported in the reply to the questionnaire of February 21, already cited.

There is still another clue to the relative part assignable to the streptococcus in the empyemata at different periods. In the published article referred to [14] there were 9 cases of empyema among negroes, in which the streptococcus was present in 4, the pneumococcus alone in 5. Among the contemporary white troops there were 15 cases of empyema in which the streptococcus either alone (4 cases), or associated with pneumococcus (8 cases) was found in 12, or 80 per cent. These cases must be assigned to the months of April and May since the number of negroes in camp prior to April was negligible. Before this date there were 53 empyema cases among the white troops, 35 with streptococcus alone, three with admixture of pneumococcus, and 13 with the latter alone. These figures indicate that up to April a streptococcus was associated with approxi-

mately 72 per cent of the cases. There appears, therefore, to have been a very slightly increasing preponderance of the streptococcus with the progress of time from the autumn of 1917 to the spring of 1918. There was certainly no diminution in its relative frequency as compared with the pneumococcus. Nor is there any evidence that the postmeasles cases which were most numerous about the middle of this period were peculiarly prone to association with streptococci.

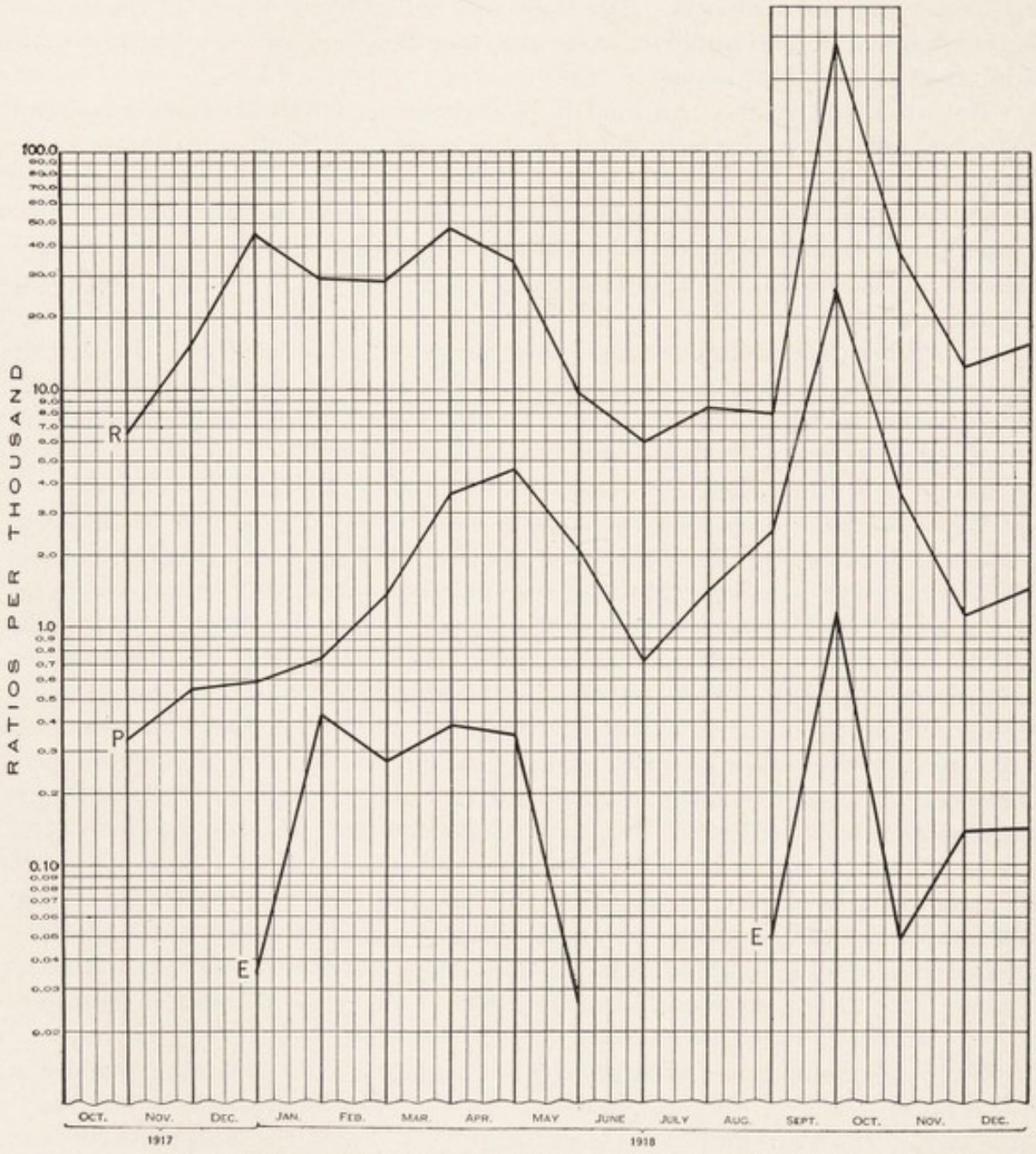


CHART IV.—Epidemiological chart for Camp Devens, Mass., in monthly ratios per thousand men.

The reduced significance of the streptococcus during the influenza epidemic as indicated in the special empyema reports is also emphasized by the bacteriological data published by Gage,[15] who contrasts the two periods. In the earlier group of 77 cases the streptococcus was present in 53, or 69 per cent; in the later group of 61 cases, in 26 per cent. The pneumococcus alone appears in 28 per cent of the first group, and in 45 per cent of the second.

The statistical material bearing upon the epidemiology of empyema at Camp Devens, drawn from the special empyema reports, is presented in Table 6 and Charts IV and V. On the latter, all the data are presented in terms of ratios per 1,000 men in camp, based upon the average strength for the corresponding month.

The general impression conveyed by Chart IV is that the incidence of empyema bore a closer relation to the admissions for upper respiratory diseases than to those for pneumonia, particularly in the early months of 1918. It is noticeable

CHART V.—Relationship of the pneumococcus and the streptococcus to the incidence of empyema at Camp Devens, Mass.

that when the curve "R" falls distinctly below the ratio of 10 per thousand men, i. e., 1 per cent, there are no cases of empyema, and when the curve "R" is at the level of 1 per cent, in May, 1918, the single case of empyema was associated with pneumococcus, while before that time, streptococci predominated.

Turning now to the curve "P" representing admissions for primary pneumonias, these were at approximately the same level in January, 1918, when the incidence of empyema was maximum, as in June of that year when no cases of empyema were reported.

The relationship between the pneumonia and empyema curves does not display such divergences during the pandemic of influenza, but it is worthy of remark that in the beginning of this period the pneumococcus was closely related to empyema, the curves for this organism being exactly parallel to the empyemata between September and October, and that the streptococcus did not acquire great relative prominence until after the epidemic had subsided. The fact that the pneumococcus played the most dominant part in the empyemata at this time may perhaps be correlated with the fact that among the pneumonias nearly six out of seven were of the lobar variety.

TABLE 6.[a]—*Epidemiological table for Camp Devens, Mass.*

| | Absolute numbers. | | | | | Ratios per 1,000 men. | | | | | Empyema, mortality percentage. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Empyema, totals. | Empyema, deaths. | Streptococcus group. | Pneumococcus group. | Staphylococcus. | Pneumonia. | Common respiratory diseases. | Empyema. | Streptococcus group. | Pneumococcus group. | |
| 1917 | | | | | | | | | | | |
| October | 0 | 0 | 0 | 0 | 0 | 0.33 | 6.42 | 0 | 0 | 0 | 0 |
| November | 0 | 0 | 0 | 0 | 0 | .55 | 15.72 | 0 | 0 | 0 | 0 |
| December | 1 | 1 | 1 | 0 | 0 | .59 | 45.61 | 0.0346 | 0.0348 | 0 | 100 |
| 1918 | | | | | | | | | | | |
| January | 12 | 0 | 9 | 2 | 0 | .75 | 29.05 | .4285 | .3214 | 0.0714 | 0 |
| February | 7 | 3 | 7 | 0 | 0 | 1.36 | 28.65 | .2703 | .2705 | 0 | 43 |
| March | 11 | 4 | 6 | 0 | 0 | 3.56 | 47.57 | .3880 | .2117 | 0 | 36 |
| April | 11 | 2 | 8 | 2 | 0 | 4.51 | 34.31 | .3550 | .2569 | .0642 | 18 |
| May | 1 | 0 | 0 | 1 | 0 | 2.10 | 9.77 | .0262 | 0 | .0262 | 0 |
| June | 0 | 0 | 0 | 0 | 0 | .72 | 5.98 | 0 | 0 | 0 | 0 |
| July | 0 | 0 | 0 | 0 | 0 | 1.41 | 8.31 | 0 | 0 | 0 | 0 |
| August | 2 | 0 | 1 | 1 | 0 | 2.50 | 7.91 | .0499 | .0252 | .0252 | 0 |
| September | 52 | 20 | 10 | 25 | 0 | 26.81 | 282.39 | 1.1477 | .2207 | .5578 | 39 |
| October | 2 | 1 | 1 | 0 | 0 | 3.63 | 37.18 | .0487 | .0243 | 0 | 50 |
| November | 6 | 2 | 6 | 0 | 0 | 1.13 | 12.33 | .1399 | .1398 | 0 | 33 |
| December | 4 | 0 | 2 | 1 | 0 | 1.47 | 15.88 | .1409 | .0705 | .0353 | 0 |
| | 109 | 33 | 49 | 32 | 0 | ..... | ..... | ..... | ..... | ..... | 30.3 |

[a] Sources of information: 1. Reports of sick and wounded made to the Office of the Surgeon General. 2. Special empyema reports made to the Office of the Surgeon General.

## CAMP UPTON.

Camp Upton was about 5 miles from Yaphank, a small village on Long Island, N. Y., 65 miles from New York City.[10]

Drafted men from Greater New York were the first increment received, approximately 2,000 arriving between September 1 and 15.[10] By the end of October the number had increased to about 30,000.[10]

Frame barracks served as quarters.

The incidence of infectious diseases, excluding those of venereal origin, was low. There were only 51 cases of measles during the latter part of 1917, and the highest number of admissions to hospitals for this disease was in July, 1918, when 63 cases were admitted. The monthly average for that year was 28.[11]

Five cases of empyema following measles are on record; [12] two occurred in December, 1917, two in March, 1918, and one in June. Three of these post-measles cases were associated with hemolytic streptococci, and two were apparently sterile. Of these five cases, two died; one with sterile fluid, and one with hemolytic streptococci in the exudate. The latter had bilateral empyema. The other fatal case had pneumococcus, Type III, in the sputum, but the pleural fluid yielded no growth in culture, and at autopsy the case proved

to have general miliary tuberculosis as well as lobar pneumonia and empyema on the left side. The total number of measles cases for the camp was 386 for the three last months of 1917 and the whole of 1918.[11] The percentage of those developing empyema was therefore 1.3 per cent.[12]

Mumps preceded two cases of empyema, one in February, and one in March, 1918.[12] Both were associated with hemolytic streptococci. One convalesced; but the other died two days after recognition of the empyema, a fibrinopurulent pericarditis being found at autopsy. The preceding occurrence of mumps in these cases appears to have little significance, for there were 1442 cases of mumps in the camp up to the end of 1918.[12]

In March, 1918, in one case empyema followed scarlet fever.[12] The sputum contained hemolytic streptococcus, but the pleural exudate was reported sterile. This case appears to have recovered without operation.

The data from Camp Upton contained in the special empyema reports include many cases transferred from elsewhere or who had contracted the precedent disease while away from camp on furlough. The transferred cases were either from other military organizations in the United States or from overseas, this camp being used as an embarkation and debarkation camp after the 77th Division was moved overseas about April, 1918.[10] The transferred cases are eliminated from consideration in this chapter, which is confined to cases arising in the camp itself. This elimination reduces the number of empyema cases in the special empyema records very considerably.

It is fortunate, however, that another source of information is available for Camp Upton prior to the departure of the 77th Division. "A Study of Eighty Cases of Empyema at Camp Upton," published by Brooks and Cecil,[16] contains data concerning 59 cases unfortunately omitted from the special empyema reports when these were compiled from the records of the base hospital many months after the period embraced by that article. The data used here are combined from these two sources, transferred cases being omitted.

There is no record of empyema during September, October and November, 1917, but in December, 10 cases, that subsequently developed empyema, were admitted to the hospital.[12]

The first case was admitted for measles on December 6, but did not develop empyema until nearly eight weeks later, on January 27. Resection was done and a sterile exudate obtained, though the sputum had yielded pneumococcus, Type I, previously. This case recovered.[12]

The second case was severe in character, empyema being noted December 15, and death taking place on the 29th. At autopsy, an interstitial bronchopneumonia, with multiple pulmonary abcesses, was found with an empyema on the left side. The pus contained streptococcus viridans. Pneumococcus, Type II, had previously been obtained from the sputum.[12]

One case, in which staphylococcus aureus was found in the pleural exudate, was admitted December 22 with a primary pneumonia.[12] Pneumococcus, Type IV, was present in the sputum. Empyema appeared January 20, and death supervened February 11. There is no record of an autopsy. With this exception, and the case of miliary tuberculosis already mentioned, all the five fatal cases were associated with streptococcus, two with viridans and one with hemolyticus. Of the five surviving cases, the pleural fluid either contained pneumococcus (three), was sterile (one), or not recorded (one.)

The total number of empyema cases developing within the hospital was 107.[12] Of these, 48 died, a case mortality of 45 per cent. Of 87 cases, 65 (75 per cent) were associated with streptococcus, six with streptococcus viridans, and 51 with hemolytic strains, the specific character of the remaining eight being undefined. In addition, there was one case associated with staphylococcus aureus. This has already been briefly detailed. Of the 15 cases of pneumococcus empyema which were typed, eight were Type IV, four Type II

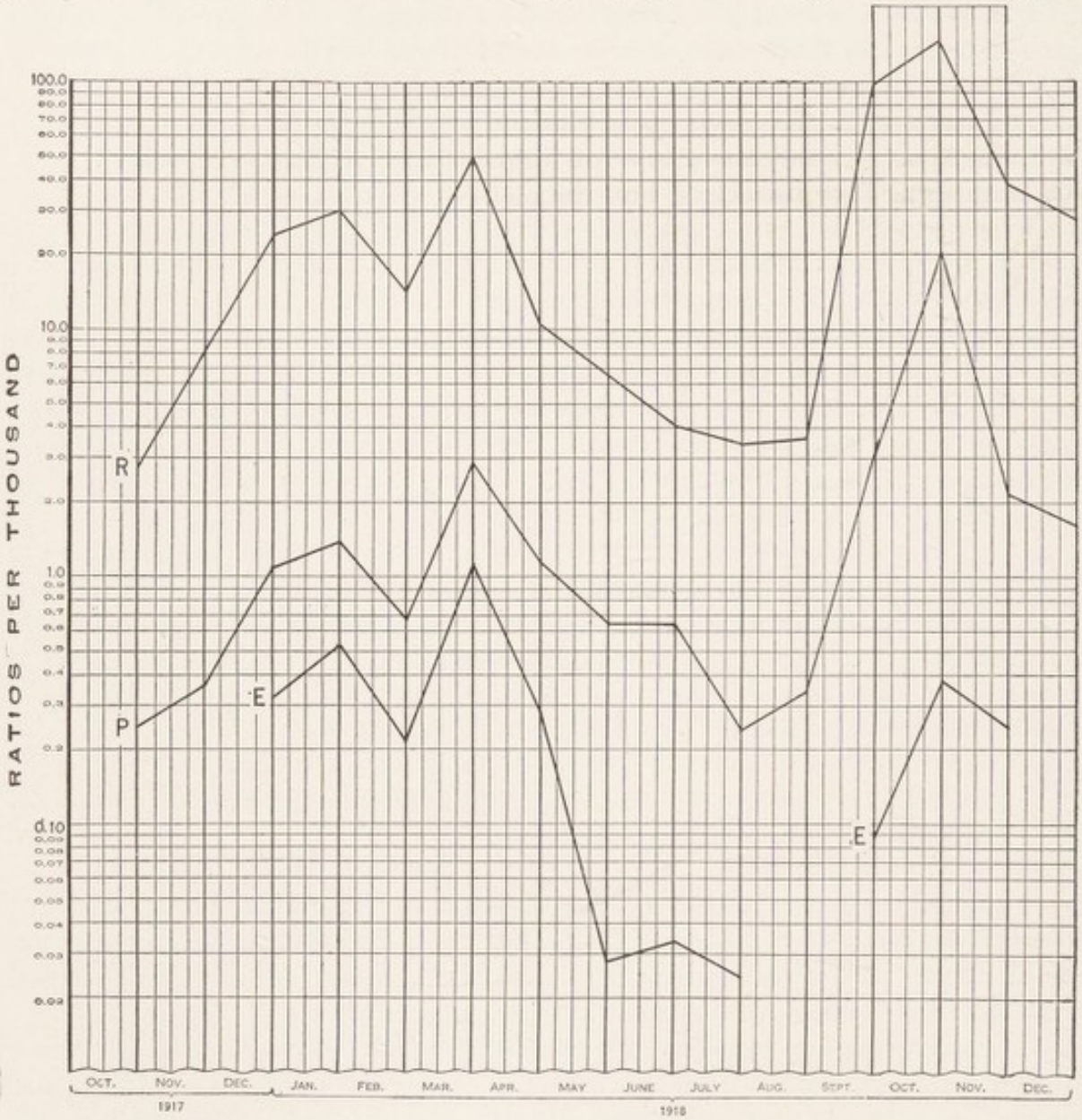


CHART VI.—Epidemiological chart for Camp Upton, N. Y., in monthly ratios per thousand men.

and three Type I. All of these 15 cases recovered. There were five deaths associated with pneumococcus; three of these were Type IV, the others Type II.

Table 7 and Chart VI give the relations between pneumonias and diseases of the upper respiratory tract, and Chart VII exhibits the associated microorganisms found in the pleural fluids. Chart VI, while differing considerably in detail from that for Camp Devens, presents several features of similar import. The general parallelism between the empyema curve "E" and "R" for the first few months is striking, although the curve "P" also closely conforms. There is the same exaggerated decrease of empyema when "R"

crosses the 1 per cent level, but not the complete extinction noted at Camp Devens. It seems as though during May, June, and July the influences determining the development of empyema persisted in a sporadic manner, giving rise to one case a month in fortuitous fashion. It is well to inquire into the character of these three cases. The first was admitted May 17 for lobar pneumonia in the lower lobe on both sides.[12] Nineteen days later a rib was resected and 20 c. c. of creamy pus yielding no growth on culture were evacuated. The wound was sutured about four weeks later and the patient was returned

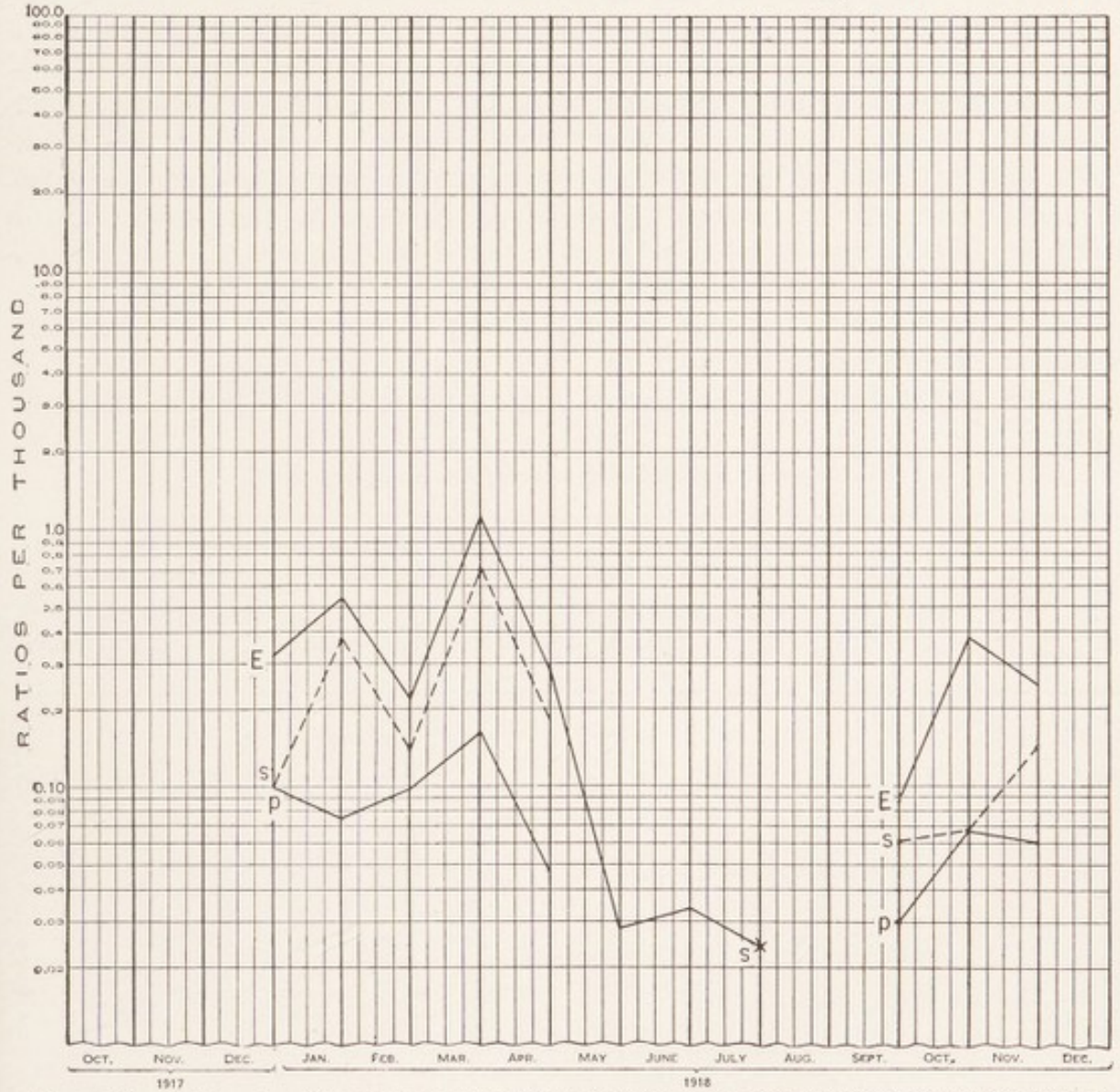


CHART VII.—Relationship of the pneumococcus and the streptococcus to the incidence of empyema at Camp Upton, N. Y.

to duty without any recorded complications. This history points to the probability of a pneumococcus infection overcome by natural processes, the operation promoting recovery through evacuation of a small residual pocket of pus. The June case was of a quite different character. The patient was admitted for measles, was operated (rib resected) 50 days later,[12] and ran a protracted course, being discharged from the Army on May 9, 1919, at General Hospital No. 12. There are no records of bacteriological findings. Finally, the July case was admitted for pneumonia on the 29th.[12] A rib was resected about three weeks later, about 150 c. c. of pus discharged, and an uneventful convalescence followed. Streptococci were found in the exudate.

There appears to be nothing of epidemiological interest in these cases. Two were mild cases, and all may be regarded as an aftermath of the preceding group of greater severity.

The curve of streptococcus, as shown in Chart VII cases, closely parallels that of the total empyema cases in the first period. This is not due to arbitrarily including doubtful diagnosis among the streptococci. There was only one record of "diplococcus" and this was in September, 1918. The prevailing streptococcus was hemolytic, but there were four cases associated with streptococcus viridans, all occurring in January, 1918. Of the pneumococci, 19 per cent were Type I; 25 per cent Type II, and 56 per cent Type IV. There was a considerable number of sterile fluids. Brooks and Cecil report 15 such among the 80 cases studied by them,[16] representing 18 per cent of the total. Seven died and only six are definitely reported as having operative treatment beyond aspiration. It is difficult to avoid the impression that a more careful study would have associated these cases with a definite infection of the pleura. They leave an unexplained hiatus in the records. A single autopsy in this group of sterile fluids revealed general miliary tuberculosis. This case has already been referred to (p. 67).

The bacteriological data of cases during the influenzal period are very meager.

TABLE 7.[a]—*Epidemiological table for Camp Upton, N. Y.*

| | Absolute numbers. | | | | | Ratios per 1,000 men. | | | | | Empyema, mortality percentage. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Empyema, totals. | Empyema, deaths. | Streptococcus group. | Pneumococcus group. | Staphylococcus. | Pneumonia. | Common respiratory diseases. | Empyema. | Streptococcus group. | Pneumococcus group. | |
| 1917. | | | | | | | | | | | |
| October | 0 | 0 | 0 | 0 | 0 | 0.25 | 2.81 | 0 | 0 | 0 | 0 |
| November | 0 | 0 | 0 | 0 | 0 | .37 | 8.52 | 0 | 0 | 0 | 0 |
| December | 10 | 5 | 3 | 3 | 0 | 1.17 | 24.19 | 0.3343 | 0.1003 | 0.1003 | 50 |
| 1918. | | | | | | | | | | | |
| January | 15 | 7 | 10 | 2 | 0 | 1.46 | 30.67 | .5605 | .3736 | .0747 | 47 |
| February | 7 | 4 | 4 | 3 | 0 | .69 | 15.93 | .2290 | .1308 | .0982 | 57 |
| March | 40 | 20 | 25 | 6 | 0 | 2.98 | 49.89 | 1.1321 | .7076 | .1398 | 50 |
| April | 10 | 6 | 7 | 2 | 0 | 1.38 | 12.40 | .2344 | .1641 | .0469 | 60 |
| May | 1 | 0 | 0 | 0 | 0 | .68 | 6.79 | .0273 | .0 | .0 | 0 |
| June | 1 | 0 | 0 | 0 | 0 | .65 | 4.07 | .0332 | .0 | .0 | 0 |
| July | 1 | 0 | 1 | 0 | 0 | .24 | 3.60 | .0257 | .0257 | .0 | 0 |
| August | 0 | 0 | 0 | 0 | 0 | .35 | 3.72 | .0 | .0 | .0 | 0 |
| September | 3 | 0 | 2 | 1 | 0 | 3.22 | 98.73 | .0915 | .0610 | .0305 | 0 |
| October | 6 | 1 | 3 | 3 | 0 | 20.03 | 151.65 | .3776 | .0687 | .0687 | 17 |
| November | 4 | 0 | 2 | 1 | 0 | 2.25 | 39.64 | .2448 | .1224 | .0612 | 0 |
| December | 0 | 0 | 0 | 0 | 0 | 1.71 | 20.87 | .0 | .0 | .0 | 0 |
| | 98 | 43 | 57 | 2.1 | 0 | ..... | ..... | ..... | ..... | ..... | 18.8 |

[a] Sources of information: 1. Reports of sick and wounded made to the Office of the Surgeon General. 2. Special empyema reports made to the Office of the Surgeon General.

## CAMP MEADE.

Camp Meade, Md., was situated a considerable distance from any large town, on rolling ground drained by sluggish streams.[10]

Drafted men were inducted into the National Army at this camp. They came from eastern Pennsylvania, Maryland, and the District of Columbia, a territory in which the inhabitants are 68.5 per cent urban. In November the strength of the camp averaged 31,000, including about 2,000 colored troops.[10]

Cases of communicable diseases were relatively few. Measles cases were most abundant in December, 1917 (113), and November, 1918 (161); the total number being 857 for the 15 months from and including October, 1917.[11] Eight cases of empyema, with five deaths, were associated with this disease, a little more than 0.9 per cent. It is noteworthy that none of these occurred in November, 1918, when the incidence of measles was maximum, but that two empyema cases fall in the month just preceding when the incidence of measles

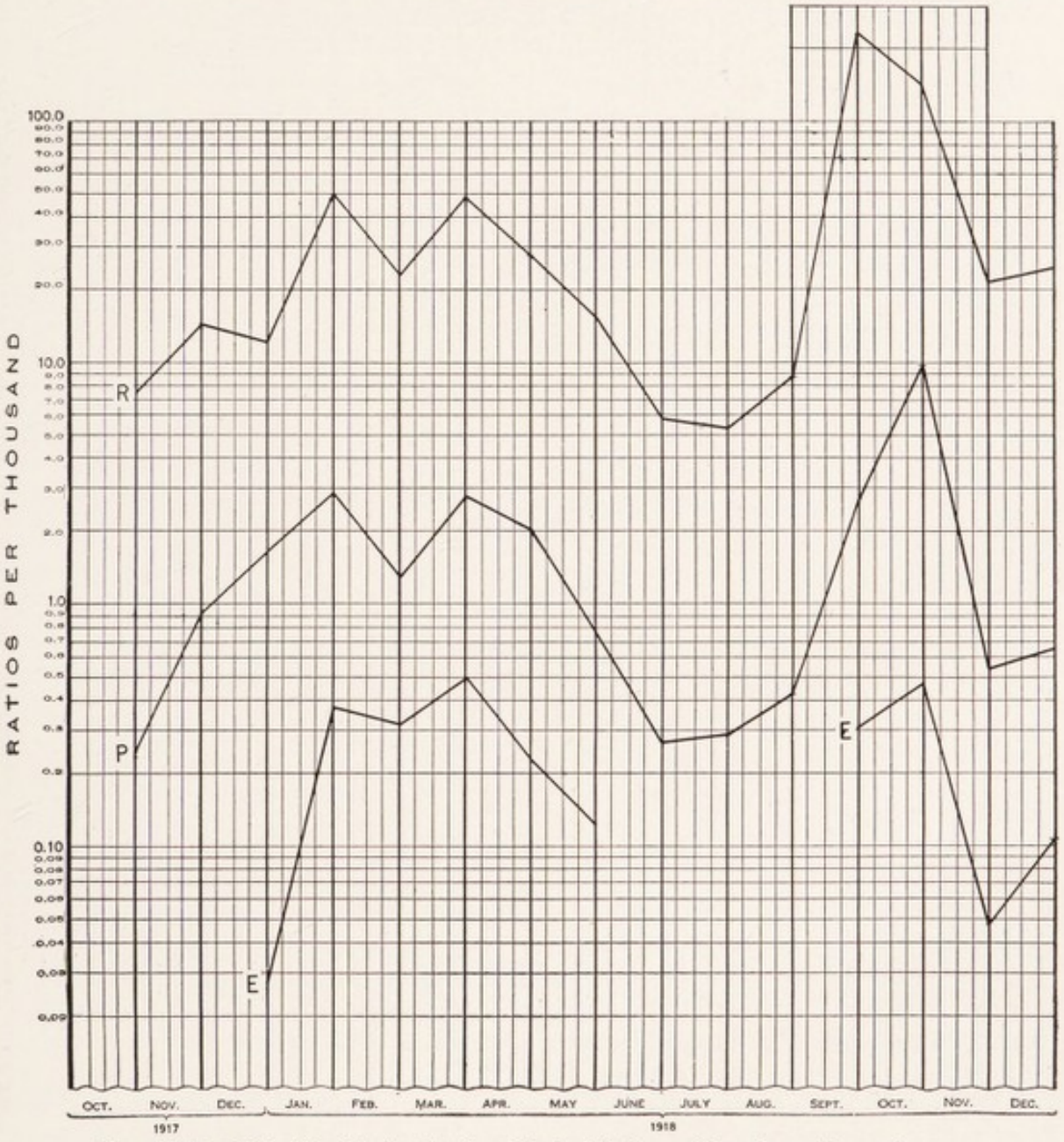


CHART VIII.—Epidemiological chart for Camp Meade, Md., in monthly ratios per thousand men.

was hardly more than one-third as great (55). Two cases of postmeasles empyema also occurred in March, 1919, when there were but 31 cases of measles. Bacteriological data are available in all but one of these empyema cases. With one exception, yielding pneumococcus, Type IV, they were all associated with a streptococcus, three definitely described as hemolytic, three undefined as to species.

Two cases of empyema were preceded by mumps, one in February and one in November, 1918. Both were associated with hemolytic streptococcus,

and both survived. The total incidence of mumps in camp during the period of 15 months was 897.[12]

Scarlet fever was followed by one case of empyema associated with streptococcus and proved fatal on the ninth day after admission.[12]

As happened so frequently elsewhere, the first case to develop empyema at Camp Meade followed measles. The date of admission of this case to the base hospital was December 29, 1917.[12] Lobar pneumonia in the right lower

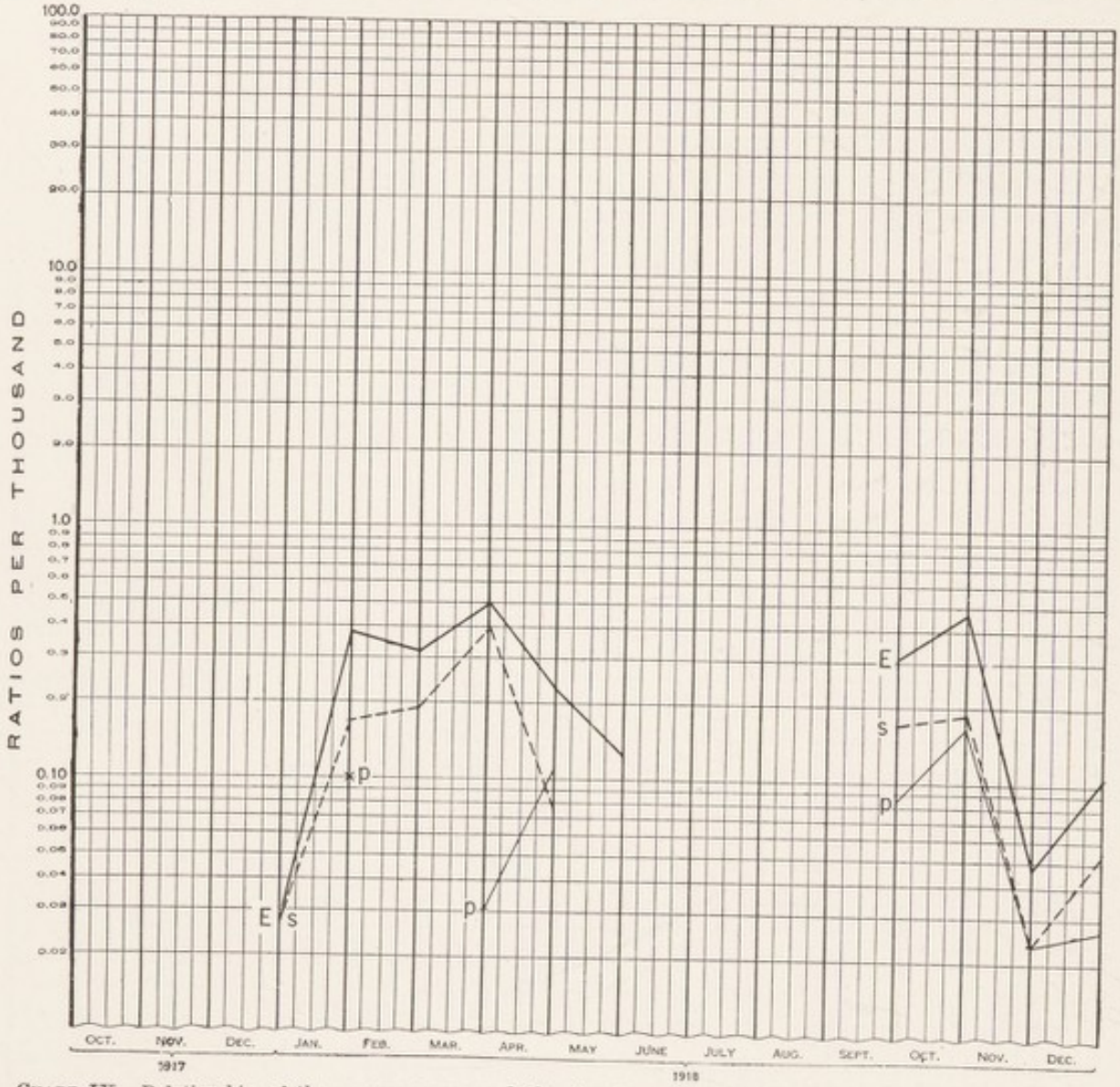


CHART IX.—Relationship of the pneumococcus and the streptococcus to the incidence of empyema at Camp Meade, Md.

lobe ensued 20 days later, followed by empyema for which a thoracotomy was done on the thirty-first day after entering the hospital. On April 14, 1918, half an inch of the eighth rib was resected and 300 c. c. of thick green pus containing hemolytic streptococci were evacuated. Postoperative treatment with Dakin's solution was instituted, but the wound did not close until nearly 100 days after this second operation. Complete recovery ensued without subsequent disability.[12]

The special empyema reports give a total of 87 empyema cases at Camp Meade during the latter part of 1917 and the whole of 1918.[12] Of these, 27 (or 31 per cent) died. Bacteriological examinations of the pleural exudate of 64 of these cases (74 per cent) were made, and of these, 70 per cent were streptococcus

and 27 per cent pneumococcus. One case was reported in May, 1918, as associated with staphylococcus. This patient recovered without marked subsequent disability. Finally, in one fatal case, occurring in October, 1918, the influenza bacillus alone was found. It is worthy of note that, during the first period of high incidence from December, 1917, to April, 1918, when there were 48 empyema cases, with a mortality of 20 (42 per cent), the streptococcus was found in the pleural fluids approximately four times as often as the pneumococcus, while in the later period of high incidence, with a mortality of 18 per cent, the proportion was 9.5, or somewhat less than half.

The curves for upper respiratory diseases, pneumonia and empyema all show a close similarity. The apparent irrelevancy of the pneumococcus in the first period and its prominence in the second are clearly shown. It is also noticeable that toward the end of the first period the pneumococcus rises in importance, while the streptococcus falls. This modification in the relative frequency of occurrence of these two organisms begins with that subsidence in the curve of common respiratory diseases leading without interruption to the minimum in July. There is no ambiguity in the bacteriological diagnoses from Camp Meade; but many cases were either not examined or the results of examination were not noted; otherwise, the curves representing the bacteria would have been closer to that of empyema.

It is particularly striking that the gap in the incidence of empyema, which separates the two periods, exactly corresponds to the drop of common respiratory diseases below 1 per cent of the men in camp. While, therefore, the pneumonias and other respiratory diseases remain in a nearly constant ratio to each other, there is some factor influencing the development of empyema which becomes inoperative when the incidence of the common respiratory diseases drops below a certain point. This point at Camp Meade and at Camp Devens is approximately 1 per cent of the command. At this point the evidence that streptococci were present in the pleural exudate also ceases. (Charts VIII and IX.)

TABLE 8.[a]—*Epidemiological table for Camp Meade, Md.*

| | Absolute numbers. | | | | | Ratios per 1,000 men. | | | | | Empyema, mortality percentage. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Empyema, totals. | Empyema, deaths. | Streptococcus group. | Pneumococcus group. | Staphylococcus. | Pneumonia. | Common respiratory diseases. | Empyema. | Streptococcus group. | Pneumococcus group. | |
| 1917. | | | | | | | | | | | |
| October | 0 | 0 | 0 | 0 | 0 | 0.24 | 7.44 | 0 | 0 | 0 | 0 |
| November | 0 | 0 | 0 | 0 | 0 | .93 | 14.17 | 0 | 0 | 0 | 0 |
| December | 1 | 0 | 1 | 0 | 1 | 1.61 | 12.07 | 0.0269 | 0.0269 | 0 | 0 |
| 1918. | | | | | | | | | | | |
| January | 11 | 5 | 5 | 3 | 0 | 2.87 | 49.33 | .3667 | .1667 | 0.1000 | 45 |
| February | 10 | 6 | 6 | 0 | 0 | 1.28 | 22.94 | .3167 | .1900 | .0 | 60 |
| March | 16 | 7 | 13 | 1 | 0 | 2.75 | 47.94 | .4931 | .4007 | .0308 | 44 |
| April | 6 | 2 | 2 | 3 | 0 | 2.02 | 27.80 | .2233 | .0744 | .1116 | 33 |
| May | 4 | 0 | 0 | 0 | 0 | .78 | 15.13 | .1222 | .0 | .0 | 0 |
| June | 0 | 0 | 0 | 0 | 0 | .26 | 5.72 | 0 | .0 | .0 | 0 |
| July | 0 | 0 | 0 | 0 | 0 | .29 | 5.34 | 0 | .0 | .0 | 0 |
| August | 0 | 0 | 0 | 0 | 0 | .42 | 8.77 | 0 | .0 | .0 | 0 |
| September | 11 | 1 | 6 | 3 | 0 | 2.66 | 231.74 | .3093 | .1688 | .0844 | 9 |
| October | 22 | 4 | 9 | 5 | 0 | 9.79 | 140.69 | .4592 | .1878 | .1669 | 18 |
| November | 2 | 0 | 1 | 1 | 0 | .54 | 21.12 | .0465 | .0232 | .0232 | 0 |
| December | 4 | 2 | 2 | 1 | 0 | .64 | 24.53 | .1082 | .0541 | .0271 | 50 |
| | 87 | 27 | 45 | 17 | 1 | ..... | ..... | ..... | ..... | ..... | 31 |

[a] Sources of information: 1. Reports of sick and wounded made to the Office of the Surgeon General. 2. Special empyema reports made to the Office of the Surgeon General.

## CAMP LEE.

Camp Lee, Va., was situated about 3 miles from Petersburg, on a plateau of sandy loam, muddy in wet weather, dusty in dry. It was a National Army cantonment, composed, in 1917, of drafted men from Virginia, West Virginia, and Pennsylvania.[10] It contained over 12,000 enlisted men in September of that year and the number rapidly increased, the average strength in November exceeding 35,000.[10] After the departure of the 80th Division, about May, 1918, Camp Lee was used as a replacement camp, but its strength was maintained at a high level throughout 1918. Nearly two-thirds of the men reaching camp in 1917 came from rural districts. On an average, approximately 13 per cent of the enlisted men were colored.[10]

There were 1,575 cases of measles during the 15 months from October, 1917, to December, 1918.[11] These measles cases presented two periods of high incidence. The first embraced November and December, 1917, and January, 1918, the cases for these months aggregating 549; the other extended through June, July, and August, 1918, and totaled 438. The cases of empyema, recorded as following measles, were 23 in number, constituting 1.4 per cent of the measles, and a little less than 15.5 per cent of the total for empyema (149). The chronological distribution of these diseases shows little relation between the two. In the first period the high incidence of empyema continued two months after that for measles had fallen off, while in the second period, also of three months' duration, only two cases of empyema appeared, while the total incidence of measles was, as stated, 438 cases. In the first period, the percentage for empyema was 17 of the total for measles, in the later period it was less than one-half of 1. Of the 23 cases of postmeasles empyema, so designated in the special empyema records, 3 died, a mortality of 13 per cent, whereas the mortality for all the empyemata, based on the same data, was 16.1 per cent. This low mortality in the postmeasles cases of empyema does not correspond with the experience in other camps.

Usually these cases fared less well than those with other histories. It is not possible to determine the reason for this apparent exception at Camp Lee, but reference may be made, in this connection, to the fact that fatal cases generally reveal adequate explanation of death irrespective of the empyema. It is a question whether empyema alone was responsible for many fatalities. In most cases it may be viewed as merely complicating pathological conditions of greater gravity. It might appear reasonable to class cases of death with empyema as due to the conditions with which it was associated, such as an extensive bilateral pneumonia, pericarditis, peritonitis, or meningitis following otitis media. Were this view consistently held, the number of deaths attributed to empyema would be materially affected, and some cases might be overlooked in examining the records. It is not feasible to determine whether these considerations apply to the records at Camp Lee. It appears quite certain, however, from the data already given, that no evidence is available in support of a close relation between measles and empyema, although the impression that such was the case prevailed during the first period of high incidence.[11]

Eleven cases of empyema are noted as following rubella.[12] One of these also had measles and is included among the fatal postmeasles cases already cited. The disease occurred in December, 1917, and as this death was the

only one at Camp Lee following rubella, it can not be associated with that disease except by coincidence. The other 10 cases were prior to the spring of 1918, and nearly all before the middle of January. Since about 400 cases of rubella had appeared in camp by that time, and there were subsequently over 2,000 cases, no epidemiological importance can be attached to a relationship between the two diseases.

There were but few (26) cases of scarlet fever, and none was followed by empyema.[11]

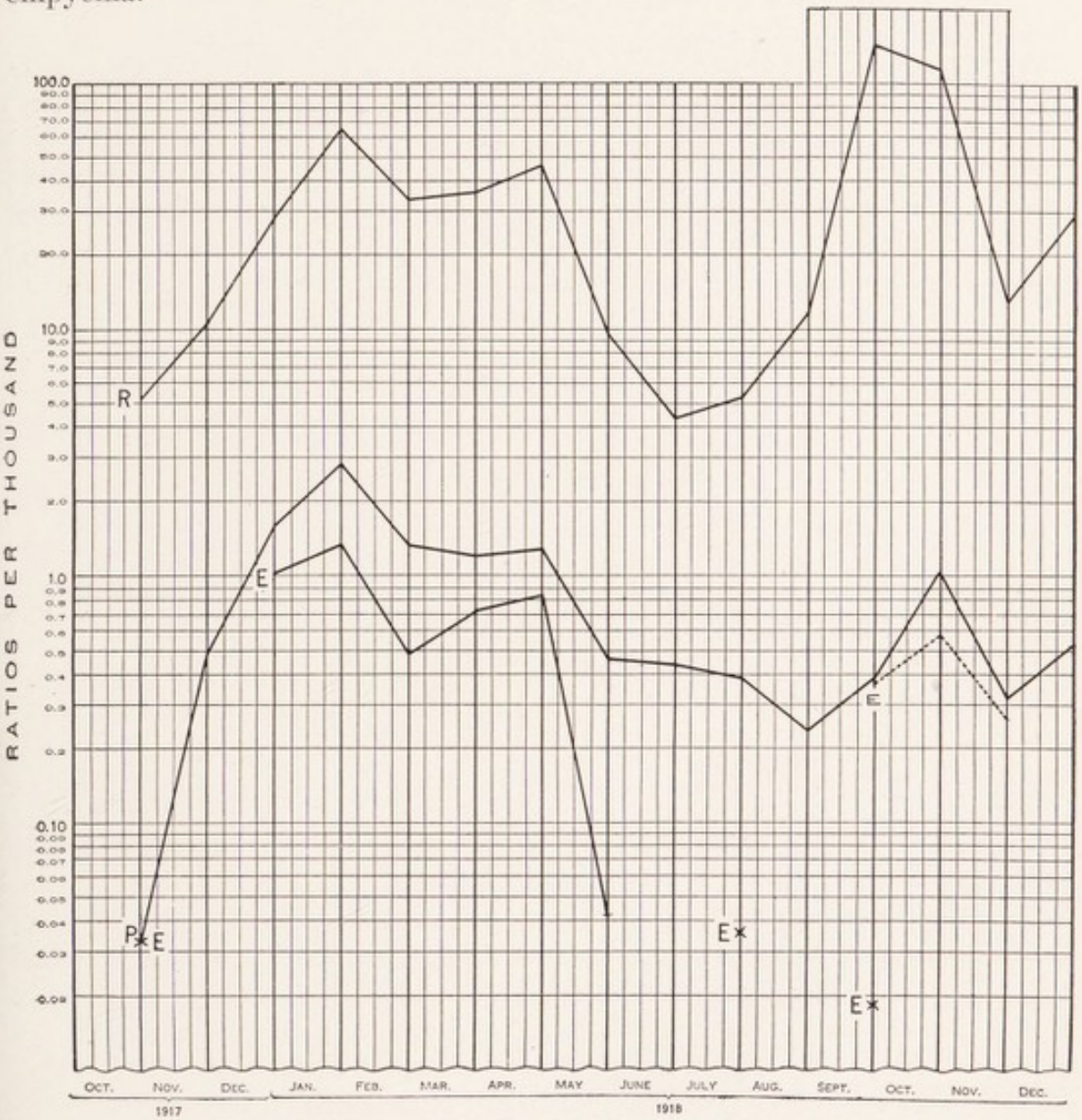


CHART X.—Epidemiological chart for Camp Lee, Va., in monthly ratios per thousand men.

The relation between streptococcus infection and empyema is particularly striking in the special empyema records from Camp Lee. Of the 149 cases, bacteriological examinations were reported in 114 (76.5 per cent).[12] Of these, 109 (95.6 per cent) show the presence of streptococcus in the pleural fluid, usually the hemolytic variety, and 5 (4.4 per cent) show the presence of pneumococcus. Four of the cases in which the exudate contained pneumococcus alone were in January, 1918, when the incidence of empyema was greatest (43 cases). They all appear to have followed primary lobar pneumonia and resulted in

recovery with but slight disability. The fifth was in July, following lobar pneumonia. This case was operated and returned to duty 72 days after admission, the history having been uneventful. The other case, occurring at about the same time, was also a lobar pneumonia and recovered without operation. There was no record of a bacteriological examination.

These last two cases are particularly referred to because they fall into a period of low incidence of respiratory diseases at Camp Lee. They appear to have been sporadic cases of no considerable epidemiological importance.

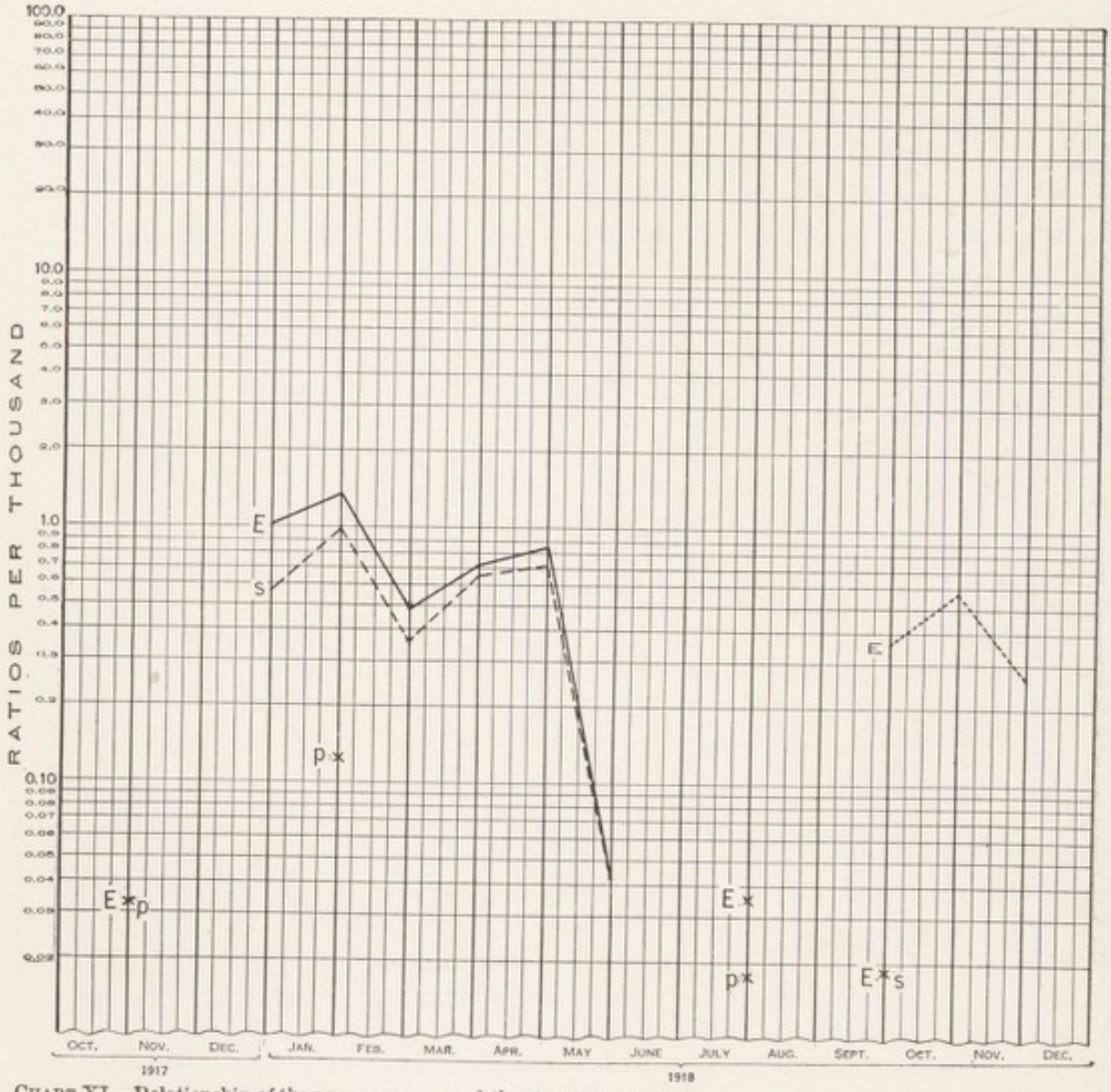


CHART XI.—Relationship of the pneumococcus and the streptococcus to the incidence of empyema at Camp Lee, Va.

When compared with those of the preceding camps, the graphic chart for Camp Lee is remarkable for the low position of the curve for pneumonia. It is very close to that of empyema and relatively distant from that representing diseases of the upper respiratory tract, nor does it so closely follow the direction of the latter as was the case at Camp Meade. Apparently the pneumonias were relatively less abundant, but more frequently complicated with empyema. This close relationship between the pneumonias and empyemata was presumably due to the prevalence of hemolytic streptococci at that time. The path-

ology of pneumonias associated with this organism shows that they are prone to develop empyema. (Vide Chapter III.)

The special empyema records contain but a single case of empyema during the pandemic of influenza in the autumn of 1918.[12] But in a "Diary of the Base Hospital, Camp Lee, Va.," [17] by the commanding officer, it is stated that cases of influenza appeared on September 13, and that 8 days later bronchopneumonia made its appearance, being followed, up to December 1, by 60 cases of empyema, with only 2 deaths due to complications. Thirty-seven of the cases came to operation. Neither the distribution in time nor the bacteriology of these cases is given. They can not, therefore, be accurately included in the tabulation of cases for this camp. In Charts X and XI they are represented by a dotted line indicating the probable distribution. The total number of empyema cases is small; for there were 7,773 cases of influenza during this period (September 13 to December 1, 1918) and the mortality was low. This may be attributed to the successful efforts to avoid crowding the patients, barracks being evacuated for their reception, and additional medical officers and nurses being provided for their care. All these provisions were made in advance of the requirements, so that no overwhelming emergency occurred at any time. It is believed that the low incidence of pneumonias, as well as empyemata, was due to this foresight and energy.

TABLE 9.[a]—*Epidemiological table for Camp Lee, Va.*

| | Absolute numbers. | | | | | Ratios per 1,000 men. | | | | | Empyema, mortality percentage. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Empyema, totals. | Empyema, deaths. | Streptococcus group. | Pneumococcus group. | Staphylococcus. | Pneumonia. | Common respiratory diseases. | Empyema. | Streptococcus group. | Pneumococcus group. | |
| 1917. | | | | | | | | | | | |
| October | 1 | 0 | 0 | 0 | 0 | 0.03 | 5.17 | 0.0324 | 0.0 | 0.0324 | 0 |
| November | 0 | 0 | 0 | 0 | 0 | .48 | 10.57 | .0 | .0 | .0 | 0 |
| December | 34 | 8 | 19 | 0 | 0 | 1.58 | 28.16 | 1.0235 | .5722 | .0 | 24 |
| 1918. | | | | | | | | | | | |
| January | 43 | 1 | 32 | 4 | 0 | 2.84 | 64.05 | 1.3190 | .9820 | .1228 | 2 |
| February | 16 | 0 | 12 | 0 | 0 | 1.31 | 32.88 | .4779 | .3540 | .0 | 0 |
| March | 23 | 6 | 20 | 0 | 0 | 1.17 | 35.50 | .7256 | .6532 | .0 | 26 |
| April | 27 | 8 | 23 | 0 | 0 | 1.28 | 45.58 | .8411 | .7180 | .0 | 30 |
| May | 2 | 1 | 2 | 0 | 0 | .46 | 9.74 | .0419 | .0419 | .0 | 50 |
| June | 0 | 0 | 0 | 0 | 0 | .43 | 4.28 | .0 | .0 | .0 | 0 |
| July | 2 | 0 | 0 | 1 | 0 | .38 | 5.28 | .0349 | .0 | .0175 | 0 |
| August | 0 | 0 | 0 | 0 | 0 | .23 | 11.72 | .0 | .0 | .0 | 0 |
| September | 1 | 0 | 1 | 0 | 0 | .38 | 142.78 | .0183 | .0183 | .0 | 0 |
| October | 0 | 0 | 0 | 0 | 0 | 1.06 | 114.16 | .0 | .0 | .0 | 0 |
| November | 0 | 0 | 0 | 0 | 0 | .32 | 12.95 | .0 | .0 | .0 | 0 |
| December | 0 | 0 | 0 | 0 | 0 | .53 | 28.71 | .0 | .0 | .0 | 0 |
| | 149 | 24 | 109 | 5 | 0 | | | | | | 16.1 |

[a] Sources of information: 1. Reports of sick and wounded made to the Office of the Surgeon General. 2. Special empyema reports made to the Office of the Surgeon General.

## CAMP GREENE.

Camp Greene, near Charlotte, N. C., was a tent camp used to organize the 4th and 5th Regular Divisions. There were several thousand troops there during the latter part of 1917, but the strength increased very considerably during the first few months of 1918.[10] The weather proved wet and cold, and the men were much exposed both outside and in the tents, fuel and clothing being insufficient for this particular season. The ensuing close crowding probably influenced the spread of infections among the men.[10]

Information concerning empyema at Camp Greene is not confined to the special empyema records, which are mainly concerned with cases reaching the surgical service of the base hospital. The reply, dated March 5, to the questionnaire of February 21 gives an account of 26 cases prior to March 1, not included in the special records.[9] Of these 26 cases, 25 were not operated. The discrepancy between the two is therefore reduced to a single operated case. A published article by Elwyn, the internist on the local empyema team, includes a discussion of complicating empyema based upon the data given in the reply to the questionnaire.[18]

There were many cases of measles at Camp Greene during the last three months of 1917 and the first three months of 1918, aggregating 1,435 for the six months.[11] During this period there were 73 cases of empyema upon which operations were performed and the 25 additional unoperated cases just referred to, making a total of 98, or 6.8 per cent of the measles. But the records specify only 43 cases of postmeasles empyema. This figure would reduce the ratio to 3 per cent. But even this is a higher proportion than those in the camps hitherto studied. The mortality was also higher (28 cases), reaching 65 per cent. The explanation of these high ratios is furnished by the bacteriology. In the reply to the questionnaire, it is stated that the organisms found in the order of their frequency were streptococcus hemolyticus, streptococcus viridans, and pneumococcus—never alone. The special empyema records, out of a total of 32 examinations, report 31 (97 per cent) as yielding a streptococcus, and only 1 associated with the pneumococcus.

Extending the period under consideration to include the whole of 1918, out of a total of 125 empyema cases, there are bacteriological records concerning 47 cases. In 42 of these (89 per cent) streptococci were found, in 5 (11 per cent) the pneumococcus.[12]

There were 4 cases of empyema following rubella, with 1 death. All of the 4 cases of empyema were associated with the streptococcus in pleural exudate. There were over 2,500 cases of rubella in the camp.[11]

In no case is there a record of scarlet fever preceding empyema.[12]

The reply to the questionnaire contains one very suggestive group of cases: "(d) Empyema without measles or pneumonia: Total cases 14; deaths, 4; mortality, 28.5 per cent; operated cases, 11; deaths, 1; mortality 9.1 per cent." No further details are given in the reply to the questionnaire; but in Elwyn's article there are several references to such cases.[18]

In this article Elwyn states that, in addition to the empyemata complicating lobar pneumonia, there were many empyemata complicating the purulent bronchitis following measles, and some empyemata secondary to other infections. From the beginning of the epidemic to March 1, 1918, there were 14 cases of empyema following bronchopneumonia or lobar pneumonia complicating measles, with 10 deaths (71.4 per cent mortality); 29 cases of empyema complicating measles alone, with 18 deaths (62 per cent mortality); and 14 cases of empyema unassociated with either measles or pneumonia with 4 deaths (28.5 per cent mortality).

Among the 393 cases of primary lobar pneumonia there were 45 cases of empyema (11.4 per cent) with 21 deaths (46.6 per cent mortality).

A class of empyemata is described that presented a picture totally unlike any other cases of empyema the writer (Elwyn) had seen.[18] These were very

severe cases and frequently appeared after the pneumonia had subsided; they appeared also in the course of measles, bronchitis, and, in a few cases, secondary to tonsillitis, or without any assignable cause. The course of events was as follows: "The patient was admitted for measles, and developed during the course the ordinary mild bronchitis accompanying measles. This gradually increased in severity, and after a time became purulent, involving every bronchus and bronchiole in both lungs. This was followed by consolidation of one or

CHART XII.—Epidemiological chart for Camp Greene, N. C., in monthly ratios per thousand men.

more lobes. Empyema complicated the pneumonia or occurred without the pneumonia." [18]

A more extended discussion of such cases must be deferred to the chapter on pathology; but that streptococcic infections may penetrate the pleura without clearly defined clinical evidence of pulmonary consolidation has much epidemiological significance. It suggests that empyema is not always and necessarily a sequela of pneumonia, but that the incidence of the two may to some extent be dissociated.

For the later, or influenzal, period of high incidence, data additional to those in the special empyema records are furnished by an article in the current medical literature.[19] The period covered is from September 1, 1918, to February 28, 1919, but doubtless most of the cases included were in October, 1918. Of the 39 cases with pleuritic effusion, positive bacteriological data are given in 16. Of these, 56 per cent (9 cases) fall into the streptococcus group and 44 per cent (7 cases) into the group of pneumococcus infections. This proportion is of the same order as that furnished by the special empyema records for the

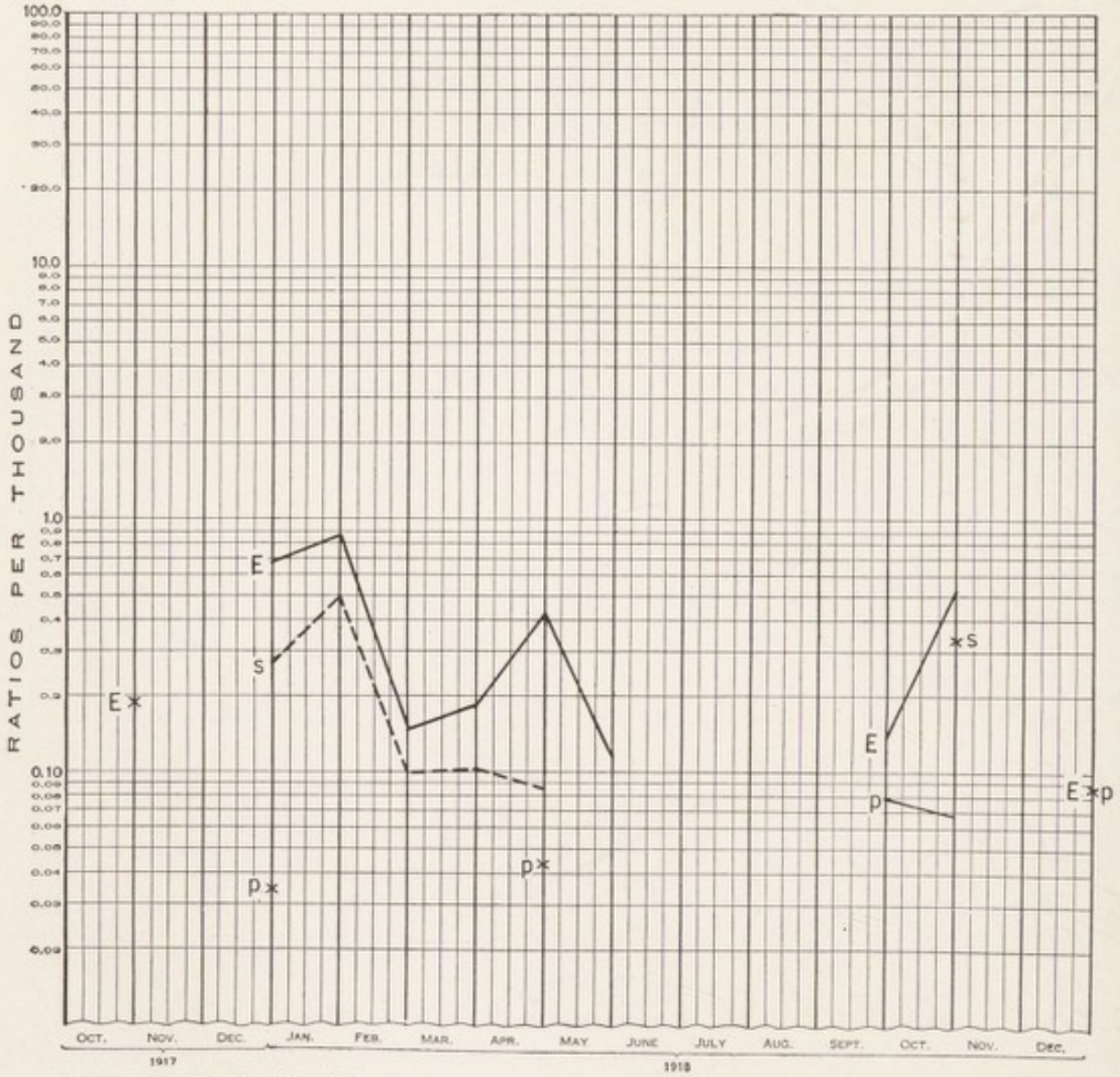


CHART XIII.—Relationship of the pneumococcus and the streptococcus to the incidence of empyema at Camp Greene, N. C.

shorter period ending with December, 1918. Although the number of cases is smaller, streptococci constituted 62.5 per cent, pneumococcus 37.5 per cent.

A mere glance at the curves given in Chart XII suffices to reveal the opposed trend of the pneumonias and empyemata, and the general correspondence of the latter to diseases of the upper respiratory tract. In this camp the empyema curve is interrupted between June and October, there being no case for July, August, and September. During those three months, the incidence of upper respiratory diseases was less than 1 per cent of the command. This

relationship between affections of the upper respiratory tract and empyema was called to the attention of the medical officers at the time, as is evidenced by the information abstracted from the article by Elwyn.[18] The clinical detection of inconspicuous pneumonic processes in the presence of empyema is clearly shown to be difficult.

TABLE 10.[a]—*Epidemiological table for Camp Greene, N. C.*

| | Absolute numbers. | | | | | Ratios per 1,000 men. | | | | | Empyema, mortality percentage. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Empyema, totals. | Empyema, deaths. | Streptococcus group. | Pneumococcus group. | Staphylococcus. | Pneumonia. | Common respiratory diseases. | Empyema. | Streptococcus group. | Pneumococcus group. | |
| 1917. | | | | | | | | | | | |
| October | 3 | 0 | 0 | 0 | 0 | 0.82 | 7.29 | 0.1863 | 0.0 | 0.0 | 0 |
| November | 0 | 0 | 0 | 0 | 0 | .60 | 7.83 | .0 | .0 | .0 | 0 |
| December | 20 | 6 | 8 | 1 | 0 | 1.78 | 46.96 | .6734 | .2689 | .0336 | 30 |
| 1918. | | | | | | | | | | | |
| January | 33 | 16 | 19 | 0 | 0 | 3.65 | 52.85 | .8518 | .4908 | .0 | 48 |
| February | 6 | 3 | 4 | 0 | 0 | 1.74 | 27.80 | .1499 | .0991 | .0 | 50 |
| March | 7 | 3 | 4 | 0 | 0 | 1.59 | 20.72 | .1808 | .1029 | .0 | 43 |
| April | 10 | 4 | 2 | 1 | 0 | 3.57 | 60.99 | .4292 | .0860 | .0429 | 40 |
| May | 2 | 0 | 0 | 0 | 0 | .24 | 11.44 | .1130 | .0 | .0 | 0 |
| June | 0 | 0 | 0 | 0 | 0 | .18 | 8.41 | .0 | .0 | .0 | 0 |
| July | 0 | 0 | 0 | 0 | 0 | .13 | 6.46 | .0 | .0 | .0 | 0 |
| August | 0 | 0 | 0 | 0 | 0 | 1.06 | 7.16 | .0 | .0 | .0 | 0 |
| September | 2 | 0 | 0 | 1 | 0 | .54 | 22.94 | .1386 | .0 | .0793 | 0 |
| October | 15 | 2 | 5 | 1 | 0 | 3.91 | 149.67 | .5386 | .3315 | .0663 | 13 |
| November | 0 | 0 | 0 | 0 | 0 | 3.63 | 15.99 | .0 | .0 | .0 | 0 |
| December | 1 | 0 | 0 | 1 | 0 | 2.91 | 15.39 | .0873 | .0 | .0873 | 0 |
| | 99 | 28 | 42 | 5 | 0 | ..... | ..... | ..... | ..... | ..... | 28.3 |

[a] Sources of information: 1. Reports of sick and wounded made to the Office of the Surgeon General. 2. Special empyema reports made to the Office of the Surgeon General.

## CAMP HANCOCK.

Camp Hancock, Ga., located near the city of Augusta, was used for men of the National Guard from Pennsylvania, reinforced later from New York and to a relatively slight extent from other States.[10] The 28th Division, organized here, was moved overseas about May, 1918, after which the camp was used as a machine-gun replacement camp.[10] The men were quartered in tents. The weather during the winter of 1917-18 was unusually cold for this part of the country, but not wet, and there is no indication that the men suffered hardship from exposure.

The strength of the camp was high from the beginning, 27,000 men were received in September, 1917, and the number in camp ranged between this figure and 34,000 until May, 1918, when it fell to somewhat under 12,000 on the departure of the 28th Division.[10]

The special empyema records from this camp are deficient in the number of cases given for the early months. They detail only 6 cases prior to March, 1918,[12] whereas the reply to the questionnaire of February 21 records 18 for this period;[8] but the actual dates for these 18 are not given, so that it is not possible to place them in chronological order. The cases which occurred during the 1918 autumnal period of high incidence are probably more correctly reported in the special empyema records.

Cases of measles were not numerous at Camp Hancock. For the whole period of 15 months to and including December, 1918, there were 640, but 434 of these were during the last 4 months.[11] Prior to March 1, 1918, 96 cases were admitted to the base hospital. Four of these developed pneumonia, but none an empyema which could be demonstrated clinically, though in one case a small pocket of pus was found at autopsy on the under surface of the right lower lobe and not at the periphery of the lung. Counting this case, less than 1 per cent of the measles during this period developed empyema.[11]

In the following November there was another postmeasles case, following bronchopneumonia. This was associated with pneumococcus, Type IV, and recovered. During this month there were 238 cases of measles, 45 complicated with pneumonia, almost exclusively lobular.[11]

There were nearly a thousand cases of mumps at Camp Hancock during the 15 months, but none of these developed empyema.[11]

Empyema followed scarlet fever in two cases.[11] In the pleural fluid of one, pneumococcus, Type IV, was found; in the other, a diplococcus, the species not defined. Both cases originated in November, within two days of each other, and both recovered. The total number of cases of scarlet fever for 1918 was 388, but the chronological distribution of these can not be given.

In the reply cited above the following data concerning the organisms found in pleural fluids are given: Pneumococcus alone (9); streptococcus alone (3); streptococcus and pneumococcus together (2); undetermined (4). Taking into account only the positive findings and giving precedence to the streptococcus, this would be associated with 36 per cent of the cases. According to the special empyema reports, the ratio was 38 per cent for the whole 15 months. The streptococcus apparently played a much less important part at Camp Hancock than in the camps hitherto considered in this chapter. It is possible, however, that this would be an erroneous conclusion were it applied to all periods. In October, 1918, there was a marked rise in the number of empyema cases. Taking the total for the whole 15 months at the known figure, 60 (probably too low), 25 (40 per cent) fall in the month of October, 1918, with a mortality of 24 per cent (six cases). The bacteriology for the 19 surviving cases is given as pneumococcus, Type IV, 16; Type IV with hemolytic streptococcus, 1; Type I, 1; "diplococcus," 1. The bacteriology for the six fatal cases is given as Type IV, 3; Type III, with hemolytic streptococcus, 1; hemolytic streptococcus alone, 1; "streptococcus," 1. It is striking that, out of the 25 cases, 19 should be associated with pneumococcus, Type IV, and that streptococci should have played a rôle so minor, for: "Prior to the epidemic of influenza at Camp Hancock there occurred in one company an outbreak of hemolytic streptococcus infection of peculiar virulence and uniform course. There is reason for thinking that the spread of disease in these cases was by food or milk infection." [20] There were but few cases of empyema at that time. Autopsy showed a streptococcus infection, with a remarkable affinity for the trachea, gradually extending down through the bronchi; and, though there was a visible peribronchitis and peritracheitis, the larynx and the lungs escaped invasion. This series of cases is mentioned because there were points of similarity with the bronchitis which accompanied influenza infection later and which uniformly showed a bronchitis and peribronchitis very similar to these cases, but accompanied by pulmonary emphysema and what was called bronchopneumonia.

In October, 1918, the influenza epidemic reached its height at this camp, and in the article just quoted[20] appears a description of cases of interstitial pneumonia like those described at other camps, with localized and often multiple empyemata and pulmonary abscesses. It appears probable that streptococcus was associated with many of these cases. The bacteriological findings are given as varied, but no statistics are presented. The involvement of the pleura is described as tardy and was attributed, at least in some cases, to rupture of lung abscesses into the pleural cavity after adhesions had formed. In consequence, the empyemata were localized and in some cases drained spontaneously through a bronchial communication. Cases of this character are of great interest; they suggest a slowing down of a process which at other camps proceeded with great rapidity. There were 6,813 cases of influenza at Camp Hancock in October, 1918, with 274 deaths, a mortality of 4 per cent.

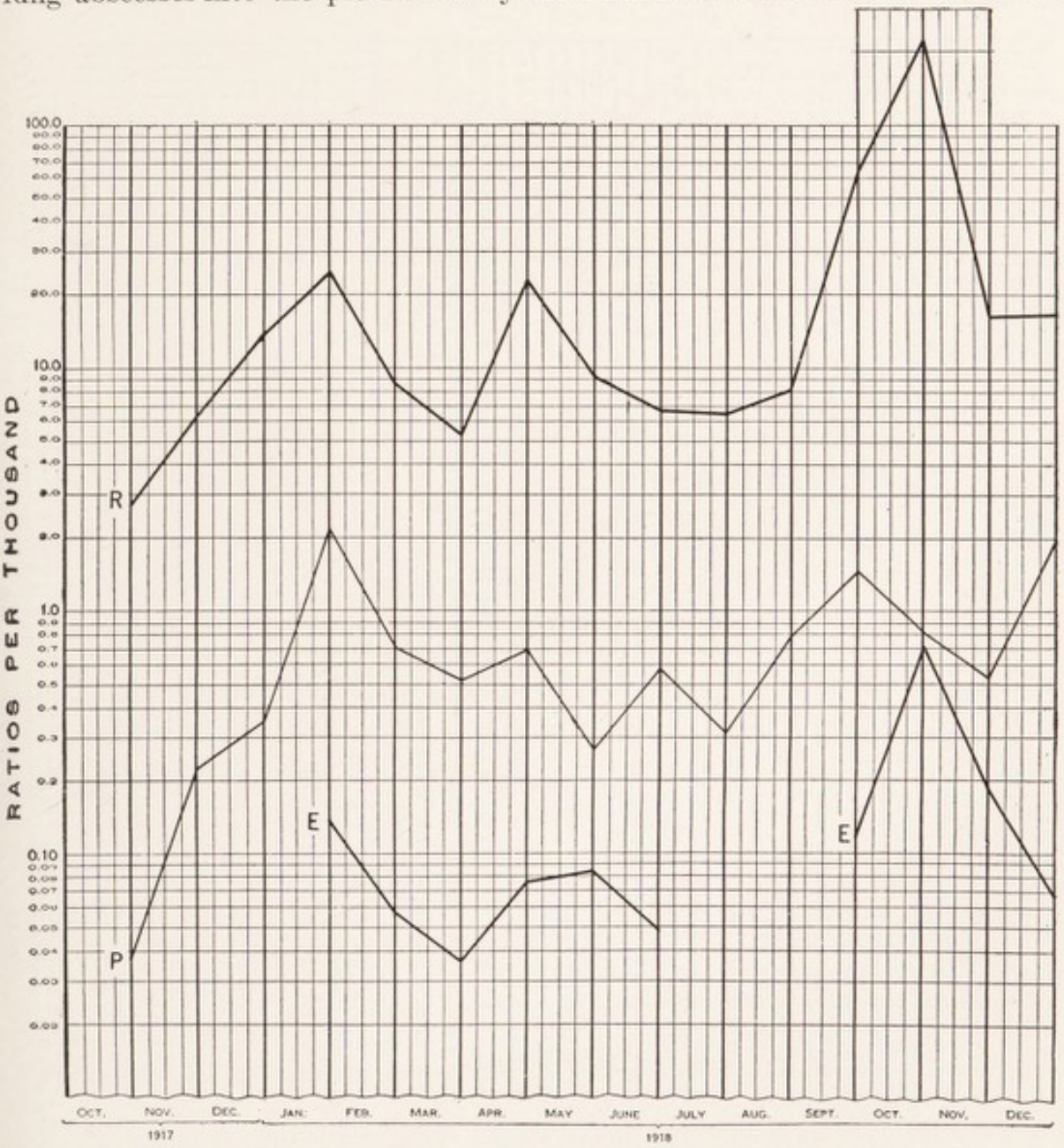


CHART XIV.—Epidemiological chart for Camp Hancock, Ga., in monthly ratios per thousand men.

Chart XIV, based, as to empyema, on the special empyema records, but in all other respects upon the sick and wounded records in the office of the Sur-

geon General of the Army, is of interest because of the low incidence of common respiratory affections (R) until the advent of epidemic influenza. In February and March, the incidence of these diseases fell below 1 per cent of the command, and was but a little over 0.5 per cent in the latter month. After the relatively high incidence in April, the number again fell off and did not rise above 1 per cent until the following September.

If the observations made in the preceding camps on the relations between empyema and common respiratory diseases were applicable to Hancock, one

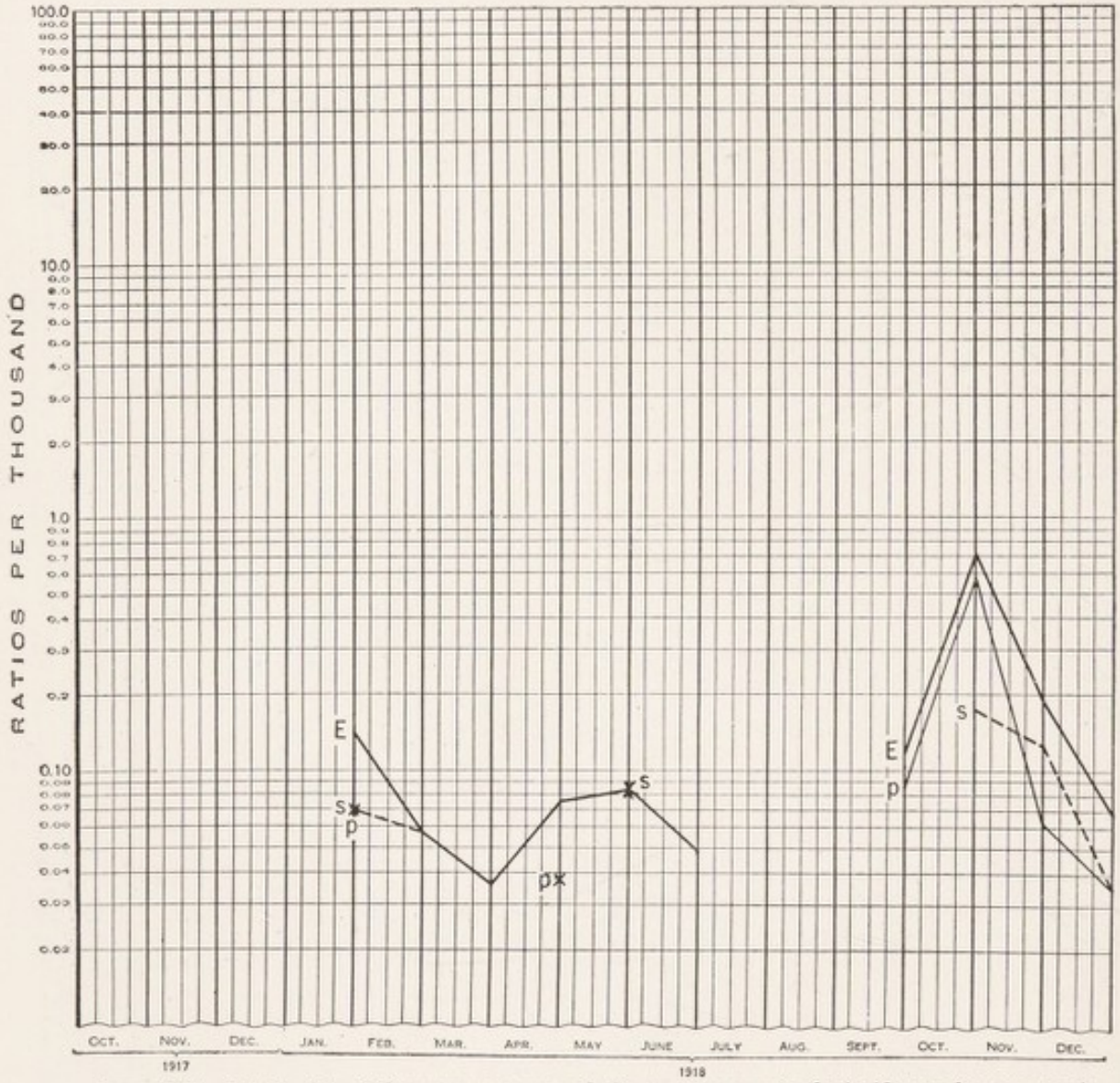


CHART XV.—Relationship of the pneumococcus and the streptococcus to the incidence of empyema at Camp Hancock, Ga.

might expect an absence of empyema in March, May, and June. According to the records,[12] there actually was but one case in each of these months, and the histories of these are not without some significance. The case occurring in March developed a pneumonia in the right lower lobe after an operation (appendectomy) presumably performed under general anesthesia. Empyema was discovered 10 days later when 20 c. c. of pus were aspirated from the chest. A portion of the eighth rib was removed the following day. Later, a substernal abscess was drained; and about four months after admission to the hospital, the case was transferred to Fort McPherson, Ga. There does not appear to have been fur-

ther operative treatment, and the patient was discharged from the Army on January 25, 1919. There is no bacteriological record of this case. The case in May also followed anesthesia. Bronchopneumonia of the left lower lobe was diagnosticated on May 9, and empyema on the right side three days later. Resection of the eighth rib was done on May 18, and the wound closed about three months later. Influenza bacilli and nonhemolytic streptoccoci were obtained from the purulent exudate. The case made a good recovery. The last of this group of cases was admitted for lobar pneumonia on June 3, developed empyema 12 days thereafter, and four days later was operated, a portion of the ninth rib being resected, and about 100 c. c. of pus evacuated. A good recovery followed, but the patient suffered from shortness of breath and was discharged from the Army on December 17. There are no bacteriological data.[12]

The foregoing histories definitely connect two of these cases with a preceding anesthesia which probably had an influence in determining the empyema. The third case appears to have been a sporadic case of pneumococcus pleural infection, such as might occur at any time of year appear in a population of over 20,000 people. None of the cases necessarily invalidates the impression that empyema cases drop to insignificant figures when infections of the upper respiratory tract fall below 1 per cent.

TABLE 11.[a]—*Epidemiological table for Camp Hancock, Ga.*

| | Absolute numbers. | | | | | Ratios per 1,000 men. | | | | | Empyema, mortality percentage. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Empyema, totals. | Empyema, deaths. | Streptococcus group. | Pneumococcus group. | Staphylococcus. | Pneumonia. | Common respiratory diseases. | Empyema. | Streptococcus group. | Pneumococcus group. | |
| 1917. | | | | | | | | | | | |
| October | 0 | 0 | 0 | 0 | 0 | 0.04 | 2.74 | 0 | 0 | 0 | 0 |
| November | 0 | 0 | 0 | 0 | 0 | .22 | 6.32 | 0 | 0 | 0 | 0 |
| December | 0 | 0 | 0 | 0 | 0 | .35 | 13.94 | 0 | 0 | 0 | 0 |
| 1918. | | | | | | | | | | | |
| January | 4 | 1 | 2 | 2 | 0 | 2.18 | 24.44 | 0.1380 | 0.0690 | 0.0690 | 25 |
| February | 2 | 2 | 2 | 0 | 0 | .71 | 8.69 | .0571 | .0571 | .0 | 100 |
| March | 1 | 0 | 0 | 0 | 0 | .52 | 5.30 | .0357 | .0 | .0 | 0 |
| April | 2 | 0 | 0 | 1 | 0 | .69 | 22.82 | .0745 | .0 | .0373 | 0 |
| May | 1 | 0 | 1 | 0 | 0 | .26 | 9.26 | .0846 | .0846 | .0 | 0 |
| June | 1 | 0 | 0 | 1 | 0 | .58 | 6.62 | .0487 | .0 | .0 | 0 |
| July | 0 | 0 | 0 | 0 | 0 | .31 | 6.44 | .0 | .0 | .0 | 0 |
| August | 0 | 0 | 0 | 0 | 0 | .78 | 8.03 | .0 | .0 | .0 | 0 |
| September | 4 | 0 | 0 | 3 | 0 | 1.45 | 63.91 | .1177 | .0 | .0859 | 0 |
| October | 25 | 6 | 6 | 19 | 0 | .82 | 220.63 | .7112 | .1710 | .5700 | 24 |
| November | 6 | 0 | 4 | 2 | 0 | .53 | 16.15 | .1841 | .1232 | .0615 | 0 |
| December | 2 | 0 | 1 | 1 | 0 | 1.99 | 16.59 | .0682 | .0341 | .0341 | 0 |
| | 48 | 9 | 16 | 27 | 0 | ..... | ..... | ..... | ..... | ..... | 18.8 |

[a] Sources of information: 1. Reports of sick and wounded made to the Office of the Surgeon General. 2. Special empyema reports made to the Office of the Surgeon General.

## CAMP SEVIER.

Camp Sevier, S. C., was about 4 miles from Greenville, a city with about 20,000 inhabitants.[10]

Troops of the National Guard from Tennessee, North Carolina, and South Carolina were assembled here, but were soon augmented by drafted men transferred from other camps.[10] Early in November, 1917, the strength reached 27,000 and remained at about that figure until May, 1918, when the 30th Division was sent overseas. The number of men in camp did not again reach 20,000 until the following September. There were no colored men prior to September, 1918. The troops were quartered in tents.[10]

The incidence of measles in this camp was high.[11] For the months of 1917 the total admissions for this disease were 3,005. For 1918 they were 665. The largest number for any single month was 2,524 in November, 1917, after which there was an abrupt falling off to 150 in December, and in March, 1918, only seven cases were admitted. There were four cases of postmeasles empyema included in the special empyema records.[12] One of these was admitted November 23, and the three others between December 3 and 7, 1917. The first case ended in death six days after the onset of empyema; an autopsy re-

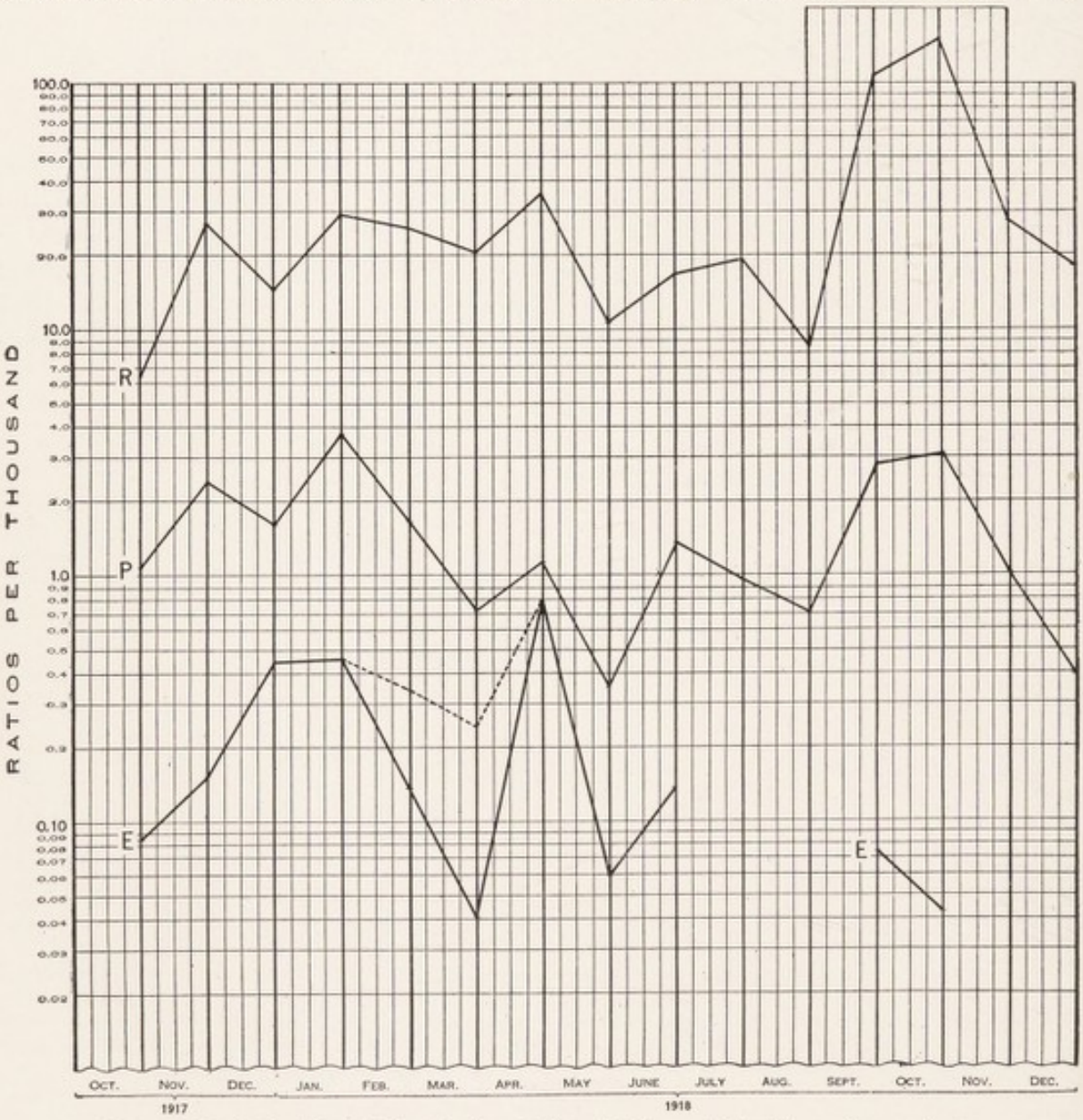


CHART XVI.—Epidemiological chart for Camp Sevier, S. C., in monthly ratios per thousand men.

vealed general bronchopneumonia with pulmonary abscesses, bilateral empyema and mediastinal abscesses; and smears of the pus contained pneumococcus and streptococcus. In the three surviving cases a bacteriological examination is recorded for one only, a pneumococcus being found. Even though a small number of empyema cases probably escaped inclusion in these records, it is obvious that measles had little to do with the incidence of empyema.

The same is true of mumps. Only one case of empyema appears to have followed this infection; a fatal case, admitted for mumps December 31, 1917,

a month when there were 306 admissions for this disease, while in January, February, and March, 1918, there were over 3,900 such admissions with no cases of empyema developing among them. There was no postscarlatinal empyema.[12]

Table 12 is based upon the special empyema reports, to preserve uniformity in this respect with the other camps represented on the map shown in Figure 3 (p. 49). But as already set forth, these data must be regarded as minimal rather than absolute. Thus, for Camp Sevier, in the reply to the question-

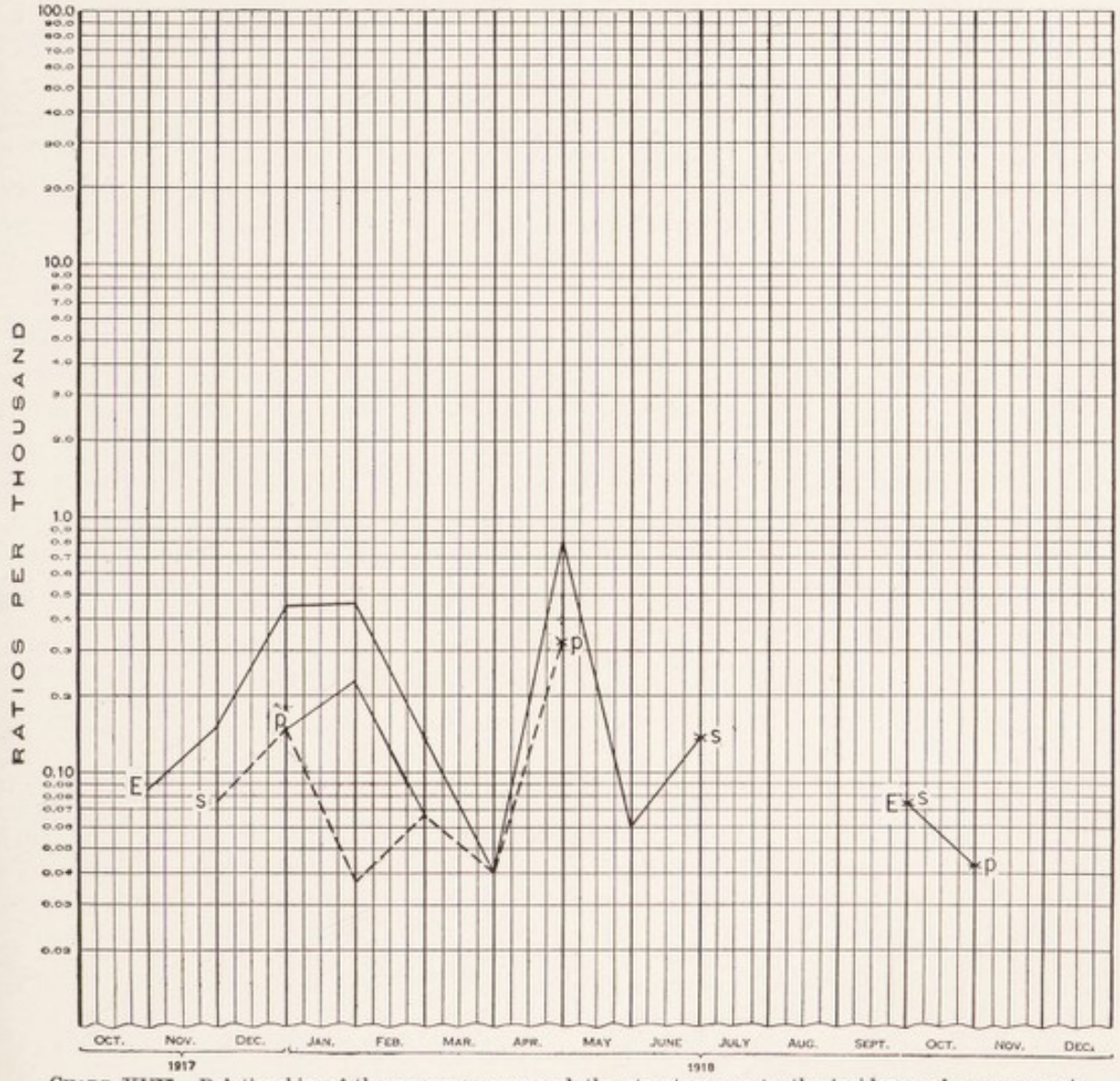


CHART XVII.—Relationship of the pneumococcus and the streptococcus to the incidence of empyema at Camp Sevier, S. C.

naire of February 21, 1918,[9] dated March 18, it is stated that there had been 46 cases of operated empyema, up to that time, 27 following lobar pneumonia and 19 following bronchopneumonia. This is 11 more than those contained in the special empyema reports. In the reply, there is no mention of any organism except pneumococcus. Of 42 positive findings, 39 were Type IV, two Type I, and one Type II. It appears justifiable to conclude that, at Camp Sevier, the streptococcus of whatever strain was less significant than in many other localities, and that, like Camp Hancock, pneumococcus, Type IV, predominated.

In Chart XVI the graphic transcription of the table brings to the eye very clearly the anomalous returns for February and March. According to the trend of curves at other camps, there should have been more empyemata in these months at Camp Sevier than were included in the special empyema records. As a matter of fact, as stated in the preceding paragraph, such was the case. There were 11 additional empyema cases that belong to the period prior to April 1, but among which months they should be distributed is unknown. If, purely as a matter of speculation, these 11 cases are divided as evenly as possible between February and March, six cases in the former and five in the latter month, the empyema curve would be modified as shown by the dotted line, giving to it a general resemblance to the curve "R."

The high incidence in April was coincident with a considerable increase of cases of influenza, which reached 653 in that month, in contrast to 143 the month preceding and 47 the month following. The organisms associated with the empyemata in April were about equally divided between the streptococcus and pneumococcus groups. Such has been the case in postinfluenzal empyema elsewhere.

The unusual rise of the curve "R" in June and July was not due to influenza, but to an increase in the "other respiratory diseases," and, corresponding to this, is a sympathetic rise in the empyema curve, coupled with an increase in the importance of the streptococcus. It would be straining the evidence to lay stress on particular deductions from such a small number of cases, but when such small groups of cases show the same correlation between empyema and infections of the upper respiratory tract as is displayed by much larger numbers in other and widely separated localities, this circumstance is not without significance.

TABLE 12[a].—*Epidemiological table for Camp Sevier, S. C.*

| | Absolute numbers. | | | | | Ratios per 1,000 men. | | | | | Empyema, mortality percentage. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Empyema, totals. | Empyema, deaths. | Streptococcus group. | Pneumococcus group. | Staphylococcus. | Pneumonia. | Common respiratory diseases. | Empyema. | Streptococcus group | Pneumococcus group. | |
| 1917. | | | | | | | | | | | |
| October | 2 | 1 | 0 | 0 | 0 | 1.05 | 6.28 | 0.0849 | 0 | 0 | 50 |
| November | 4 | 1 | 2 | 0 | 0 | 2.35 | 26.88 | .1519 | 0.0760 | 0 | 25 |
| December | 12 | 4 | 4 | 4 | 0 | 1.59 | 14.42 | .4396 | .1465 | 0.1465 | 33 |
| 1918. | | | | | | | | | | | |
| January | 12 | 5 | 1 | 6 | 0 | 3.70 | 29.17 | .4493 | .0374 | .2246 | 42 |
| February | 4 | 0 | 2 | 2 | 0 | 1.62 | 25.46 | .1343 | .0671 | .0671 | 0 |
| March | 1 | 1 | 1 | 0 | 0 | .72 | 20.37 | .0405 | .0405 | .0 | 100 |
| April | 10 | 4 | 4 | 4 | 0 | 1.12 | 34.43 | .7911 | .3166 | .3166 | 40 |
| May | 1 | 0 | 0 | 0 | 0 | .34 | 10.59 | .0596 | .0 | .0 | 0 |
| June | 1 | 0 | 1 | 0 | 0 | 1.32 | 16.75 | .1353 | .1353 | .0 | 0 |
| July | 0 | 0 | 0 | 0 | 0 | .95 | 19.05 | .0 | .0 | .0 | 0 |
| August | 0 | 0 | 0 | 0 | 0 | .71 | 8.46 | .0 | .0 | .0 | 0 |
| September | 2 | 1 | 2 | 0 | 0 | 2.81 | 108.56 | .0741 | .0741 | .0 | 50 |
| October | 1 | 1 | 0 | 1 | 0 | 3.08 | 149.78 | .0420 | .0 | .0420 | 100 |
| November | 0 | 0 | 0 | 0 | 0 | 1.01 | 27.51 | .0 | .0 | .0 | 0 |
| December | 0 | 0 | 0 | 0 | 0 | .39 | 17.93 | .0 | .0 | .0 | 0 |
| | 50 | 18 | 17 | 17 | 0 | ..... | ..... | ..... | ..... | ..... | 36 |

[a] Sources of information: 1. Reports of sick and wounded made to the Office of the Surgeon General. 2. Special empyema reports made to the Office of the Surgeon General.

## CAMP WHEELER.

Camp Wheeler, Ga., was situated about 5 miles from Macon, a city of 40,000 inhabitants. The first contingent to arrive was composed of men of the National Guard from Alabama, Florida, and Georgia, supplemented by transfers from other camps.[10] The troops were quartered in tents. The winter was unusually cold, and the consequent exposure of the men was aggravated by a severe storm of snow and sleet about the middle of December, the effects of which were said to last 10 days. In dry weather the camp was very dusty.

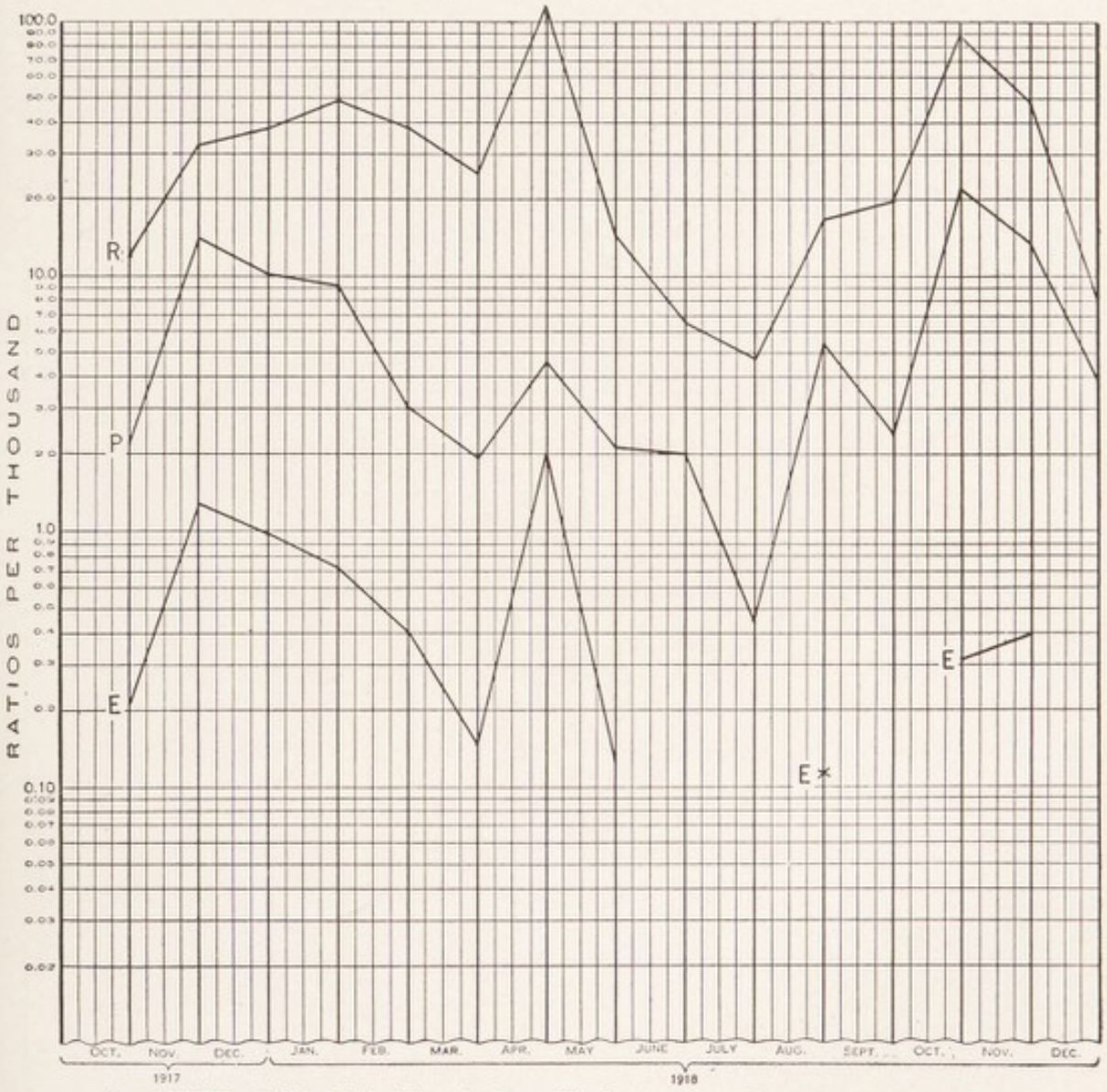


CHART XVIII.—Epidemiological chart for Camp Wheeler, Ga., in monthly ratios per thousand men.

These conditions may account, at least in part, for the relatively high incidence of respiratory diseases.[10]

As the base hospital was not fully established until the beginning of 1918, there were no special empyema records from this camp. The sources of information concerning the occurrence of empyema at Camp Wheeler, and upon which this study is based, are the reply to the questionnaire of February 21, 1918,[9] the clinical histories transmitted to the Surgeon General's Office after the base hospital was closed,[21] and unpublished clinical notes furnished by the chief of the surgical service.[22] Lacking a full index of diseases, the records from the

hospital were not in shape for ready reference, and in view of this and of the many thousand pages of daily notes which it was necessary to study, it appears unavoidable that some cases of empyema have been overlooked. Furthermore, under the conditions of unpreparedness just indicated, facilities for bacteriological examinations must have been deficient, and it is not surprising that in many cases records are entirely lacking. Notwithstanding these difficulties in obtaining them, it is probable that the data actually used compare favorably with those obtained from other camps from which the special empyema records were received.

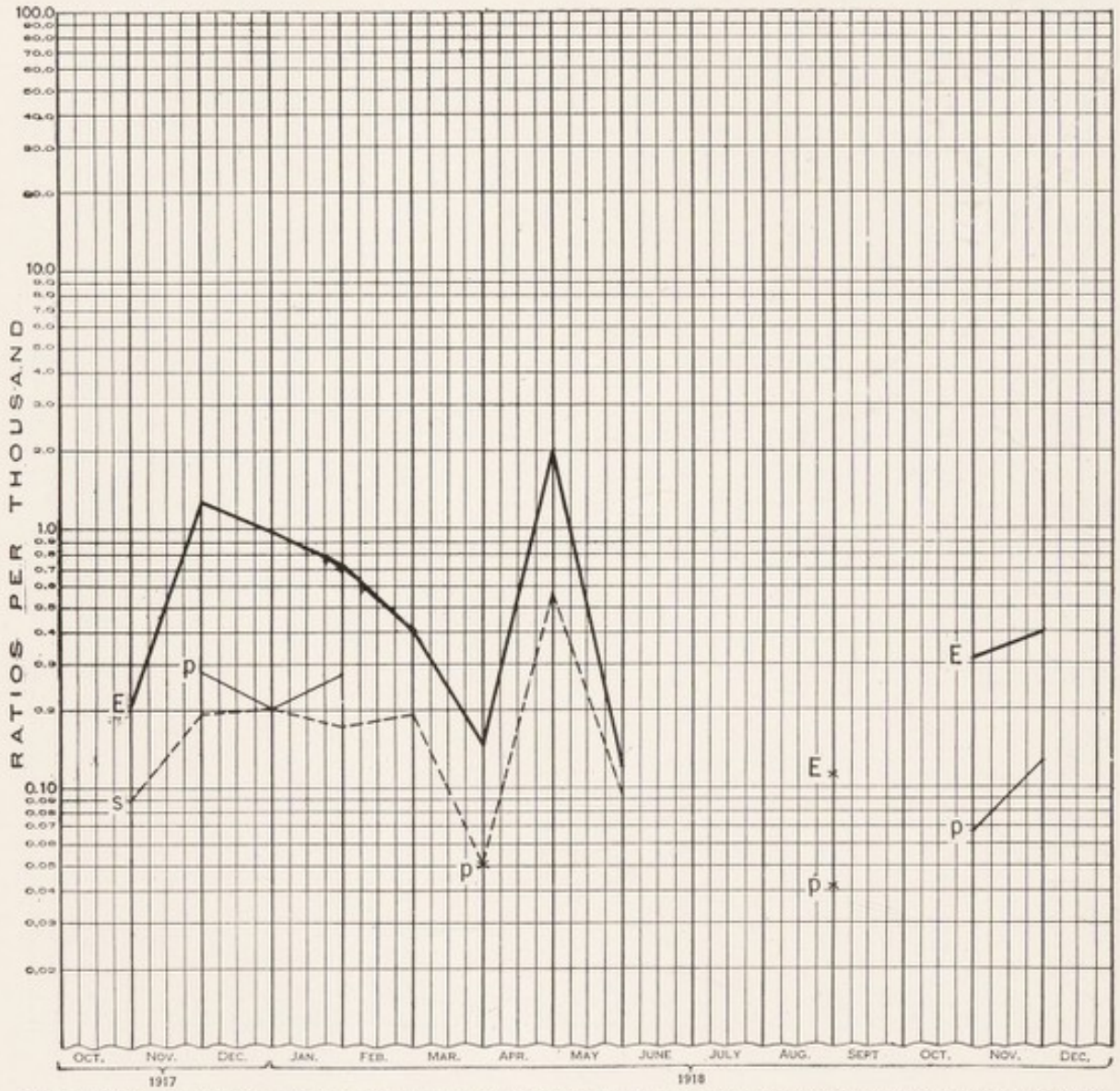


CHART XIX.—Relationship of the pneumococcus and the streptococcus to the incidence of empyema at Camp Wheeler, Ga.

There was a very high incidence of measles in the fall of 1917.[11] For November there were 2,421 cases, 86 of which were complicated with pneumonia, about equally divided between the lobar and lobular varieties. Ten of these 86 pneumonias developed empyema, with 6 deaths. This is a ratio of empyema to measles of about 0.41 per cent but a mortality of 60 per cent among the postmeasles empyemata, against 38.3 per cent for the total number of empyemata. During the remainder of the year there were three postmeasles

cases, with one death, although the admissions for measles had fallen to a relatively insignificant number.

Following mumps, five cases of empyema are on record, none fatal, although the admissions for mumps reached 5,379.[11]

There was no case of postscarlatinal empyema.[12]

It is important to note that in 20 cases during the autumn of 1917 and early in 1918 it is stated that the men suffered from severe colds (in one case with tonsillitis) prior to admission. This number would constitute about 22 per cent of the empyema cases recorded for that period.

The available bacteriological data indicate that 70 per cent of the cases examined belong to the streptococcus group and 30 per cent to the various types of pneumococcus.[12]

Chart XVIII for Camp Wheeler resembles Chart XVI for Camp Sevier. There is a similar abrupt but transient increase of empyema in April. This is here, also, coincident with an outbreak of influenza, which claimed 1,967 cases in that month against 245 in March and 167 in May. This outbreak occasioned a rise in the curve "R" higher than the autumnal peak in October. The course of the pneumonia curve in relation to the curve "R" suggests a possible difficulty in deciding how to classify some of the respiratory diseases at this camp, an uncertainty as to whether they should be placed among the influenza cases, regarded as bronchitis, or classed as pneumonia. In general, it may be observed that while all three curves rise or fall together, the excursions of the empyema curve are intermediate in extent between those of "P" and "R." If the grouping of the respiratory diseases were somewhat uncertain and not always completely consistent this might readily be reflected in the curves on the chart in just the way actually shown. It is not possible with the available data to analyze the conditions prevailing from month to month. Were it certain that the statistical data were complete, the chief interest would lie in a study of the pneumonias and other respiratory diseases rather than the empyemata.

TABLE 13.[a]—*Epidemiological table for Camp Wheeler, Ga.*

| | Absolute numbers. | | | | | Ratios per 1,000 men. | | | | | Empyema, mortality percentage. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Empyema, totals. | Empyema, deaths. | Streptococcus group. | Pneumococcus group. | Staphylococcus. | Pneumonia. | Common respiratory diseases. | Empyema. | Streptococcus group | Pneumococcus group. | |
| 1917. | | | | | | | | | | | |
| October | 5 | 2 | 2 | 0 | 0 | 2.41 | 13.95 | 0.2211 | 0.0885 | 0 | 40 |
| November | 35 | 13 | 3 | 2 | 0 | 15.34 | 33.99 | 1.3905 | .1985 | 0.2780 | 37 |
| December | 24 | 11 | 6 | 2 | 0 | 10.68 | 38.21 | .9673 | .2015 | .2015 | 46 |
| 1918. | | | | | | | | | | | |
| January | 16 | 8 | 4 | 5 | 0 | 9.22 | 49.20 | .7263 | .1818 | .2727 | 50 |
| February | 10 | 5 | 4 | 0 | 0 | 3.04 | 38.90 | .3977 | .1900 | .0 | 50 |
| March | 3 | 1 | 1 | 1 | 0 | 1.96 | 26.44 | .1507 | .0502 | .0502 | 33 |
| April | 18 | 6 | 11 | 1 | 0 | 4.65 | 119.81 | 1.9212 | .5640 | .0 | 33 |
| May | 3 | 1 | 2 | 0 | 0 | 1.11 | 15.20 | .1432 | .0958 | .0 | 33 |
| June | 0 | 0 | 0 | 0 | 0 | 1.03 | 6.71 | .0 | .0 | .0 | 0 |
| July | 0 | 0 | 0 | 0 | 0 | .47 | 4.72 | .0 | .0 | .0 | 0 |
| August | 3 | 1 | 2 | 1 | 0 | 5.49 | 16.74 | .1290 | .0 | .0429 | 33 |
| September | 0 | 0 | 0 | 0 | 0 | 2.46 | 19.33 | .0 | .0 | .0 | 0 |
| October | 5 | 1 | 0 | 1 | 0 | 23.40 | 89.61 | .3370 | .0 | .0675 | 20 |
| November | 6 | 0 | 0 | 2 | 0 | 14.69 | 48.13 | .3942 | .0 | .1315 | 0 |
| December | 0 | 0 | 0 | 0 | 0 | 3.91 | 8.16 | .0 | .0 | .0 | 0 |
| | 128 | 49 | 35 | 15 | 0 | ..... | ..... | ..... | ..... | ..... | 38.3 |

[a] Sources of information: 1. Reports of sick and wounded made to the Office of the Surgeon General. 2. Special empyema reports made to the Office of the Surgeon General.

## CAMP GORDON.

Camp Gordon, Ga., was situated on rolling ground previously occupied by small farms, within 10 miles of Atlanta, a city of over 150,000 inhabitants. It was a National Army cantonment, receiving drafted men from Alabama, Georgia, and Tennessee, but also contingents of considerable size from other camps.[10] In November, 1917, the average strength for the month had reached 27,000. The 82d Division moved overseas from here about May, 1918, but this did not materially reduce the average monthly strength, which

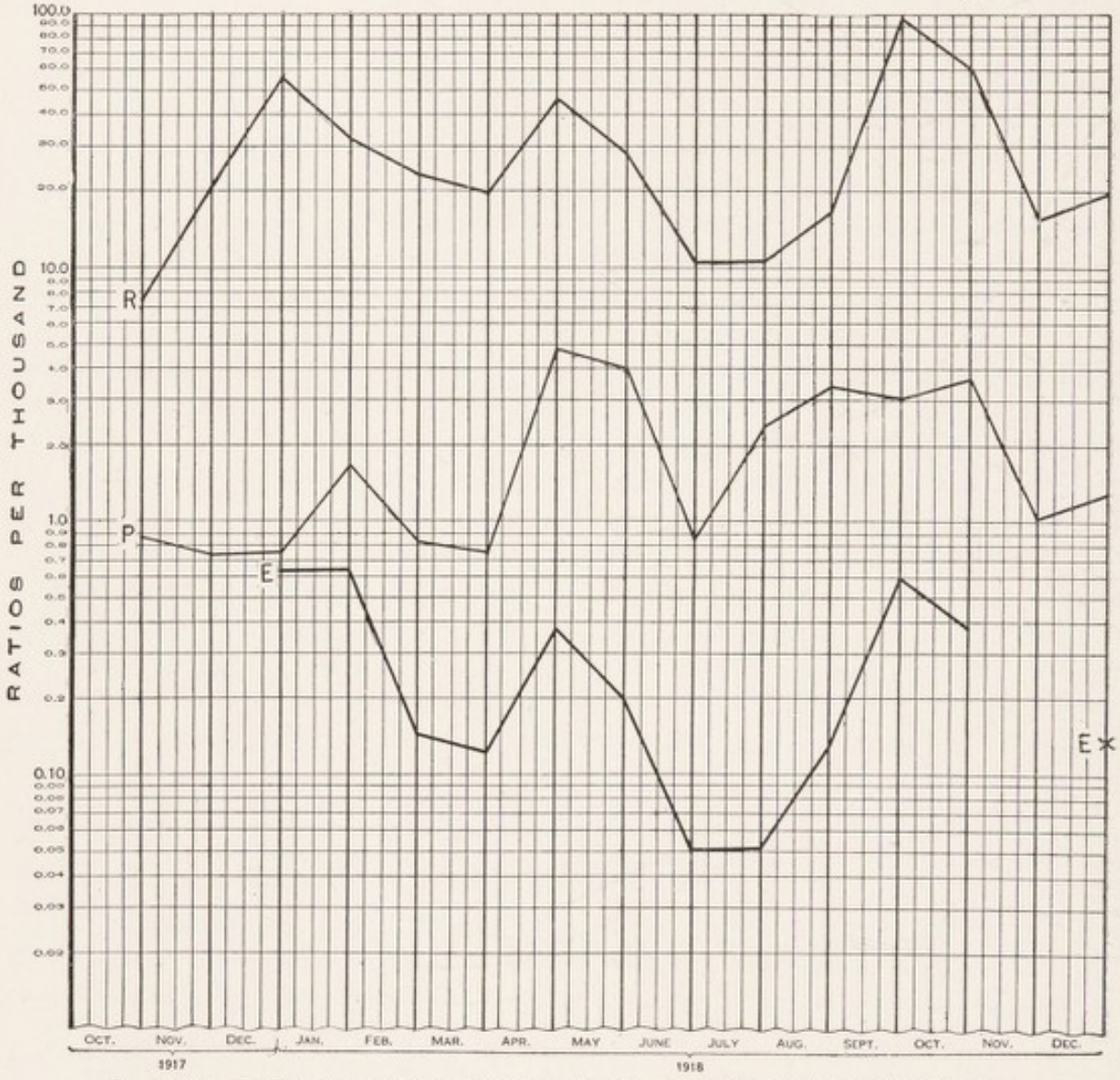


CHART XX.—Epidemiological chart for Camp Gordon, Ga., in monthly ratios per thousand men.

was maintained at from 27,000 to 46,000 by fresh accessions of drafted or transferred men.[10] Colored troops were included almost from the start.

The troops were quartered in frame barracks, which were heated with stoves, and poorly ventilated in cold weather.

Cases of measles were numerous during the last three months of 1917 and January, 1918, aggregating 1,051 cases for that period and 2,288 for the 15 months to and including December, 1918.[11] The postmeasles empyema cases are recorded in the special empyema reports as 27 for the first four months, with 18 deaths, and 13 for the remaining 11 months, all surviving.[12] In the

early period the mortality was, therefore, nearly 67 per cent; in the later, nil. Among the fatal cases (18) there are bacteriological records for 13. They were all associated with streptococci. Of the surviving (nine) cases in the earlier period, seven were streptococcic; in one a staphylococcus was found; and for the remaining case no data are given. Finally, among the 12 cases subsequent to January, 1918, 7 were associated with streptococcus, 2 with pneumococcus, Type IV, and for 3, data are lacking.

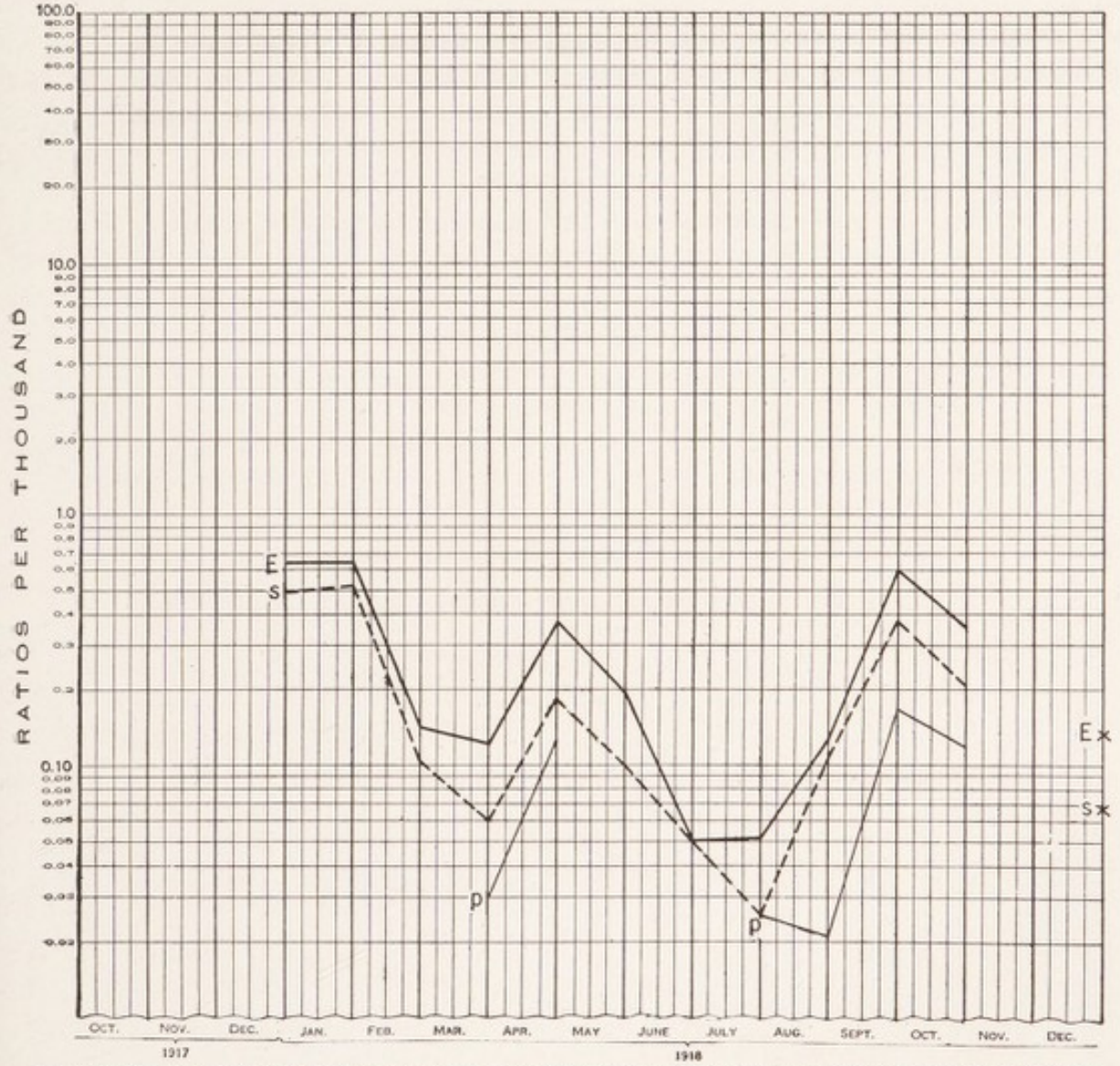


CHART XXI.—Relationship of the pneumococcus and the streptococcus to the incidence of empyema at Camp Gordon, Ga.

In the aggregate, 1.7 per cent of the total number of measles cases developed empyema, but of the postmeasles pneumonia cases, which were 119 for the whole period, 33.6 per cent were complicated with empyema, and, inferentially, the streptococcus must have been an important causative agency in the incidence of pneumonia among patients with measles.

No cases are recorded as following either mumps or scarlet fever, although there were nearly 5,000 admissions for the former disease.[12] The admissions for scarlet fever were only 10 for the whole period of 15 months.[12]

The number of cases of empyema, preceded by "colds," the exact character of which can not be stated, is considerable.

On Chart XX the similarity between the curves "R" and "E" is very striking, but in the early portion of "E" the excursions are exaggerations of those exhibited by "R." An explanation of this may be sought by inquiry into the nature of the diseases represented by the curve "R." As was the case at both Camp Sevier and Camp Wheeler, influenza was particularly prevalent at Camp Gordon in April, when there were 887 admissions classed as such. But there was also a high incidence in December, 1917, when 724 cases were reported. Since influenza throughout all the camps, with the possible exception of Camp Lee, appears to have predisposed to empyema, the high incidence of empyema in December and April may be correlated with that of influenza, added to the upper respiratory affections prevailing at the time. Cases of influenza were also relatively numerous in January and in May, but less so than in the months immediately preceding these.

Reference is especially made to the preponderance of streptococcus infections in December, January, and February, notwithstanding the prevalence of influenza, as contrasted with the advent of pneumococcus cases in March and April, which were then in about the same proportion to the streptococcus cases as in August and September, when influenza again showed a rise in incidence.

The curve of upper respiratory diseases never fell to quite 1 per cent of the command at Camp Gordon, and though the empyemata fell to a minimum with the lowest incidence shown by "R" in June and July, they did not entirely disappear. The histories of the four cases falling within these two months do not differ essentially from those of cases which developed at other times.

TABLE 14.[a]—*Epidemiological table for Camp Gordon, Ga.*

| | Absolute numbers. | | | | | Ratios per 1,000 men. | | | | | Empyema, mortality percentage. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Empyema, totals. | Empyema, deaths. | Streptococcus group. | Pneumococcus group. | Staphylococcus. | Pneumonia. | Common respiratory diseases. | Empyema. | Streptococcus group. | Pneumococcus group. | |
| 1917. | | | | | | | | | | | |
| October | 0 | 0 | 0 | 0 | 0 | 0.89 | 7.48 | 0 | 0 | 0 | 0 |
| November | 0 | 0 | 0 | 0 | 0 | .74 | 20.99 | 0 | 0 | 0 | 0 |
| December | 22 | 12 | 17 | 0 | 0 | .76 | 56.70 | 0.6388 | 0.4936 | 0 | 55 |
| 1918. | | | | | | | | | | | |
| January | 21 | 13 | 17 | 0 | 0 | 1.67 | 31.99 | .6444 | .5216 | 0 | 62 |
| February | 4 | 0 | 3 | 0 | 0 | .81 | 22.98 | .1404 | .1053 | 0 | 0 |
| March | 4 | 0 | 2 | 1 | 0 | .75 | 19.51 | .1200 | .0600 | 0.0300 | 0 |
| April | 12 | 2 | 6 | 1 | 0 | 4.79 | 46.68 | .3696 | .1848 | .1232 | 17 |
| May | 6 | 0 | 3 | 0 | 0 | 3.98 | 28.36 | .1993 | .0993 | .0 | 0 |
| June | 2 | 1 | 2 | 0 | 0 | .86 | 10.46 | .0506 | .0506 | .0 | 50 |
| July | 2 | 0 | 1 | 1 | 0 | 2.39 | 10.93 | .0511 | .0255 | .0255 | 0 |
| August | 6 | 0 | 5 | 1 | 0 | 3.36 | 16.98 | .1263 | .1052 | .0210 | 0 |
| September | 25 | 3 | 16 | 7 | 0 | 3.05 | 96.06 | .5910 | .3786 | .1656 | 12 |
| October | 12 | 1 | 7 | 4 | 0 | 3.60 | 60.42 | .3577 | .2086 | .1192 | 8 |
| November | 0 | 0 | 0 | 0 | 0 | 1.18 | 15.56 | .0 | .0 | .0 | 0 |
| December | 2 | 0 | 1 | 0 | 0 | 1.29 | 19.97 | .1328 | .0664 | .0 | 0 |
| | 118 | 32 | 80 | 15 | 0 | ..... | ..... | ..... | ..... | ..... | 27.1 |

[a] Sources of information: 1. Reports of sick and wounded made to the Office of the Surgeon General. 2. Special empyema reports made to the Office of the Surgeon General.

## CAMP McCLELLAN.

Camp McClellan, Ala., situated about 4 miles from Anniston, a city of approximately 14,000 inhabitants, was first used by the National Guard from New Jersey, Virginia, Maryland, and the District of Columbia, with small additions from other camps.[10] During the month of December, 1917, the strength

reached approximately 27,000.[10] The number of colored troops was negligible until September, 1918, when 2,480 arrived, chiefly if not wholly from Alabama.[10]

The men were quartered in tents.[10]

The total admissions for measles for the 15 months beginning October, 1917, was 939, 24 of which were complicated with pneumonia.[11] The months of highest incidence were December, 1917 (120 cases), January (168), and September, 1918 (184), but no cases of postmeasles empyema are recorded for these

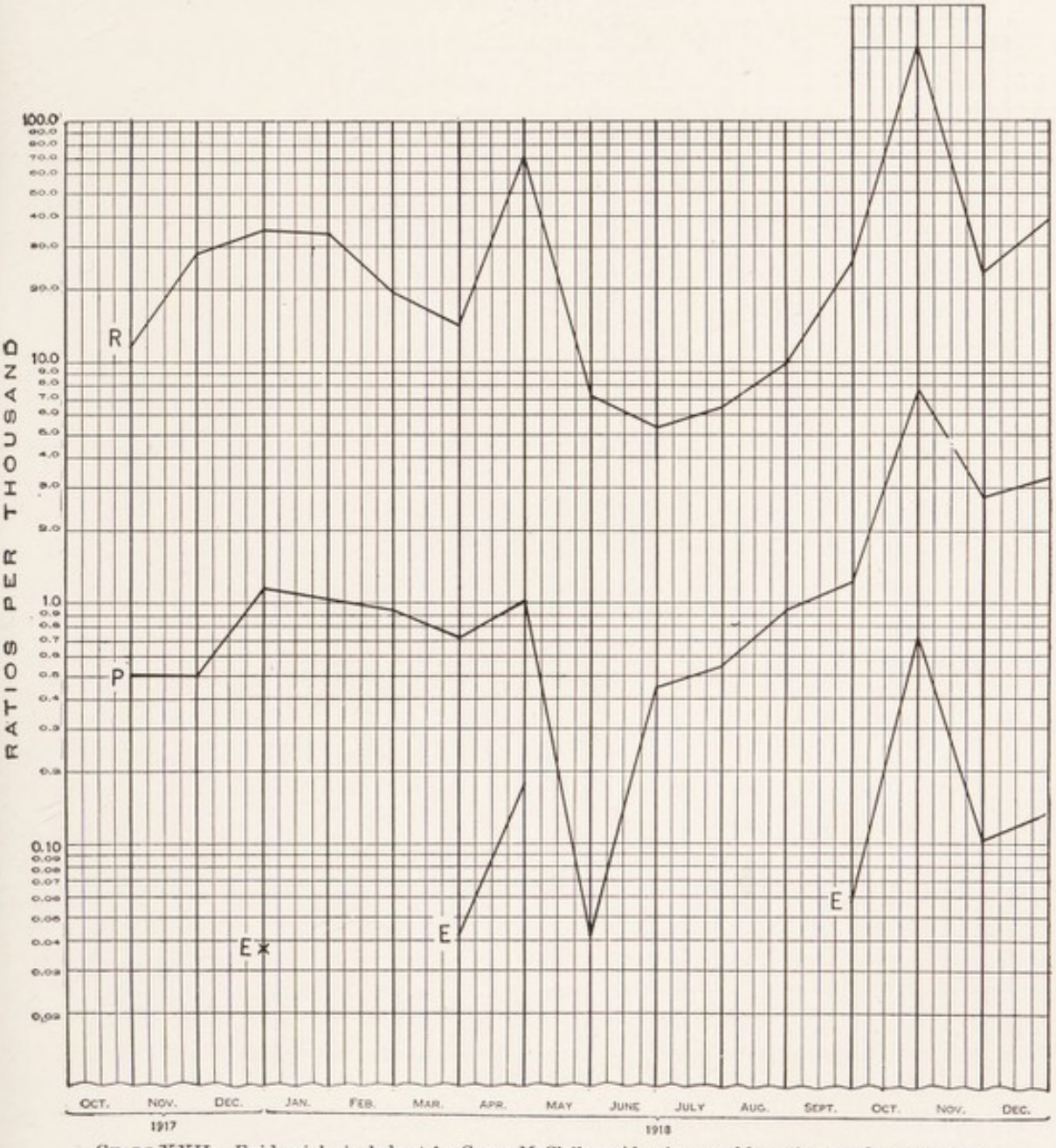


CHART XXII.—Epidemiological chart for Camp McClellan, Ala., in monthly ratios per thousand men.

months.[12] In fact, the only case of empyema reported as following measles was admitted November 29, 1918, when the incidence of measles had fallen to 84, with only 4 cases of pneumonia, all lobular. Bacteriological data concerning this single case are lacking.[11]

There were no cases preceded by either mumps or scarlet fever.[11]

The total incidence of empyema at Camp McClellan was small.[12] Were it not for the postinfluenzal accession of cases the number would appear negligible.

Until the beginning of March, 1918, the special empyema records contain only 2 cases. This number must, however, be supplemented by at least 4, for the reply, dated March 8, to the questionnaire of February 21 gives 6 cases, all following lobar pneumonia, of which there had been 92 within the same period. The organisms obtained from the pleural fluids were streptococcus, 2; pneumococcus, Type II, 1; Type IV, 1; influenza bacillus, 1; and mixed, 1. The cases included in the special empyema records were both associated with streptococcus and may be identical with the two of like association contained

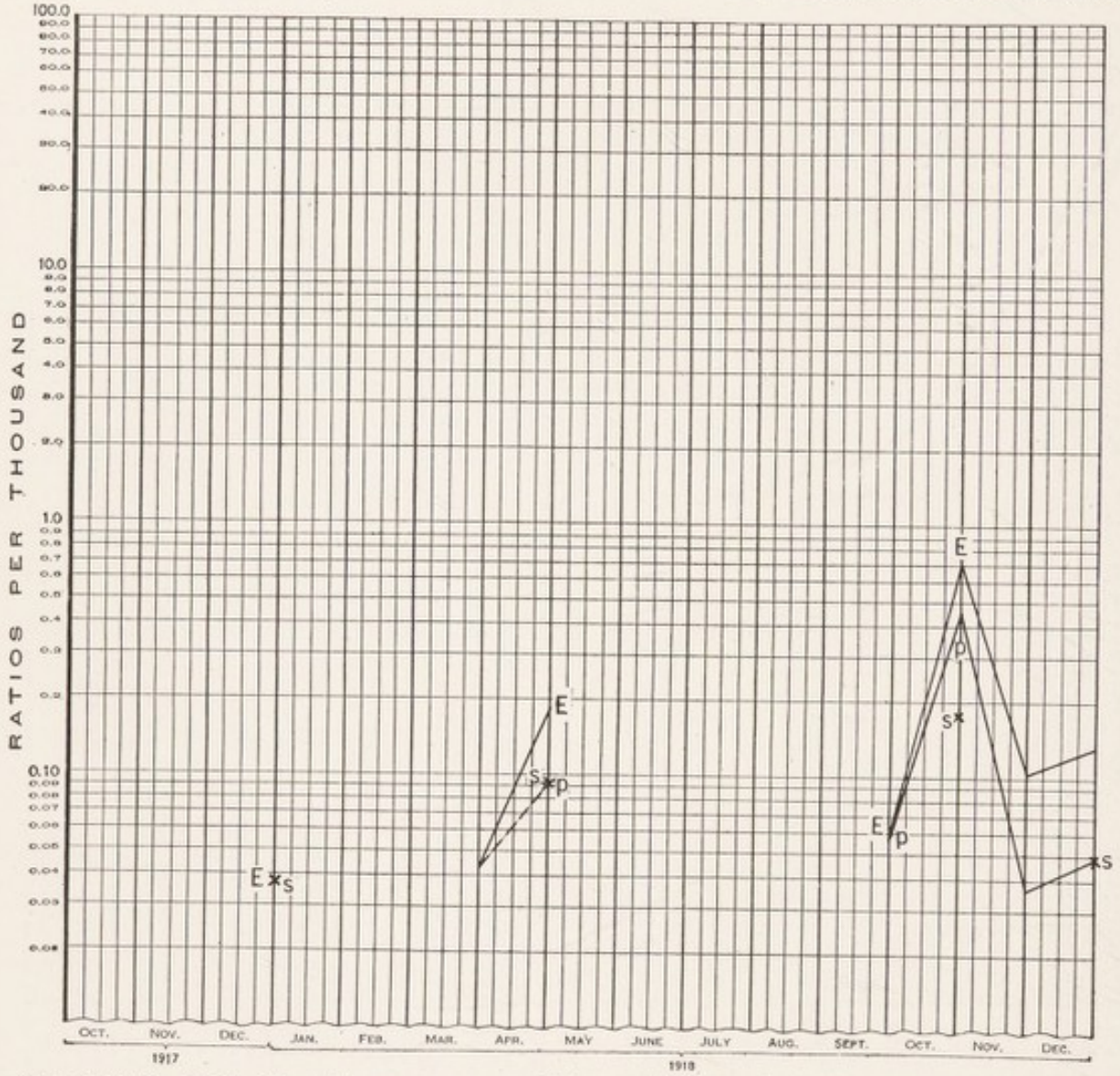


CHART XXIII.—Relationship of the pneumococcus and the streptococcus to the incidence of empyema at Camp McClellan, Ala.

in the reply. During the high postinfluenzal incidence of empyema the streptococcus was not prominent, nor did it play a conspicuous part at any time.

The high peak shown for April on the chart coincided with a sudden increase in cases of influenza, which reached 1,277 in that month, although only 84 in March and 107 in May. The slight effect this outbreak had upon the incidence of the pneumonias, and the abrupt drop in the number of pneumonia cases to an extraordinarily low minimum immediately afterwards, are very striking.

Notwithstanding the small total number of empyema cases at Camp McClellan, their distribution in time closely follows the incidence of common respiratory diseases and become nil when this incidence falls below 1 per cent.

TABLE 15.[a]—*Epidemiological table for Camp McClellan, Ala.*

| | Absolute numbers. | | | | | Ratios per 1,000 men. | | | | | Empyema, mortality percentage. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Empyema, totals. | Empyema, deaths. | Streptococcus group. | Pneumococcus group. | Staphylococcus. | Pneumonia. | Common respiratory diseases. | Empyema. | Streptococcus group. | Pneumococcus group. | |
| 1917. | | | | | | | | | | | |
| October | 0 | 0 | 0 | 0 | 0 | 0.52 | 12.28 | 0 | 0 | 0 | 0 |
| November | 0 | 0 | 0 | 0 | 0 | .51 | 28.06 | 0 | 0 | 0 | 0 |
| December | 1 | 0 | 1 | 0 | 0 | 1.26 | 35.89 | 0.0367 | 0.0367 | 0 | 0 |
| 1918. | | | | | | | | | | | |
| January | 0 | 0 | 0 | 0 | 0 | 1.09 | 34.33 | 0 | .0 | 0 | 0 |
| February | 0 | 0 | 0 | 0 | 0 | .94 | 19.21 | 0 | .0 | 0 | 0 |
| March | 1 | 0 | 1 | 0 | 0 | .72 | 15.81 | .0432 | .0432 | 0 | 0 |
| April | 4 | 0 | 2 | 2 | 0 | 1.06 | 71.89 | .1851 | .0920 | .0920 | 0 |
| May | 0 | 0 | 0 | 0 | 0 | .04 | 7.26 | .0 | .0 | .0 | 0 |
| June | 0 | 0 | 0 | 0 | 0 | .45 | 5.40 | .0 | .0 | .0 | 0 |
| July | 0 | 0 | 0 | 0 | 0 | .56 | 6.55 | .0 | .0 | .0 | 0 |
| August | 0 | 0 | 0 | 0 | 0 | .95 | 9.95 | .0 | .0 | .0 | 0 |
| September | 1 | 0 | 0 | 1 | 0 | 1.38 | 26.24 | .0580 | .0 | .0581 | 0 |
| October | 20 | 0 | 5 | 13 | 0 | 7.66 | 209.80 | .7148 | .1785 | .4650 | 0 |
| November | 3 | 0 | 0 | 1 | 0 | 2.86 | 24.44 | .1130 | .0 | .0377 | 0 |
| December | 3 | 1 | 1 | 1 | 0 | 3.24 | 30.97 | .1476 | .0493 | .0493 | 33 |
| | 33 | 1 | 10 | 18 | 0 | ..... | ..... | ..... | ..... | ..... | 3 |

[a] Sources of information: 1. Reports of sick and wounded made to the Office of the Surgeon General. 2. Special empyema reports made to the Office of the Surgeon General.

## CAMP SHERMAN.

Camp Sherman, Ohio, close to Chillicothe, with approximately 15,000 inhabitants, was used for drafted men of the National Army from Ohio and western Pennsylvania, with a small contingent from Oklahoma.[10] The strength for December, 1917, was approximately 34,500, but was not far below this figure in the preceding October.[10] The 83rd Division left for overseas about June, 1918, after which Camp Sherman became a replacement camp, receiving men from Tennessee, Indiana, West Virginia, and Alabama, as well as from Ohio and Pennsylvania.[10] After October, 1917, there were from 2,000 to 8,000 colored troops present in camp.[10]

Two-story frame barracks were provided for quarters and at times were overcrowded, kitchens and mess halls being used as sleeping quarters.[10]

There were 1,714 cases of measles at Camp Sherman during the 14 months beginning October, 1917, but this disease was most prevalent in January and February, 1918, when 859 cases were admitted.[11] It was during these two months that postmeasles empyema displayed the highest incidence, 10 cases out of a total of 12 falling within this period. Seven of these died, a mortality of 70 per cent. Yet the proportion of empyema to measles was less than 1.2 per cent. The other 2 cases of postmeasles empyema fell in December, 1918, when measles cases were reported at 55. Bacteriological data are missing with respect to 2 cases, but the other 10 were all associated with streptococcus. Indeed, during the period including December, 1917, to April, 1918, out of 54 bacteriological examinations 51, or 94 per cent, showed that the empyema was streptococcic, with only 6 per cent associated with pneumococcus. These figures are derived from the special empyema reports,[12] and are in substantial accord with data obtained through other and more contemporaneous sources.

There were no cases following mumps.

Two followed scarlet fever in April, 1918, with an intervening lobar pneumonia and with streptococci in the pleural fluids. The total cases of scarlet fever for 1918 numbered 329.[11]

The curve for respiratory diseases other than pneumonia (R) on the chart for Camp Sherman shows a high incidence from January until May. This high incidence is largely due to the elevated ratio for influenza during these months, though common respiratory diseases exhibited a similar increase during this time. Possibly it was difficult to separate the two and decide upon the proper group in which to place a given individual case. The fact remains, however, that many cases of influenza were recorded. This is of interest

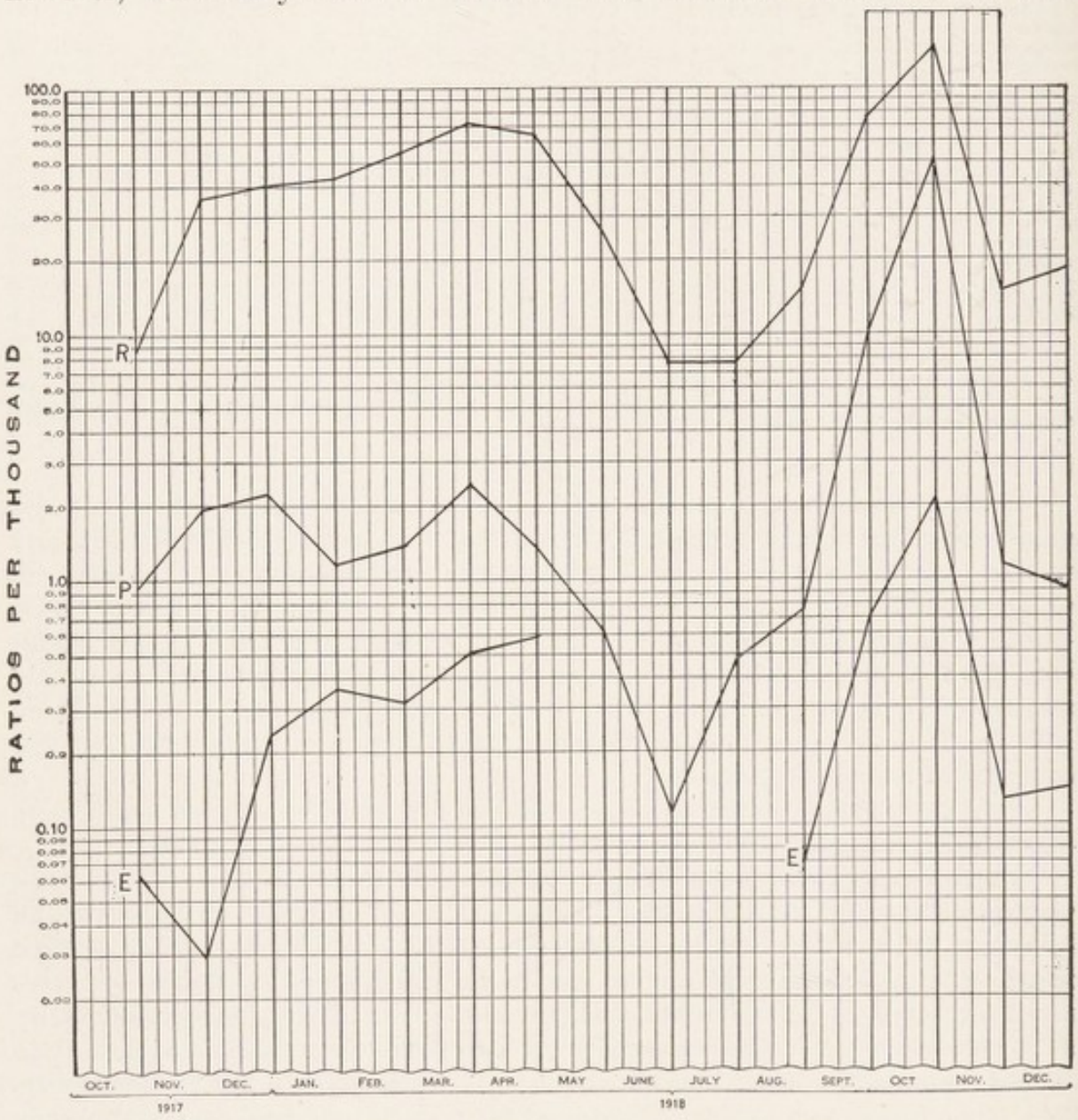


CHART XXIV.—Epidemiological chart for Camp Sherman, Ohio, in monthly ratios per thousand men.

because the bacteriological reports indicate such a great preponderance of streptococci. It may be inferred from this and similar observations in other camps that in the fall of 1917 and in the early months of 1918 the streptococcus was unusually prevalent, and further, that at this time the high incidence of diseases of the upper respiratory tract was associated with organisms of the streptococcus group.

The abrupt cessation of empyema after a period of high incidence and also the drop in pneumonia when the incidence of common respiratory diseases fell in May and June are very striking. Empyema did not reappear until August, when the admissions for diseases of the upper respiratory tract again exceeded 1 per cent of the command.

CHART XXV.—Relationship of the pneumococcus and the streptococcus to the incidence of empyema at Camp Sherman, Ohio.

TABLE 16.[a]—*Epidemiological table for Camp Sherman, Ohio.*

| | Absolute numbers. | | | | | Ratios per 1,000 men. | | | | | Empyema, mortality percentage. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Empyema, totals. | Empyema, deaths. | Streptococcus group. | Pneumococcus group. | Staphylococcus. | Pneumonia. | Common respiratory diseases. | Empyema. | Streptococcus group. | Pneumococcus group. | |
| 1917. | | | | | | | | | | | |
| October | 2 | 0 | 0 | 1 | 0 | 0.95 | 8.41 | 0.0630 | 0 | 0.0315 | 0 |
| November | 1 | 1 | 0 | 1 | 0 | 1.90 | 35.01 | .0290 | 0 | .0290 | 100 |
| December | 8 | 6 | 5 | 2 | 0 | 2.35 | 40.27 | .2312 | .1441 | .0577 | 75 |
| 1918. | | | | | | | | | | | |
| January | 12 | 8 | 10 | 0 | 0 | 1.26 | 43.43 | .3663 | .3055 | .0 | 67 |
| February | 10 | 5 | 8 | 0 | 0 | 1.44 | 56.77 | .3172 | .2521 | .0 | 50 |
| March | 13 | 7 | 11 | 0 | 0 | 2.53 | 71.78 | .5091 | .4240 | .0 | 54 |
| April | 18 | 9 | 17 | 1 | 0 | 1.48 | 65.46 | .5810 | .5190 | .0305 | 50 |
| May | 0 | 0 | 0 | 0 | 0 | .63 | 27.62 | .0 | .0 | .0 | 0 |
| June | 0 | 0 | 0 | 0 | 0 | .12 | 7.62 | .0 | .0 | .0 | 0 |
| July | 0 | 0 | 0 | 0 | 0 | .49 | 7.63 | .0 | .0 | .0 | 0 |
| August | 2 | 0 | 0 | 2 | 0 | .77 | 10.63 | .0716 | .0 | .0716 | 0 |
| September | 22 | 10 | 12 | 7 | 0 | 10.11 | 77.73 | .7058 | .3850 | .2245 | 45 |
| October | 73 | 40 | 30 | 31 | 0 | 51.39 | 154.59 | 2.1264 | .8773 | .9050 | 55 |
| November | 4 | 3 | 1 | 0 | 0 | 1.29 | 16.30 | .1310 | .0328 | .0 | 75 |
| December | 2 | 1 | 1 | 0 | 0 | .90 | 18.28 | .1441 | .0793 | .0 | 50 |
| | 167 | 90 | 95 | 45 | 0 | ..... | ..... | ..... | ..... | ..... | 53.8 |

[a] Sources of information: 1. Reports of sick and wounded made to the Office of the Surgeon General. 2. Special empyema reports made to the Office of the Surgeon General.

## CAMP CUSTER.

Camp Custer, Mich., located 5 miles from Battle Creek, a manufacturing city with a population of about 30,000. The camp was about 4½ miles long, situated on a ridge roughly parallel to the Kalamazoo River. It was a National Army camp, the drafted men coming from Minnesota and the eastern part of Wisconsin, which includes the city of Milwaukee, with nearly 430,000 inhabitants.[10] The strength of the camp was about 24,000 men in December, 1917, and was maintained at about this, or a somewhat higher figure, until July, 1918, the approximate time of departure of the 85th Division.[10] In April a contingent of 2,000 men was received from Alabama, and early in the summer there were transfers hither from camps in North Dakota and West Virginia.[11] There were colored troops as early as December, 1917, but the number was small until the middle of 1918.[10]

The enlisted men were quartered in two-story frame barracks. In general, the health of the command was good, the admission rate for all diseases being comparatively low. Notwithstanding this good showing, the respiratory diseases were at times high, and this is attributed, by contemporary observers, to the arrival of fresh troops from places previously suffering from such complaints.[11] Colds, sore throat, and tonsillitis became prevalent after such accessions, often aggravated by long journeys in crowded trains and attended with fatigue and loss of sleep. Such conditions were obviously not confined to this particular camp. Many sudden outbreaks of measles elsewhere were attributed to like circumstances. Their consideration is not germane to the present study as it appears clear that measles is not in itself closely associated with the inci dence of empyema. For this reason attention has not been called to such occurrences. But it has already become evident that certain infections of the upper air passages are potent factors in determining the occurrence of empyema, and this is a reason for dwelling somewhat on the experience at Camp Custer, where definite studies in this direction were undertaken.[23] The table and graphic charts for Camp Custer illustrate the relationships referred to.

It is of interest to note that there were 20 cases of postmeasles empyema between December 4, 1917, and February 15, 1918,[11] a period during which there must have been somewhat less than 443 cases of measles, for that is the number of admissions for this disease for the whole of December, 1917, January and February, 1918. The ratio between empyema and measles, taking this figure, would be over 4.5 per cent, an unusually high proportion. This could not have been because of special virulence of the measles or peculiar susceptibility to this disease on the part of the men, for the total number of cases of measles for 15 months was 794 and of the measles-pneumonias for the three months in question only 2, and of measles with other complications, 82.[11] The explanation is to be sought in the nature of the infections fortuitously associated with the measles as well as with other diseases. Thus, there are 6 cases, in which pneumonia was not noted, that were admitted with such varying diagnoses as "suspected spinal meningitis," "acute catarrhal stomatitis," "intestinal autointoxication," "rheumatic fever," "mitral stenosis," and "septicemia" (2 cases). Empyema was discovered within a few days after the admission of these cases; the first 3 recovered, the remaining 3 died. Such occurrences point to underlying causes, as was particularly recognized by medical officers in Camp Custer at

the time. The most potent factor was considered by them to be infections of the upper respiratory tract by streptococci, most commonly of the hemolytic variety.[23]

Only 1 case of empyema followed mumps, although there were 1,800 admissions for this disease.[11]

No postscarlatinal cases are included in the special empyema records.[12]

As must follow from the foregoing statements, the charts for Camp Custer show a very close parallelism between the curves of common respiratory diseases,

CHART XXVI.—Epidemiological chart for Camp Custer, Mich., in monthly ratios per thousand men.

empyema, and streptococcus, while the curve of the pneumonias takes an almost independent course until August, when it also partakes of the general character of the other three. It is particularly noteworthy that the incidence of lobar and broncho pneumonia combined falls below that of empyema in February, an almost unique occurrence and very striking, when the high incidence of affections of the upper air passages at this time is taken into account.

Again, there is a break in the empyema curve, when "R" falls below 1 per cent, but this is not so exact in time as has often been observed in other camps

This circumstance directs attention to the nature of the single case of empyema in June and the 2 cases in August, when the respiratory curve exhibits minima.[12]

The first of these 3 cases was admitted June 11, with bronchopneumonia extending over the whole right lung. Aspiration, 18 days later, showed the presence of pus on the right side, and examination of this exudate revealed pneumococcus, Type II. Three days later there was a costectomy of the ninth rib in the postaxillary line, and 800 c. c. of thick pus were removed. The wound closed about three weeks later, and the soldier returned to duty

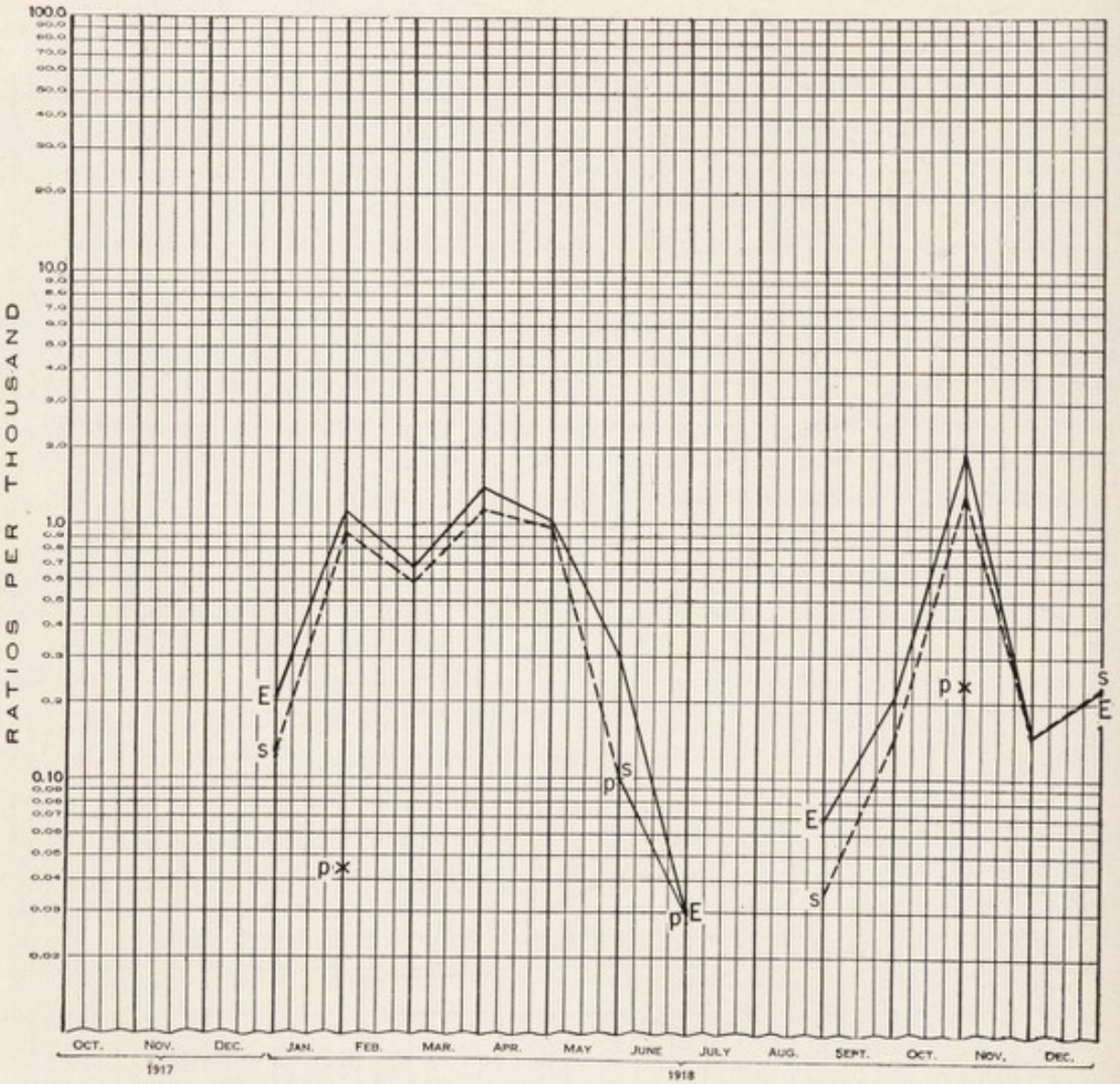


CHART XXVII.—Relationship of the pneumococcus and the streptococcus to the incidence of empyema at Camp Custer, Mich.

two months after entering the hospital. The case was evidently mild and followed a simple and normal course toward speedy convalescence without complication. It resembles the sporadic cases of pneumococcus empyema common in civil life.

The first case in August was admitted on the 2nd of the month with acute catarrhal bronchitis.[12] No definite diagnosis of pneumonia was ever recorded, but aspiration 25 days after admission resulted in 20 c. c. of straw-colored fluid. Nine subsequent aspirations, at which amounts of fluid varying from

50 c. c. to 2,000 c. c. were withdrawn, were made at different intervals until finally, on the one hundred twenty-second day, a portion of the ninth rib was removed, and a seropurulent fluid evacuated. About seven weeks later it was determined that the case was tuberculous. The patient was transferred to General Hospital No. 12, where the wound closed, and the man returned to duty, but was subsequently admitted to the base hospital at Camp Sherman, and thence transferred to Fort McPherson. At one time streptococci (unclassified), and at another, hemolytic streptococci were reported as found in the pleural discharge, but these examinations were made nearly three months after the first aspiration, and can not be trusted as evidence of the nature of the primary infection, which was apparently tuberculous.

The second case in August was admitted on the 9th of that month, with right suppurative pleurisy following an accidental gunshot wound.

The last two cases in the above list certainly have no epidemiological value for present purposes, and the first departs materially in its clinical features from the cases occurring during the period of high incidence of empyema in the preceding months. The fact that these cases occurred when acute respiratory diseases were minimal in number does not militate against the general rule that empyemas are absent when upper respiratory diseases lead to admissions less in number than 1 per cent of the strength of the camp.

TABLE 17.[a]—*Epidemiological table for Camp Custer, Mich.*

| | Absolute numbers. | | | | | Ratios per 1,000 men. | | | | | Empyema, mortality percentage. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Empyema, totals. | Empyema, deaths. | Streptococcus group. | Pneumococcus group. | Staphylococcus. | Pneumonia. | Common respiratory diseases. | Empyema. | Streptococcus group. | Pneumococcus group. | |
| 1917. | | | | | | | | | | | |
| October | 0 | 0 | 0 | 0 | 0 | 0.52 | 7.56 | 0 | 0 | 0 | 0 |
| November | 0 | 0 | 0 | 0 | 0 | .39 | 15.16 | 0 | 0 | 0 | 0 |
| December | 5 | 1 | 3 | 0 | 0 | .59 | 19.35 | 0.2075 | 0.1244 | 0 | 20 |
| 1918. | | | | | | | | | | | |
| January | 27 | 14 | 21 | 1 | 1 | 1.67 | 40.10 | 1.1389 | .9198 | 0.0438 | 52 |
| February | 15 | 4 | 13 | 0 | 0 | .64 | 31.29 | .6824 | .5915 | .0 | 26 |
| March | 25 | 12 | 21 | 0 | 0 | 1.75 | 51.45 | 1.3774 | 1.1570 | .0 | 48 |
| April | 26 | 10 | 25 | 0 | 0 | 3.36 | 44.18 | 1.0397 | .9626 | .0 | 38 |
| May | 9 | 4 | 3 | 3 | 1 | 2.15 | 15.91 | .2999 | .1000 | .1000 | 45 |
| June | 1 | 0 | 0 | 1 | 0 | .46 | 6.95 | .0294 | .0 | .0294 | 0 |
| July | 0 | 0 | 0 | 0 | 0 | .19 | 9.99 | .0 | .0 | .0 | 0 |
| August | 2 | 0 | 1 | 0 | 0 | .18 | 6.61 | .0685 | .0343 | .0 | 0 |
| September | 8 | 2 | 5 | 0 | 1 | 4.38 | 58.54 | .2086 | .1408 | .0 | 25 |
| October | 76 | 13 | 52 | 9 | 1 | 16.16 | 174.88 | 1.9284 | 1.3295 | .2301 | 17 |
| November | 5 | 0 | 5 | 0 | 1 | .82 | 13.03 | .1448 | .1448 | .0 | 0 |
| December | 7 | 0 | 7 | 0 | 0 | .30 | 20.81 | .2239 | .2240 | .0 | 0 |
| | 206 | 60 | 156 | 14 | 5 | ..... | ..... | ..... | ..... | ..... | 29.1 |

[a] Sources of information: 1. Reports of sick and wounded made to the Office of the Surgeon General. 2. Special empyema reports made to the Office of the Surgeon General.

## CAMP GRANT.

Camp Grant, Ill., situated near Rockford, a manufacturing city of about 50,000 inhabitants, was used for the National Army. The drafted men first came from Illinois and Wisconsin, largely from urban homes.[10] In September, 1917, the strength averaged approximately 13,000, but rose to over 28,000 in November.[10] There were a few men transferred from other camps as early as October, 1917, and in March and April, 1918, contingents of from 1,000 to 3,000 were received from Idaho, North Carolina, Louisiana, South Dakota, and

Nebraska.[10] In consequence the urban class must have become less dominant after these accessions. There were nearly a thousand colored troops in November, 1917, and from that time their number increased, ranging from 3,000 to 8,000 until September, 1918, when they reached 10,000, about one-fifth of the total number of enlisted men.[10]

Barracks served as quarters for the troops.

The noneffective rate in the early months was very low, being next to that at Camp Upton, where it was least of all. This is in harmony with the fact that the men at both these camps were drawn chiefly from large cities. With the arrival of colored troops admissions for measles became augmented, though they were never conspicuously large as compared with some of the southern camps.[11]

The total admissions for measles for the 15 months including and following October, 1917, was 1,006; the largest number for any month was 391 in January, 1918. The number of postmeasles empyema cases reported in the special empyema records for the 15 months was nine, with two deaths.[12] Of the total measles cases, less than 1 per cent developed empyema. In January, 1918, there were four postmeasles empyema cases, a trifle over 1 per cent of the measles in that month. Two of these cases were associated with streptococcus (one death), and two with staphylococcus, both recovering.[12]

One fatal case of empyema followed mumps, in February, 1918, when there were 226 admissions for the latter disease, nearly the highest incidence for the whole period of 15 months, the highest (278 cases) falling in December, 1918.[12]

Two postscarlatinal empyema cases are recorded for late February and early March, both associated with streptococcus and both surviving. At that time there were relatively many admissions for scarlet fever, the totals being 38 in February and 20 in March, out of 188 for the 15 months.[11]

There are 118 cases of empyema for which bacteriological data are given, out of a total of 134 cases, representing 88 per cent, and may be accepted as representing the general character of the infections. During the early period of high incidence streptococci were found nearly three times as often as pneumococci, but there are three cases reported as associated with staphylococcus, an unusually high number, making 8 per cent of the total positive findings during this period. In the fall of 1918 the streptococci are only about one-third more frequent than pneumococci. This falling off in the preponderance of streptococci in the later period, as compared with the earlier period of high incidence, was an almost universal experience throughout all the camps.[12]

The approximate constancy of the ratio between empyema and diseases of the upper respiratory tract is clearly shown by Chart XXVIII. In contrast to this is the irregular course of the pneumonia curve. The lapse of empyema is complete in June, but the curve "R" falls below 1 per cent in June, July, and August, and this circumstance calls for inquiry into the histories of the four cases of empyema occurring within these three months.[12]

The first of these was admitted May 18, with bilateral follicular tonsillitis. This was speedily followed by pleurisy on the left side. On the 18th day after admission 550 c. c. of a cloudy fluid were aspirated from the left pleural cavity, and the following day upon resecting a portion of the eighth rib 500 c. c. of a seropurulent fluid were evacuated. The wound had closed by the end of the

fourth month after admission, and the patient returned to duty shortly afterwards. The organism in the pleural exudate was a streptococcus. No clinical evidence of pneumonia was recorded in the history of this case, and it is evident that it was most intimately associated with an infection of the upper respiratory tract, although the incidence of these infections at the time was rapidly waning.

The second case in this series was admitted July 6, with a lobar pneumonia of the left lower lobe. Empyema was recognized on the 24th day after admission, and was treated by resection the day following. There is no record of the

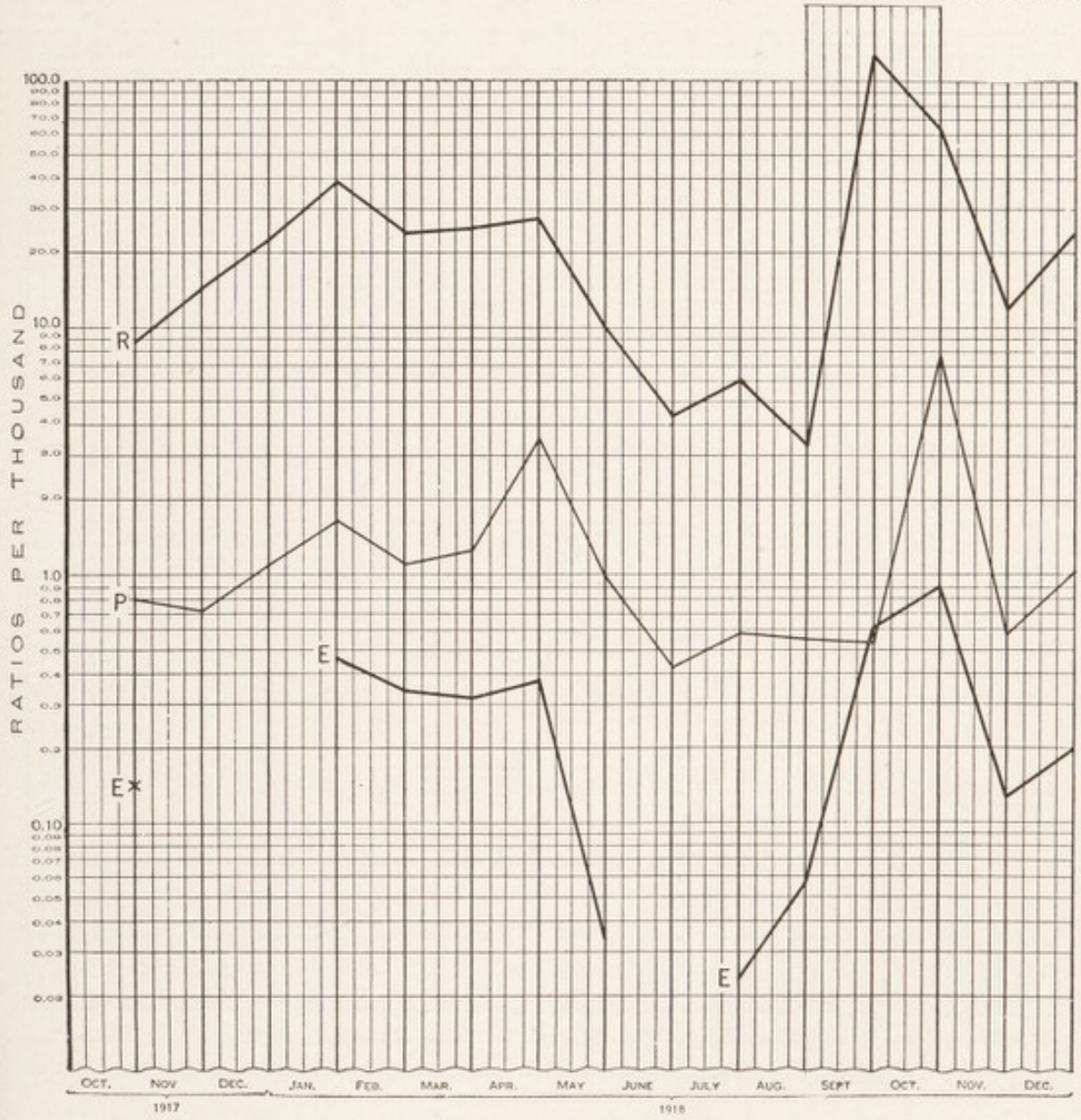


CHART XXVIII.—Epidemiological chart for Camp Grant, Ill., in monthly ratios per thousand men.

amount or character of the fluid, but convalescence appears to have been uninterrupted and the patient returned to duty, and about a year later wrote that he was fireman in a hotel. Pneumococci were obtained from the pleural exudate.

The third case, admitted August 5, for appendicitis, had an appendectomy four days later, and 10 days thereafter developed an empyema that was speedily cured after resection. The seropurulent exudate contained pneumococci. About a year later he was employed in a laundry and complained of no disability. This case almost certainly followed general anesthesia.

Finally, the fourth case was admitted August 3, as "suspected lobar pneumonia." Pus was discovered in the left pleural cavity on the day of admission and rib resection was done five days later. The exudate contained pneumococci. About five weeks later an abscess in one of the abdominal muscles was drained and the streptococcus viridans was cultivated from this pus. A week later purulent arthritis of the left knee developed, which was opened. Death occurred 62 days after admission. There was no autopsy. While it is not possible to discover the nature of the primary disease or the time of its occurrence, there

CHART XXIX.—Relationship of the pneumococcus and the streptococcus to the incidence of empyema at Camp Grant, Ill.

was evidently a latent empyema that had not been recognized for some time. Were the date of the primary disease known, the case would have been included among those occurring earlier.

From an epidemiological standpoint the case occurring in May presents an isolated instance of the persistence of conditions existing during the preceding period of high incidence, and its occurrence supports the general conclusion that throat infections are connected with those of the pleura.

The other cases require no special comment. They are of a character that may occur at any period of year in a community as large as this camp.

TABLE 18.[a]—*Epidemiological table for Camp Grant, Ill.*

| | Absolute numbers. | | | | | Ratios per 1,000 men. | | | | | Empyema, mortality percentage. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Empyema, totals. | Empyema, deaths. | Streptococcus group. | Pneumococcus group. | Staphylococcus. | Pneumonia. | Common respiratory diseases. | Empyema. | Streptococcus group. | Pneumococcus group. | |
| 1917. | | | | | | | | | | | |
| October | 3 | 0 | 0 | 2 | 0 | 0.80 | 8.72 | 0.1047 | 0.0349 | 0.0698 | 0 |
| November | 0 | 0 | 0 | 0 | 0 | .73 | 14.16 | .0 | .0 | .0 | 0 |
| December | 0 | 0 | 0 | 0 | 0 | 1.11 | 22.77 | .0 | .0 | .0 | 0 |
| 1918. | | | | | | | | | | | |
| January | 12 | 3 | 9 | 1 | 1 | 1.68 | 38.98 | .4644 | .3496 | .0387 | 25 |
| February | 8 | 1 | 4 | 1 | 0 | 1.10 | 24.17 | .3368 | .1684 | .0421 | 13 |
| March | 9 | 1 | 6 | 1 | 1 | 1.28 | 25.07 | .3151 | .2101 | .0350 | 11 |
| April | 10 | 3 | 4 | 5 | 1 | 3.50 | 27.65 | .3670 | .1468 | .1374 | 30 |
| May | 1 | 0 | 1 | 0 | 0 | .98 | 10.02 | .0331 | .0331 | .0 | 0 |
| June | 0 | 0 | 0 | 0 | 0 | .42 | 4.34 | .0 | .0 | .0 | 0 |
| July | 1 | 0 | 0 | 1 | 0 | .58 | 6.04 | .0235 | .0 | .0235 | 0 |
| August | 2 | 1 | 0 | 1 | 0 | .56 | 3.28 | .0572 | .0 | .0572 | 50 |
| September | 29 | 11 | 13 | 12 | 0 | .53 | 126.11 | .6010 | .2901 | .2487 | 38 |
| October | 50 | 6 | 26 | 21 | 0 | 7.65 | 63.35 | .9068 | .4716 | .3734 | 12 |
| November | 4 | 1 | 3 | 1 | 0 | .58 | 11.91 | .1258 | .1006 | .0251 | 25 |
| December | 5 | 1 | 2 | 0 | 0 | 1.11 | 23.25 | .1975 | .0789 | .0 | 20 |
| | 134 | 28 | 69 | 46 | 0 | | | | | | 20.9 |

[a] Sources of information: 1. Reports of sick and wounded made to the Office of the Surgeon General. 2. Special empyema reports made to the Office of the Surgeon General.

## CAMP DODGE.

Camp Dodge, Iowa, on a sandy ridge about 10 miles from Des Moines, a city of about 100,000 inhabitants, was a National Army camp. A large majority of the drafted men came from Iowa, Illinois, Minnesota, and North Dakota, and were drawn from regions about 32 per cent urban.[10] But between the middle and the end of October, 1917, about 3,400 men arrived from Alabama, and from that time there were from 3,000 to 6,000 colored troops in camp throughout 1918.[10] In the early and middle summer of that year contingents were received also from Tennessee, Montana, South Dakota, and Indiana. In origin, the troops at this camp were far from homogeneous.

The enlisted men at this camp were quartered in frame barracks.

From the very beginning there was a rather high incidence of infectious diseases, measles, mumps, and scarlet fever, as well as lobar and bronchopneumonia, contributing a quota.[11]

The admissions for measles were 366 in the last three months of 1917; and in 1918 they reached 2,038, making a total of 2,409 for the 15 months. For the longer period, the postmeasles lobar pneumonia cases were reported as 12, and the bronchopneumonia cases as 22, or 34 in all. The postmeasles empyema cases do not fall short of this total, being 31, with 22 deaths, a mortality of 71 per cent.

On the other hand, the ratio between postmeasles empyema and total measles is under 1.4 per cent, leading to the inference that measles was not a strikingly predisposing disease, but that empyema, when complicating measles, was indicative of a very serious infection. Of the 9 surviving cases of postmeasles empyema there are bacteriological data concerning 7: streptococcus, 4; and pneumococcus, 3. Among the 22 fatal cases, the bacteriological findings are available in 17. Of these 17 fatal cases all were streptococcic; and 12 are specifically described as hemolytic, the question of hemolysis not being touched upon in the remaining 5 cases.[11] Considered in conjunction with the tabulated

record of all the empyemata at Camp Dodge the inference appears justified that the majority of the total cases of empyema were associated with virulent strains of streptococci and that the high mortality was largely owing to this circumstance.[12] There is no imperative reason why, in this respect, the post-measles cases should be segregated in a group by themselves. The statistics from other camps have already suggested this, but the large number of post-measles cases at Camp Dodge gives it a particular emphasis.

Only two cases of empyema are reported as following primary mumps, although there were 3,200 admissions for mumps.[11] In one case the organism was a hemolytic streptococcus, whereas, in the other case, the causative organism is unknown. Both survived.

Five postscarlatinal empyema cases occurred. The first in February, 1918, two in March, and two in April. The admissions for scarlet fever for those months were 43, 76, and 92, respectively.[11] Four of these cases yielded hemolytic streptococcus; no bacteriological record is given for the fifth.

The increased incidence of empyema in March and April, shown on Chart XXX as relatively greater than a corresponding rise in common respiratory diseases, coincides with a period when there was a considerably larger proportion of cases of influenza than during February and May. Presumably, influenza was of greater severity at that time. This is reflected in the preponderance among the empyemata of streptococcus infections, which rise proportionately to the rise in the empyema curve, while the pneumococcus cases remain about stationary.

The occurrence of several cases of empyema in July and August, amounting to six cases in the former month, and eight in the latter, at a time when diseases of the upper respiratory tract were at or close to the minimum for the year, is the most striking feature of this chart and, from an epidemiological standpoint, the most important. For this reason particular attention must be given to the nature of these 14 cases, as has already been done concerning cases occurring at unusual periods in other camps.

Of the six cases in July, three died. Two of these fatal cases were associated with streptococcus and one with pneumococcus, Type I. The bacteriological findings in the surviving three cases were the same: two streptococcus and one pneumococcus, Type I.

The histories may be given in a much abbreviated form as follows:[12]

1. Admitted July 7. Suspected lobar pneumonia. Empyema found on day of admission. Pneumococcus, Type I, in 150 c. c. fluid removed by aspiration. No operation. Returned to quarters on eighty-seventh day.

2. Admitted July 27. Measles. Pneumonia and empyema found three months later. Seven hundred c. c. purulent fluid contained hemolytic streptococci, influenza bacilli, and a few staphylococci. Treated by catheter drainage, and discharged from the Army on surgeon's certificate of disability four months later.

3. Admitted July 26. Acute catarrhal bronchitis. Lobar pneumonia on second day and empyema three weeks later with streptococci in seropurulent fluid. Thoracotomy. Death on forty-third day. At autopsy, acute hemorrhagic tracheitis and bronchitis, bronchopneumonia, general peritonitis, multiple abscesses of liver. General streptococcus infection.

4. Admitted July 25. Lobar pneumonia. No operation. Empyema revealed post mortem with pneumococcus, Type I, in pleural fluid. Acute hemorrhagic tracheitis and bronchitis, bilateral lobar pneumonia involving both lobes on the left and the lower right lobe.

5. Admitted July 30. Observation for measles. Lobar pneumonia about three weeks later, and empyema about three weeks after the pneumonia. Streptococcus in pleural exudate.

Pericarditis with effusion. Abscess under shoulder of side opposite to the empyema. Death on sixty-eighth day. No autopsy.

6. Admitted July 31. Measles. Bilateral bronchopneumonia. Empyema with hemolytic streptococci. Thoracotomy. Discharged on surgeon's certificate of disability on the two hundred and sixteenth day.

It will be observed that three of these cases followed measles and were all associated with streptococci. They resemble the cases occurring at periods

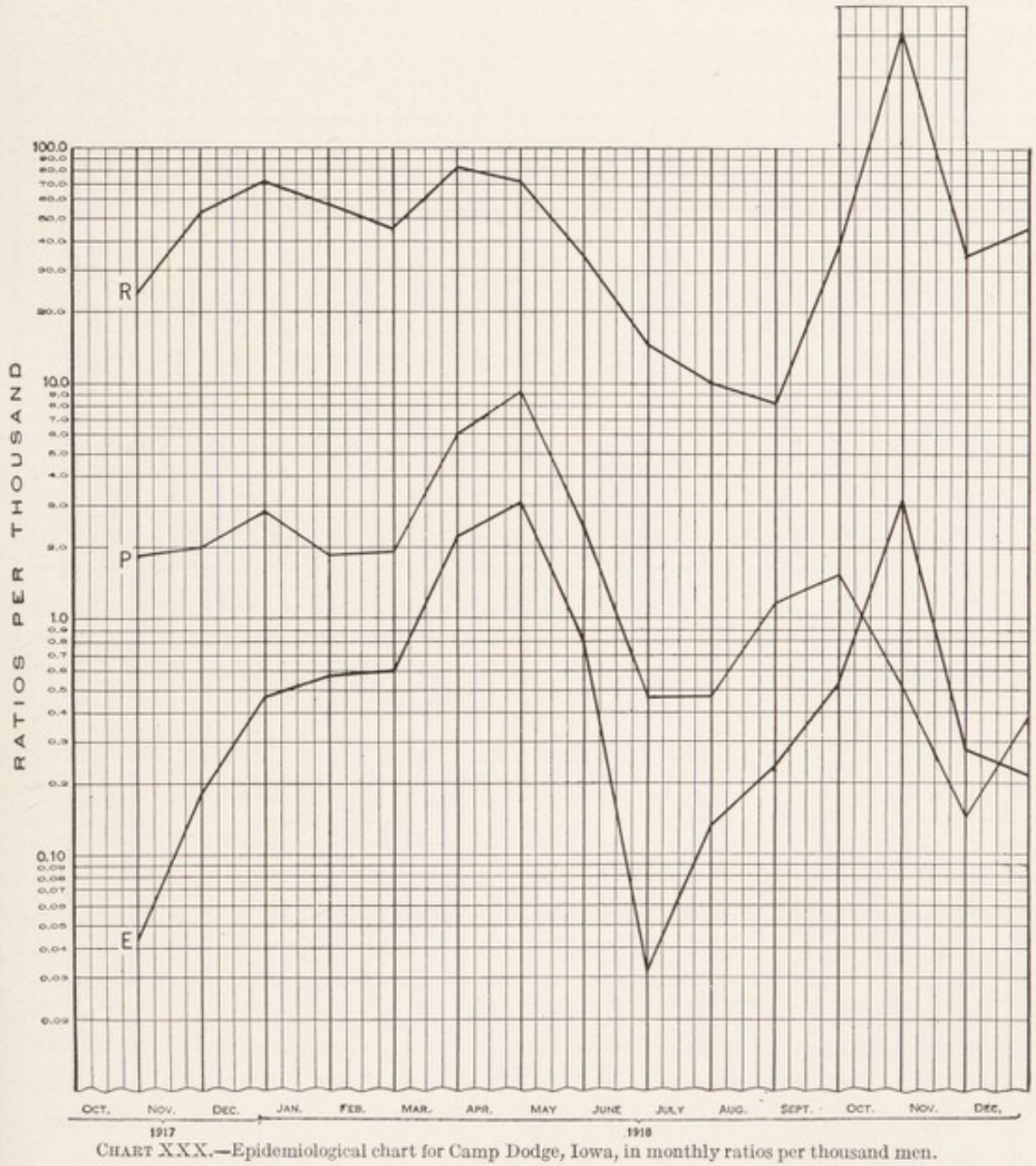


CHART XXX.—Epidemiological chart for Camp Dodge, Iowa, in monthly ratios per thousand men.

of high incidence and suggest a persistence in minor degree of the conditions determining the occurrence of empyema at such times notwithstanding the decrease of total incidence of upper respiratory diseases. It would be very enlightening were records available of bacteriological surveys of throat conditions at this time, as they might have revealed the existence of a considerable number of streptococcus carriers. Case 3 originated in the upper air passages and was also associated with streptococci. The remaining two (Nos. 1 and 4)

were Type I pneumococcus cases and are apparently unassociated with prevailing infections of the upper respiratory tract. Their epidemiological importance attaches more to the pneumonia than to the empyema complicating it.

Six of the eight cases originating in August died. There are only five among the eight cases concerning which there are positive bacteriological findings. In four of these, streptococci were found, suggesting the continued presence of carriers of this organism.

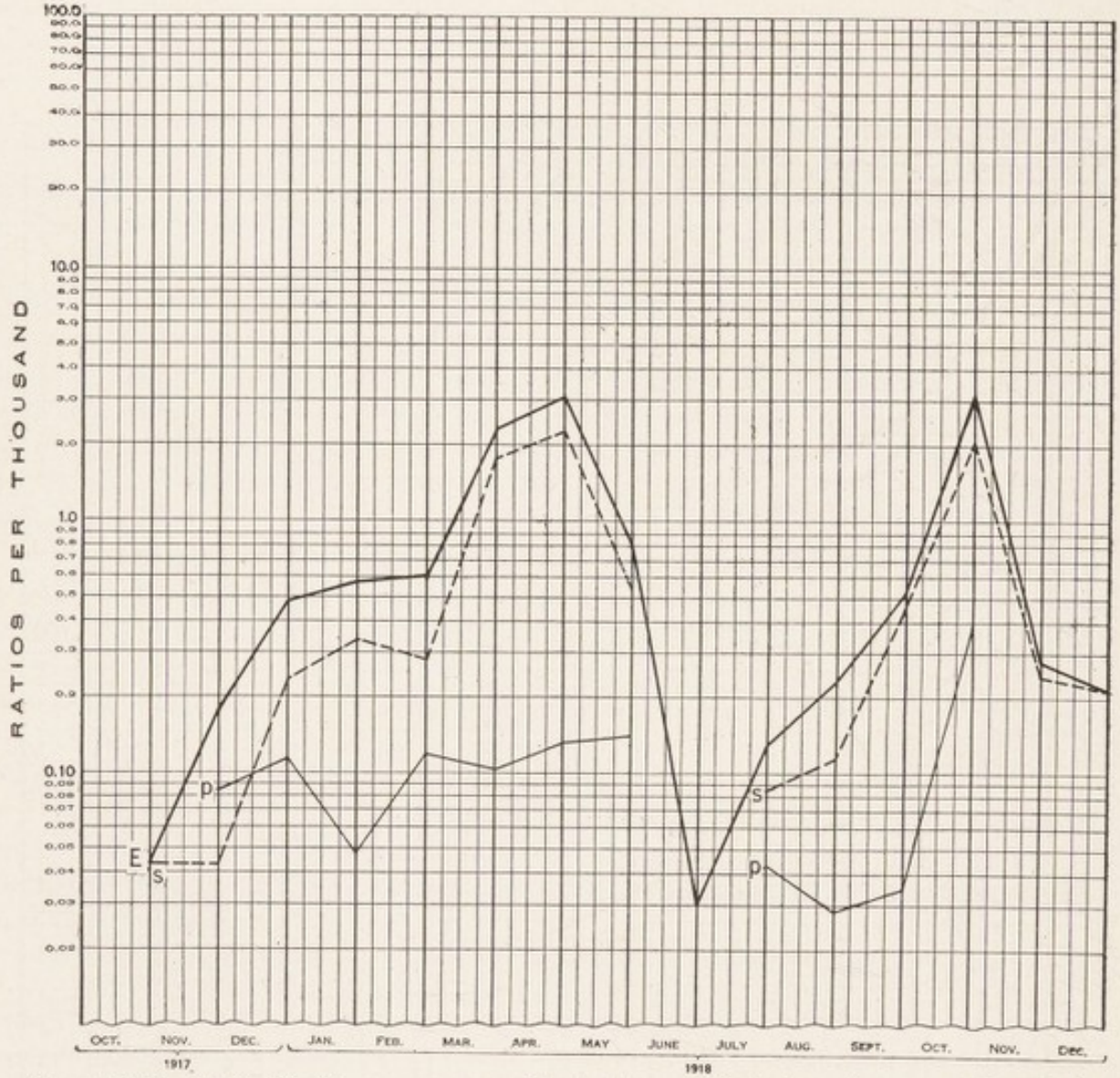


CHART XXXI.—Relationship of the pneumococcus and the streptococcus to the incidence of empyema at Camp Dodge, Iowa.

The following condensed histories of these cases are given, arranged in chronological order:[12]

1. Admitted August 1. Acute appendicitis. Lobar pneumonia and empyema developed almost simultaneously within a week. Thoracotomy three months later. Discharged on surgeon's certificate of disability, two hundred and sixty-sixth day. No report of bacteriological findings or concerning operation for appendicitis.

2. Admitted August 2. Measles; tonsillectomy; bronchopneumonia, empyema, not operated. No bacteriological report. Death on sixty-ninth day. No autopsy.

3. Admitted August 2. Vincent's angina. Bronchopneumonia sixty-fifth day. Died 70 days after admission. Empyema revealed on post-mortem. Autopsy: Acute hemorrhagic tracheitis and bronchitis, bronchopneumonia, bilateral empyema, purulent pericarditis. Hemolytic streptococci, in pleural fluid, pericardium and blood from cavity of heart.

4. Admitted August 4. Lobar pneumonia. Empyema with bloody serous fluid, third day. Death, fourth day. Autopsy notes lacking.

5. Admitted August 10. Observation for measles. Lobar pneumonia in 2 days, empyema in 20. Straw-colored fluid. Pneumococcus, Type IV. Treated by aspiration. No operation. Returned to quarters in two months.

6. Admitted August 12. For observation. Lobar pneumonia in three days, empyema (110 c. c. turbid fluid with pneumococcus, Type III, and non-hemolytic streptococcus) six days after admission, and death the same day. Autopsy: Bilateral lobar pneumonia, purulent tracheitis and bronchitis, bilateral empyema, purulent pericarditis. Pneumococcus, Type III, from left pleural fluid, non-hemolytic streptococci in right pleural fluid.

7. Admitted August 20. Phimosis and chancroid. Lobar pneumonia. Empyema with streptococci. Thoracotomy. Death 54 days after admission. No autopsy.

8. Admitted August 23. Acute suppurating bubo. Lobar pneumonia and empyema with aspiration of 300 c. c. pus containing hemolytic streptococci, eleventh day. No operation. Death 42 days after admission. Autopsy. Bilateral interstitial pneumonia, acute hemorrhagic tracheitis and bronchitis, empyema right side with 1,000 c. c. seropurulent fluid.

Although somewhat more abbreviated, as here given, the available histories of all these cases are meager. Cases No. 2 and No. 3 evidently started as serious throat infections; Case No. 2, and possibly Case No. 3, may have followed anesthesia. With regard to the remaining cases, it may be said that none was a typical pneumonia of classic nature. All, with the possible exception of Nos. 1 and 5, offer evidence of some underlying, severe infection, the exact nature of which is not revealed. The repeated report of acute processes in the trachea and bronchi do, however, call attention to the upper air passages as a site where such infections had found lodgment.

The very great prevalence of streptococci in this camp leaves little doubt that this was the infecting organism.

TABLE 19.[a]—*Epidemiological table for Camp Dodge, Iowa.*

| | Absolute numbers. | | | | | Ratios per 1,000 men. | | | | | Empyema, mortality percentage. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Empyema, totals. | Empyema, deaths. | Streptococcus group. | Pneumococcus group. | Staphylococcus. | Pneumonia. | Common respiratory diseases. | Empyema. | Streptococcus group. | Pneumococcus group. | |
| 1917. | | | | | | | | | | | |
| October | 1 | 0 | 1 | 0 | 0 | 1.83 | 23.54 | 0.0430 | 0.0430 | 0 | 0 |
| November | 4 | 3 | 1 | 2 | 1 | 2.01 | 53.08 | .1777 | .0427 | 0.0854 | 75 |
| December | 9 | 4 | 5 | 2 | 0 | 2.82 | 72.83 | .4683 | .2281 | .1141 | 45 |
| 1918. | | | | | | | | | | | |
| January | 12 | 6 | 7 | 1 | 0 | 1.83 | 57.45 | .5680 | .3313 | .0473 | 50 |
| February | 13 | 8 | 7 | 3 | 0 | 1.94 | 45.96 | .6030 | .2777 | .1190 | 62 |
| March | 64 | 48 | 49 | 3 | 0 | 6.04 | 84.52 | 2.2292 | 1.7038 | .1043 | 75 |
| April | 69 | 46 | 51 | 2 | 0 | 9.26 | 72.33 | 3.0330 | 2.2418 | .1319 | 67 |
| May | 23 | 16 | 15 | 4 | 0 | 2.48 | 34.93 | .8096 | .5397 | .1408 | 70 |
| June | 1 | 0 | 0 | 0 | 0 | .47 | 14.59 | .0316 | .0 | .0 | 0 |
| July | 6 | 3 | 4 | 2 | 0 | .47 | 10.07 | .1290 | .0860 | .0430 | 50 |
| August | 8 | 6 | 4 | 1 | 0 | 1.16 | 8.29 | .2296 | .1148 | .0287 | 75 |
| September | 15 | 12 | 13 | 1 | 0 | 1.51 | 38.78 | .5237 | .4546 | .0349 | 80 |
| October | 105 | 58 | 72 | 13 | 6 | .53 | 305.48 | 3.1334 | 2.0591 | .3879 | 55 |
| November | 8 | 5 | 6 | 1 | 0 | .14 | 34.88 | .2740 | .2406 | .0 | 63 |
| December | 4 | 1 | 4 | 0 | 0 | .38 | 45.21 | .2125 | .2125 | .0 | 25 |
| | 342 | 216 | 239 | 35 | 7 | | | | | | 63.1 |

[a] Sources of information: 1. Reports of sick and wounded made to the Office of the Surgeon General. 2. Special empyema reports made to the Office of the Surgeon General.

## CAMP PIKE.

Camp Pike, Ark., about 3 miles from Little Rock, a city with a population approximating 55,000, was a cantonment for the National Army.[10] The men were drafted from Arkansas, Louisiana, Mississippi, and the western part of Alabama, and were chiefly from rural homes, the relative urbanity of the territory from which they came being about 20 per cent.[10] There were colored troops almost from the start, varying from about a tenth to a third of the command.[10]

The enlisted men were quartered in barracks, which at times (chiefly in summer) were overcrowded. The general admissions for disease were high. Measles started in September (42 cases) and rapidly increased, reaching over 1,800 in November.[11] Mumps and scarlet fever were also prevalent.[11] There were 196 cases of scarlet fever in hospital on December 15, 1918.

The total admissions for measles during the 15 months ending with December, 1918, were 6,959. The special empyema records give the total of post-measles empyema as 57 cases, a proportion of a little over 0.8 per cent of the total measles.[12]

Two cases of empyema were secondary to mumps.[12] Both were associated with hemolytic streptococci and both recovered. This is a negligible proportion of the total admissions for mumps, which numbered 6,462.

Following scarlet fever there were three cases of empyema,[12] all occurring in November and December, 1917. During these 2 months there was an epidemic of scarlet fever, the number of admissions amounting to 275.[11] The bacteriological history of the three cases of postscarlatinal empyema is uncertain.

In Table 20 the figures given for the associated bacteria are derived from the special empyema records [12] compiled at the base hospital. In the early period of high incidence these records indicate only a moderate preponderance of streptococci, but in the reply to the questionnaire of February 21, 1918,[9] transmitted from the base hospital March 23, it is stated that "Of the 85 cases (of empyema) giving positive findings in both culture and the stain, the following grouping is warranted: Streptococci, 63 (74 per cent); pneumococci, 22 (26 per cent). Of the various types of pneumococci we find the following: Type I, 2; Type II, 7; Type IV, 6; not agglutinated, 7." Further information concerning associated microorganisms is given by Maj. Hugh McKenna, M. R. C., then chief of the surgical service.[24] The cases he deals with occurred prior to April 27, 1918. The bacteriological findings were: Streptococcus hemolyticus, 101 (80 per cent); pneumococcus, 25: Type I, 2; Type II, 7; Type IV, 6; not typed, 10.

These sources of information are in accord respecting the preponderance of streptococci in the pleural exudates, and give ratios of 74 per cent and 80 per cent, respectively.

The foregoing data apply to the period prior to May, 1918. A member of the local empyema team reported 88 positive bacteriological findings in empyema cases during September, October, and the first half of November, 1918.[25] There were 61 (69 per cent) associated with streptococci, and 27 (31 per cent) with pneumococci.

All the available evidence indicates a great preponderance of streptococci throughout the history of the camp. This is reflected in the streptococcus curve on Chart XXXIII, which, however, is placed too low at many points. It is not possible to make corrections, for the contemporary reports do not contain figures for individual months.

In commenting upon the curves on Chart XXXII there are few points not touched upon already to which attention may be directed. The high

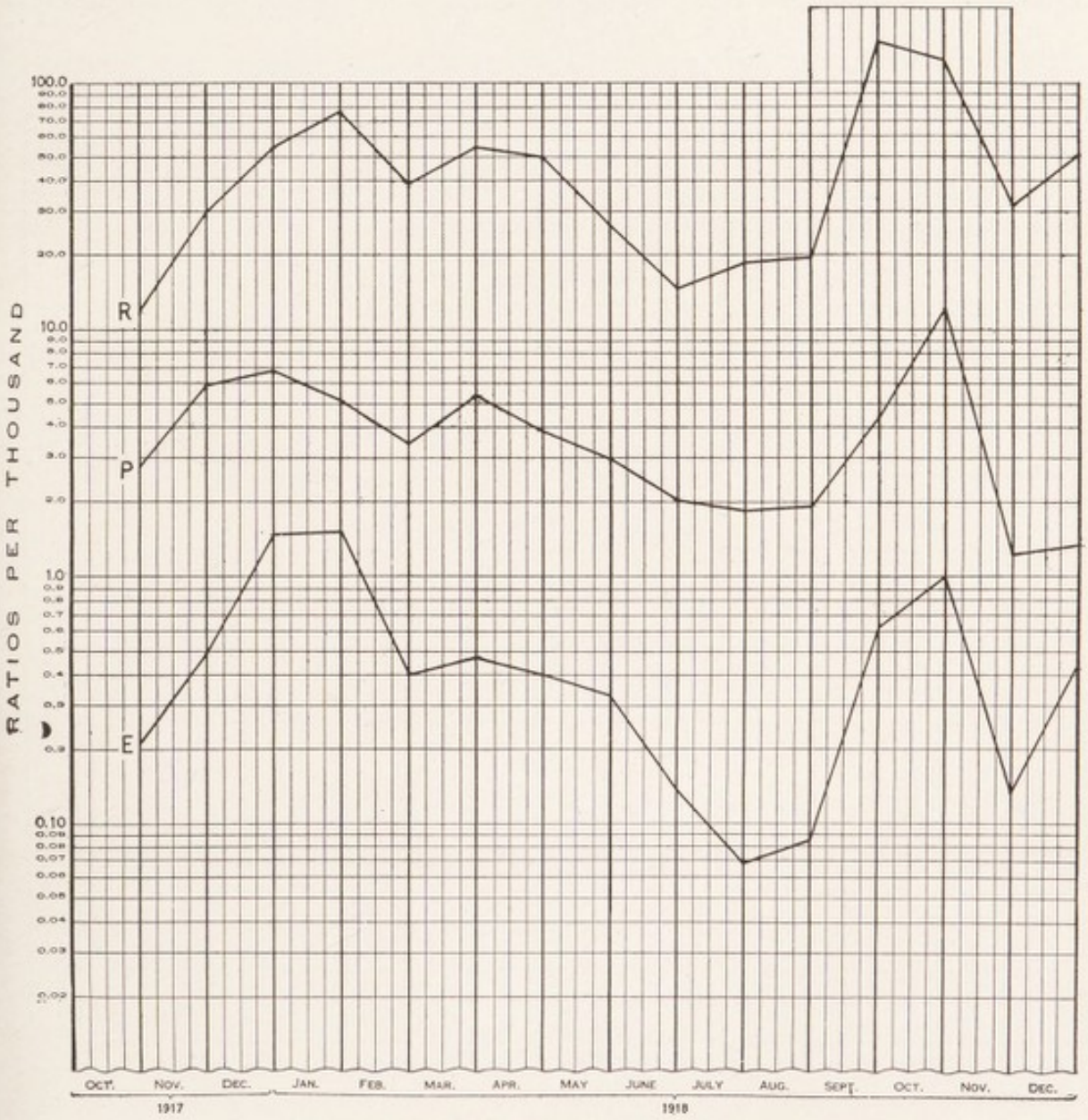


CHART XXXII.—Epidemiological chart for Camp Pike, Ark., in monthly ratios per thousand men.

level of the empyema curve in December and January coincides with a relatively high incidence of influenza in those months, which is not again so marked until this camp participated in the great pandemic in September.

It will be noticed here that during this epidemic the incidence of upper respiratory diseases is greater in September than in October, while the reverse holds for the empyema curve. This was the case in many if not most of the other camps.

A possible explanation of this circumstance is furnished by a comparison of the ratios of deaths per thousand men, from influenza with complications, in September and October.[12] The monthly ratios were 1.98 and 1.25, respectively, i. e., the deaths per 1,000 men were 58 per cent greater in September than in October. It is not probable that the difference in the incidence of empyema was due to variations in the complicating infections giving rise to empyema. It is much more likely that the character of the complications attending the influenza remained substantially the same. But since it takes

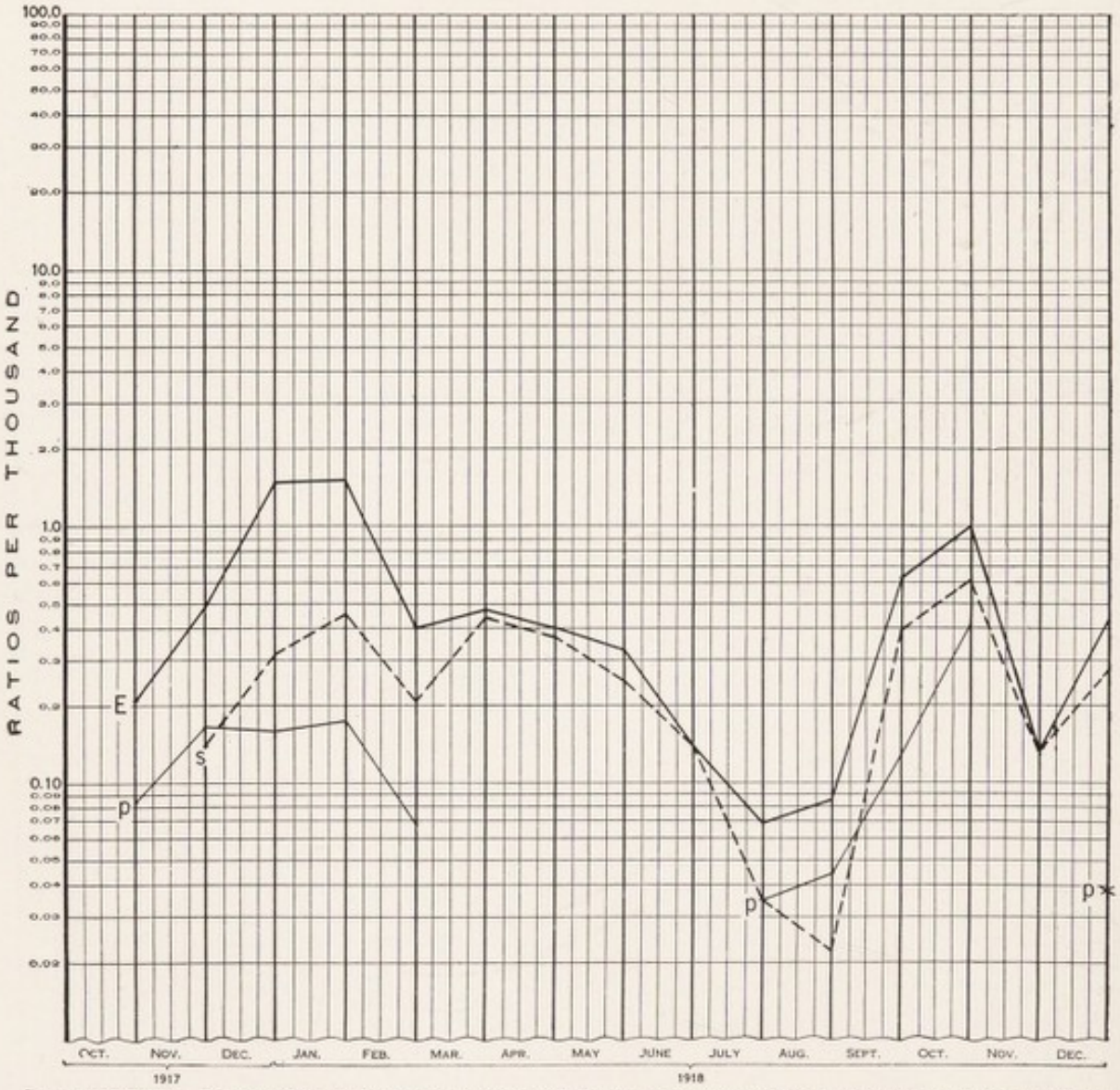


CHART XXXIII.—Relationship of the pneumococcus and the streptococcus to the incidence of empyema at Camp Pike, Ark.

some time for a pleural infection to reach a stage in its evolution when an empyema would be recognized clinically, it follows that in cases of early death the pleural infection would not be detected, while in those that lived longer it would become manifest as a fully developed empyema. The post-mortem observations on cases which died soon after the onset of influenza have frequently demonstrated the presence of a fibrinopurulent exudate upon the pleural surfaces which would have become empyemata had the cases survived. This delay in the development of empyema would depress the curve of apparent

incidence during a severe epidemic to a degree roughly proportionate to the ratio of early deaths. This same reasoning applies to all periods during which secondary infections of the respiratory organs soon proved fatal. At such times the number of cases in which empyema is established upon clinical evidence falls short of the actual number of serious pleural infections.

At Camp Pike the incidence of upper respiratory diseases never fell below 1 per cent of the men in camp, and corresponding to this is the persistence of empyema throughout the whole period studied.

TABLE 20.[a]—*Epidemiological table for Camp Pike, Ark.*

| | Absolute numbers. | | | | | Ratios per 1,000 men. | | | | | Empyema, mortality percentage. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Empyema, totals. | Empyema, deaths. | Streptococcus group. | Pneumococcus group. | Staphylococcus. | Pneumonia. | Common respiratory diseases. | Empyema. | Streptococcus group. | Pneumococcus group. | |
| 1917. | | | | | | | | | | | |
| October | 5 | 1 | 0 | 2 | 0 | 2.76 | 11.58 | 0.2095 | 0 | 0.0838 | 20 |
| November | 14 | 7 | 4 | 5 | 1 | 5.87 | 29.65 | .4829 | 0.1380 | .1625 | 50 |
| December | 47 | 30 | 10 | 5 | 0 | 6.74 | 54.52 | 1.4665 | .3120 | .1560 | 64 |
| 1918. | | | | | | | | | | | |
| January | 43 | 18 | 13 | 5 | 0 | 5.14 | 76.11 | 1.4900 | .4505 | .1732 | 42 |
| February | 12 | 4 | 6 | 5 | 0 | 3.37 | 38.40 | .4088 | .2045 | .0681 | 33 |
| March | 14 | 5 | 13 | 0 | 0 | 5.54 | 55.29 | .4611 | .4282 | .0 | 36 |
| April | 11 | 0 | 10 | 0 | 0 | 3.79 | 49.75 | .3993 | .3630 | .0 | 0 |
| May | 12 | 2 | 9 | 0 | 0 | 2.97 | 26.75 | .3289 | .2466 | .0 | 17 |
| June | 4 | 0 | 4 | 0 | 0 | 2.03 | 14.47 | .1373 | .1373 | .0 | 0 |
| July | 4 | 0 | 2 | 2 | 0 | 1.84 | 18.64 | .0678 | .0339 | .0339 | 0 |
| August | 4 | 1 | 1 | 2 | 0 | 1.90 | 19.65 | .0861 | .0220 | .0440 | 25 |
| September | 34 | 13 | 21 | 7 | 2 | 4.37 | 145.59 | .6242 | .3856 | .1285 | 38 |
| October | 55 | 14 | 33 | 22 | 0 | 10.22 | 122.64 | 1.0176 | .6105 | .4070 | 25 |
| November | 5 | 0 | 5 | 0 | 0 | 1.22 | 31.53 | .1310 | .1310 | .0 | 0 |
| December | 11 | 2 | 7 | 1 | 0 | 1.32 | 50.49 | .4232 | .2690 | .0380 | 18 |
| | 275 | 97 | 138 | 56 | 3 | ..... | ..... | ..... | ..... | ..... | 35.3 |

[a] Sources of information: 1. Reports of sick and wounded made to the Office of the Surgeon General. 2. Special empyema reports made to the Office of the Surgeon General.

## CAMP SHELBY.

Camp Shelby, about 11 miles from Hattiesburg, Miss., a city of 16,000 inhabitants, was used at first for men of the National Guard from Kentucky and Indiana, but in October and November, 1917, there were large additions of drafted men, transferred from other camps.[10] There were but few colored troops until July, 1918.[10] The men were quartered in tents.

There was a sudden and rapid onset of measles in the autumn of 1917.[11] After this the incidence was small, numbering only 521 cases for the whole of 1918. Empyema followed this disease in five instances with one fatality.[12] All five cases occurred between November 19 and December 11, 1917. For those two months the incidence of measles was 1,501 cases. The cases of measles, followed by empyema, closely approximated 1 in 300. The surviving cases were associated, one with pneumococcus, the other three with streptococcus. The bacteriological history of the fatal case is not known.[12]

Four cases of empyema followed mumps, the first in the last week of October, 1917, the last on January 25, 1918.[12] During these four months the admissions for mumps were 1,395.[11] No postscarlatinal cases are recorded.[11]

Of particular interest in Chart XXXIV for Camp Shelby is the abrupt rise in the curve "R" in April, and the slight degree in which this is reflected

in the curve "E," for in many of the camps a rise in "R" at this time of year coincides with a disproportionately greater rise in "E." At Camp Shelby, as elsewhere, the phenominally increased incidence of diseases of the upper respiratory tract was due to an outbreak of influenza, which raised the level of the curve from 13.21 per 1,000 men to a ratio of nearly 117, or an increase of more than 785 per cent. The coincident increase in the empyemata was 44. This is so strikingly different from the experiences in other camps that it must

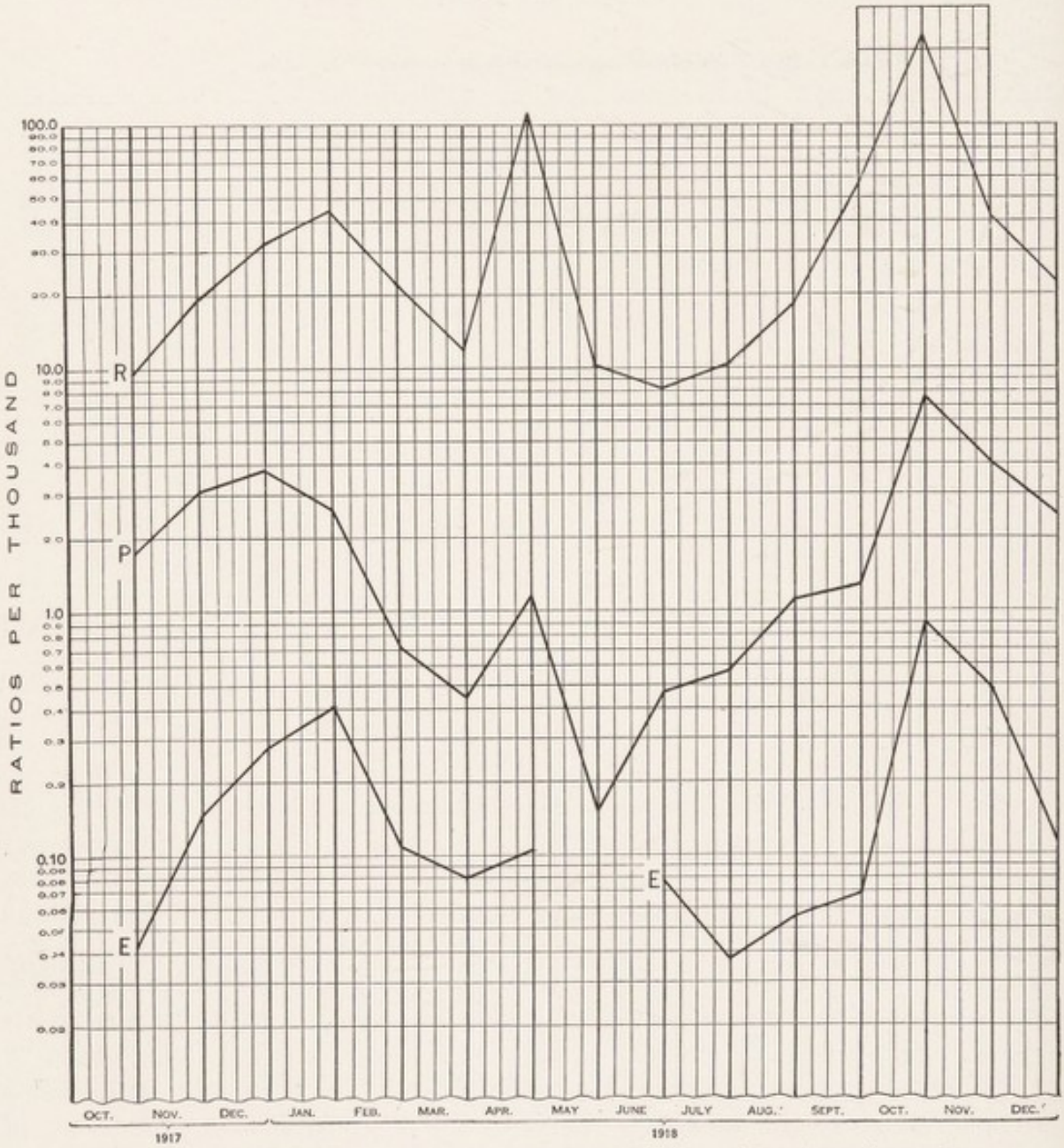


CHART XXXIV.—Epidemiological chart for Camp Shelby, Miss., in monthly ratios per thousand men.

be due to circumstances of great practical importance, particularly as the relations between influenza and empyema in the fall were those common to nearly all camps. The probable explanation is discovered when the attention is directed to two series of related facts concerning the influenza during these two periods. In April the incidence of complications in cases of influenza was only 2.40 per 1,000 men in camp, and there were no deaths whatever from either uncomplicated or complicated influenza. But in October the

incidence of complications was 33.20 and the deaths following influenza (complicated and uncomplicated) 3.65 per 1,000 men.

Turning to the histories of the three cases of empyema in April,[12] it is found that only one is recorded as following influenza and that this was associated with streptococcus viridans in the pleural exudate. The other two cases followed pneumonia and were associated with pneumococcus, Types I and II, respectively.

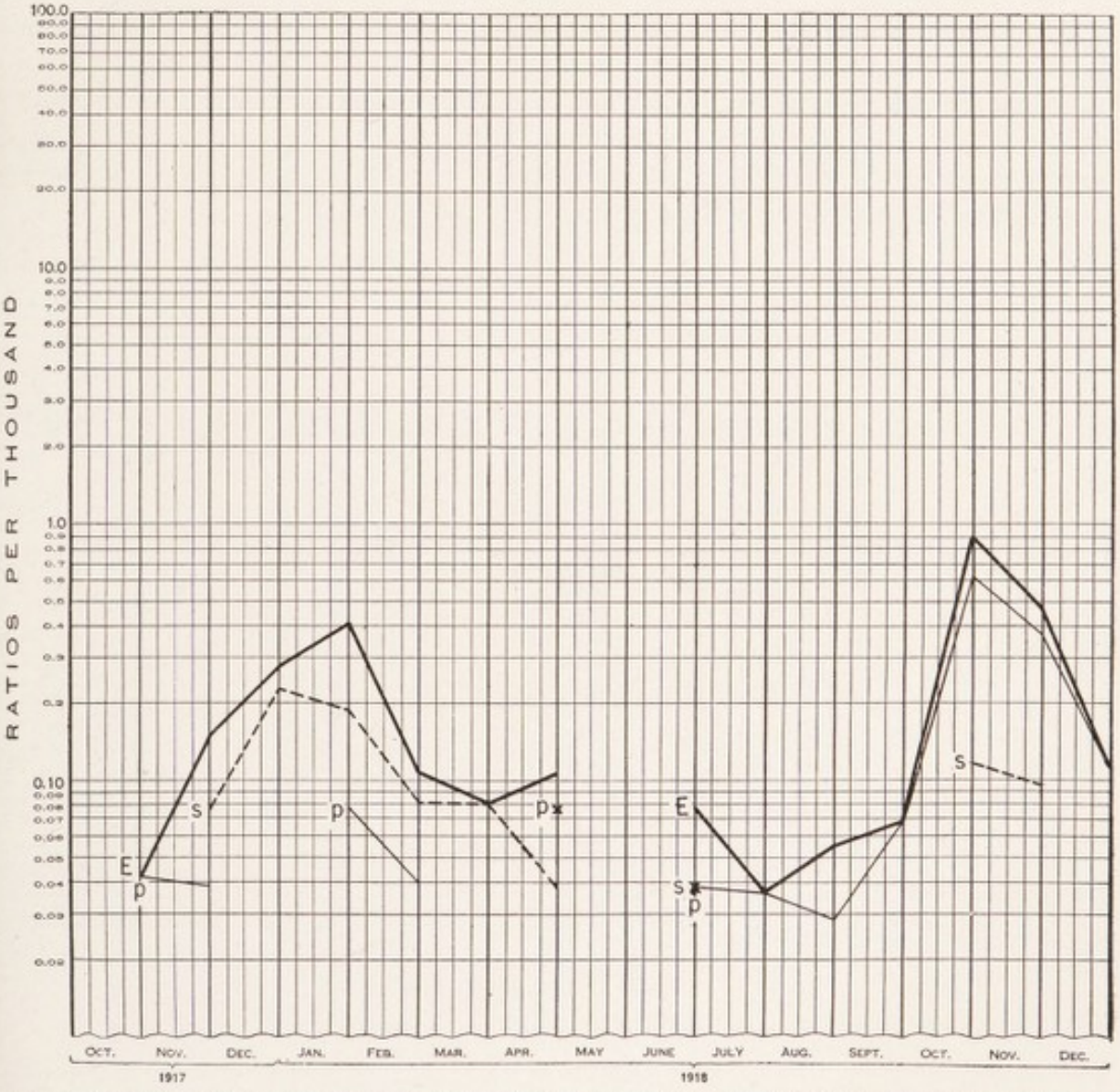


CHART XXXV.—Relationship of the pneumococcus and the streptococcus to the incidence of empyema at Camp Shelby, Miss.

The foregoing observations, when correlated with the experience in other camps, clearly suggest that influenza is of epidemiological importance in the incidence of empyema in proportion to the prevalence, at the time, of organisms prone to infect the pleura as secondary invaders, and that a pure influenzal infection does not threaten this serous cavity.

It remains to inquire into the nature of the two cases of empyema in June, at the time when diseases of the respiratory tract showed the minimal incidence.

The history of the first case is obscure; the patient was admitted June 8, with a diagnosis of "hyperthyroidism, fever type."[12] It is explicitly stated that the case progressed without pneumonia. Empyema on the right side following a diaphragmatic pleurisy was noted eight days after admission, and one week later a portion of the sixth rib was resected and 720 c. c. of foul-smelling pus were evacuated. This pus apparently contained streptococcus viridans. A little more than five weeks later, a portion of the fourth rib was resected, and 1,000 c. c. of pus were obtained. After this second operation, convalescence began and the case pursued an uneventful course. The patient returned to duty 131 days after admission.

The second case in June was admitted on the 20th with suspected lobar pneumonia.[12] He developed empyema, with thick pus containing Type I pneumococcus, 33 days later, was subjected to thoracotomy, and finally returned to duty 152 days after admission to the hospital.

TABLE 21.[a]—*Epidemiological table for Camp Shelby, Miss.*

| | Absolute numbers. | | | | | Ratios per 1,000 men. | | | | | Empyema, mortality percentage. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Empyema, totals. | Empyema, deaths. | Streptococcus group. | Pneumococcus group. | Staphylococcus. | Pneumonia. | Common respiratory diseases. | Empyema. | Streptococcus group. | Pneumococcus group. | |
| 1917. | | | | | | | | | | | |
| October | 1 | 0 | 0 | 1 | 0 | 1.73 | 9.56 | 0.0437 | 0 | 0.0437 | 0 |
| November | 4 | 0 | 2 | 1 | 1 | 2.13 | 19.25 | .1577 | .0772 | .0386 | 0 |
| December | 7 | 2 | 6 | 0 | 0 | 2.81 | 33.38 | .2712 | .2321 | .0 | 29 |
| 1918. | | | | | | | | | | | |
| January | 8 | 0 | 5 | 2 | 0 | 1.73 | 45.35 | .3095 | .1933 | .0775 | 0 |
| February | 3 | 0 | 2 | 1 | 0 | .70 | 23.37 | .1190 | .0795 | .0398 | 0 |
| March | 2 | 1 | 2 | 0 | 0 | .46 | 13.21 | .0798 | .0800 | .0 | 50 |
| April | 3 | 0 | 1 | 2 | 0 | 1.28 | 116.95 | .1150 | .0382 | .0763 | 0 |
| May | 0 | 0 | 0 | 0 | 0 | .16 | 10.87 | .0 | .0 | .0 | 0 |
| June | 2 | 0 | 1 | 1 | 0 | .48 | 8.13 | .0760 | .0380 | .0380 | 0 |
| July | 1 | 0 | 0 | 1 | 0 | .57 | 10.71 | .0368 | .0 | .0368 | 0 |
| August | 2 | 1 | 0 | 1 | 0 | 1.28 | 18.00 | .0552 | .0 | .0276 | 50 |
| September | 1 | 0 | 0 | 1 | 0 | 1.40 | 55.84 | .0680 | .0 | .0681 | 0 |
| October | 7 | 2 | 1 | 4 | 0 | 7.73 | 238.07 | .8906 | .1272 | .6370 | 29 |
| November | 5 | 2 | 1 | 4 | 0 | 4.00 | 41.91 | .4753 | .0950 | .3790 | 40 |
| December | 1 | 0 | 0 | 1 | 0 | 2.51 | 24.34 | .1261 | .0 | .1262 | 0 |
| | 47 | 8 | 21 | 20 | 1 | ..... | ..... | ..... | ..... | ..... | 17 |

[a] Sources of information: 1. Reports of sick and wounded made to the Office of the Surgeon General. 2. Special empyema reports made to the Office of the Surgeon General.

## CAMP BEAUREGARD.

Camp Beauregard, La., about 6 miles from Alexandria, the population of which was 15,000, was at first used for men of the National Guard received from Arkansas, Louisiana, and Mississippi, numbering about 7,000 men.[10] Additions of drafted men from other camps gradually raised the strength to an average of 20,000 in December, 1917. Among these transfers were 9,000 from Camp Pike in November, a time when Camp Pike was heavily infected with measles. The proportion of troops from rural homes was large, presumably nearly 80 per cent of the total number, but negroes never exceeded 1,000 and there was none until after April, 1918.[10] Tents were used to house the men.

Admissions for measles began in October (149 cases).[11] The number increased to 1,546 in November, many cases being imported from Camp Pike;[11] fell to 120 in December; and was negligible through the winter and early

spring of 1918. Postmeasles empyema was reported in nine cases, with two deaths, all occurring between November 17 and December 13, 1917.

Among the 4,574 cases of mumps, none was followed by empyema.[12]

For scarlet fever, there were only three admissions, and none of these developed pleurisy.[11]

The meager data furnished by the special empyema records for the months of the epidemic of influenza fortunately can be supplemented from a pub-

CHART XXXVI.—Epidemiological chart for Camp Beauregard, La., in monthly ratios per thousand men.

lished report by Capt. J. E. McClelland, M. C., who, in 29 cases of empyema, found hemolytic streptococci in three (10 per cent) and pneumococci in 19 (66 per cent).[26] The remaining seven effusions were sterile. Among the pneumococci, 4 were Type I, 6, Type III, 7, Type IV, and 2 were not typed.

At first glance, Chart XXXVI for Camp Beauregard, with particular reference to empyema, appears to be an erratic distribution of unrelated lines.

In the light of the studies on the data from other camps, the empyema curve is interrupted where it should be continuous, reappears where it should be absent, and, as shown on Chart XXXVII, is associated everywhere with the wrong dominance in bacterial species. It is just such phenomena that particularly invite study and are likely to prove more than ordinarily instructive.

It is evident that during the two preceding months all the respiratory diseases were on the down grade, tending toward a point where empyema

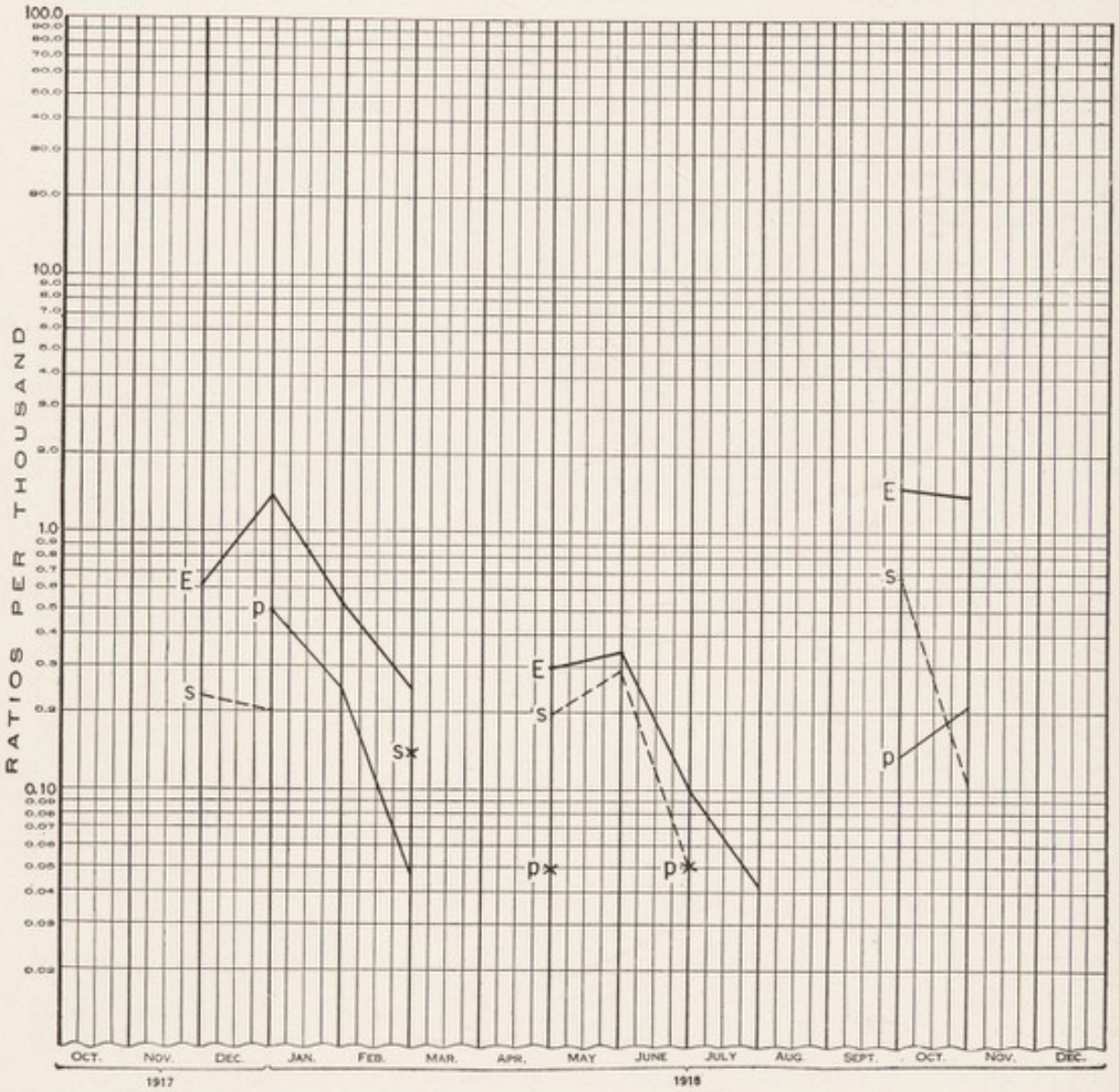


CHART XXXVII.—Relationship of the pneumococcus and the streptococcus to the incidence of empyema at Camp Beauregard, La.

would entirely disappear, and that during these preceding months the character of the pleural infections was of the less serious type, when abruptly something happened in April which for a time changed the course of events. As far as available data can throw light on the nature of this reversing influence, it was an outbreak of influenza with an unusually high proportion of complications, these being about one-seventh of the whole number of cases. Now, it is evident from Chart XXXVII that, at least as far as empyemata are concerned, the streptococcus entered here as a potent factor in secondary infections for the first time in this camp. Furthermore, it continued to so act in September, and was still prevalent in October.

It would be of very great interest could this comparatively late entrance of the streptococcus as a complicating factor be explained by some coincident or immediately preceding event in the history of the camp. The only suggestion offered by the special empyema records lies in the earlier sporadic appearance of this organism in a few cases of empyema. Possibly the advent of influenza among the troops with a slight increase in the strength of the camp, leading to closer contacts among the men, may have been the determining factors leading to a dissemination of the streptococcus. Possibly the weather may have made such contacts particularly close in March and early April. Questions such as these must be left unanswered for lack of data; but, though the explanation is not forthcoming, the sudden, coincident appearance of influenza, empyema and the streptococcus, at a time when previous conditions would have warranted a favorable forecast, is very striking. A similar occurrence took place in September, equally abrupt and also transient.

TABLE 22.[a]—*Epidemiological table of Camp Beauregard, La.*

| | Absolute numbers. | | | | | Ratios per 1,000 men. | | | | | Empyema, mortality percentage. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Empyema, totals. | Empyema, deaths. | Streptococcus group. | Pneumococcus group. | Staphylococcus. | Pneumonia. | Common respiratory diseases. | Empyema. | Streptococcus group | Pneumococcus group. | |
| 1917. | | | | | | | | | | | |
| October | 0 | 0 | 0 | 0 | 0 | 1.14 | 5.42 | 0 | 0 | 0 | 0 |
| November | 11 | 4 | 4 | 0 | 0 | 6.77 | 13.48 | 0.6264 | 0.2280 | 0 | 36 |
| December | 27 | 4 | 4 | 10 | 0 | 8.29 | 33.87 | 1.3508 | .2000 | 0.5000 | 15 |
| 1918. | | | | | | | | | | | |
| January | 13 | 5 | 0 | 6 | 0 | 3.93 | 30.35 | .5272 | .0 | .2440 | 38 |
| February | 5 | 1 | 3 | 1 | 0 | 2.50 | 25.07 | .2399 | .1380 | .0460 | 20 |
| March | 0 | 0 | 0 | 0 | 0 | 1.35 | 15.11 | .0 | .0 | .0 | 0 |
| April | 6 | 3 | 4 | 1 | 0 | 2.95 | 51.11 | .2966 | .1975 | .0494 | 50 |
| May | 7 | 3 | 6 | 0 | 0 | 1.16 | 27.55 | .3377 | .2895 | .0 | 43 |
| June | 2 | 0 | 1 | 1 | 0 | .95 | 7.43 | .1005 | .0503 | .0503 | 0 |
| July | 1 | 1 | 0 | 0 | 0 | .99 | 10.11 | .0412 | .0 | .0 | 100 |
| August | 0 | 0 | 0 | 0 | 0 | 5.00 | 18.75 | .0 | .0 | .0 | 0 |
| September | 11 | 2 | 5 | 1 | 0 | 13.39 | 500.41 | 1.4628 | .6650 | .1330 | 18 |
| October | 13 | 5 | 6 | 1 | 0 | 21.44 | 271.64 | 1.3753 | .1057 | .2114 | 38 |
| November | 0 | 0 | 0 | 0 | 0 | .99 | 32.81 | .0 | .0 | .0 | 0 |
| December | 0 | 0 | 0 | 0 | 0 | 1.79 | 26.27 | .0 | .0 | .0 | 0 |
| | 96 | 28 | 33 | 21 | 0 | ..... | ..... | ..... | ..... | ..... | 29.2 |

[a] Sources of information: 1. Reports of sick and wounded made to the Office of the Surgeon General. 2. Special empyema reports made to the Office of the Surgeon General.

## CAMP LOGAN.

Camp Logan, Tex., in the immediate outskirts of Houston, a city of approximately 110,000 inhabitants, was first occupied by 20,000 men of the National Guard of Illinois, arriving in September, 1917.[10] These were augmented by men transferred from other camps during the next two months. Colored troops were present from the beginning, but in very fluctuating numbers, and never much over 2,500. The men were quartered in tents.[10]

Two cases of empyema followed measles, one in December, 1917, and one in February, 1918.[12] The admissions for measles in those months were 195 and 197, respectively.[11] In neither case is there any record of bacteriological findings.

No cases followed either mumps or scarlet fever, the admissions for which were 471 and 37, respectively.[11]

The incidence of respiratory diseases appears to have been governed by a continual presence of influenza, which showed almost as high a rate in April (86.21) as in October (88.29), although the climax was in September (200.86).[11]

The curve of incidence for empyema shows, in general, a closer correspondence to that of upper respiratory diseases than to that of the pneumonias, but displays wider fluctuations than either. This suggests an influence affecting the development of empyema, but not reflected in the incidence

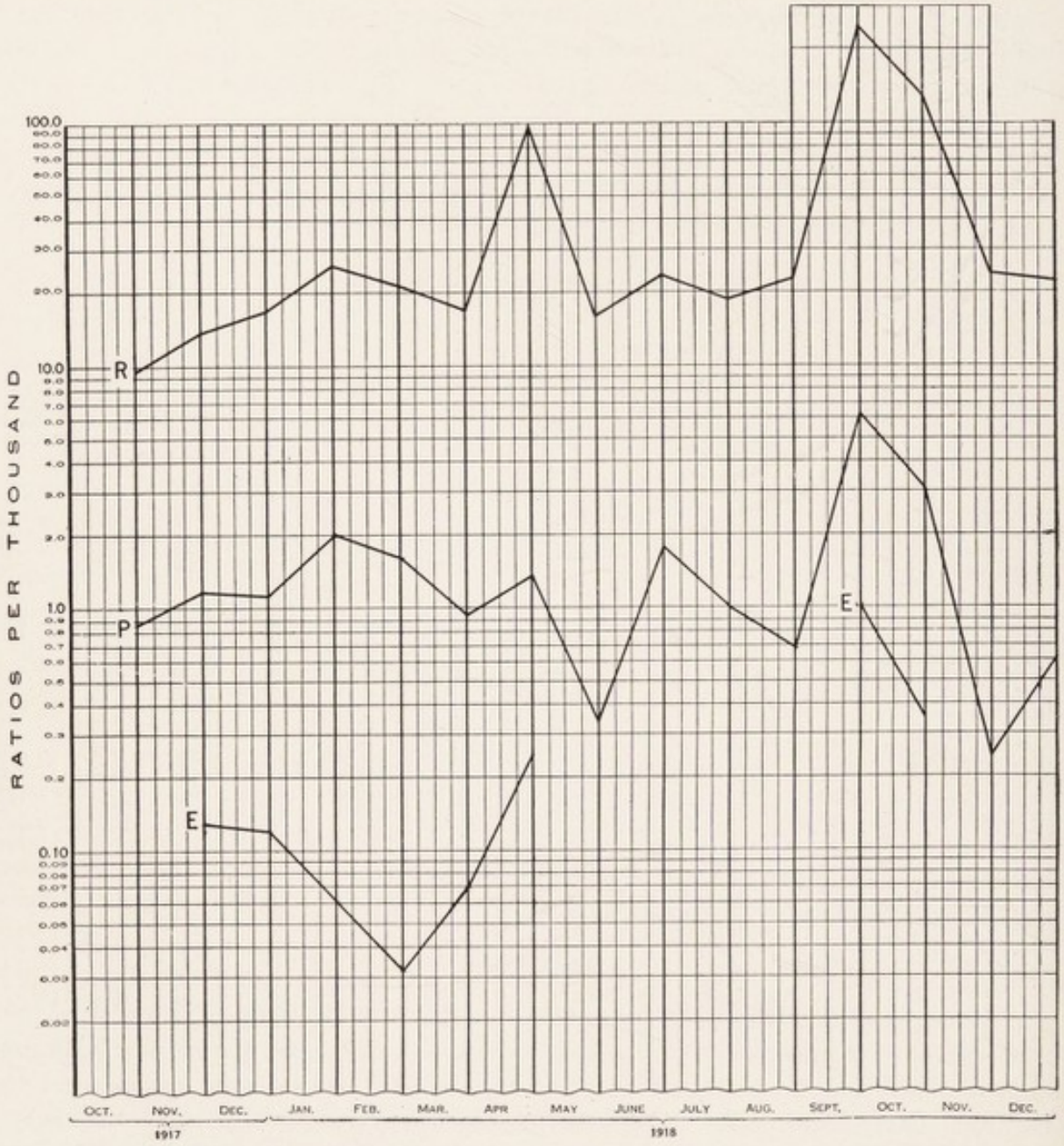


CHART XXXVIII.—Epidemiological chart for Camp Logan, Tex., in monthly ratios per thousand men.

of primary respiratory diseases. This influence may well be the prevalence or rarity in camp of the organisms commonly found in pleural exudates. These may fail to occasion infection of the more remote respiratory organs unless some intercurrent circumstance creates conditions favoring such a development. When this occurs the resulting empyema may appear out of proportion to this favoring factor.

The high incidence of respiratory diseases in May, June, July, and August, 1918, when empyema failed to occur, was due to an unusual number of uncomplicated cases of influenza without any fatalities.

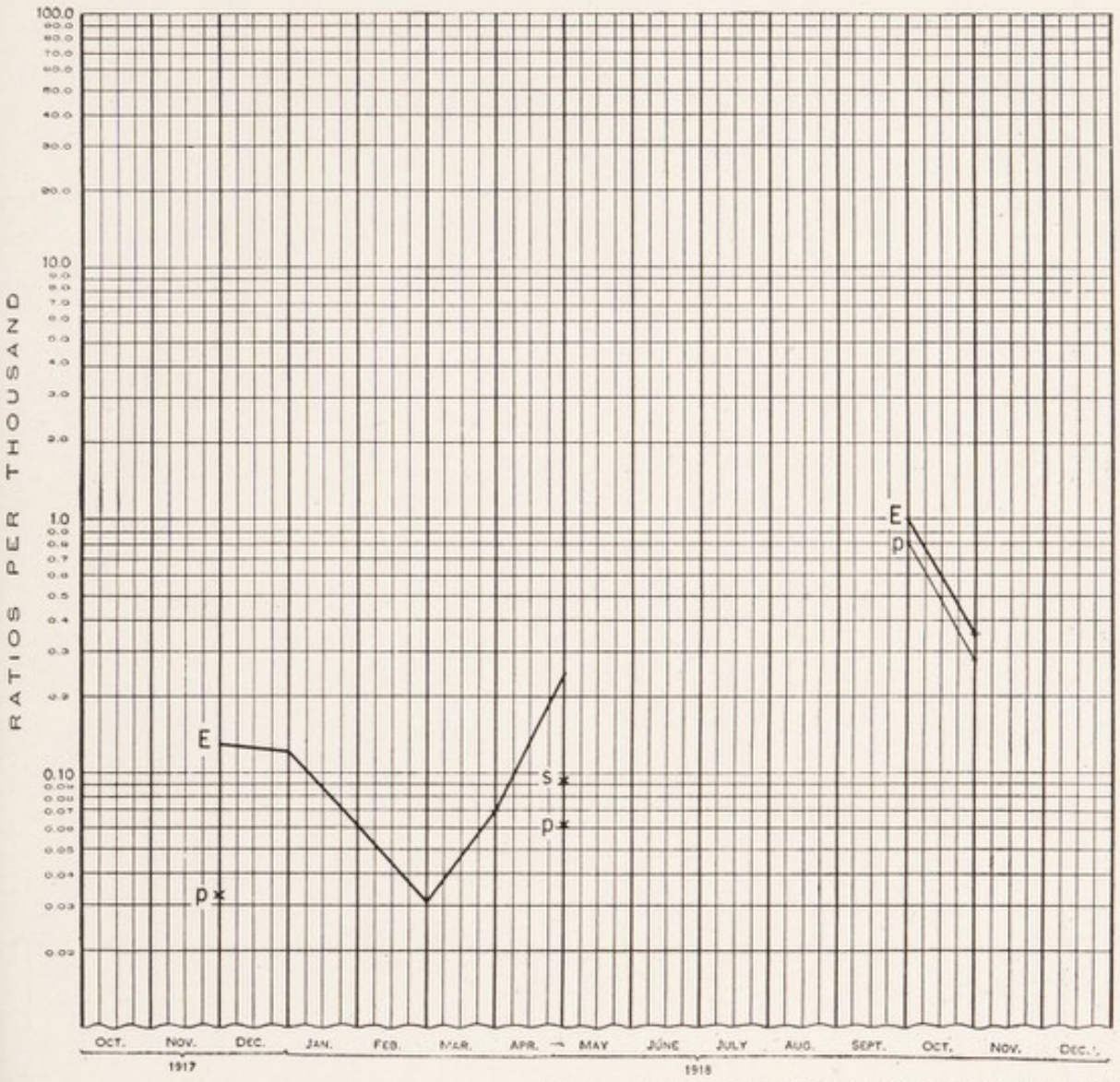


CHART XXXIX.—Relationship of the pneumococcus and the streptococcus to the incidence of empyema at Camp Logan, Tex.

TABLE 23.[a]—*Epidemiological table for Camp Logan, Tex.*

| | Absolute numbers. | | | | | Ratios per 1,000 men. | | | | | Empyema, mortality percentage. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Empyema, totals. | Empyema, deaths. | Streptococcus group. | Pneumococcus group. | Staphylococcus. | Pneumonia. | Common respiratory diseases. | Empyema. | Streptococcus group. | Pneumococcus group. | |
| 1917. | | | | | | | | | | | |
| October | 0 | 0 | 0 | 0 | 0 | 0.85 | 9.53 | 0.0 | 0.0 | 0.0 | 0 |
| November | 4 | 1 | 0 | 1 | 0 | 1.16 | 13.80 | .1282 | 0 | .0321 | 25 |
| December | 4 | 0 | 0 | 0 | 0 | 1.12 | 16.90 | .1199 | 0 | .0 | 0 |
| 1918. | | | | | | | | | | | |
| January | 2 | 1 | 0 | 0 | 0 | 2.04 | 25.89 | .0613 | 0 | .0 | 50 |
| February | 1 | 0 | 0 | 0 | 0 | 1.59 | 21.14 | .0314 | 0 | .0 | 0 |
| March | 2 | 0 | 0 | 0 | 0 | .94 | 16.85 | .0690 | 0 | .0 | 0 |
| April | 8 | 3 | 3 | 2 | 1 | 1.33 | 97.58 | .2476 | 0.0918 | .0612 | 38 |
| May | 0 | 0 | 0 | 0 | 0 | .33 | 15.85 | .0 | .0 | .0 | 0 |
| June | 0 | 0 | 0 | 0 | 0 | 1.74 | 23.23 | .0 | .0 | .0 | 0 |
| July | 0 | 0 | 0 | 0 | 0 | 1.01 | 18.80 | .0 | .0 | .0 | 0 |
| August | 0 | 0 | 0 | 0 | 0 | .66 | 22.54 | .0 | .0 | .0 | 0 |
| September | 10 | 1 | 0 | 7 | 1 | 6.20 | 219.12 | 1.0215 | .0 | .8160 | 10 |
| October | 5 | 1 | 0 | 4 | 0 | 3.06 | 125.60 | .3470 | .0 | .2773 | 20 |
| November | 0 | 0 | 0 | 0 | 0 | .24 | 23.57 | .0 | .0 | .0 | 0 |
| December | 0 | 0 | 0 | 0 | 0 | .60 | 22.03 | .0 | .0 | .0 | 0 |
| | 36 | 7 | 3 | 14 | 2 | ..... | ..... | ..... | ..... | ..... | 19.4 |

[a] Sources of information: 1. Reports of sick and wounded made to the Office of the Surgeon General. 2. Special empyema reports made to the Office of the Surgeon General.

## CAMP BOWIE.

Camp Bowie, Tex., located in the suburbs of Fort Worth, a city of 100,000 inhabitants, served at first for men of the National Guard from Texas and Oklahoma, who began to arrive the latter part of August, 1917, and by the end of September numbered approximately 17,000.[10] In October drafted troops arrived from other camps, notably Camp Travis, bringing the strength up to slightly over 30,000.[10] The 36th Division moved overseas about July, 1918,

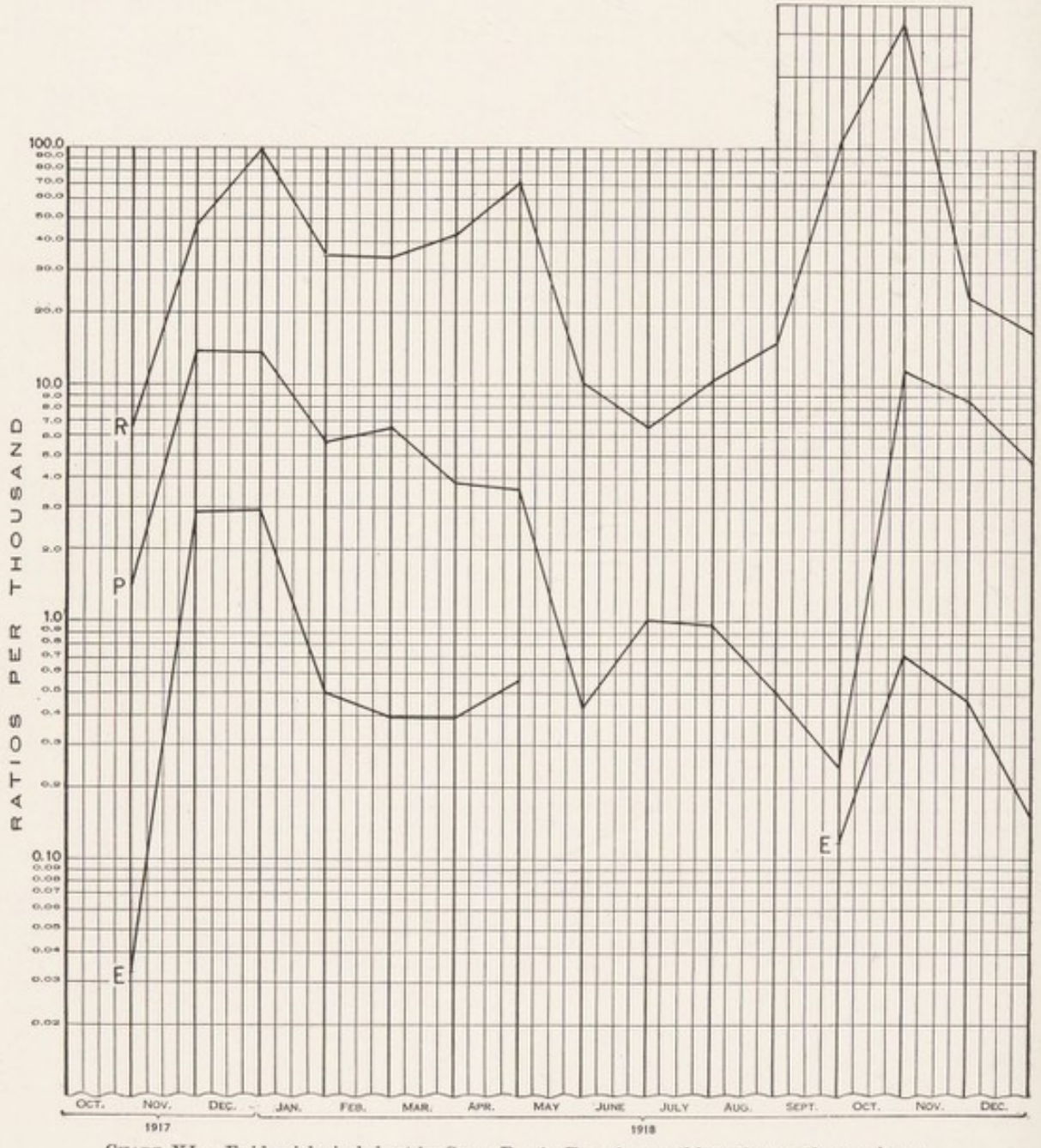


CHART XL.—Epidemiological chart for Camp Bowie, Tex., in monthly ratios per thousand men.

after which the camp was used for training replacement Infantry, men coming from such widely separated localities as California and Louisiana.[10] There were no colored troops until September, 1918, and the average number in any one month never reached 3,000. The troops were quartered in tents.

An epidemic of measles visited the camp in the autumn of 1917.[11] As early as October, 293 cases were admitted for this disease. For November

the number rose to 3,163, fell in December to 178, and thereafter became negligible. All the postmeasles empyema occurred during this initial period of high incidence of the primary disease and amounted to 55 cases, including 38 that died.[12] The first case occurred November 4 and proved fatal, having developed a bilateral pneumonia. The incidence of these empyemata was 1.6 per cent of the total measles; the mortality among the postmeasles cases was 69 per cent. Concerning the bacteriology of the pleural exudates in these particular cases the data are very deficient. Among the 17 surviving cases,

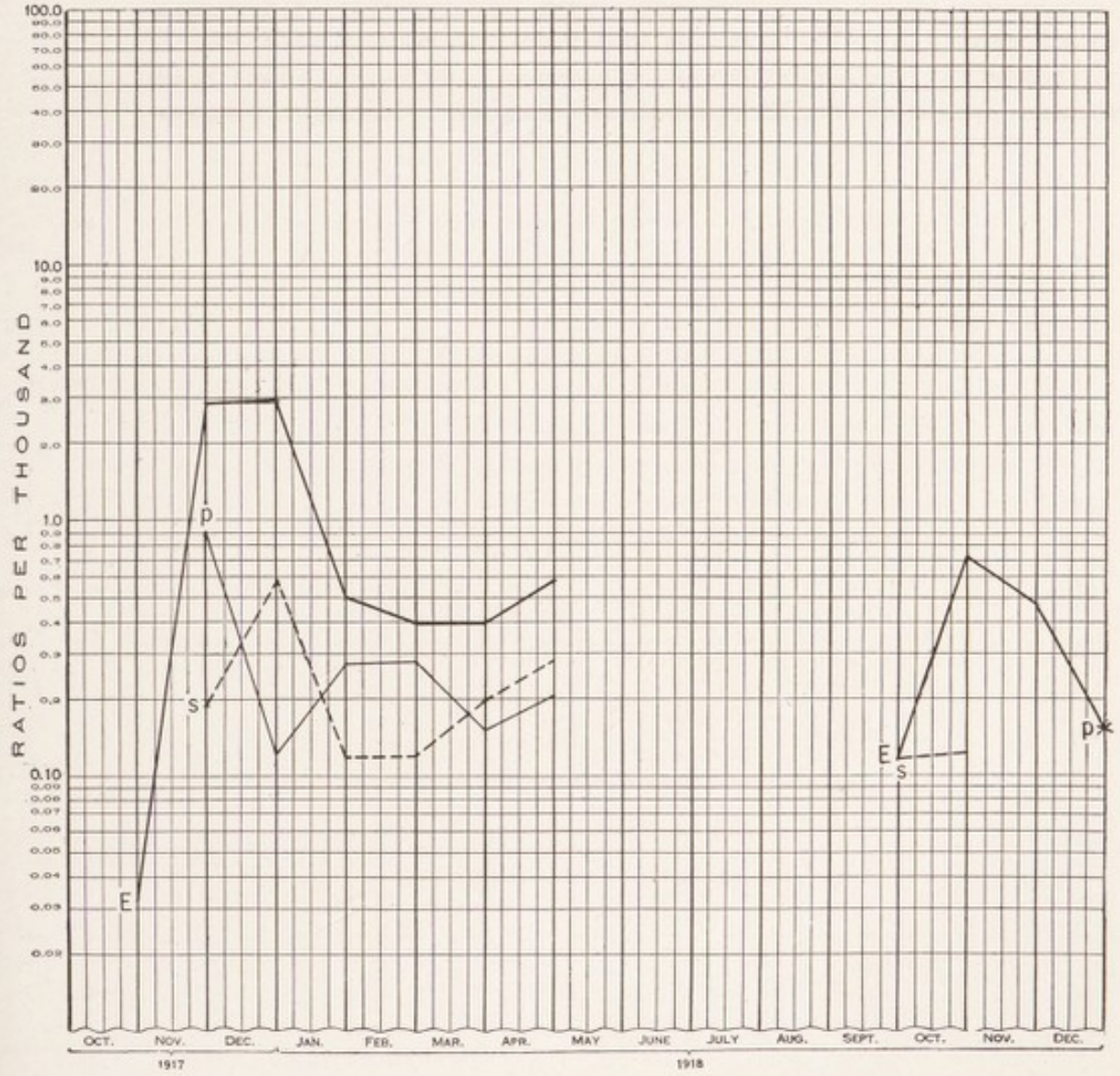


CHART XLI.—Relationship of the pneumococcus and the streptococcus to the incidence of empyema at Camp Bowie, Tex.

4 yielded pneumococci, 1, streptococci, 1, staphylococci, but there are no available data for the remaining 11. Information concerning 38 fatal cases is equally disappointing—6, pneumococci, 6, streptococci, and 26, unrecorded.[12]

There were only 2 cases of empyema preceded by mumps, although the admissions for the latter were 5,317.[11] Both of these cases recovered; one was associated with pneumococcus, the other was without data concerning the organism present. No postscarlatinal cases were reported, and there were altogether only seven admissions for scarlet fever.[11]

The bacteriological findings in the empyema cases at Camp Bowie, limited to those contained in the special empyema records, are given in Table 24. It will be noted that the pneumococcus is the predominant organism. For the period which extended to about March 22, 1918, this relative preponderance of pneumococci is substantiated by the reply to the questionnaire of February 21.[9] Of 146 cases a pneumococcus was found alone in 100 (69 per cent), associated with streptococcus in 28, streptococcus alone in 17, and staphylococcus in 1. Taking all cases in which the streptococcus was present, the proportion was 31 per cent.

For the later period of high incidence of empyema, light is thrown by data in an article published in July, 1919,[27] on the relative frequency with which the pleural exudate yielded pneumococci or streptococci. It was shown that there were of the pneumococcus alone, 32; pneumococcus with hemolytic streptococcus, 30; hemolytic streptococcus alone, 3.

Chart XL shows a marked likeness between the curves "R" and "E," with a typical interruption of the latter when "R" drops to the level of 1 per cent. The rise in April is coincident with the familiar increased incidence of influenza at that time. But the upward trend of "E" at this time is not exaggerated, and in Chart XLI the curves "s" and "p" show that, in so far as the bacteriological data are available, neither the pneumococcus nor the streptococcus was greatly predominant at this time. Taken in connection with the information garnered from other camps as well as from Camp Bowie it would appear that the incidence of empyema depends upon two factors: The prevalence at the time of organisms capable of inducing empyema, and the occurrence of infections favoring the migration of these organisms from the upper respiratory tract into the lungs.

TABLE 24.[a]—*Epidemiological table for Camp Bowie, Tex.*

| | Absolute numbers. | | | | | Ratios per 1,000 men. | | | | | Empyema, mortality percentage. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Empyema, totals. | Empyema, deaths. | Streptococcus group. | Pneumococcus group. | Staphylococcus. | Pneumonia. | Common respiratory diseases. | Empyema. | Streptococcus group. | Pneumococcus group. | |
| 1917. | | | | | | | | | | | |
| October | 1 | 0 | 0 | 0 | 0 | 1.42 | 6.68 | 0.0324 | 0 | 0 | 0 |
| November | 76 | 45 | 5 | 24 | 1 | 13.81 | 47.64 | 2.8718 | 0.1890 | 0.9080 | 59 |
| December | 64 | 12 | 14 | 9 | 0 | 13.63 | 98.48 | 2.9343 | .5804 | .1201 | 19 |
| 1918. | | | | | | | | | | | |
| January | 13 | 4 | 3 | 7 | 0 | 5.74 | 35.13 | .5039 | .1164 | .2710 | 31 |
| February | 10 | 1 | 3 | 8 | 0 | 6.53 | 33.81 | .3940 | .1182 | .2768 | 10 |
| March | 10 | 1 | 5 | 4 | 0 | 3.83 | 42.83 | .3925 | .1963 | .1510 | 10 |
| April | 14 | 2 | 7 | 5 | 1 | 3.55 | 71.68 | .5702 | .2844 | .2040 | 14 |
| May | 0 | 0 | 0 | 0 | 0 | .44 | 10.20 | .0 | .0 | .0 | 0 |
| June | 0 | 0 | 0 | 0 | 0 | 1.02 | 6.57 | .0 | .0 | .0 | 0 |
| July | 0 | 0 | 0 | 0 | 0 | .97 | 10.36 | .0 | .0 | .0 | 0 |
| August | 0 | 0 | 0 | 0 | 0 | .51 | 15.08 | .0 | .0 | .0 | 0 |
| September | 1 | 1 | 1 | 0 | 0 | .24 | 106.18 | .1148 | .1148 | .0 | 100 |
| October | 12 | 2 | 2 | 0 | 0 | 11.67 | 336.39 | .7260 | .1209 | .0 | 17 |
| November | 4 | 1 | 0 | 0 | 0 | 8.68 | 23.74 | .4662 | .0 | .0 | 25 |
| December | 1 | 0 | 0 | 1 | 0 | 4.72 | 16.66 | .1506 | .0 | .1506 | 0 |
| | 206 | 69 | 40 | 58 | 2 | ..... | ..... | ..... | ..... | ..... | 33.5 |

[a] Sources of information: 1. Reports of sick and wounded made to the Office of the Surgeon General. 2. Special empyema reports made to the Office of the Surgeon General.

## CAMP TRAVIS.

Camp Travis, Tex., bordering upon and partly within the city limits of San Antonio, which has a population of about 100,000, was a National Army cantonment.[10] Drafted men came here from Texas and Oklahoma. They were mostly from rural districts, the territory furnishing them being, as a whole, about 23 per cent urban.[10] Starting early in September, the strength of the

camp rapidly increased, and by the end of that month reached 18,000.[10] In October the average strength was 26,000 and in November, 33,000. In this month nearly 8,000 of the men were colored, and until the end of 1918 there was always a large contingent of negroes in the command.[10] The 90th Division moved overseas about June, 1918, but accessions maintained the previous strength of the camp.[10] The quarters were frame barrack buildings.[10]

As in most of the camps of this general character, the admissions for the usual infectious diseases were high, particularly during the early months.[11]

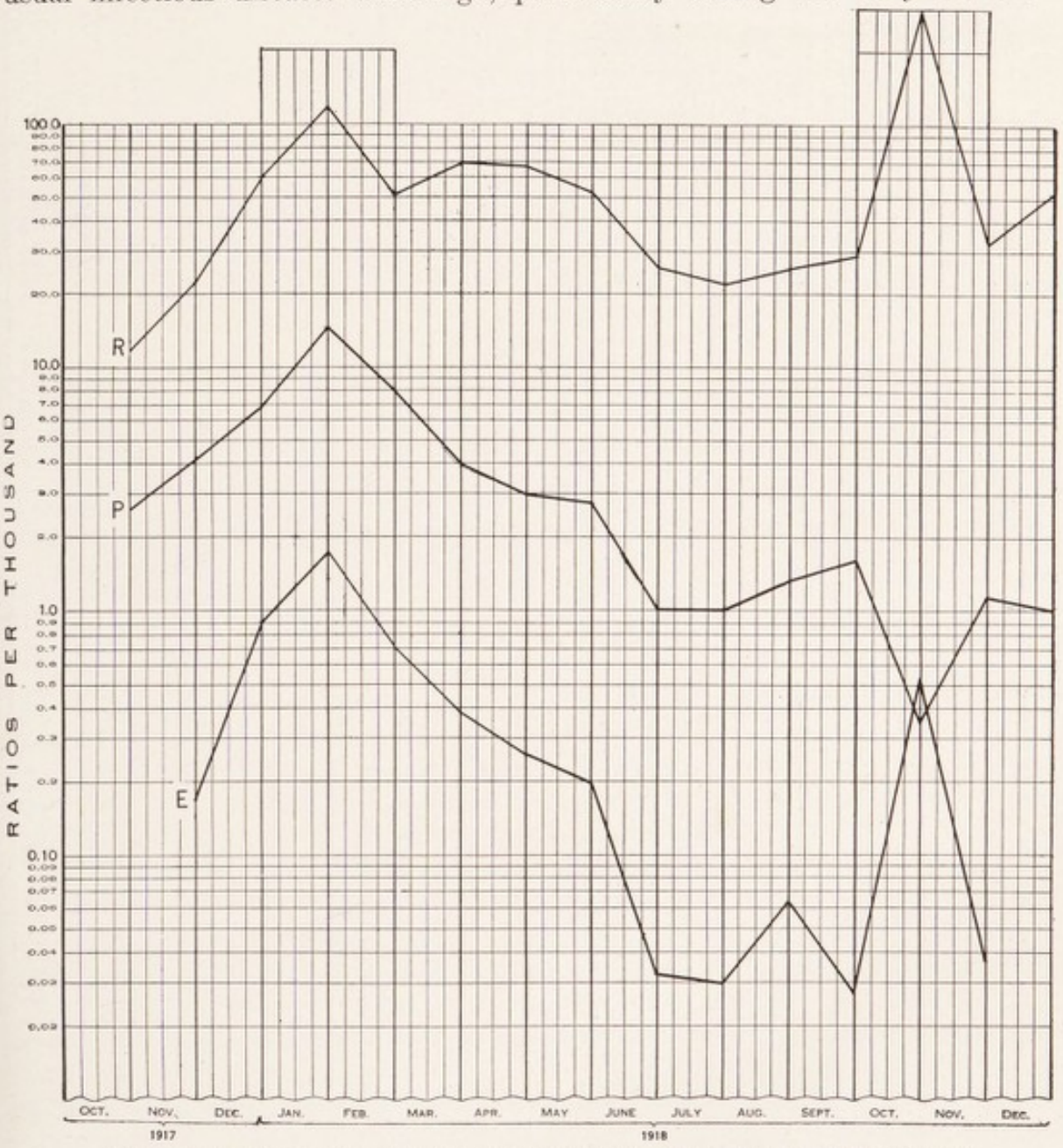


CHART XLII.—Epidemiological chart for Camp Travis, Tex., in monthly ratios per thousand men.

The cases of measles, after small beginnings in October, abruptly rose to 2,671 in November, were 1,435 in December, and then fell to 46 in January, after which there were only 545 during the remainder of 1918.[11] Corresponding to these figures were 14 cases of postmeasles empyema between November 24 and December 14. Two of these, one associated with streptococcus, proved fatal. In the other, the pneumococcus was found in the pleural exudate.[12]

Only one case of empyema followed mumps, notwithstanding a record of 8,277 admissions for this disease.[11] There were no postscarlatinal cases.[12]

The special empyema records give bacteriological data for 107 out of the 158 cases reported. The pneumococcus was found in 63 per cent of these, and appears to have been the predominating organism associated with empyema at Camp Travis. Possibly the low mortality, 17 per cent, is related to this circumstance. There are no available data other than the special empyema records concerning the bacteriology in the earlier months, but the findings in 49 pleuritic effusions and empyemata during the epidemic of influenza were

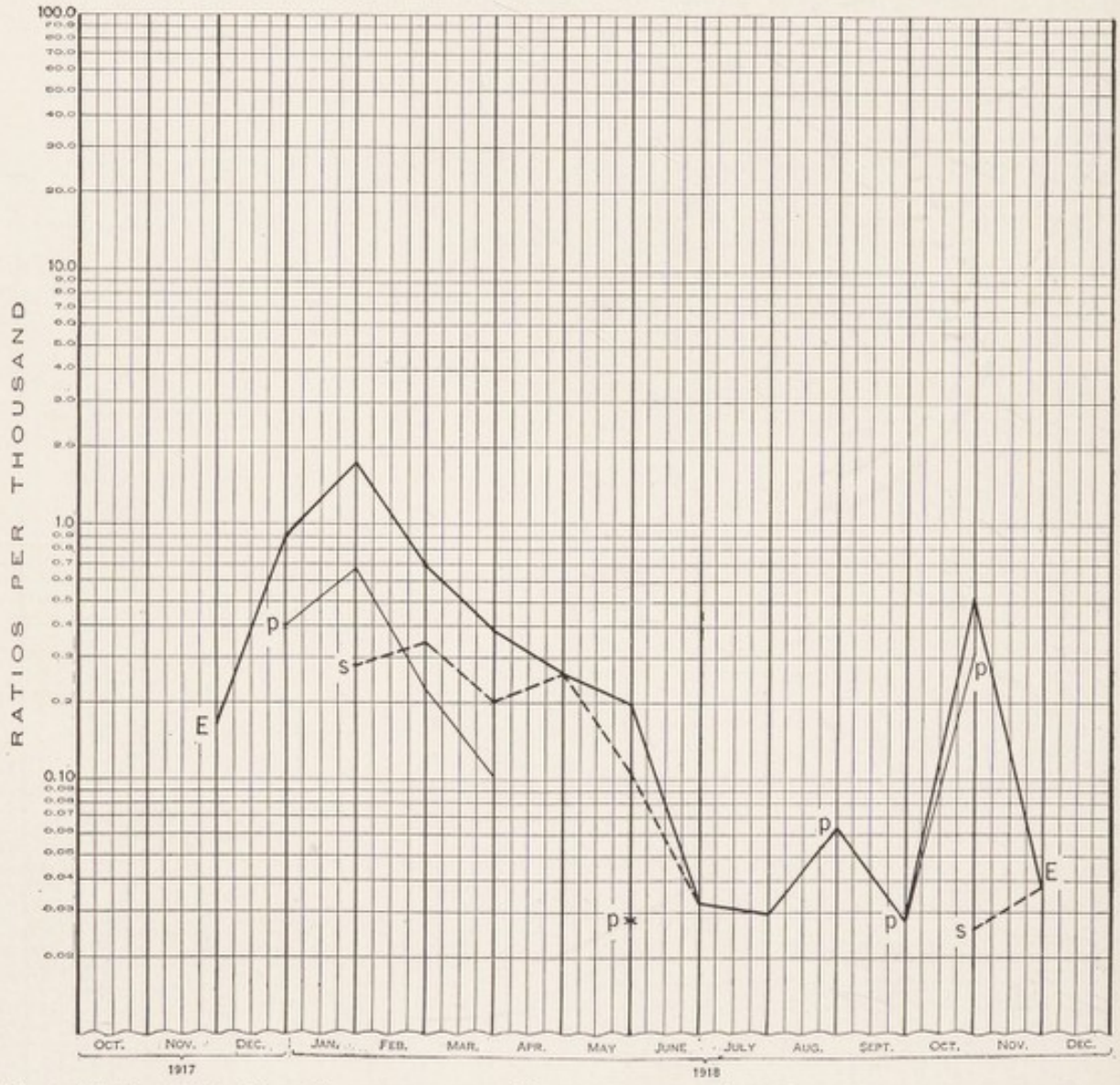


CHART XLIII.—Relationship of the pneumococcus and the streptococcus to the incidence of empyema at Camp Travis, Tex.

published by the chief of the laboratory service.[28] Twenty-four of these gave negative cultures. In the 25 giving positive findings the results were pneumococcus alone, 13; pneumococcus with influenza bacillus, 5; influenza bacillus alone, 1; Friedländer bacillus, 1; streptococcus alone, 3; and streptococcus with pneumococcus, 2. The cases associated with the pneumococcus were, therefore, about four times as numerous as those associated with the streptococcus. It is of interest to note that the pneumococcus predominated in other complications during this epidemic. In 16 cases of meningitis the article referred to reports that a pneumococcus was found in all, without a single case in which streptococci were present.

Cases of empyema were continuously present at Camp Travis during the period of low incidence of upper respiratory diseases, but it will be noted that these never fell in number to 1 per cent of the command.[12]

In October, 1918, the cases of empyema were more numerous than those of lobar and bronchopneumonia combined. This illustrated the difficulty of untangling the confusing physical signs presented by the cases at this time.[12]

TABLE 25.[a]—*Epidemiological table for Camp Travis, Tex.*

| | Absolute numbers. | | | | | Ratios per 1,000 men. | | | | | Empyema, mortality percentage. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Empyema, totals. | Empyema, deaths. | Streptococcus group. | Pneumococcus group. | Staphylococcus. | Pneumonia. | Common respiratory diseases. | Empyema. | Streptococcus group. | Pneumococcus group. | |
| 1917. | | | | | | | | | | | |
| October | 0 | 0 | 0 | 0 | 0 | 2.59 | 11.59 | 0 | 0 | 0 | 0 |
| November | 6 | 0 | 0 | 0 | 0 | 4.14 | 22.07 | 0.1786 | 0 | 0 | 0 |
| December | 30 | 6 | 1 | 13 | 0 | 6.79 | 60.32 | .9157 | 0 | 0.3960 | 20 |
| 1918. | | | | | | | | | | | |
| January | 52 | 10 | 9 | 21 | 0 | 14.62 | 128.01 | 1.6977 | 0.2839 | .6850 | 19 |
| February | 19 | 5 | 9 | 6 | 0 | 8.05 | 51.38 | .7032 | .3333 | .2222 | 26 |
| March | 11 | 2 | 6 | 3 | 0 | 3.92 | 68.41 | .3781 | .2060 | .1030 | 18 |
| April | 7 | 1 | 7 | 0 | 0 | 3.01 | 66.35 | .2568 | .2564 | .0 | 14 |
| May | 7 | 0 | 4 | 1 | 0 | 2.74 | 52.86 | .1962 | .1120 | .0280 | 0 |
| June | 1 | 1 | 1 | 0 | 0 | 1.04 | 25.45 | .0335 | .0335 | .0 | 100 |
| July | 1 | 0 | 0 | 0 | 0 | 1.02 | 21.96 | .0294 | .0 | .0 | 0 |
| August | 2 | 0 | 0 | 2 | 0 | 1.31 | 24.93 | .0642 | .0 | .0642 | 0 |
| September | 1 | 0 | 0 | 1 | 0 | 1.64 | 28.59 | .0271 | .0 | .0271 | 0 |
| October | 20 | 2 | 1 | 20 | 1 | .36 | 293.30 | .5306 | .0265 | .3184 | 10 |
| November | 1 | 0 | 1 | 0 | 0 | 1.11 | 32.70 | .0366 | .0366 | .0 | 0 |
| December | 0 | 0 | 0 | 0 | 0 | 1.04 | 52.96 | .0 | .0 | .0 | 0 |
| | 158 | 27 | 39 | 67 | 1 | ..... | ..... | ..... | ..... | ..... | 17.1 |

[a] Sources of information: 1. Reports of sick and wounded made to the Office of the Surgeon General. 2. Special empyema reports made to the Office of the Surgeon General.

## CAMP CODY.

Camp Cody, N. Mex., about 3 miles from Deming, a town of approximately 5,000 inhabitants, was first occupied by men of the National Guard from Minnesota, Iowa, Nebraska, North Dakota, and South Dakota.[10] They were not wholly without experience as soldiers but were from regions in which there were few large cities. The arrivals during September, 1917, were about 12,000.[10] In October over 10,000 men came from other camps.[10] These were drafted men and their arrival disturbed the uniformity in origin of the command. The average strength in October was about 22,000 men and ranged between this and 28,000 until the departure of the 34th Division, about August, 1918, when the strength fell to nearly 4,000 and was not again increased beyond about 9,000.[10] At no time were there more than a very few colored troops. The men were quartered in tents.

Measles was not prevalent at Camp Cody. The total number of admissions for the 15 months beginning October 1, 1917, was 550.[11] The highest incidence was in the fall of 1917, when there were 164 in November with 11 with pneumonia, and, in December 169, of which 14 were complicated with pneumonia. During this period there were 8 cases of postmeasles empyema, 3 dying.[12] Of the total measles (333) this would be 2.4 per cent developing emypema, but 34 per cent of the measles-pneumonias. In four of the cases, streptococci were found in the pleural exudate; in one the pneumococcus; and in the remaining three there are no bacteriological data.

No cases of empyema followed either mumps or scarlet fever.[11]

In Table 26, based on the special empyema records,[12] the proportion of streptococcus empyemas is 60 per cent. In the reply to the questionnaire of

February 21, 1918, it is 62.5 per cent.[3] The two reports are in substantial harmony and do not indicate a considerable preponderance of streptococcus infections.

The relation of the incidence of empyema to that of upper respiratory diseases as shown on Chart XLIV is of interest. When the latter fell to approximately 1 per cent in May, there was no empyema reported. In June, however,

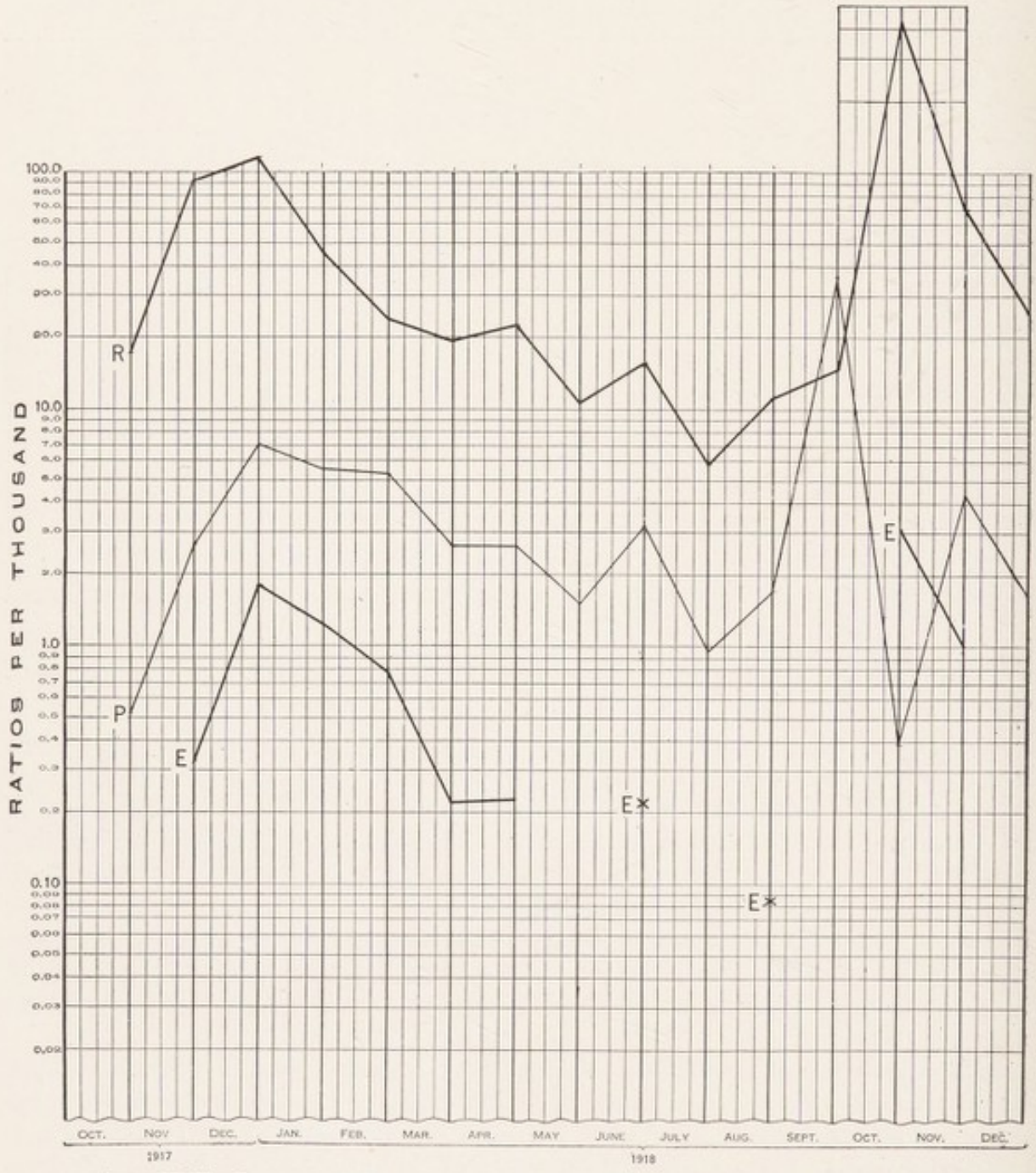


CHART XLIV.—Epidemiological chart for Camp Cody, N. Mex., in monthly ratios per thousand men.

a month when empyema is usually absent, the respiratory diseases rose and three cases of empyema appear, two of which were associated with streptococci. In the following month the conditions noted in May are repeated, and in August, again an unusual month for empyema, these reappear with the rise in diseases of the upper respiratory tract. Had there been one or two cases of empyema in September this series of coincidences would have been unbroken from January to November, inclusive.

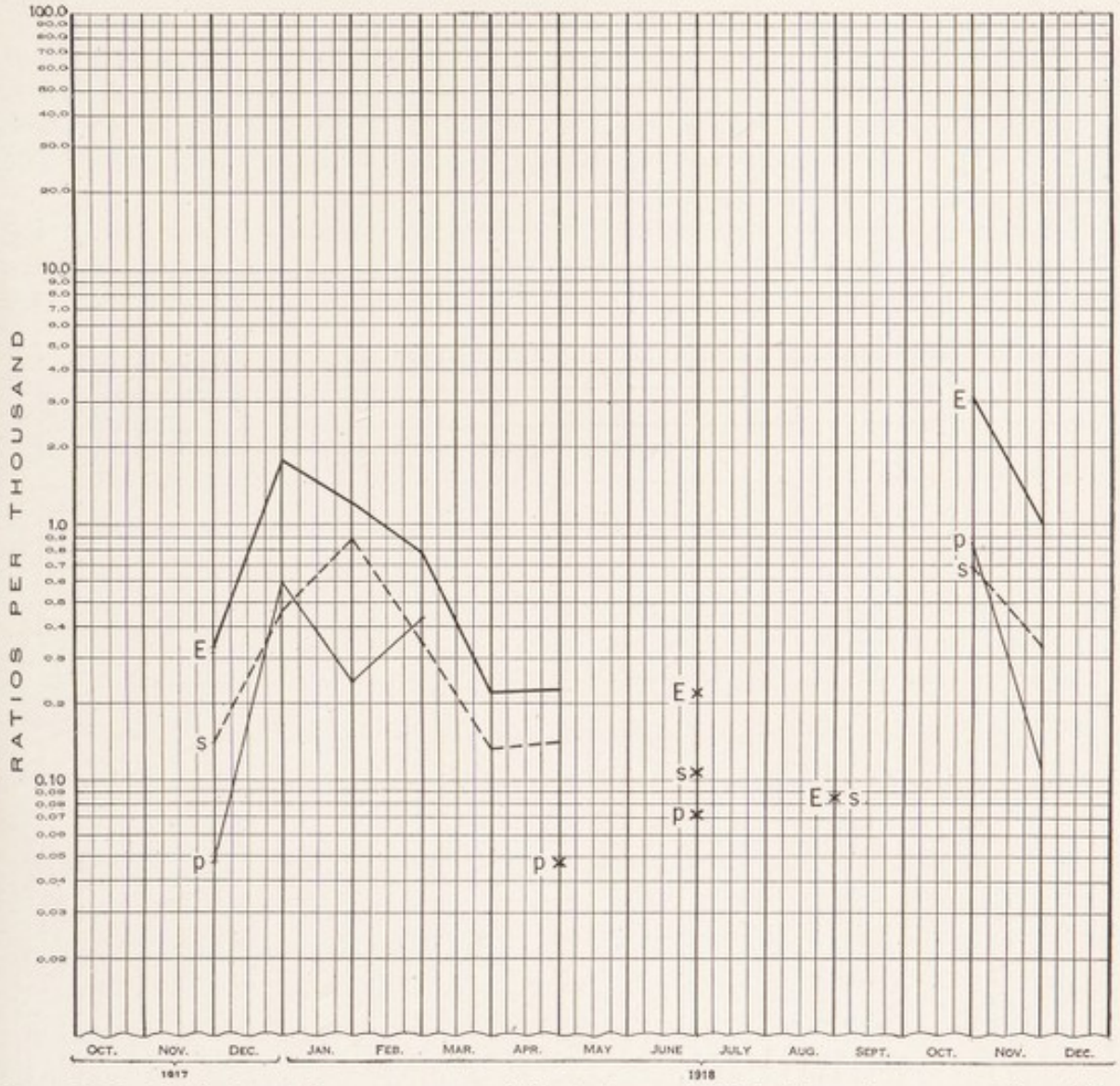


CHART XLV.—Relationship of the pneumococcus and the streptococcus to the incidence of empyema at Camp Cody, N. Mex.

TABLE 26.[a]—*Epidemiological table for Camp Cody, N. Mex.*

| | Absolute numbers. | | | | | Ratios per 1,000 men. | | | | | Empyema, mortality percentage. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Empyema, totals. | Empyema, deaths. | Streptococcus group. | Pneumococcus group. | Staphylococcus. | Pneumonia. | Common respiratory diseases. | Empyema. | Streptococcus group. | Pneumococcus group. | |
| 1917. | | | | | | | | | | | |
| October | 0 | 0 | 0 | 0 | 0 | 0.52 | 17.01 | 0 | 0 | 0 | 0 |
| November | 7 | 1 | 3 | 1 | 0 | 2.66 | 92.99 | 0.3269 | 0.1401 | 0.0468 | 14 |
| December | 39 | 12 | 10 | 13 | 0 | 7.07 | 114.96 | 1.7852 | .4575 | .5970 | 31 |
| 1918. | | | | | | | | | | | |
| January | 30 | 10 | 22 | 6 | 0 | 5.62 | 46.06 | 1.2146 | .8907 | .2430 | 33 |
| February | 18 | 2 | 8 | 10 | 0 | 5.39 | 23.69 | .7739 | .3440 | .4290 | 11 |
| March | 5 | 2 | 3 | 0 | 0 | 2.65 | 19.62 | .2182 | .1310 | .0 | 40 |
| April | 5 | 1 | 3 | 1 | 0 | 2.63 | 22.32 | .2241 | .1407 | .0469 | 20 |
| May | 0 | 0 | 0 | 0 | 0 | 1.51 | 10.84 | .0 | .0 | .0 | 0 |
| June | 6 | 0 | 3 | 2 | 0 | 3.19 | 15.82 | .2164 | .1082 | .0721 | 0 |
| July | 0 | 0 | 0 | 0 | 0 | .96 | 5.82 | .0 | .0 | .0 | 0 |
| August | 1 | 0 | 1 | 0 | 0 | 1.69 | 11.22 | .0858 | .0858 | .0 | 0 |
| September | 0 | 0 | 0 | 0 | 0 | 36.27 | 14.95 | .0 | .0 | .0 | 0 |
| October | 17 | 3 | 4 | 5 | 1 | .39 | 431.70 | 3.0965 | .6810 | .8510 | 18 |
| November | 9 | 1 | 3 | 1 | 0 | 4.36 | 70.40 | .9978 | .3330 | .1110 | 11 |
| December | 0 | 0 | 0 | 0 | 0 | 1.65 | 25.09 | .0 | .0 | .0 | 0 |
| | 137 | 31 | 60 | 40 | 1 | ..... | ..... | ..... | ..... | ..... | 22.6 |

[a] Sources of information: 1. Reports of sick and wounded made to the Office of the Surgeon General. 2. Special empyema reports made to the Office of the Surgeon General.

CAMP FREMONT.

Camp Fremont, Calif., near Palo Alto, the population of which was about 5,000, served for the organization of the 8th Division of the Regular Army, beginning in January, 1918, when the average strength in enlisted men was 6,744.[10] This strength gradually increased to June, when it was 23,000. The number of colored troops was negligible.[10]

The admissions for measles and mumps were moderate in number, being 474 and 443, respectively, for the year.[11] Two cases of postmeasles empyema are recorded in February, 1918, when the total admissions for measles was 24.[12]

CHART XLVI.—Epidemiological chart for Camp Fremont, Calif., in monthly ratios per thousand men.

Both cases were associated with streptococcus, and both recovered. No empyema developed in cases of mumps, or in the cases of scarlet fever for which there was a total of 14 admissions.[11]

The total number of empyema cases at Camp Fremont was so small and their distribution was on the whole so nearly uniform, that the data derived from them offer little opportunity for deductions of epidemiological value. One feature of interest shown on Chart XLVI is the independence of the empyema in respect to pneumonia, and the comparative faithfulness with which it conforms to the curve for diseases of the upper respiratory tract, notwithstanding the inexplicable exception in March.

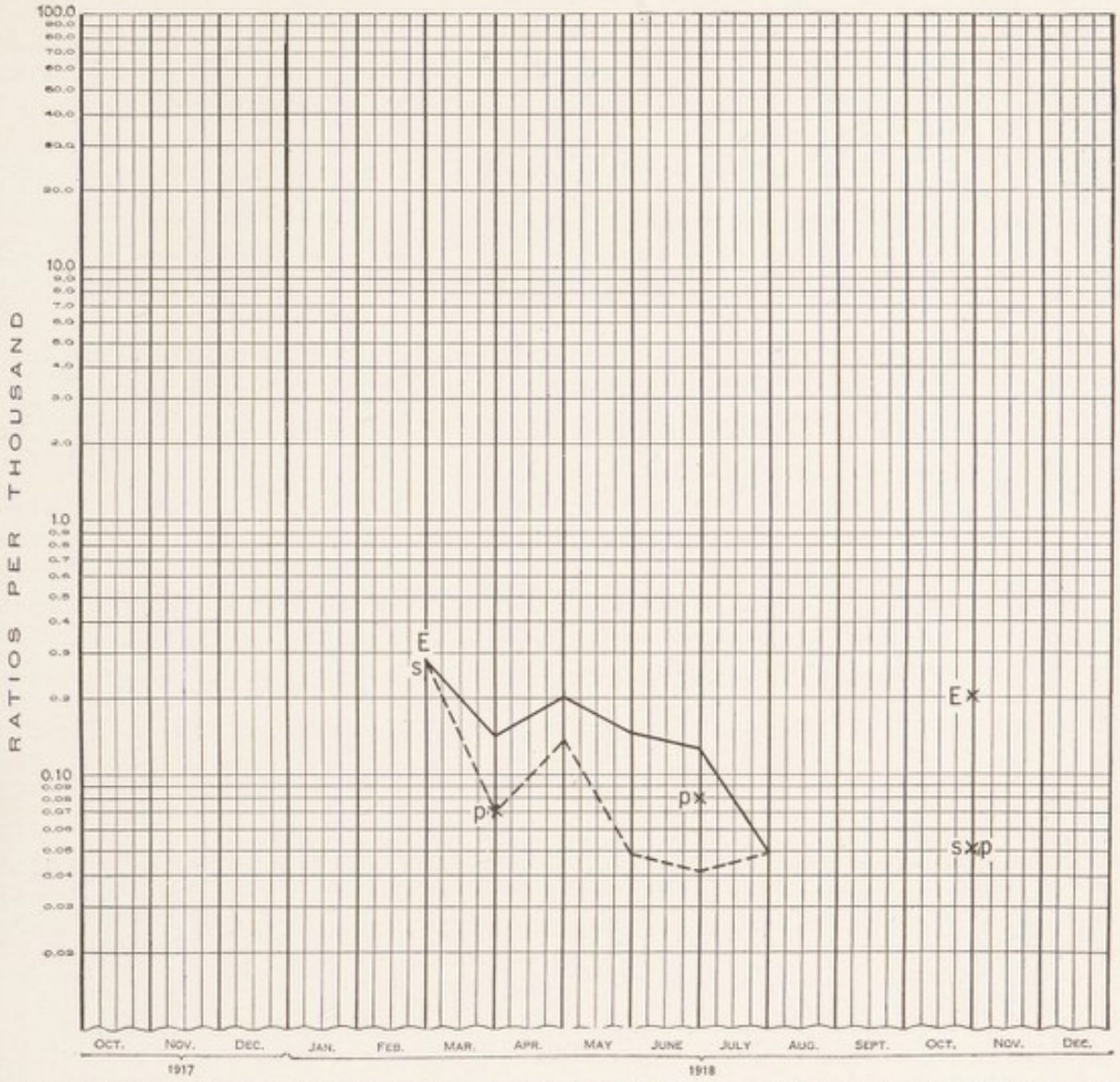


CHART XLVII.—Relationship of the pneumococcus and the streptococcus to the incidence of empyema at Camp Fremont, Calif.

TABLE 27.[a]—*Epidemiological table for Camp Fremont, Calif.*

| | Absolute numbers. | | | | | Ratios per 1,000 men. | | | | | Empyema, mortality percentage. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Empyema, totals. | Empyema, deaths. | Streptococcus group. | Pneumococcus group. | Staphylococcus. | Pneumonia. | Common respiratory diseases. | Empyema. | Streptococcus group. | Pneumococcus group. | |
| 1917. | | | | | | | | | | | |
| October | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| November | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| December | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1918. | | | | | | | | | | | |
| January | 0 | 0 | 0 | 0 | 0 | 1.93 | 22.54 | 0 | 0 | 0 | 0 |
| February | 3 | 0 | 3 | 0 | 0 | 1.11 | 17.90 | 0.2814 | 0.2814 | 0 | 0 |
| March | 2 | 0 | 1 | 1 | 0 | .60 | 25.40 | .1403 | .0701 | 0.0701 | 0 |
| April | 2 | 0 | 2 | 0 | 0 | .29 | 86.71 | .2057 | .1370 | .0 | 0 |
| May | 3 | 0 | 1 | 0 | 1 | 1.26 | 26.43 | .1444 | .0481 | .0 | 0 |
| June | 3 | 0 | 1 | 3 | 0 | 1.09 | 18.92 | .1248 | .0415 | .0830 | 0 |
| July | 1 | 0 | 1 | 0 | 0 | .26 | 10.17 | .0493 | .0493 | .0 | 0 |
| August | 0 | 0 | 0 | 0 | 0 | 1.88 | 13.72 | .0 | .0 | .0 | 0 |
| September | 0 | 0 | 0 | 0 | 0 | .44 | 13.53 | .0 | .0 | .0 | 0 |
| October | 2 | 0 | 1 | 1 | 0 | 13.17 | 112.50 | .2043 | .0513 | .0513 | 0 |
| November | 0 | 0 | 0 | 0 | 0 | 1.14 | 24.35 | .0 | .0 | .0 | 0 |
| December | 0 | 0 | 0 | 0 | 0 | .70 | 17.55 | .0 | .0 | .0 | 0 |
| | 17 | 0 | 10 | 5 | 1 | ..... | ..... | ..... | ..... | ..... | 0 |

[a] Sources of information: 1. Reports of sick and wounded made to the Office of the Surgeon General. 2. Special empyema reports made to the Office of the Surgeon General.

CAMP LEWIS.

Camp Lewis, Wash., about 13 miles from Tacoma, a city of over 100,000 population, was a National Army cantonment. The drafted men came from Washington, Montana, Utah, California, Idaho, Wyoming, and a few from New York State.[10] In September, 1917, the mean strength was 18,000, and the following three months it stood at about 36,000.[10] Colored troops were present, but in small numbers in October, 1917, and continuously thereafter. Frame barracks were provided for quarters.[10]

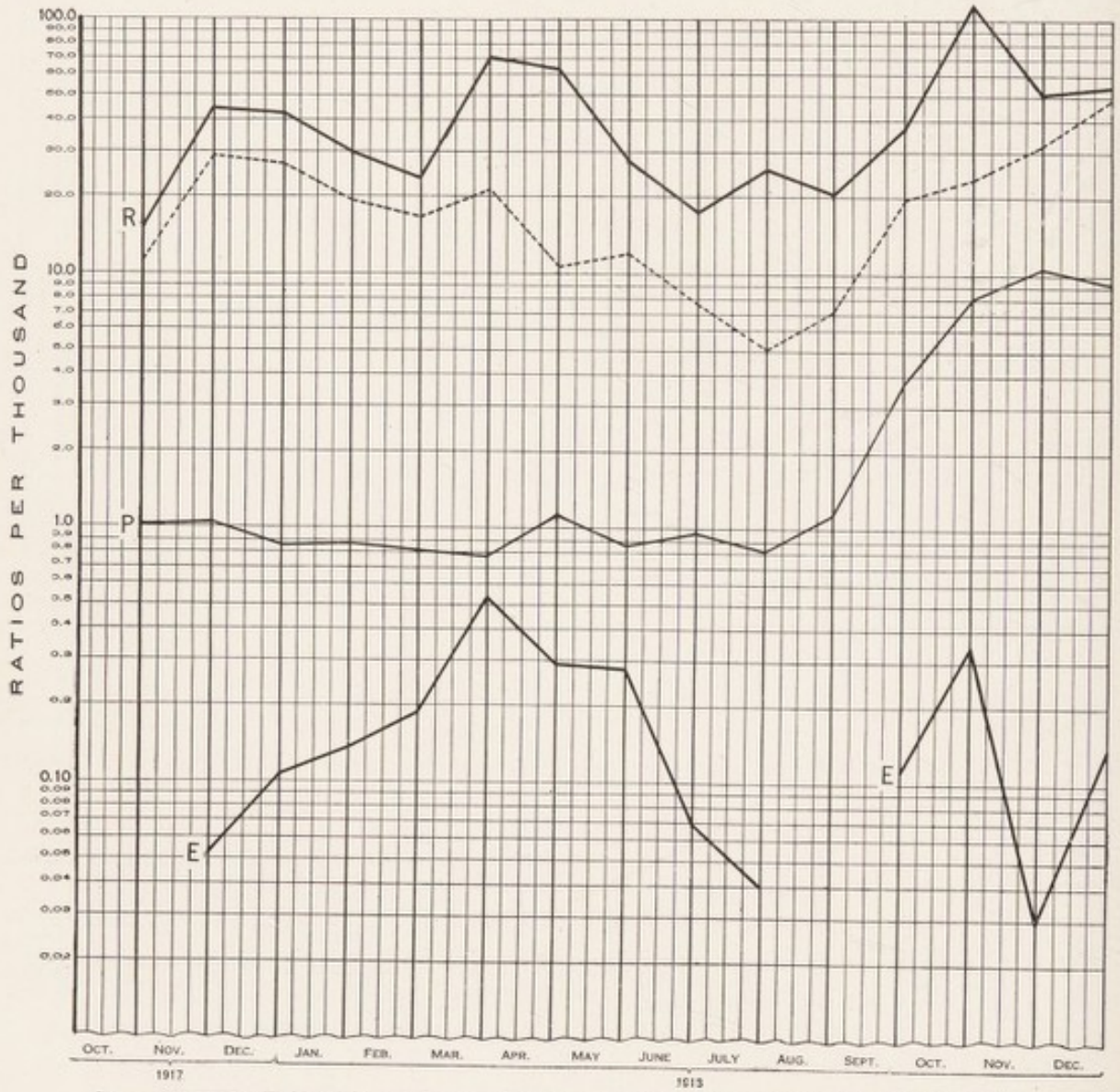


CHART XLVIII.—Epidemiological chart for Camp Lewis, Wash., in monthly ratios per thousand men.

During January, February, and March, 1918, there were five cases of postmeasles empyema, one of which died.[11] These five cases constituted 1.6 per cent of the total admissions for measles during the three months. The mortality among the postmeasles empyema cases was 20 per cent, which is a lower rate than that in many other camps.[11]

There was one case of empyema following rubella.[11] This occurred in December, 1917, when there were 1,063 admissions for the latter disease. As elsewhere, so here, there appears to be no significant relation between the two conditions.

Two out of 3,690 cases of mumps developed empyema.[11]

Among the 500 scarlet fever cases, none, followed by empyema, is reported.[11]

The proportion of streptococcus empyema was similar to that which obtained in so many of the eastern camps. The findings are reported for nearly 80 per cent of the cases, and of these 75 per cent were streptococcus and 25 per cent pneumococcus.[11]

The high incidence of total respiratory diseases at Camp Lewis is attributable to cases of uncomplicated influenza of a mild character.

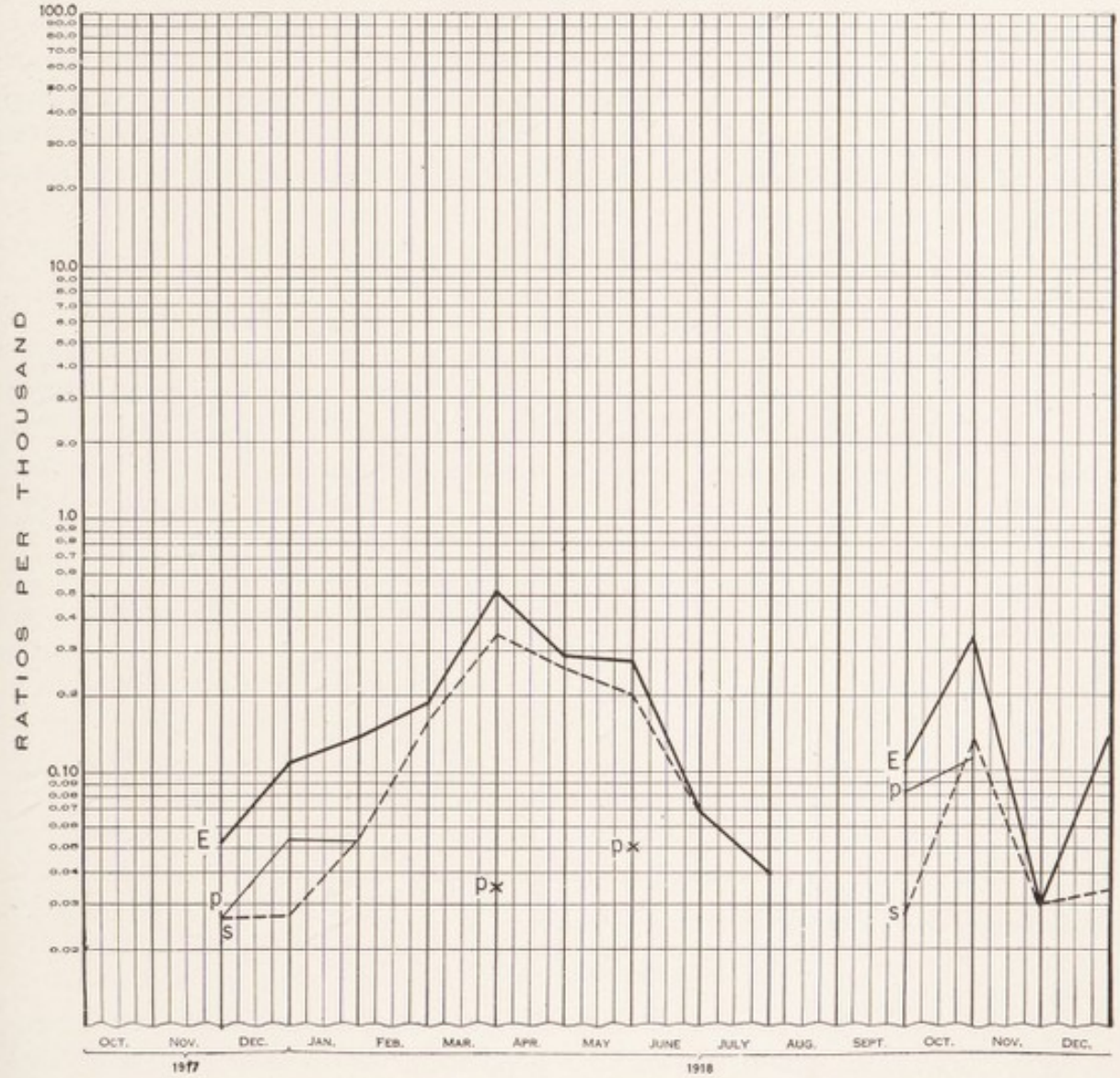


CHART XLIX.—Relationship of the pneumococcus and the streptococcus to the incidence of empyema at Camp Lewis, Wash.

In Chart XLVIII for Camp Lewis a dotted line gives the incidence of common respiratory diseases. If the cases of influenza are added to this, the curve "R" is obtained. In preparing the charts for the various camps the above separation has not been made, because it was doubtful whether cases reported as influenza would be consistently similar in all parts of the country. Except during the great epidemics, the diagnosis "influenza" does not very clearly define the exact nature of the affection to which it is applied. It appears certain that in different localities the practice in using this term varied.

Under the circumstances, the safer course to pursue for epidemiological studies appeared to be to include influenza among the diseases of the upper respiratory tract. A pharyngeal inflammatory reaction appears to be a constant manifestation of this disease, while a true pneumonia is developed in only a limited number of cases.

The chart for Camp Lewis very clearly exhibits the closer analogy of the empyema curve to that of upper respiratory diseases than to that of the pneumonias. While the pneumonia curve takes a nearly horizontal course up to July, the two former curves show wide fluctuations roughly corresponding to each other. The study of these relations in other camps has indicated that the occurrence of influenza disturbs in some degree an otherwise close parallelism between the curves for empyema and diseases of the upper respiratory tract. So here, the empyema curve takes a course which in general is intermediate between "R" and the dotted line representing common respiratory diseases alone.

TABLE 28.[a]—*Epidemiological table for Camp Lewis, Wash.*

| | Absolute numbers. | | | | | Ratios per 1,000 men. | | | | | Empyema, mortality percentage. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Empyema, totals. | Empyema, deaths. | Streptococcus group. | Pneumococcus group. | Staphylococcus. | Pneumonia. | Common respiratory diseases. | Empyema. | Streptococcus group. | Pneumococcus group. | |
| 1917. | | | | | | | | | | | |
| October | 0 | 0 | 0 | 0 | 0 | 1.06 | 15.04 | 0 | 0 | 0 | 0 |
| November | 2 | 0 | 1 | 1 | 0 | 1.16 | 44.09 | 0.0533 | 0.0263 | 0.0263 | 0 |
| December | 4 | 1 | 1 | 2 | 0 | .86 | 42.56 | .1082 | .0271 | .0542 | 25 |
| 1918. | | | | | | | | | | | |
| January | 5 | 0 | 2 | 2 | 0 | .89 | 29.92 | .1368 | .0548 | .0548 | 0 |
| February | 6 | 2 | 5 | 0 | 0 | .82 | 23.58 | .1864 | .1551 | .0 | 33 |
| March | 15 | 1 | 10 | 1 | 0 | .78 | 70.95 | .5249 | .3486 | .0349 | 7 |
| April | 9 | 1 | 8 | 0 | 0 | 1.14 | 63.09 | .2879 | .2558 | .0 | 11 |
| May | 11 | 0 | 8 | 2 | 0 | .86 | 27.27 | .2758 | .2005 | .0501 | 0 |
| June | 3 | 1 | 3 | 0 | 0 | .96 | 17.18 | .0681 | .0681 | .0 | 33 |
| July | 1 | 0 | 0 | 0 | 0 | .81 | 25.71 | .0393 | .0 | .0 | 0 |
| August | 0 | 0 | 0 | 0 | 0 | 1.14 | 20.61 | .0 | .0 | .0 | 0 |
| September | 4 | 0 | 1 | 3 | 0 | 3.63 | 36.31 | .1104 | .0277 | .0831 | 0 |
| October | 12 | 1 | 5 | 4 | 0 | 8.12 | 112.95 | .3382 | .1338 | .1126 | 8 |
| November | 1 | 0 | 1 | 0 | 0 | 10.88 | 51.91 | .0293 | .0293 | .0 | 0 |
| December | 4 | 0 | 1 | 0 | 0 | 9.25 | 54.34 | .1345 | .0336 | .0 | 0 |
| | 77 | 7 | 46 | 15 | 0 | ..... | ..... | ..... | ..... | ..... | 9.1 |

[a] Sources of information: 1. Reports of sick and wounded made to the Office of the Surgeon General. 2. Special empyema reports made to the Office of the Surgeon General.

## SUMMARY AND CONCLUSIONS.

In the preceding studies of the 23 individual camps there are singularly few instances where the curve representing the incidence of empyema has failed to conform to that of infections of the upper respiratory tract. In several camps the parallelism between these curves is strikingly close. Frequently, the way has been indicated in which the empyema curve is entirely interrupted when the curve for this class of respiratory diseases approaches its minimum. In several camps this absence of empyema is first noticed when the admissions for these respiratory diseases reached 10 per 1,000 men in the command, or 1 per cent.

Cases of empyema again appeared among men coming to the hospital at a time when the admissions for upper respiratory diseases rose above 1 per cent of the men in camp. It has also been learned that when a case of empyema

does occur during a period of low common respiratory incidence, there is often some exceptional feature in this case which either reduces its epidemiological importance, or else supports the inference that there is a direct connection between infection of the upper respiratory tract and the development of empyema.

When the parallelism, so frequently adverted to, is disturbed by a rise in one curve which is not reflected in the other, it has most frequently been at periods when there was an exceptionally high incidence of influenza. If these cases were mild, as shown by a low mortality, the incidence of empyema has been disproportionately low, the empyema curve being less affected than the curve for respiratory diseases. When the mortality from influenza has been greater, the empyema incidence has risen more rapidly in proportion to the rise in incidence of respiratory diseases. These differences in the excursions of the two curves on different occasions probably may be accepted as evidence that the development of empyema is not directly dependent upon the influenza, but rather upon associated infections of the upper respiratory tract, the effects of which are augmented by this disease.

A comparison of the charts from different camps fails to show a fixed ratio between the empyemata and upper respiratory diseases. In some camps the average distance between the lines representing the two conditions is greater than in other camps. Therefore, it can not be asserted that such or such a percentage of men suffering from infections of the upper respiratory tract will develop empyema. This lack of a fixed ratio between these curves may depend upon variations in the infections of the upper respiratory tract, some being more prone to further invasion than others; or, it may be due to concomitant conditions in the environment which were different in the different camps.

To illustrate this, let Camps Pike and Upton be compared as offering striking contrasts in this respect. In March the ratio of empyema to the common respiratory diseases was 1:44 at Camp Upton, and at Camp Pike it was 1:119; but the incidence of common respiratory diseases at Camp Pike was slightly the greater (a difference of 5.4 cases per 1,000 men). At Camp Upton in this month there were 2.4 per cent of deaths within this group of respiratory diseases, while at Camp Pike there was none. Evidently the general severity of these affections at Camp Upton was greater than at Camp Pike, and complications were more likely to have occurred. In other words, the upper respiratory infections at Camp Upton were relatively more virulent. This is further shown by the pneumonias, which, while more numerous at Camp Pike than at Camp Upton, presented a lower mortality, the ratios being 20.6 per cent and 34 per cent, respectively. Turning now to the empyemata, the mortality among the 14 cases at Camp Pike was 36 per cent, and that at Camp Upton 50 per cent of the 40 cases. The predominating organism in the pleural fluids at both places during this month was streptococcus.

Therefore, in so far as it is proper to accept the rate of mortality as an indication of the general virulence of an infection, it is evident that the respiratory diseases at Camp Upton were occasioned by relatively more virulent infections than at Camp Pike.

It would not be justifiable to attribute this difference in virulence wholly to variations in the particular strains of streptococcus in the two camps; there are too many other factors involved to warrant so simple a conclusion. Such things as the general physical condition of the men, the exposures to inclement weather or excessive fatigue, differences in race, and in previous modes of life might influence the relative virulence even though the strain of the organism were the same.

There are no data which could be used profitably in exploring the maze of possibilities suggested by the foregoing considerations. It must suffice to infer that at Camp Upton the resultant of all the factors involved was equivalent to there being present in that camp a virulent strain of streptococcus not very widely disseminated among the men, while at Camp Pike a less virulent strain was more widely distributed. Such an inference is supported by the peaks in the curves at Camp Upton in contrast to their more uniform levels at Camp Pike. This abrupt invasion by a virulent organism at Camp Upton, if it really was this, coincides in time to the arrival of over 7,000 men from other camps.

It is evident that the questions touched upon in the preceding paragraphs could be more satisfactorily discussed had there been available records of bacteriological surveys of the throats of men already in camp, and of new contingents upon their arrival. Such data are lacking.

In the foregoing studies of individual camps the bacteria reported as present in the pleural fluids have been broadly placed in three groups. So few cases have been associated with a staphylococcus that they offer little of epidemiological importance. But the group of streptococci was evidently of preponderating influence in the autumn of 1917 and in the early months of 1918.

In few of the camps are there records of a careful distinction between the types of pneumococcus found in the exudates. Where this was made, however, it is of some significance that Type IV appeared associated with cases similar in character to those in which the hemolytic streptococcus was found. A grouping of cases based on the significance of the associated microorganisms might not unreasonably include those in which the pneumococcus, Type IV, was found in the same group with those yielding the hemolytic streptococcus.

Epidemiological studies are fruitful in proportion to the practical lessons that may be extracted from them.

There are few obvious lessons conveyed by the study of the 23 camps that have furnished the material used in this chapter, but these lessons are clear and directly practical.

When the incidence of disease of the upper respiratory tract assumes such proportions that 1 per cent of the command is referred to the hospital for treatment, it becomes almost certain that cases of empyema will develop, and that the empyema cases will increase in proportion to a rise of those particular respiratory diseases. It is probable that the increase of these infections is indicative of the presence among the men of strains of bacteria prone to involve the pleura. But whatever the explanation may be, the period of danger starts at this definite time.

This offers a forewarning of the approach of serious conditions which might be averted by suitable preventive measures. It should impel regimental surgeons to direct particular attention to the condition of the nasopharynx

and tonsils of the men in their charge. The dissemination of infections of these parts should be guarded against, through measures reducing as far as practicable direct and indirect contacts between those having, and those still free from troubles of this character. It is believed also that there is such a thing as a hygiene of the nose which is very commonly neglected. The health

CHART L.—The incidence of respiratory diseases, pneumonia, and empyema in the Army camps and cantonments in monthly ratios per thousand men.

of the nasal mucosa certainly can be promoted by the removal of accumulated secretions and these parts invigorated by proper functional exercise. With this in view, mouth breathing, whether by day or night, or while doing even heavy muscular work, should be discouraged, and it appears rational to believe that special breathing exercises, including forcible expiration through the nose, would prove beneficial in promoting resistance to infection.

The foregoing are preventive measures applicable to men who are free from infection at the time. They are based upon experience among people in civil life as well as those in military organizations, but statistical data supporting them are meager.

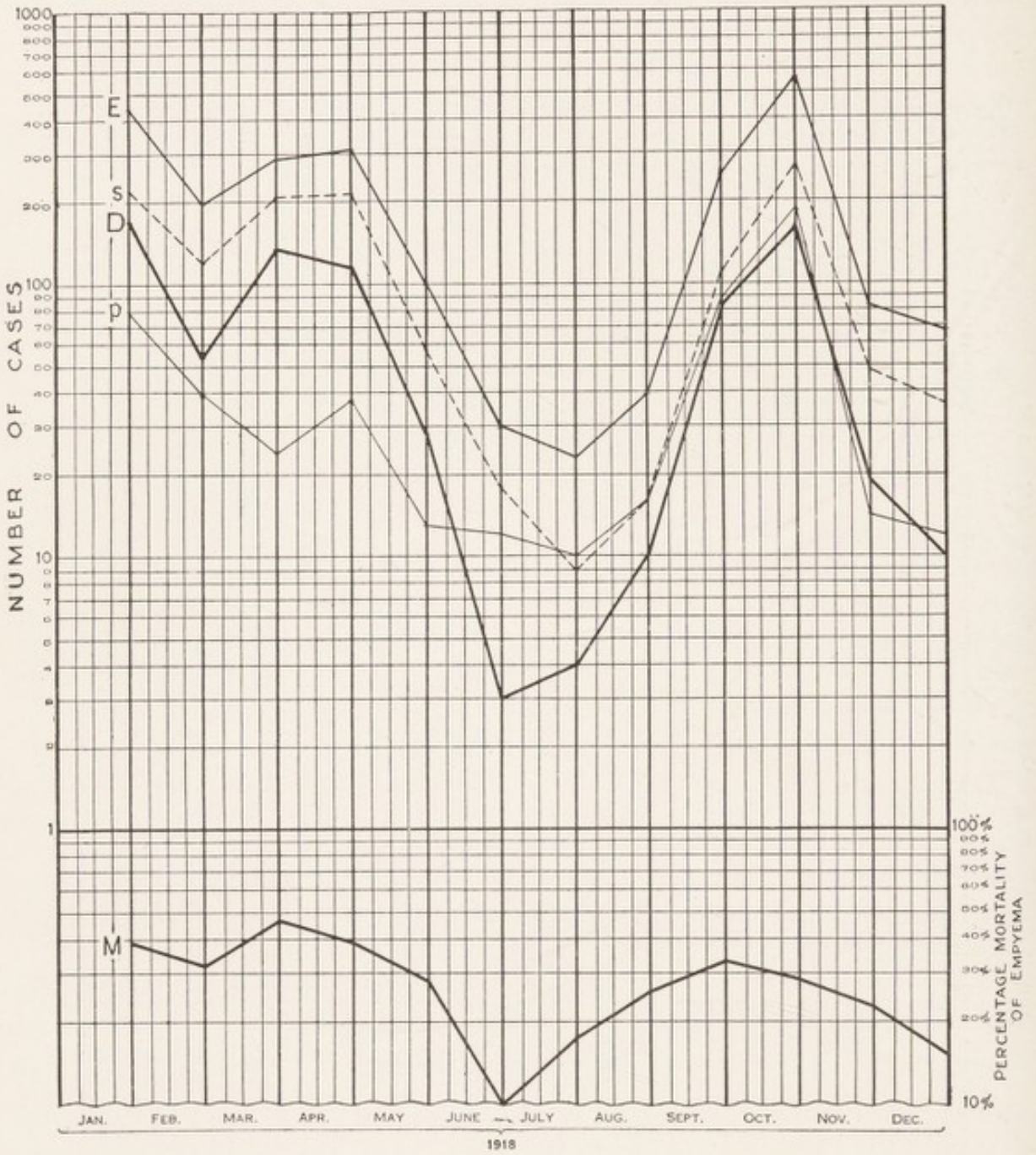


CHART LI.—Relationship of the empyemata due to streptococci and pneumococci to the mortality in the Army camps and cantonments—Absolute numbers.

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## CHAPTER III.

## PATHOLOGY.

Such studies on the epidemiology of empyema as were made possible by the information gathered through the channels described in the first chapter show that streptococci (usually hemolytic streptococci), or some variety of pneumococcus, have been most frequently found in the pleural fluids. Other organisms, a staphylococcus or the influenza bacillus alone, have been reported in some cases, but such instances are of comparatively rare occurrence. When these organisms were present, they were usually associated with streptococci and appear to have had little influence on the character of the cases. From these observations it must be concluded that the hemolytic streptococcus and the various types of pneumococcus were the organisms causing the severe and often fulminating empyemata encountered among the troops in the Army camps. The subject of inquiry in this chapter is how these organisms gain access to the pleural cavity and other parts of the body, and the nature of the lesions occasioned by their presence.

In the preceding chapter a close relation has been shown to exist between the prevalence of diseases of the upper respiratory tract and the incidence of empyema. From the data presented, it appears evident that this tract is the primary portal through which the organisms, which ultimately reach the pleural cavity, gain entrance.

### ROUTES OF EXTENSION OF INFECTION TO PLEURAL CAVITY.

There are three obvious routes offering a means for the extension of infection from the upper respiratory passages to the pleura: 1. The infecting organisms may be carried from the bronchial tree into the pulmonary alveoli and there excite an inflammatory exudate and an edema which extend into the areolar tissue underlying the pleural endothelium. The damage to the tissues, together with the production of serous exudate, offers an opportunity for the extension of the infecting organisms into these tissues and into the pleural cavity. This may be designated as the alveolar route. 2. The organisms may gain entrance to the interstitial tissues of the lungs through lesions in the bronchial lining and be carried along the spaces in the areolar tissue or through lymphatic channels directly to the pleural structures. The infection of the pulmonary alveoli would then be a less conspicuous consequence of the invasion. This mode of extension may be named the interstitial route. 3. The organisms may gain entrance to the circulating blood and be disseminated to different and widely separated parts of the body with local foci of infection wherever they find lodgment and the conditions are favorable for their development. This is the blood-stream route of dissemination.

It is by no means necessary to assume that a single one of the routes mentioned is the only one actually followed in any given case. An extension through one channel does not exclude a concomitant extension through one or both of

CUT SECTION OF LUNG SHOWING INTERSTITIAL BRONCHOPNEUMONIA OF STREPTOCOCCUS ORIGIN FOLLOWING MEASLES. ACCESSION NUMBER 606. ARMY MEDICAL MUSEUM.

the others. More than one route may be open, but it is likely that should one be the chief or more prominent channel of extension it would affect the distribution of lesions and so dominate the clinical course of that particular case.

For this reason it is important to consider first the probable consequences of a dominance of each of these possible routes and then to follow with an inquiry as to the manner in which cases of empyema may actually be grouped with respect to such possible routes for the extension of the infection.

## THE ALVEOLAR ROUTE.

Were the infection to extend only through the open air passages and thus markedly to affect the alveolar structures of the lung before the pleural surface was reached, it is evident that a pneumonia would be manifest before the pleural infection attracted the attention of the clinician. Since the pleural structures would be affected gradually, the first prominent effect upon the pleura would be an exudate which might be serous, but more frequently would be fibrinous or serofibrinous in character, and the initial damage would be relatively mild in degree.

According to the path taken within the lung, the pneumonia would be lobar in distribution, or certain lobules scattered through the lungs might be primarily affected, thus constituting a lobular or bronchopneumonia. There might be an extension and a confluence of the pneumonic patches.

In the one case the initial symptoms would be those common in a typical lobar pneumonia with an initial chill and sudden onset of fever. The pulmonary signs would be most prominent from the onset and the infection of the pleura might not be evident until a fully developed empyema had become established.

Where there is a single empyema cavity, confined to that part of the pleura overlying a consolidated area or a portion of the lung already resolving, the sequence of events may be described as follows: The damage to the vessels and tissue elements of the pleura leads to an exudate in which the formation of fibrin promptly takes place. The inflammation results in a fibrinous pleuritis and the subsequent agglutination of the pleural surfaces approximately coextensive with the underlying pneumonia. If the process progresses to the formation of pus, the pus formation takes place within the fibrinous deposit. The fibrin is then absorbed and a single cavity is formed, closely confined by the peripheral agglutination. If the pus is not formed rapidly and in large amounts, granulations springing from the less damaged pleura at the periphery of the cavity lead to permanent fibrous adhesions. In this way a single cavity is formed bounded throughout its extent by granulation tissue.

The bacteria in such cases are probably invariably pneumococci. The exudate is moderate throughout. Fibrin is formed in moderate amounts in the initial stages, but undergoes digestion when pus is formed. The organisms not infrequently die and the pus becomes sterile. If this pus is evacuated the conditions are favorable for an obliteration of the cavity because the pneumonia resolves and the lung is capable of full expansion. The pleural surfaces are brought into contact, with a blending of the granulations covering them and the production of the permanent fibrous adhesions. The pliability

and thickness of these adhesions depend upon the thickness of the layers of granulations which developed before the evacuation of the abscess.

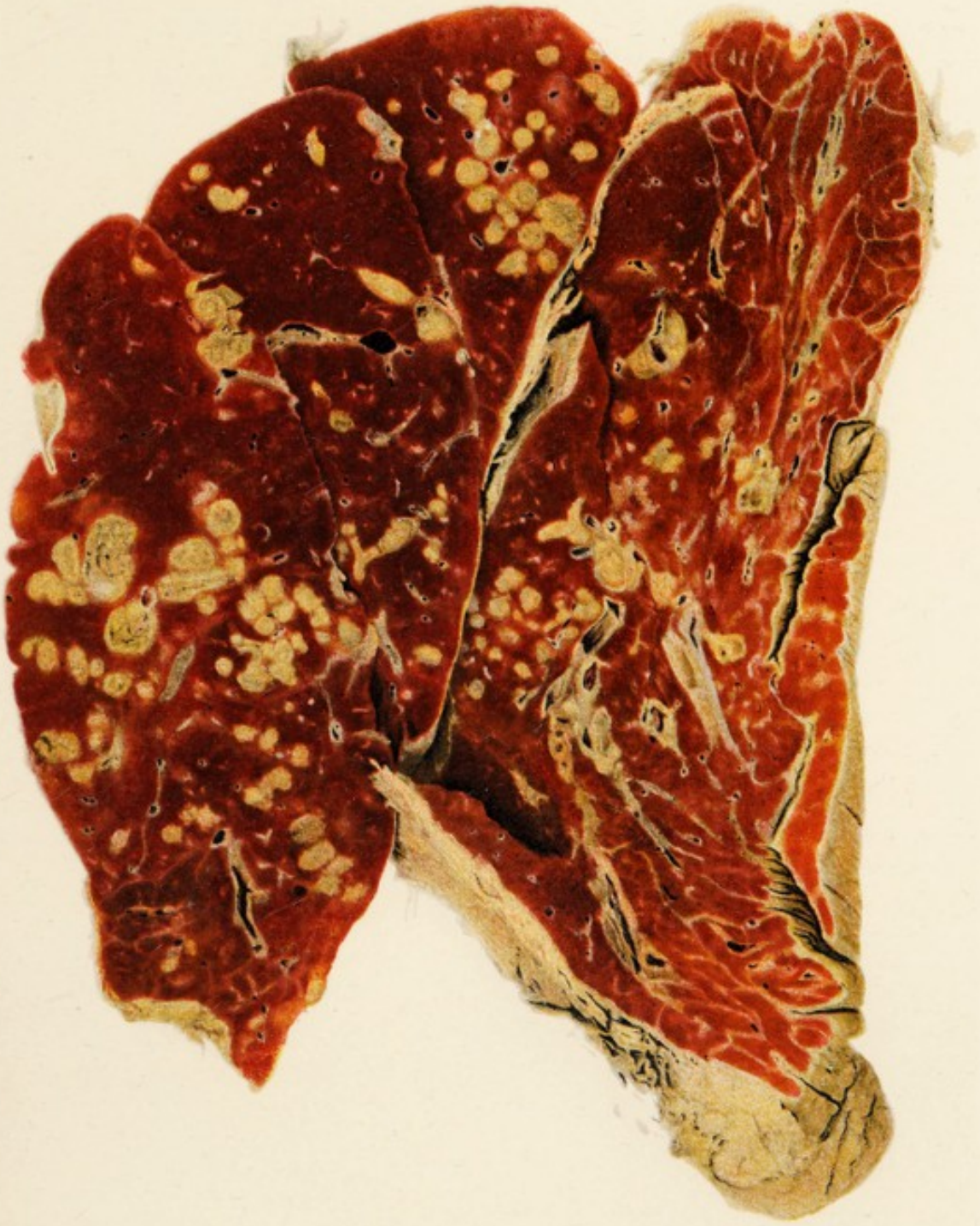
Should the extension of the infection be lobular in type, affecting several lobes, the physical signs would be diffused over wider areas of the chest. Such an infection might result in more than one empyema cavity. This is not, however, the only way in which multiple empyema cavities may be formed.

### THE INTERSTITIAL ROUTE.

In contradistinction to the alveolar route, if the bacteria should gain entrance to the areolar tissues separating the lobules of the lung, the way would be opened to extension in all directions within the meshes of this loosely arranged tissue. The extension within the lymphatic spaces would be favored by the exaggerated respiratory movements and by the coughing and the vomiting accompanying the infection. In this way infection of the pleural tissues with pleural effusion might occur before signs of pulmonary consolidation were detected. Pleural pain would be one of the first symptoms and would be followed by an accumulation of fluid in the pleural cavity in sufficient quantity to veil the physical signs of a pneumonia. In other cases the effusion and consolidation would progress simultaneously so that the clinical picture would be that of a parapneumonic pleurisy.

Cases of this type are more frequently the result of streptococcus infection, and are generally characterized by an abundant exudate. Although fibrin is formed, agglutination of the pleural surfaces can occur only when these surfaces are in contact. With the patient lying prone on the back or on the unaffected side agglutination is most likely to occur anteriorly, so that a large cavity is formed in the posterior part of the chest with pockets along the anterior margin of the lung beneath the edge of the sternum. If the patient assumed a half reclining posture on account of dyspnea, the adhesions would be in the upper portion of the chest. The empyema cavity would then be inferior. Such localizations are abundantly illustrated in the records.

Were the infection to extend through the interstitial tissues, it need not be assumed that this extension would be only in the direction of the pleural surfaces, for it might be in the opposite direction toward the hilum of the lung. The direction taken by an infected fluid would be quite independent of the normal direction taken by the lymph; for in the event of severe infection accompanied by abundant serous exudation the competence of delicate structures such as the lymphatic valves could hardly be maintained nor would the bacteria necessarily be confined within the lymphatic vessels. Infections taking this course would involve the peribronchial and mediastinal lymph nodes and frequently would invade the areolar tissue of the mediastinum. Both the parietal pleuræ and the pericardium might be infected in this manner, as well as the areolar tissues in the neck. The infections might extend through the diaphragm into the meshes of the tissues underlying the peritoneum. It must be borne in mind that the tissues referred to are subjected to periodical respiratory alterations of pressure which promote the movement of lymph even in the absence of inflammatory processes stimulating its flow.



STAPHYLOCOCCUS INFECTION OF THE LUNG WITH MULTIPLE ABSCESSES. STAPHYLOCOCCUS AUREUS WAS OBTAINED FROM THE PLEURAL CAVITIES AND THE PERICARDIUM. ACCESSION NUMBER 1,141.
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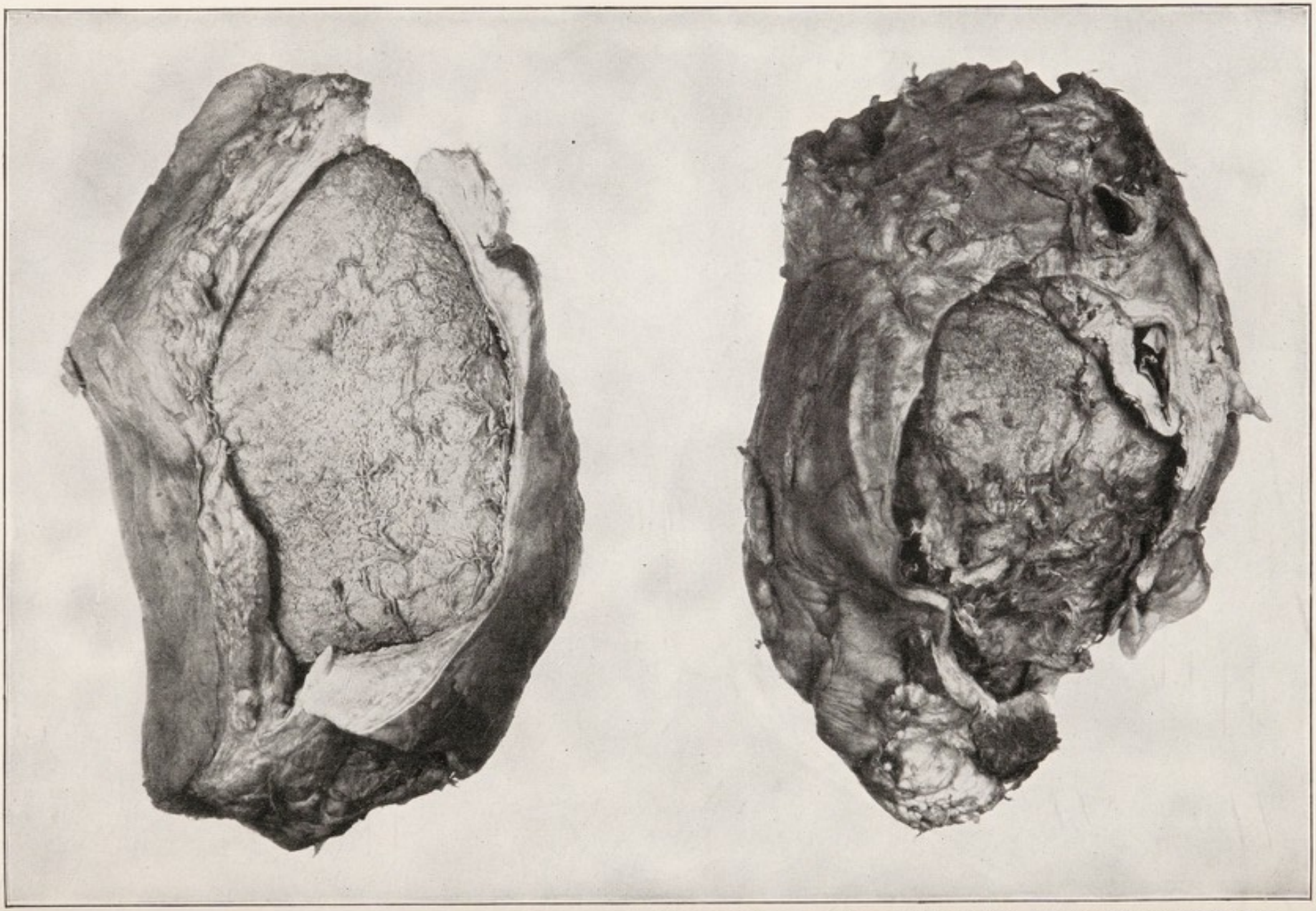

FIBRINOPURULENT PERICARDITIS COMPLICATING AN INFECTION OF THE LUNG WITH HEMOLYTIC STREPTOCOCCI. ARMY MEDICAL MUSEUM ACCESSION NO. 533.

### THE BLOOD-STREAM ROUTE.

This route of extension must be given a subordinate, though not unimportant, position. There are many instances in which distant parts have become the site of a secondary infection with the same organism found in the pleural exudate. Particular reference is made to arthritis in the wrist, ankle, or other joints, and to abscesses of the soft parts too remote to be explained readily by direct extension through lymphatic channels or areolar spaces. These can hardly have had any origin other than transmission by the circulating blood. The considerations set forth when sketching the other routes of dissemination indicate many ways in which the blood-stream might receive the infecting organism through local damage to blood vessels or through lymphatic drainage.[a] When the infecting organism is a pneumococcus, bacteriemia is known to be frequent. The direct evidence of a similar invasion of the blood current by streptococci is very much less impressive. The records contain many examinations of the blood for the detection of these bacteria, but there are few instances in which cultures have shown streptococci except during the few hours immediately before death. This does not preclude the occurrence of such an invasion as an occasional and transient event at any period in the course of some cases. There is no evidence, however, that empyema was primarily the result of a blood-stream infection. In certain instances empyema followed pneumonia occurring after an infection of the blood stream from distant foci.

### EXTENSION OF RESPIRATORY INFECTION TO PARTS OTHER THAN THE PLEURA.

In the foregoing paragraphs the paths by which infection may reach the pleura have been the chief consideration. It would not be profitable to focus the attention solely on the pathology of the inflammatory processes affecting the pleura. Autopsies on many cases of empyema revealed inflammation in other parts of the body attributable to the same infecting organism. These were often of greater importance than the empyema itself. The infection was not confined to the lungs, but often involved the pericardium and peritoneum as well as soft parts far removed from the pleural cavities. The joints, the middle ear, the nasal sinuses, and the subcutaneous areolar tissue were frequently involved. These various localizations are not all attributable to the same route of infection, nor are they all secondary to the pleuritis for they have occurred before the latter could be recognized. Those of the accessory nasal sinuses and the middle ear may be occasioned by direct extension from the upper respiratory tract. Infection of joints and distant soft parts is generally referred to dissemination of the organisms by the circulating blood, the localization being determined by a slowing of the current through pressure, some form of local damage, or peculiarities in the vascular supply of the part affected. The frequent occurrence of pericarditis and of peritonitis has also been attributed to blood stream infection. While in many cases this actually may have been the route of infection, it is not the only rational explanation of the frequency of these thoracic complications.

[a] Blake and Cecil (*Journal of Experimental Medicine*, 1920, xxxi, No. 5, 519) have observed invasion of the blood stream within six hours after intracheal inoculation of a monkey with virulent pneumococci. Such a rapid development of septicemia points to absorption through lymphatic channels.

Reports from some of the base hospitals have stressed the frequency with which pericarditis and peritonitis were associated with empyema. The authors of these reports have suggested that the organisms found in these cases showed a special predilection for serous cavities, and that the empyema was only one example of the affinity displayed by the bacteria for serous surfaces. Such reports can not but call attention to the anatomical relations of the pleuræ, pericardium, and peritoneum to the lymphatics and areolar tissue which lie immediately beneath all the intrathoracic serous surfaces, surround the intrathoracic viscera, and are continuous with the outer coats of structures passing through the diaphragm. It is necessary to consider the evidence pointing toward an extension through the mediastinal areolar tissue.

There is one striking illustration of the way in which dissemination may take place from the lung into the areolar tissues of the mediastinum, neck, and contiguous parts. This is offered by the interstitial emphysema which is not uncommon after postinfluenzal pneumonia and pleurisy. This interstitial emphysema is probably due to rupture of pulmonary alveoli, with entrance of air into the interlobular connective tissue. In such cases beaded rows of air bubbles can be seen beneath the visceral pleura; and they follow the interlobular septa to the hilum and into the areolar tissue between the parietal pleuræ of the two sides, then into the pericardium and the muscles and vessels of the neck; or the air may make its way into the subcutaneous tissues of the neck, shoulders, thorax, and abdomen. If air can be forced through these tissues there is no reason to believe that fluid may not follow the same route and that bacteria may not be carried with it.

In the great majority of cases such extensive dissemination did not take place. In the extremely fulminating cases, in which death occurred within a short time after the onset of symptoms, all the serous cavities were usually affected. This supports the view that extension through the mediastinal areolar tissue may actually occur. The mediastinal structures, however, were not always carefully examined at autopsy and bacteriologic examinations were rarely made. There are many reports of edema, purulent infiltration, or abscesses in the mediastinal tissues, and a few of phlegmons of the neck for which no obvious explanation could be found at autopsy. These findings would be expected if the mediastinal areolar tissues were infected. When pericarditis occurred later, after the acute infection had subsided, the infection probably took place through the damaged pleural tissue. There is no marked difference in the relations of the pericardium to the pleura on the two sides of the chest, and pericarditis has occurred at least as frequently with an empyema on the right side as with one on the left. Similarly, there can be no doubt that the diaphragm may be invaded by bacteria. A subphrenic abscess or a general peritonitis may occur in this way.

## MEDIASTINAL INFECTIONS.

The data relative to the infection of the mediastinum through the lymphatic channels draining the infected portions of the lung are so extensive that they can be considered only briefly in this chapter. It is necessary, however, to bring together certain of these data to aid in the correlation of the pathology and the clinical material to be considered later.

Three possible modes of infection have been mentioned in the preceding paragraphs. The alveolar route of bacterial invasion can account for the infection of the lung and subsequent infection of the pleura by direct extension.

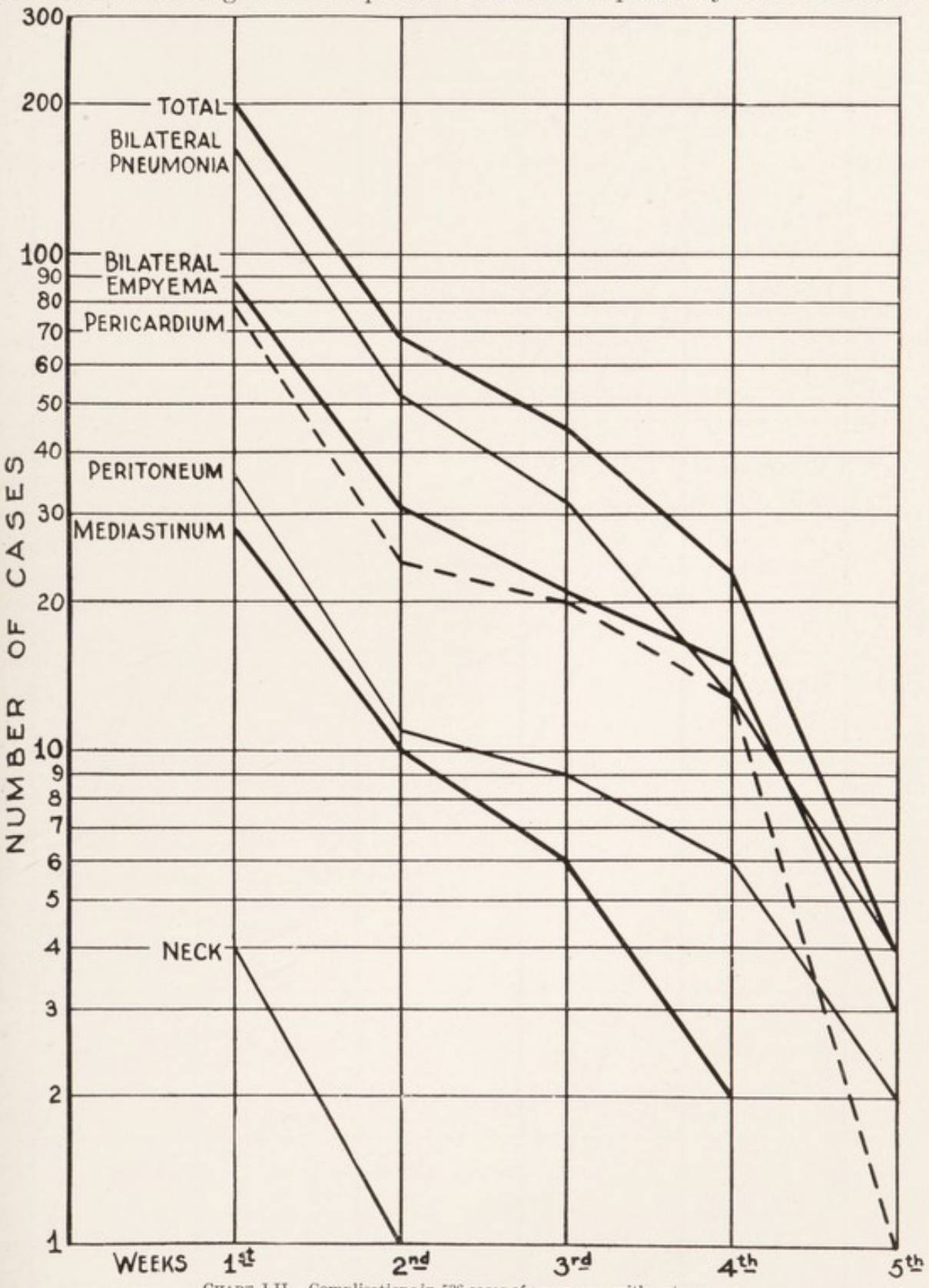


CHART LII.—Complications in 536 cases of empyema, with autopsy.

Further infection of the thoracic and abdominal viscera can not be as readily explained unless we assume that the bacteria are carried from the lung and pleura through lymphatic channels and the interstitial tissue to the mediastinum, pericardium, and peritoneum, or that they pass directly through the

pericardium and diaphragm. On the whole, there is little pathological or experimental evidence that the bacteria invade the serous cavities except through the lymphatics, since sections of the diaphragm and pericardium in the cases

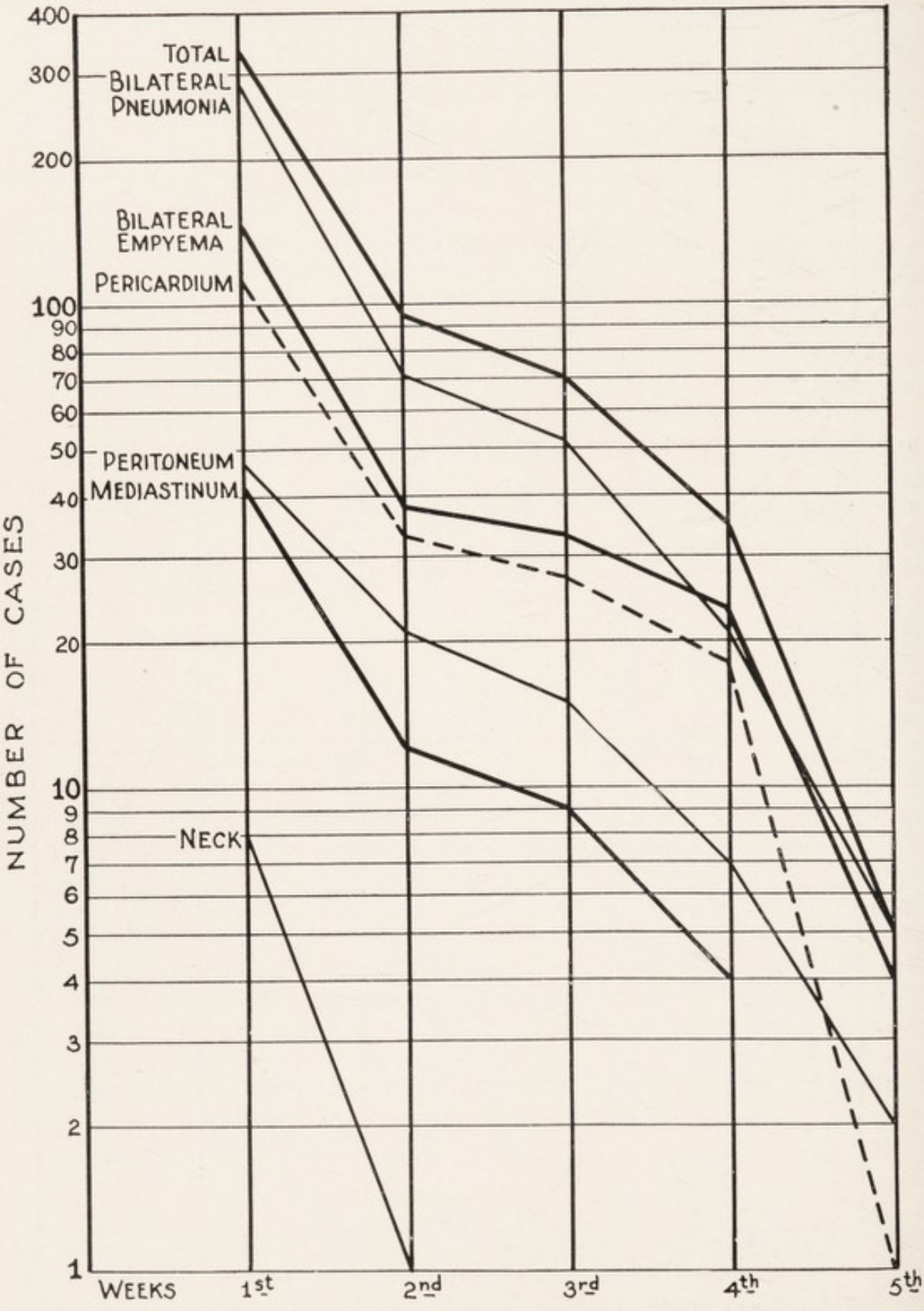


CHART LIII.—Complications in 339 cases of streptococcus empyema, with autopsy.

which have died with extensive infection do not show bacteria in the areolar tissue. Occasionally, bacteria may be found in the capillaries of the pericardium or diaphragm, but only in cases in which the blood cultures were

positive immediately before death or at autopsy. Since bacteria have been found in the blood stream ante mortem and in the capillaries post mortem, infection of the serous surfaces might have taken place through the blood stream. A serious objection to this view is the fact that the blood was seldom infected until immediately before death and not until there was previous clinical evidence of extension to the peritoneum or to thoracic viscera other than the lung and pleura. This is applicable, of course, only to streptococci.

A careful consideration of the gross pathology of cases of empyema has shown that there is a definite relation between all of these infections of the serous cavities and that this relation holds throughout a series of cases grouped according to the interval between the onset of the infection and the day of death. Tables 29 and 30 and Charts LII and LIII have been prepared to illustrate this relation.

Table 29 comprises an analysis of the autopsy findings in 536 cases of empyema grouped according to the week when the cases were terminated after the onset of the infection.[1] Six pathological conditions have been included. They are bilateral pneumonia, bilateral empyema, pericarditis, peritonitis, mediastinal infections and cervical infections. It is apparent from this table that the majority of the fatalities occur within the first week and that the complications in these cases occur most commonly in the order mentioned. Bilateral pneumonia, occurring in 86.7 per cent of the cases, is most frequent. Bilateral empyema is less common, since it occurs in 44.3 per cent. The other complications are found in 34.0 per cent, 14.2 per cent, 12.7 per cent, and 2.3 per cent, respectively. A similar analysis of the second, third, and fourth weeks shows that the percentage ratios of complications are practically identical throughout these periods. The fifth week shows considerable variations from the figures of the preceding periods but the number of autopsies is too small for accurate conclusions.

TABLE 29.[a]—*Five hundred and thirty-six cases of empyema, with autopsy showing complications—Deaths grouped in periods of one week after the onset of pneumonia.*

| Period of death. | Total cases. | Bilateral pneumonia. | Bilateral pneumonia percentage. | Bilateral empyema. | Bilateral empyema percentage. | Pericarditis. | Pericarditis percentage. | Peritonitis. | Peritonitis percentage. | Mediastinal infection. | Mediastinal infection percentage. | Cervicalinfection. | Cervicalinfection percentage. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0–1 week.. | 332 | 288 | 86.7 | 147 | 44.3 | 113 | 34.0 | 47 | 14.2 | 42 | 12.7 | 8 | 2.3 |
| 1–2 weeks. | 94 | 71 | 75.5 | 38 | 40.4 | 33 | 35.1 | 21 | 22.3 | 12 | 12.8 | 1 | 1.1 |
| 2–3 weeks. | 70 | 52 | 74.3 | 33 | 47.1 | 27 | 38.6 | 15 | 21.4 | 9 | 12.9 | 0 | 0 |
| 3–4 weeks. | 35 | 21 | 60.0 | 23 | 65.7 | 18 | 51.4 | 7 | 20.0 | 4 | 11.4 | 0 | 0 |
| | 531 | 432 | 81.4 | 241 | 45.4 | 191 | 36.0 | 90 | 16.9 | 67 | 12.6 | 9 | 1.7 |
| 4–5 weeks. | 5 | 5 | 100 | 4 | 80.0 | 1 | 20.0 | 2 | 40.0 | 0 | 0 | 0 | 0 |
| | 536 | 437 | 81.5 | 245 | 45.7 | 192 | 35.8 | 92 | 17.1 | 67 | 12.5 | 9 | 1.7 |

[a] Source of information: Special empyema reports made to the Office of the Surgeon General.

TABLE 30.[a]—*Three hundred and thirty-nine cases of streptococcus empyema, with autopsy showing complications—Deaths grouped in periods of one week after the onset of pneumonia.*

| Period of death. | Total cases. | Bilateral pneumonia. | Bilateral pneumonia percentage. | Bilateral empyema. | Bilateral empyema percentage. | Pericarditis. | Pericarditis percentage. | Peritonitis. | Peritonitis percentage. | Mediastinal infection. | Mediastinal infection percentage. | Cervicalinfection. | Cervicalinfection percentage. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0–1 week.. | 199 | 161 | 80.9 | 88 | 44.2 | 79 | 38.7 | 36 | 18.1 | 28 | 14.1 | 4 | 2.0 |
| 1–2 weeks. | 68 | 52 | 76.5 | 31 | 45.6 | 24 | 35.3 | 11 | 16.1 | 10 | 14.7 | 1 | 1.5 |
| 2–3 weeks. | 45 | 32 | 71.1 | 21 | 46.7 | 20 | 44.4 | 9 | 20.0 | 6 | 13.3 | 0 | 0 |
| 3–4 weeks. | 23 | 13 | 56.5 | 15 | 65.2 | 13 | 56.5 | 6 | 26.1 | 2 | 8.7 | 0 | 0 |
| | 335 | 258 | 77.0 | 155 | 46.3 | 136 | 40.6 | 62 | 18.5 | 46 | 13.7 | 5 | 1.5 |
| 4–5 weeks. | 4 | 4 | 100 | 3 | 75.0 | 1 | 25.0 | 2 | 50.0 | 0 | 0 | 0 | 0 |
| | 339 | 262 | 77.3 | 158 | 46.3 | 137 | 40.4 | 64 | 18.9 | 46 | 13.6 | 5 | 1.5 |

[a] Source of information: Special empyema reports made to the Office of the Surgeon General.

The cases in Table 29 include empyema irrespective of the organism causing the infection. Table 30 and Chart LIII comprise an analysis of 339 autopsies from which streptococci were recovered.[1] The same relations are found between the six pathological entities mentioned.

Such statistics are not conclusive, but suggest that infection may extend through the lymphatic tissues and invade the mediastinum, pericardium, and peritoneum. The one disturbing factor is the relatively low incidence of definite mediastinal infection. These findings, however, are not based on microscopic evidence, but merely on the gross appearance of the mediastinal tissues, so it is probable that in many of the instances there was an invasion of the mediastinum which had not yet resulted in sufficient reaction to be discerned microscopically.

An analysis of 67 cases with definite inflammatory lesions shows that streptococci were responsible for practically all of the infections. Microscopic study of sections through the lungs and mediastinum of these cases shows streptococci in the lymphatics and lymph nodes.

Figures 5, 6, and 7 are photomicrographic reproductions of sections from the fulminating streptococcus infections. They were stained by the MacCallum method at the Army Medical Museum in Washington. They illustrate the extent and character of the invasion of the lymph channels. Unfortunately the blood stream was infected in practically all these cases, so the possibility that the pericarditis and peritonitis, which were found post mortem, were not secondary to the bacteriemia rather than to the infection of the mediastinal tissues, can not be excluded. In one instance (Army Medical Museum, accession No. 6152) the pericardium and both pleuræ were infected and the post-mortem blood cultures were negative. The mediastinum was edematous; the lymph glands were enlarged and showed definite infiltration; and hemolytic streptococci were obtained from the intrathoracic serous cavities. Sections of the lung, mediastinum and pericardium, prepared from this case, have been photomicrographed to illustrate the lymphatic route of extension.

A consideration of these data brings out several important points. First, fatal cases of hemolytic streptococcus empyema die with a bilateral pneumonia and usually with extensive infection of two or more of the serous cavities. Intrathoracic complications are most common. The percentage relationship between these complications found at autopsy are similar throughout the first four weeks of the infection. Second, pericarditis and peritonitis occur, at times, before the bloodstream is infected. Third, infection of the pericardium may occur through the mediastinum. Fourth, it seems probable that the infection extends from the lung to the mediastinum, then to the pericardium and peritoneum through the lymphatics, and that the bloodstream is invaded through the lymphatics rather than by direct contamination from the infected lung.

LOBAR PNEUMONIA AND BRONCHOPNEUMONIA WITH PERICARDITIS AND MEDIASTINAL INFECTION DUE TO HEMOLYTIC STREPTOCOCCI. ACCESSION NUMBER 6,152. ARMY MEDICAL MUSEUM.

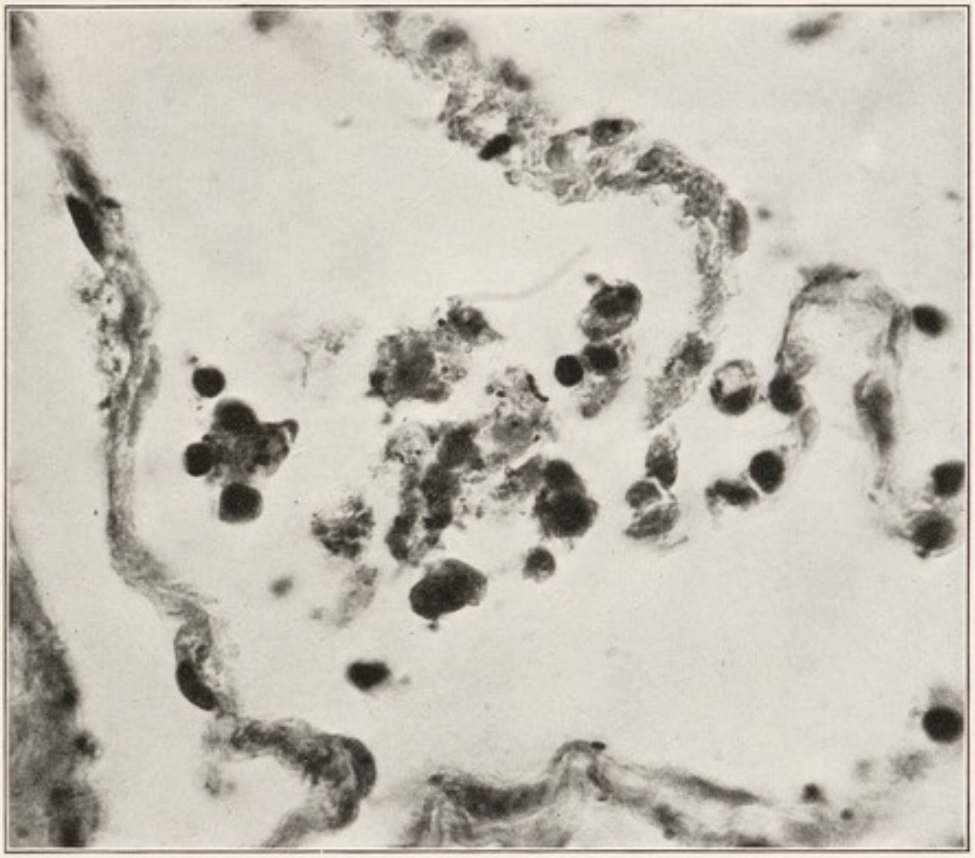

FIG. 5.—Streptococci in the intrapulmonary lymphatic channels in interstitial bronchopneumonia. Army Medical Museum, accession No. 3290. Negative 33024.

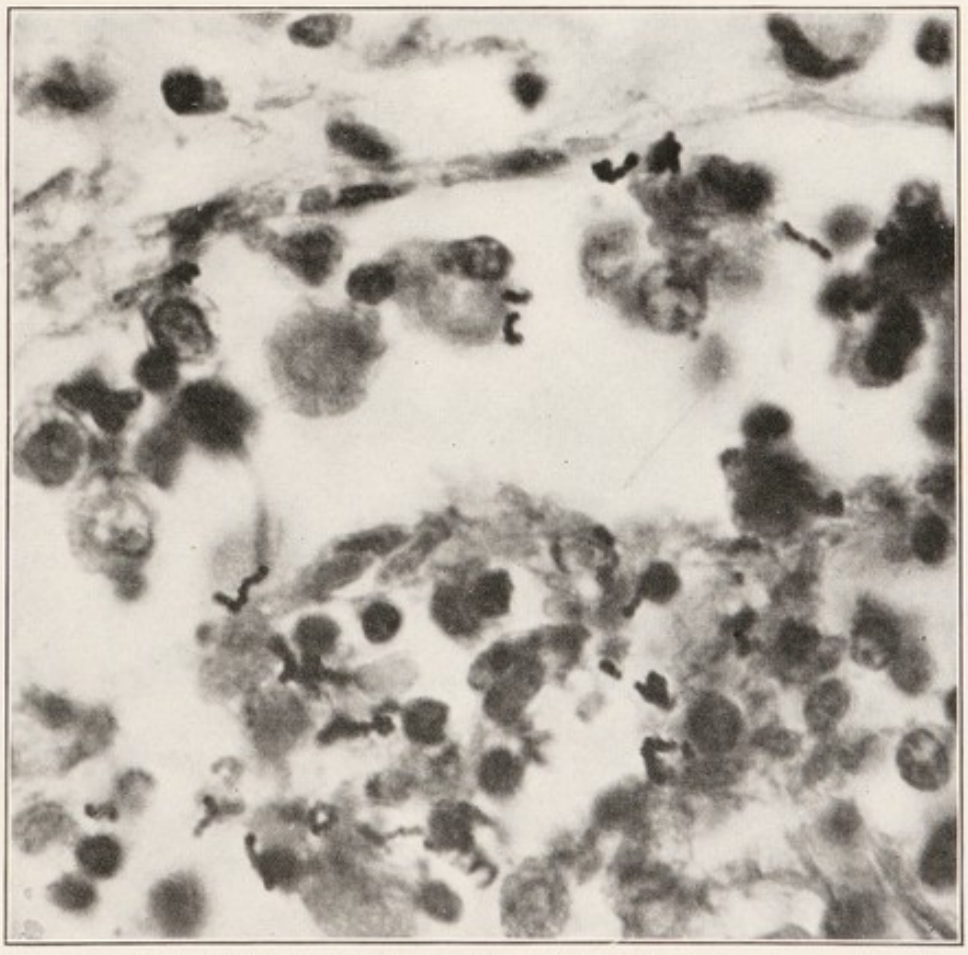

FIG. 6.—Section of mediastinal lymph gland. Army Medical Museum, accession No. 3300. Negative 33030.

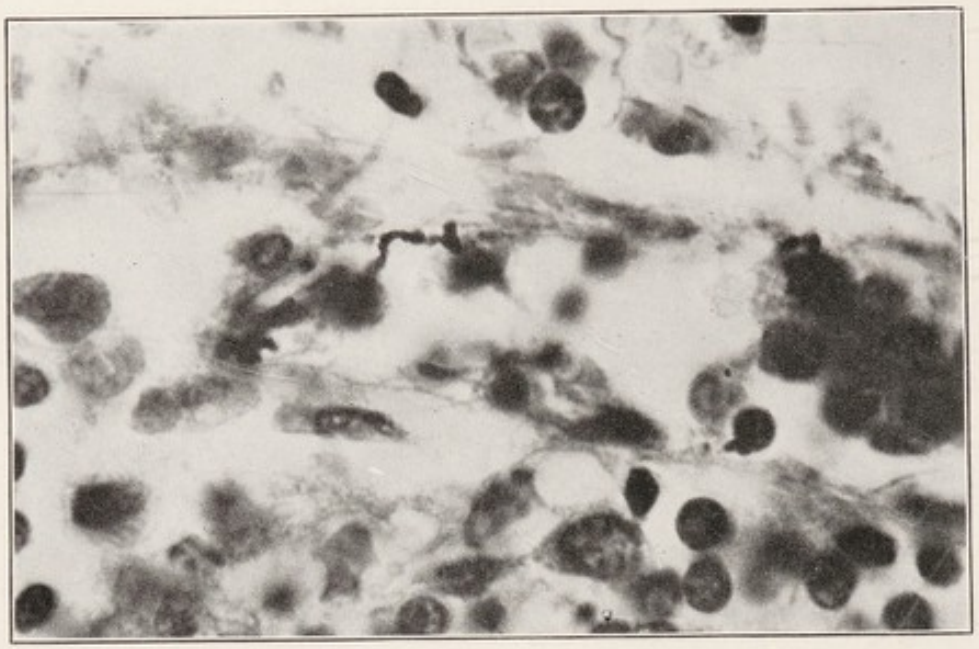

FIG. 7.—Hemolytic streptococci in peribronchial lymphatic channels. Army Medical Museum, accession No. 3300. Negative 33028.

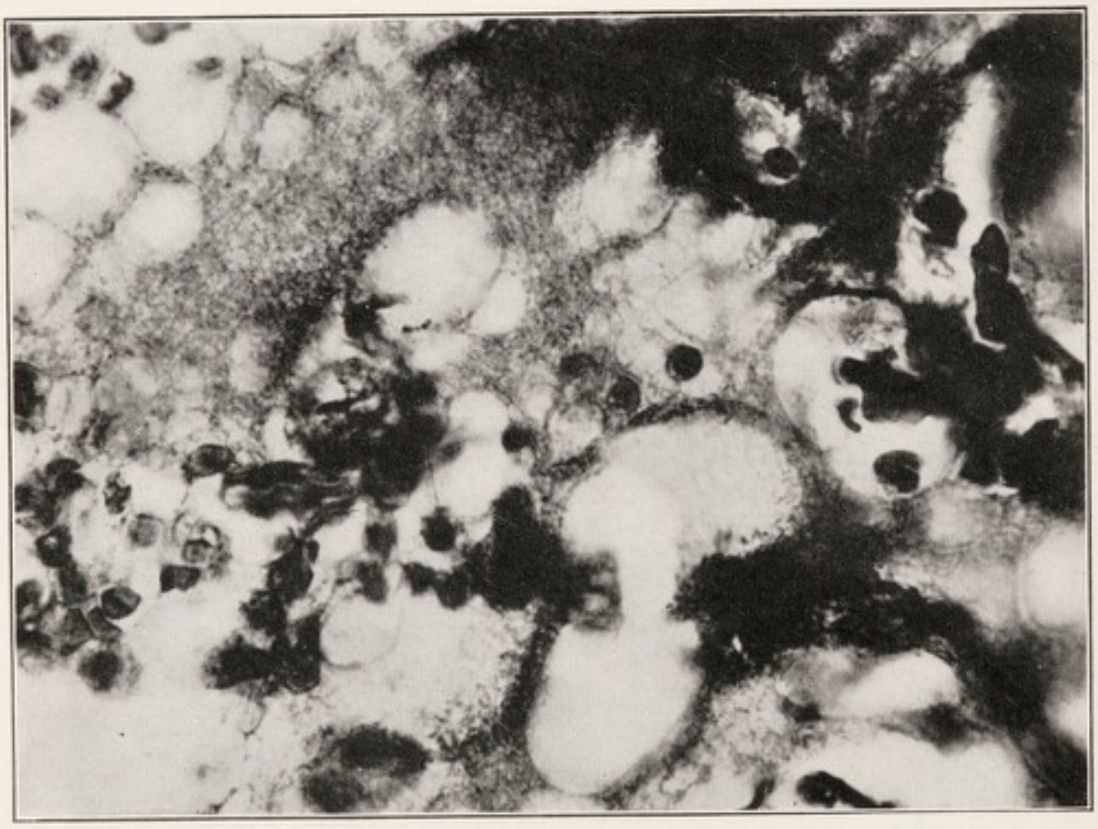

FIG. 8.—Streptococci in the peribronchial tissues. Cellular infiltration and the presence of fibrin are evidence of acute inflammation. Army Medical Museum, accession No. 6152. Slide 3a. Photographed at the Rockefeller Institute for Medical Research.

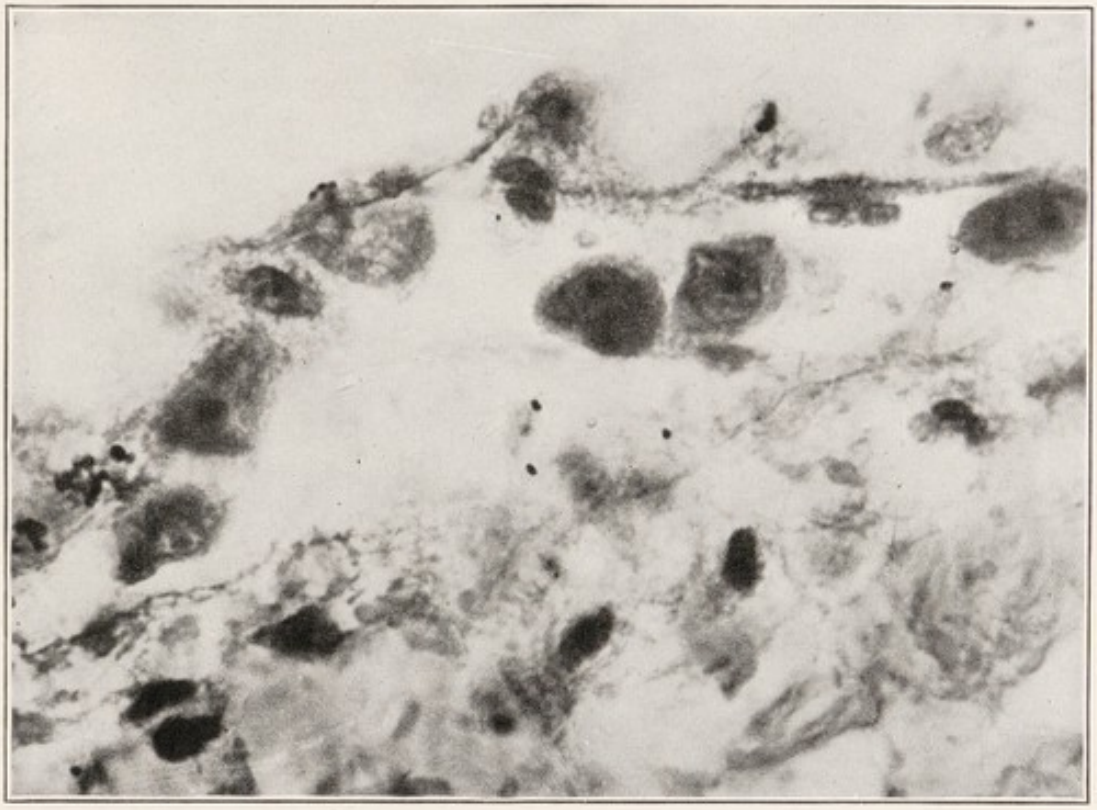

FIG. 9.—Section through mediastinal pericardium showing streptococci beneath the endothelial layer. Army Medical Museum, accession No. 6152. Negative 33027.

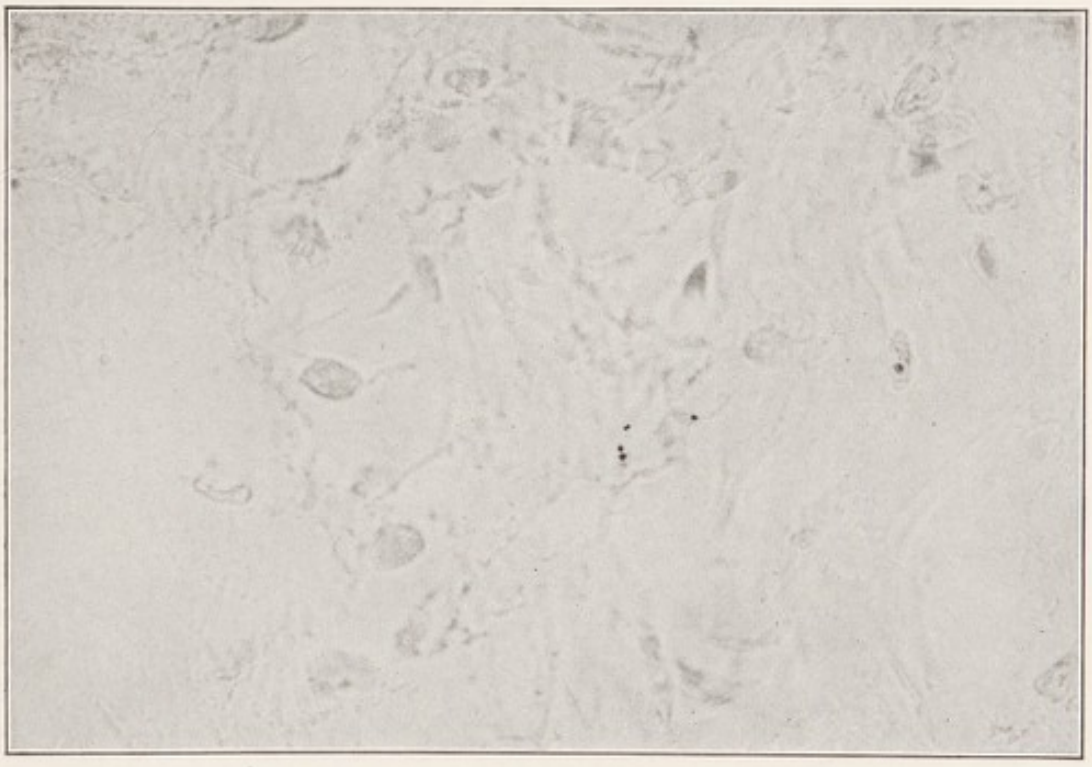

FIG. 10.—Streptococci beneath the endothelium in the subpericardial tissues of the mediastinum. Army Medical Museum, accession No. 6152. Photographed at the Rockefeller Institute for Medical Research.

FIG. 11.—Streptococci in adipose tissue, hilus of the left lung. Army Medical Museum, accession No. 6152. Photographed at the Rockefeller Institute for Medical Research.

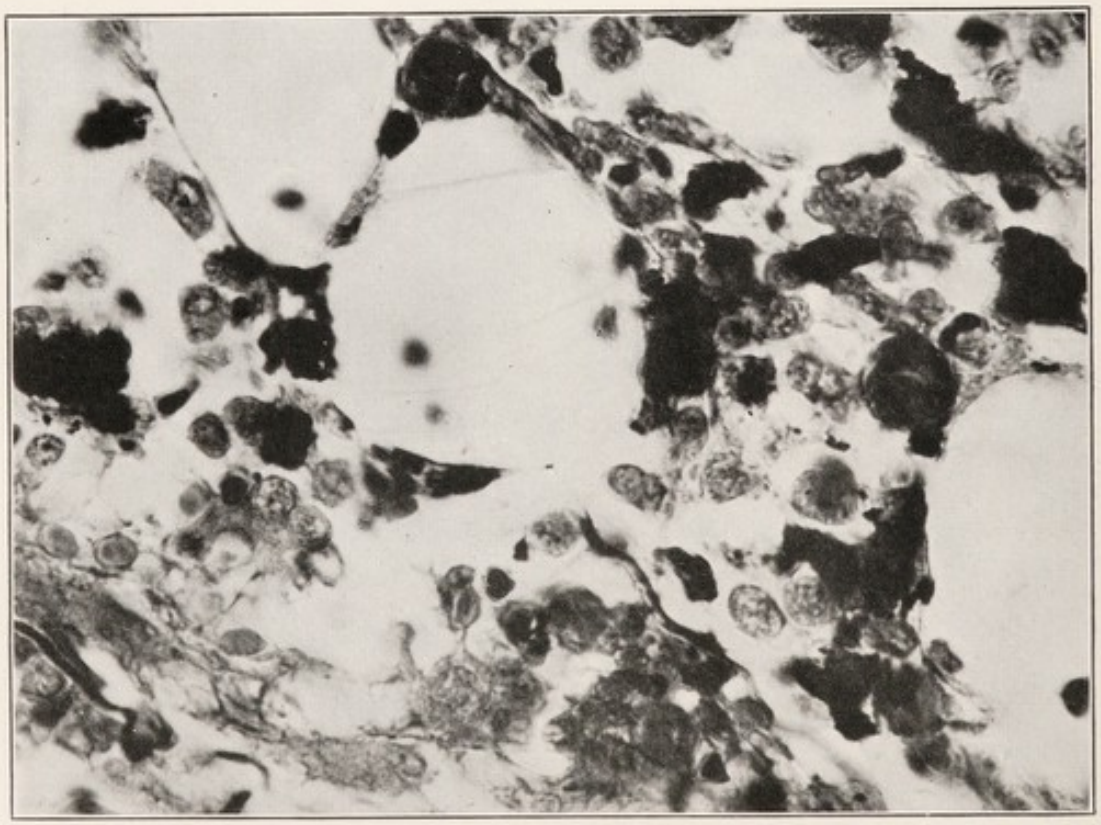

FIG. 12.—Streptococci in serofibrinous exudate in fat and areolar tissue of the mediastinum. Army Medical Museum, accession No. 6152. Photographed at the Rockefeller Institute for Medical Research.

FIG. 13.—Streptococci in the adipose and areolar tissue of the mediastinum. Army Medical Museum, accession No. 6152. Photographed at the Rockefeller Institute for Medical Research.

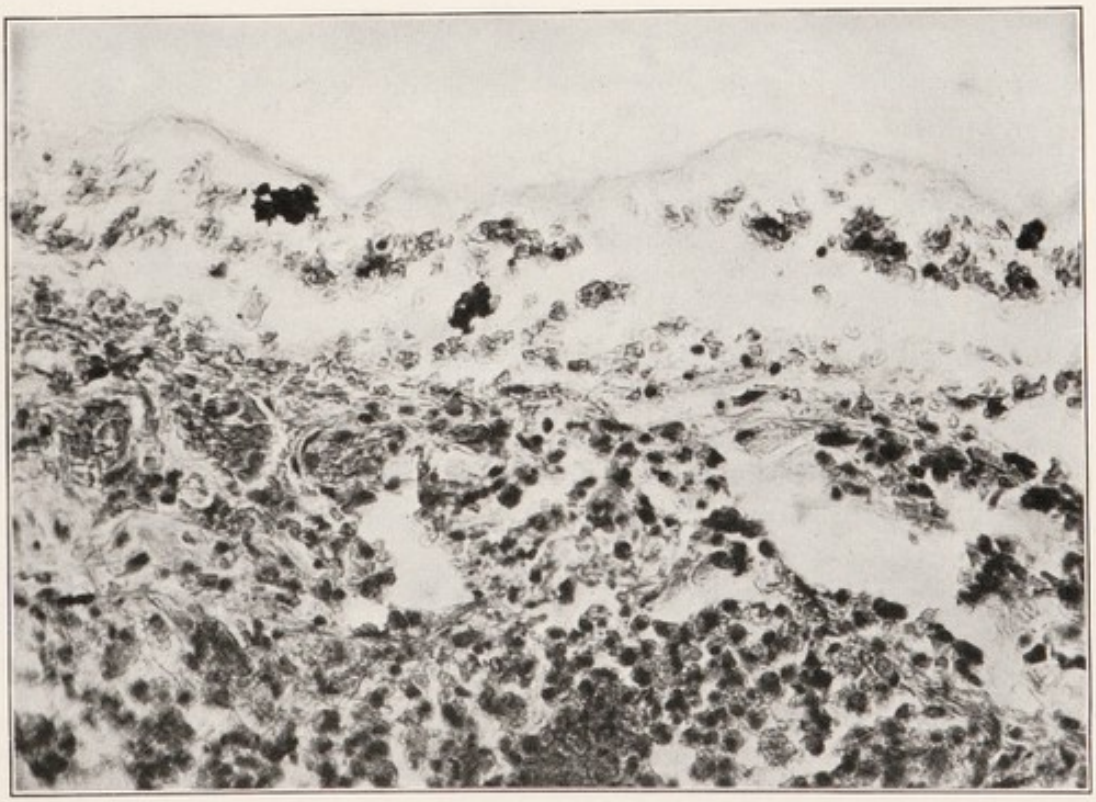

FIG. 14.—Early stage of pleuritis. Streptococci in the serous exudate beneath the endothelial layer. Army Medical Museum, negative 32446.

### THE EFFECT OF THE TYPE OF PNEUMONIA ON THE EMPYEMA.

Quite aside from the possibility of such wide distribution of the infection to the serous cavities just referred to, the interstitial route of extension favors marked diversity in the localization of the empyema. Frequently, there were two or more empyema pockets on the same side of the chest. Sometimes the cavities were superficial, one wall being formed by the costal pleura; again, pockets were found between two lobes which were otherwise adherent; while in other cases pockets were discovered between the lung and the mediastinal pleura, either posterior, near the spinal column, or anterior, beneath the sternum or costal cartilages.

This varied localization of the pleural infection leads directly to an inquiry concerning the forms of pneumonia with which empyema was most frequently associated. This may well be the first detail considered.

Of particular value are the studies of pneumonia in Army camps made by MacCallum,[2] and by Opie and his associates.[3] It appears from these studies that in addition to typical lobar pneumonia, characterized by red and gray hepatization, and associated with a pneumococcus infection, there were numerous cases of pneumonia in which the lesions were scattered throughout one or both lungs. These lesions were distributed along the bronchial tree and for this reason constituted a bronchopneumonia. These pneumonias were almost invariably associated with hemolytic streptococcus. The lesions themselves were not, however, invariably the same. They fall into two main groups: 1. Interstitial bronchopneumonia. 2. Lobular pneumonia.

#### ACUTE (SUPPURATIVE) INTERSTITIAL BRONCHOPNEUMONIA.

Here the interstitial tissues of the lungs were greatly involved in the infection and the lymphatic spaces offered channels for the dissemination of the bacteria. Empyema was an extremely frequent complication of this form of pneumonia.

Within the lung the most striking lesions were in and about the bronchioles. The walls of the bronchi themselves were densely infiltrated with mononuclear cells and markedly thickened. Extreme hyperemia and the formation of blood vessels and of connective tissue added greatly to this thickening and to the deformity of the wall. In some cases the whole lining was necrotic and coagulated and constituted a diphtheritic membrane.[4]

This destruction of the bronchial wall at times extends to and includes the muscular coat, leading to such a marked weakening of the structures that they give way under the sudden pressures to which they are exposed. Clefts in the walls may result, leading to acute bronchiectasis. The productive interstitial inflammation which follows may restore again the normal lumen, or may simply lead to a thickening of the dilated bronchial wall and a persistent chronic bronchiectasis.[5] In other cases where the destruction of tissues has been less deep, the productive processes may predominate and a narrowing of the bronchial lumen be the ultimate result. When secretions, often tenacious in character, block this narrowed bronchus or bronchiole the corresponding portion of the lung may become atelectatic.

The adjacent alveoli show infiltration of the walls and are filled with blood, dense fibrin, and desquamated epithelial cells. These changes are less marked

in alveoli further removed from the main focus of infection in the bronchus, the cellular elements are here less abundant and lie in a thick, viscid fluid. To quote MacCallum:[6]

> Streptococci may be found in tangled masses in the lumen of each bronchus or bronchiole mingled with the leucocytes of the exudate, but in most instances they are found in appreciable numbers in the substance of the tissue or in the alveolar contents.
>
> The lymphatics which run from the pleural network by way of the interlobular septa, bronchial walls, and blood vessel walls to the nodes at the hilum of the lung quickly become a channel for the transport of these bacteria. Great numbers of them are found in these canals and in the sinuses of the lymph nodes at the hilum where they appear to be halted. They cause thrombosis of the lymph channels which become distended to an enormous size and appear to the unaided eye as most conspicuous beaded white strands on the cut surface of the lung extending to connect with the pleural network which may be in places similarly injected and distended with a white infected semipurulent thrombus. These lymphatics are often 2 to 3 mm. in diameter, which is not especially greater than the diameter of the normal channels, but they become conspicuous in a way seldom observed because of their yellowish white contents. Sometimes they might almost be confused with the obstructed bronchi.
>
> It is thought that bacteria extend by growth along these obstructed channels in both directions and thus passing from the lung to the pleura (in a direction opposed to that of the current in unobstructed lymphatics) infect the walls of the pleural cavity and set up the intense inflammation with the outpouring of fluid exudate. The pleura itself and all the interlobular septa become edematous and permeated by a serofibrinous exudate with [microorganisms and] wandering cells.
>
> From the beginning of the infection of the pleura the effusion of fluid exudate becomes a dominant feature of the whole process both in the clinical signs and the anatomical changes. It takes place with extraordinary rapidity and compresses the lung to such a degree as to complete the atelectasis.

### LOBULAR PNEUMONIA.

This type of bronchopneumonia was also almost invariably associated with hemolytic streptococcus, but the bronchial and peribronchial lesions were absent. The streptococci invaded the alveoli, which became filled with blood, leucocytes and enormous numbers of these bacteria, giving rise to patches of consolidation, followed frequently by necrosis and peripheral hemorrhage.

This variety of pneumonia was prone to occasion multiple abscesses, lying mostly near the periphery of the lung, and extending to the pleural surface. A rupture of such an abscess into the pleural cavity, or an extension of the necrosis so as to involve the structures of the pleura, would inevitably lead to empyema, and the coincident communication of the abscess with a patent bronchus would establish the pleurobronchial fistulæ which not infrequently complicated the treatment. In the less fulminating cases this mode of pleural infection was very common, at least in many of the camps, and pleurobronchial fistulæ were doubtless of much more frequent occurrence than the records show. There appears to be a pronounced tendency for such lesions to heal and for the communication between the lung and pleura to close spontaneously after the empyema cavity has been evacuated. In most cases these openings are not large enough to permit escape of pus from the pleura into the lung and subsequent discharge by expectoration. The thick fibrinous deposit, usually present, suffices in most instances to prevent this occurrence.

### MIXED TYPES OF PNEUMONIA.

Since the two varieties of bronchopneumonia just described are associated with hemolytic streptococcus disseminated through the air passages, it is not surprising that in many cases the lesions within the lung should present features characteristic of both the alveolar and interstitial routes of extension.

Furthermore, a mixed infection with pneumococcus and streptococcus may lead to a complex superposition or juxtaposition of lobar and bronchopneumonia. In such cases of mixed infection the pleural effusions and other associated infections are most frequently attributable to the streptococcus.

It is evident from these descriptions of pneumonia in the Army that the hemolytic streptococcus has been the cause of many of the peculiar characters presented by this disease among the troops. This organism appears in many, perhaps most, instances to have been a secondary invader. In the early period of high incidence many cases of empyema were preceded by measles, but this was by no means invariably the case. In the later period, influenza doubtless predisposed to a secondary invasion with streptococci. The data published by Opie and his associates [3] indicate that in the postinfluenzal pneumonias, pneumococci were relatively more frequently encountered than in the winter of 1917 and 1918, though infection with hemolytic streptococcus was also common. The pneumococci in the lobar pneumonias, however, were of types commonly found in throats of healthy people (50 per cent Types III and IV). It would appear that at both periods fortuitous circumstances favored the invasion of the lungs by organisms already in the upper air passages. In some cases the condition favoring this invasion appears to have been dependent on some antecedent disease, notably measles or influenza. In other cases there is no record of events to which a lowered resistance favoring extension of upper respiratory infections can be attributed.

The foregoing descriptions of pneumonia are in complete harmony with the epidemiological studies of empyema presented in Chapter II. They also indicate that both of the first two routes of extension actually occurred, namely, that by an intermediate alveolar infection and that through lymphatic channels.

It has been suggested by MacCallum [7] that differences in tissue resistance may play an important part in determining the character of the lesions in the lung produced by the hemolytic streptococcus; the interstitial pneumonias with rapid inflammatory reactions of a productive kind being evidence of greater resistance than the lobular pneumonias in which necrotic changes prevail.

With reference to the third route of dissemination—that is, through the blood-stream—the studies show that hemolytic streptococci were rarely found in the blood except immediately before death.[a] This is in sharp contrast to the results of blood cultures in cases of pneumococcus infection. Where it was known that both streptococcus and pneumococcus were present in the lungs or pleural cavity, the pneumococcus was frequently found in blood cultures while the streptococcus was absent. In these cases of mixed infection the streptococcus tended to persist in the lungs and pleura after the pneumococcus had disappeared. This circumstance justifies the precedence given to streptococcus in the epidemiological study, where these cases of mixed infection were placed in the streptococcus group.

From the studies of pneumonia cited above light is thrown not merely on the routes by which infection reaches the pleura, but also on the varying

[a] "We have made in all about 100 blood cultures from the circulating blood taken from the arm vein at various times before death with the usual technique of adding the blood to sterile broth, etc., but none of these cultures gave a positive result except when they were taken just before death." [8]

distribution of the pleural infection. In a typical lobar pneumonia the pleural infection is prone to be confined to the area of consolidation and appears to start as a dry pleurisy, with hyperemia and a fibrinous exudate tending to agglutinate the pleural surfaces and to restrict the pleural abscess subsequently formed to a single empyemic cavity. In uncomplicated cases the infection is purely pneumococcal and the organism may die, leaving a sterile pus. The treatment in such cases is simple and the prognosis good.

Conditions are very different when the infection of the pleura follows streptococcal pneumonia of either the interstitial or lobular types or a combination of the two. The pleural infection may then be massive at the start and may lead to abundant serous effusion before fibrinous agglutinations are possible. This leads to large empyemic cavities, in some instances including the greater part of the pleural cavity. Since these forms of pneumonia frequently involve both lungs, bilateral empyema is relatively common and almost invariably fatal when both sides are infected simultaneously.

A large part of the visceral pleura covers those portions of the lungs which bound the interlobar clefts. When infected, these portions of the pleura give rise to interlobar empyemata, which may be confined between the lobes by agglutinations or may communicate more or less freely with the rest of the pleural cavity. Confined interlobar empyemata offer greater difficulty to the diagnostician than do those which have the costal wall for one of their boundaries and are less accessible to surgical evacuation and to postoperative treatment. Even when the clefts are freely open, drainage and irrigation are rendered difficult.

Extensive thickening of the pleura bounding the interlobar clefts militates against expansion of the lung to meet the costal walls along these planes, and contact between the visceral and parietal pleuræ tends to be more imperfect along the lines of these clefts than in other parts of the cavity. Contraction of cicatricial tissue formed between the pulmonary lobes would draw the lung away from the costal wall. It is probable that a number of long, narrow, and persistent superficial sinuses that have proven refractory to treatment owe their origin to interlobar bands of cicatricial tissue which have held their walls apart at a time when an approximation would have been followed by obliteration through a union of granulations lining the lumen.

If an interlobar abscess, or a subpleural abscess within the lung, should rupture into the general pleural cavity a massive infection of the pleura would result, leading to the rapid development of a large exudate.

The infection of the pleura need not be of this massive character. Fibrinous agglutinations may confine the pus to certain localized areas, forming smaller empyema pockets. These may be coincidently or successively formed in various parts of the pleura, giving rise to the multiple pockets so frequently found at autopsy.

There is, however, another way in which multiple pockets may be formed. The prominence of productive inflammatory processes in the streptococcus infections of the bronchi and peribronchial tissues has already been referred to. A similar new formation of connective tissue takes place beneath the fibrinous deposit upon the pleural surfaces. If these pleural surfaces then come in contact for a sufficient period, the granulations on the two surfaces may

blend and give rise to permanent adhesions. This coalescence of the granulations upon opposed pleural surfaces is the natural way in which empyemic cavities become obliterated with permanent healing. This may lead also to the formation of separate pockets or to irregularly shaped cavities.

There is one circumstance possibly affecting the formation of multiple pockets to which reference has not been made. The changes in the bronchial and peribronchial tissues which are so prominent in the bronchopneumonia of interstitial type, often lead to a narrowing or partial stenosis of the bronchus, so that the accumulation of secretions blocks the passage of air. This is frequently followed by atelectasis of the corresponding portion of the lung, and insufflation of such a lung leaves these portions unexpanded. When the fluid is withdrawn these scattered areas of atelectasis prevent uniform expansion of the lung and a perfect apposition of the pleural surfaces, resulting in undrained pockets.

In contrast with the pneumococcus, the hemolytic streptococcus appears to call forth little if any active immunity. The bacteria may persist in an empyema cavity for many months, may infect the periosteum after rib resection, and, at times, they appear capable of lying dormant for a long period without exciting acute inflammation. These characteristics of streptococcus infections lead to chronicity and recrudescences after long intervals.

Experiments by Blake and Cecil [9] at the Army Medical School upon the production of pneumonia by intratracheal inoculation of minute quantities of virulent pneumococci showed very conclusively that the infection was disseminated through the interstitial tissues and that the pleura might be infected before marked consolidation of the lung took place. They also observed pericarditis and occasionally peritonitis as complicating infections, and in one or two instances noted an acute infection of the mediastinal tissues.

Since larger numbers of bacteria were required to produce infection in the monkey, infection with the hemolytic streptococcus appears to have been produced with more difficulty than infection with the pneumococcus. The lesions which were produced, however, were similar in character and distribution to those observed and described by MacCallum.

The special empyema records offer examples of most, if not all, of the conditions in the pleura and viscera which might be expected from the pathology of the different forms of pneumonia. There are few cases so completely described that it is possible to trace the course of events, step by step, from the first inception of disease to its termination. It would be impossible to give a detailed history of cases illustrating all of the numerous possibilities. These records, nevertheless, contain much information of value in the clinical care of empyema and call attention to the need of studying each case with respect to its individual peculiarities.

### SERIOUS INFECTIONS COMPLICATING EMPYEMA.

From a clinical point of view the occurrence of serious infections complicating empyema is of importance. The development of pneumonia or of pleurisy on the opposite side, of pericarditis or of peritonitis not only affects the prognosis, but influences the judgment in regard to the treatment. In many of the fatal cases embodied in the special empyema records [1] autopsy has

revealed the presence of more than one of these concomitant infections. The records from Camp Dodge are numerous and particularly instructive in this respect. Charts LIV, LV, and LVI, have been prepared to set forth the relationships revealed by this single series of autopsies. The cases are represented in the central column by squares, six in each horizontal row representing a single case. The rows are arranged one beneath the other in chronological order

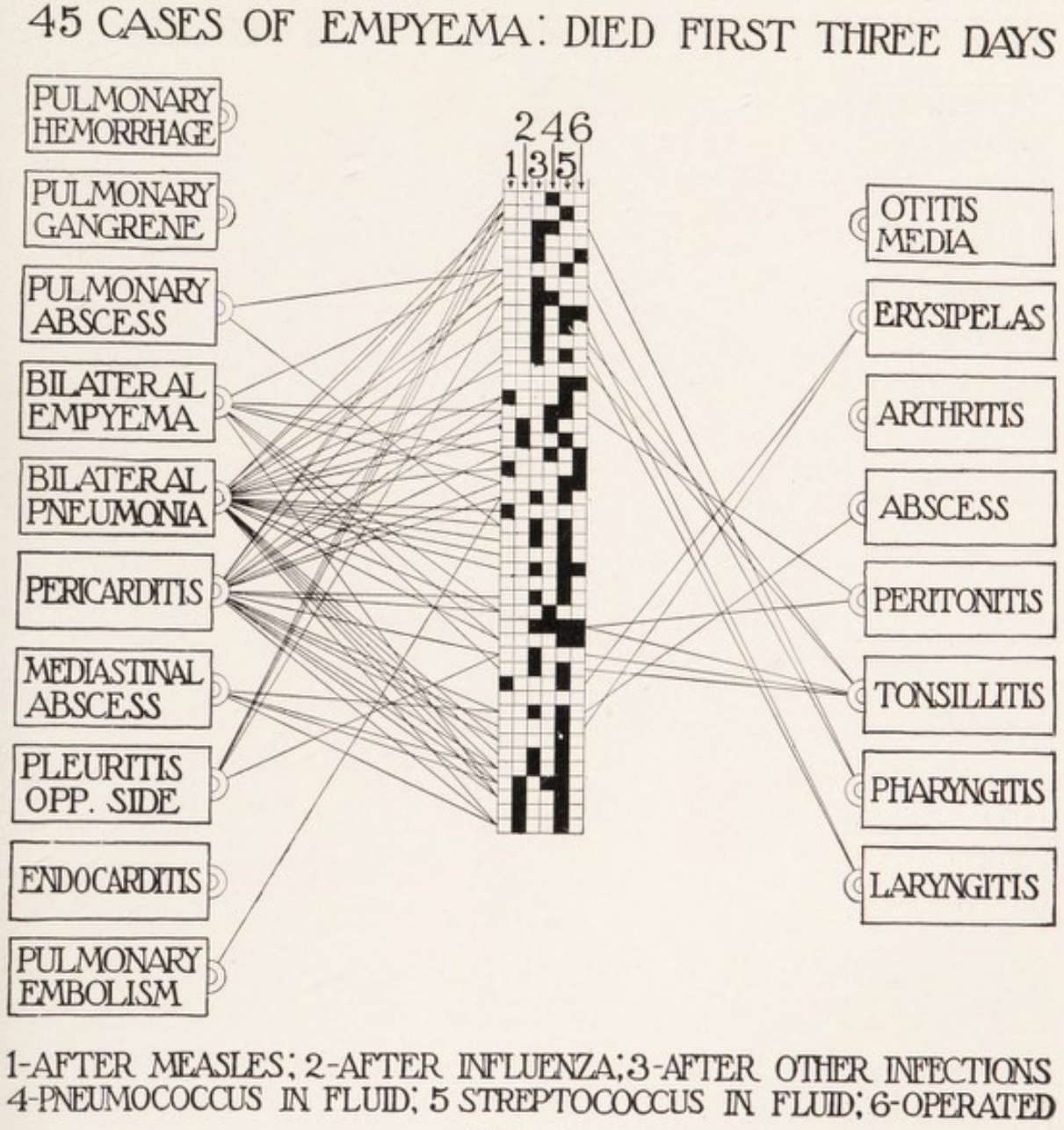


CHART LIV.

in respect to the day of death after admission to the hospital. The superimposed squares form six columns indicating the preceding disease, the organism found in the pleural fluid, and whether or not a thoracotomy or costectomy had been done. To the left of this central column 10 serious intrathoracic conditions are represented and, to the right, eight of the more important extrathoracic conditions. From the central column, lines from the row of squares representing a given case connect it with the respective intra- or extrathoracic conditions found at autopsy in that particular case.

A mere glance at these diagrams suffices to show that very few cases of empyema at Camp Dodge died without one or more complicating conditions of a serious nature and that of these bilateral empyema or pneumonia, pericarditis and peritonitis were the most frequent. These complications are found irrespective of the lapse of time between admission to the hospital and death.

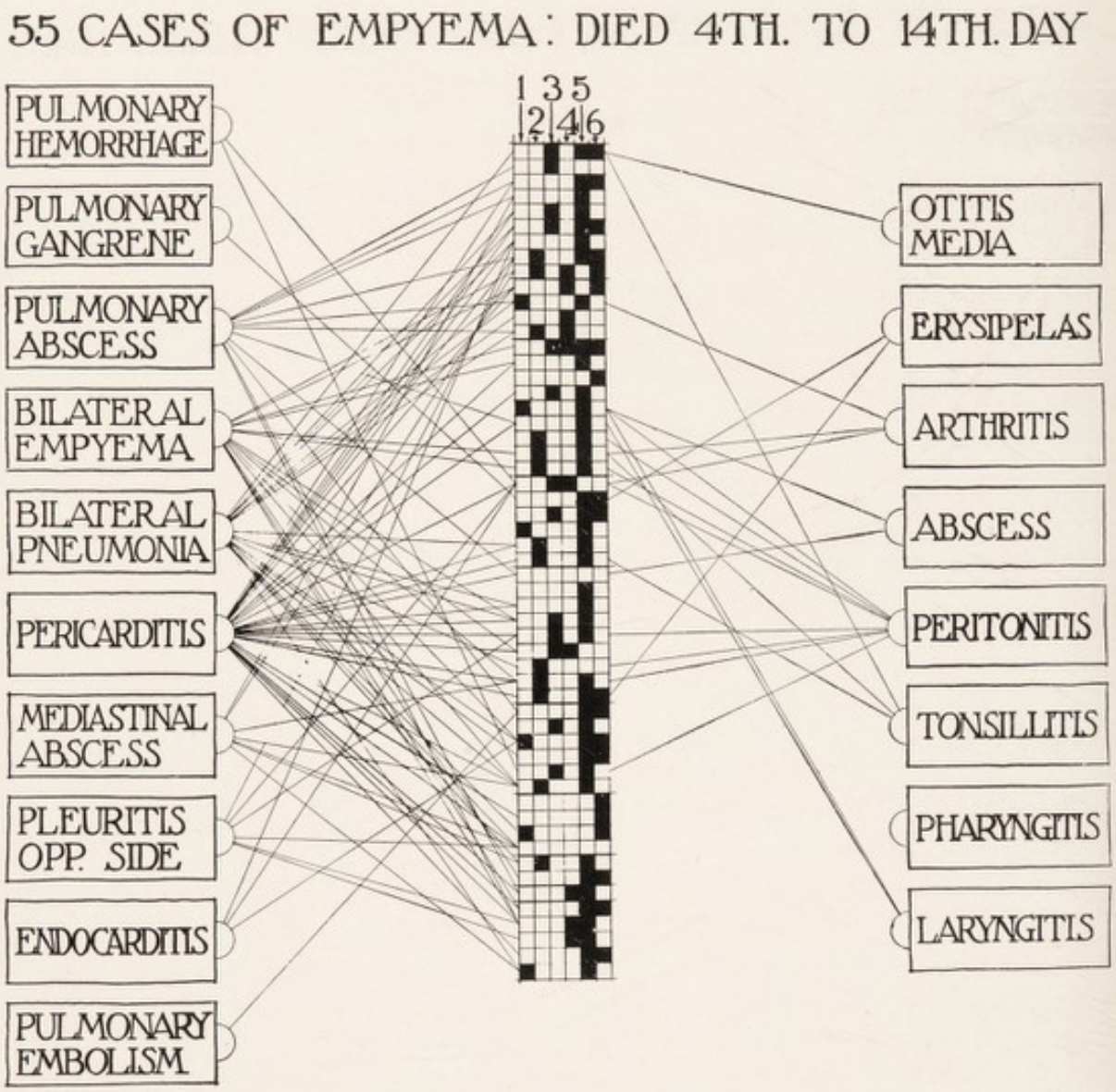


CHART LV.

That the conditions favoring the development of the most important complicating localizations of infection shown in these diagrams were not confined to Camp Dodge is shown by the following tabulation of 603 autopsies. In this tabulation the cases are grouped according to the time of death after the recognition of pneumonia and not, as in the preceding diagrams, after admission to the hospital. This furnished a more uniform grouping, since some of the cases were admitted for diseases having no direct bearing on the development of empyema. The cases at Camp Dodge are included in this series. It is obvious from the figures that many of these cases must have presented

more than one such complicating localization of the infection, but it has not appeared necessary to trace these coincidences further than was done in preparing the diagrams for Camp Dodge.

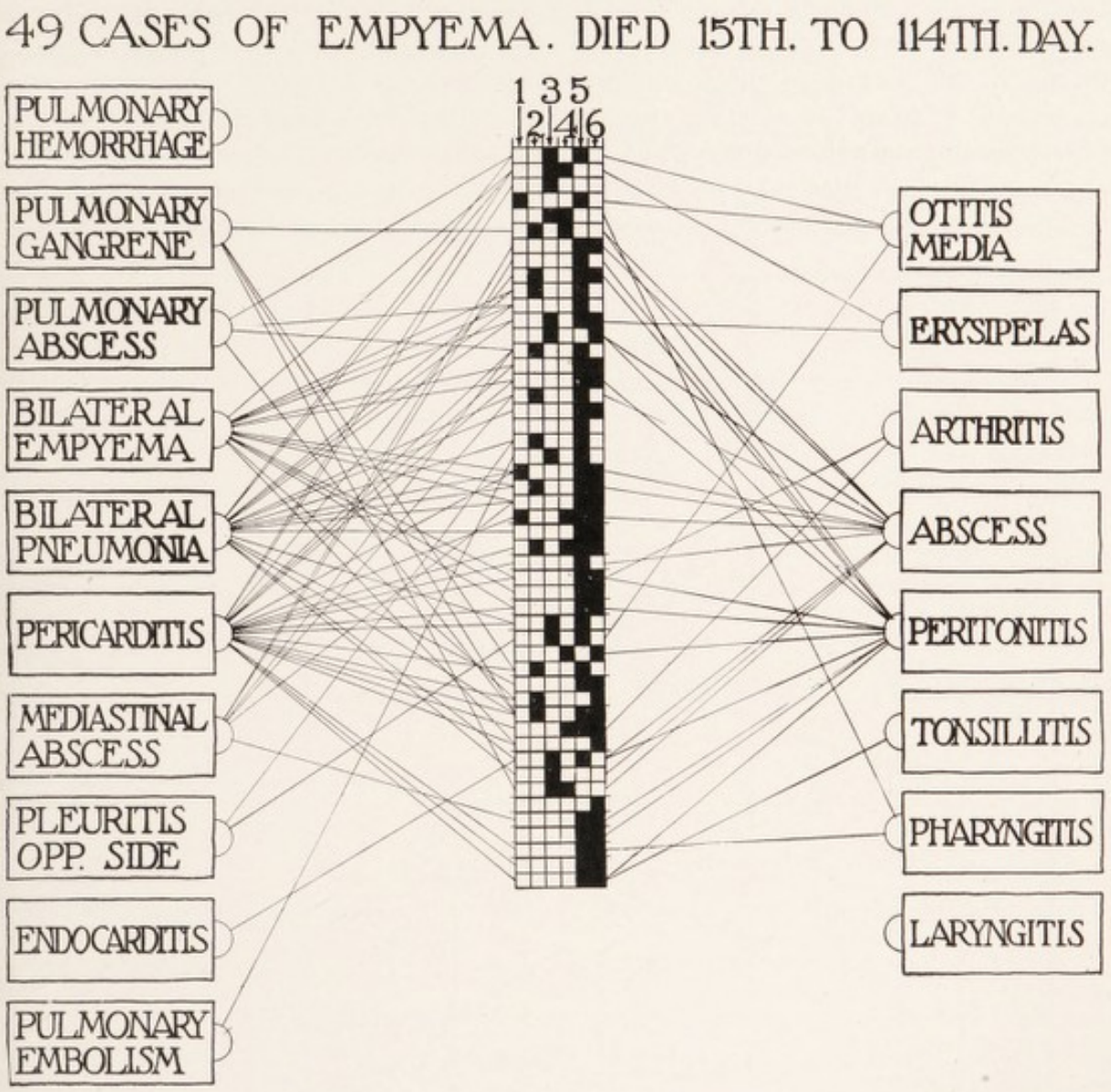


CHART LVI.

TABLE 31.[a]—*Chief complications of empyema found at autopsy in the United States Army camps during 1917–18.*

| Death after pneumonia. | Bilateral empyema. | Bilateral empyema percentage. | Bilateral pneumonia. | Bilateral pneumonia percentage. | Pericarditis. | Pericarditis percentage. | Peritonitis. | Peritonitis percentage. | Mediastinal abscess. | Mediastinal abscess percentage. | Total number of autopsies. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 days | 3 | 43 | 5 | 71 | 0 | 0 | 2 | 3 | 0 | 0 | 7 |
| 1–4 days | 21 | 31 | 36 | 53 | 23 | 34 | 15 | 22 | 1 | 1.47 | 68 |
| 4–7 days | 22 | 33 | 36 | 55 | 22 | 33 | 12 | 18 | 4 | 6.06 | 66 |
| 7–14 days | 50 | 38 | 93 | 71 | 54 | 41 | 22 | 17 | 5 | 3.82 | 131 |
| 14–21 days | 39 | 44 | 64 | 72 | 32 | 36 | 20 | 22 | 4 | 4.49 | 89 |
| 21–28 days | 28 | 55 | 38 | 75 | 24 | 47 | 12 | 24 | 3 | 5.90 | 51 |
| 28–35 days | 34 | 56 | 33 | 54 | 41 | 67 | 11 | 18 | 2 | 3.28 | 61 |
| 35–42 days | 13 | 41 | 20 | 63 | 23 | 72 | 6 | 19 | 2 | 6.25 | 32 |
| 42+ days | 43 | 44 | 36 | 37 | 44 | 45 | 26 | 26 | 3 | 3.06 | 98 |
| Total | 253 | 42 | 361 | 60 | 263 | 44 | 126 | 21 | 24 | 4 | 603 |

[a] Source of information: Special empyema reports made to the Office of the Surgeon General.

The significance of the figures in this table is made more evident when they are plotted. Chart LVII, in which the curves represent the percentages of bilateral pneumonia, bilateral empyema, pericarditis and peritonitis, shows that in fatal cases each of these conditions is found in a considerable proportion of the total; that the possibilities of bilateral pneumonia at autopsy are highest up to the conclusion of the fourth week and are never absent; that empyema on the opposite side is at a maximum toward the sixth week after the primary pneumonia; that pericarditis, which is usually fatal shortly after its occurrence, is a complication that may occur in a large percentage of the fatal cases at any time soon after the development of pneumonia, but more frequently between

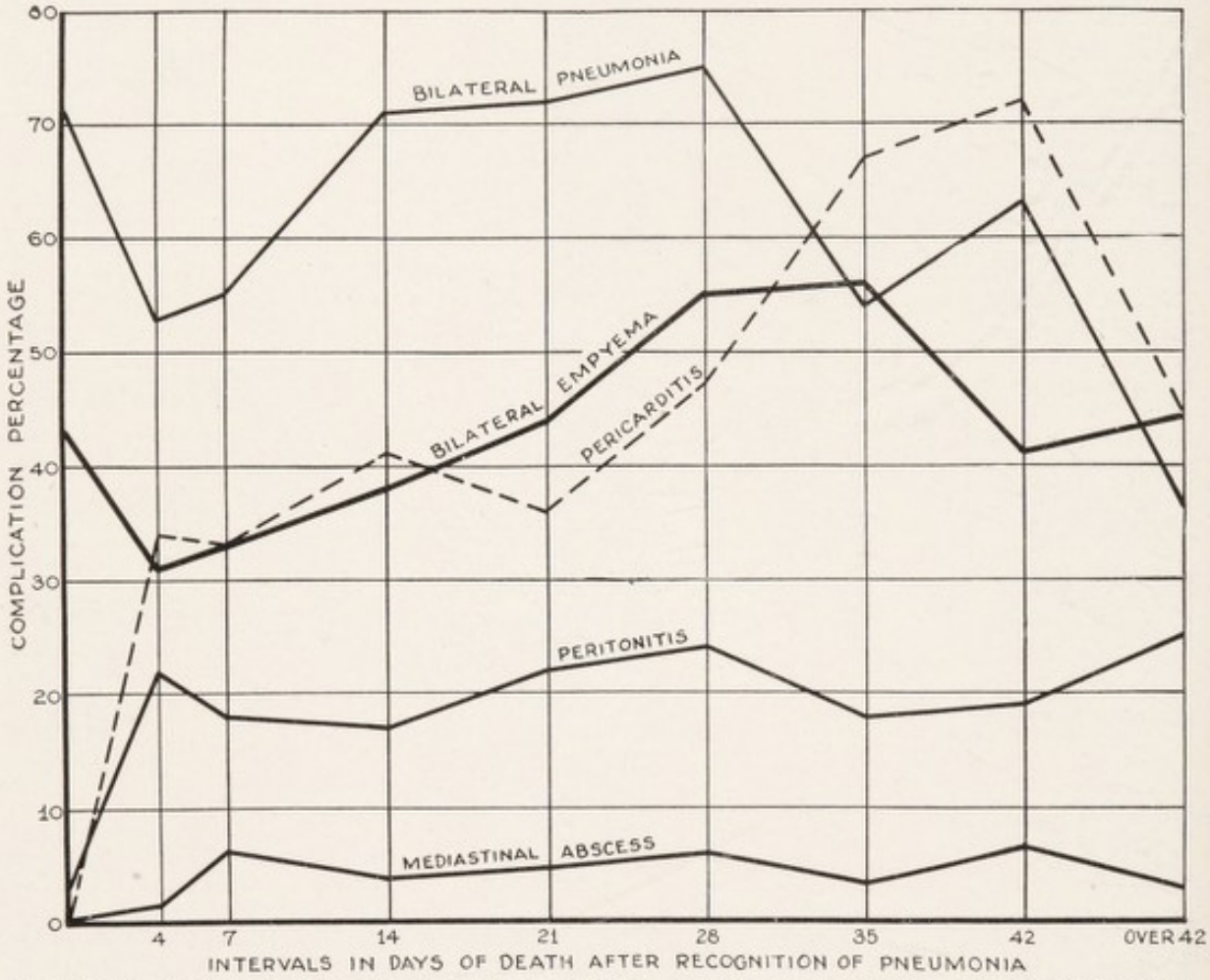


CHART LVII.—Chief complications of empyema found at autopsy. Charted according to intervals after the onset of the infection.

the 5th and 7th week, and that peritonitis claims a fairly uniform number of victims at all times. The curve of mediastinal abscess includes only cases in which suppuration in the mediastinum was definitely described. There are instances in which edema of the mediastinal tissues was noted at autopsy and at least one in which cultures from this serous fluid contained hemolytic streptococci. In this case there was bilateral empyema, but neither pericarditis nor peritonitis.

The clinical significance of these complications is evident. For several weeks after the onset of a pneumonia with unilateral empyema the possibility that one or more of these complications may take place should be borne in mind. This affects not only the prognosis but the opinion of the surgeon

as to the appropriate measures to be adopted in treatment. It is to be noted that about four-fifths of the fatal cases in which bacterial data are available were associated with a streptococcus and that among these the hemolytic streptococcus predominated. It appears, then, that caution in treatment and prognosis is particularly important in cases of streptococcal infection. This is a necessary corollary of the pathology of the pneumonias due to this organism. Cases of pneumococcus infection are not without similar dangers though of minor degree.

An inquiry concerning the microorganisms associated with these cases results in the figures given in Table 32. All the cases in which the streptococcus was found, whether alone or associated with the pneumococcus, are grouped in one class, those in which a pneumococcus alone occurred in a second class, and the staphylococcus in a third, the total of these three classes being the positive findings. The percentages of each class corresponds very closely to the results obtained from a similar analysis of the bacteriological results in pleural exudates, as shown in Table 4 (vide Chapter II, p. 55). A single case of tuberculous pleurisy has been omitted from the table.

TABLE 32.[a]—*Three chief groups of organisms in 450 fatal cases of empyema.*

| Death after pneumonia. | Streptococcus group. | Streptococcus percentage. | Pneumococcus group. | Pneumococcus percentage. | Staphylococcus group. | Staphylococcus percentage. | Total cases. |
|---|---|---|---|---|---|---|---|
| 0 days | 3 | 60 | 2 | 40 | 0 | 0 | 5 |
| 1–4 days | 56 | 98 | 0 | 0 | 1 | 2 | 57 |
| 4–7 days | 40 | 74 | 14 | 26 | 0 | 0 | 54 |
| 7–14 days | 84 | 82 | 13 | 13 | 4 | 4 | 101 |
| 14–21 days | 53 | 84 | 9 | 14 | 0 | 0 | 62 |
| 21–28 days | 27 | 77 | 6 | 17 | 2 | 6 | 35 |
| 28–35 days | 34 | 77 | 10 | 23 | 0 | 0 | 44 |
| 35–42 days | 16 | 69 | 6 | 26 | 1 | 5 | 23 |
| 42+days | 50 | 72 | 16 | 23 | 3 | 5 | 69 |
| Total | 363 | 81 | 76 | 17 | 11 | 2 | 450 |

[a] Source of information: Special empyema reports made to the Office of the Surgeon General.

In the early stages of exudation the pleural fluid in streptococcus empyema is serous, straw colored, tawny, or pinkish from admixture with blood pigment, and often slightly fluorescent, appearing brownish by transmitted light and yellowish-green by reflected light. Occasionally it appears quite clear but is usually somewhat cloudy owing to enormous numbers of microorganisms. These may be so numerous that a plate culture made from a single loopful contains half a million or more colonies, visible only under the microscope. A spontaneous coagulation of these serous fluids after their withdrawal has occasionally been observed.

The amount of serous exudate formed within a few hours may be very large. Many cases are on record in which the first aspiration yielded two or more liters, and as much as 4 or even 6 liters have been noted as obtained at a single aspiration. Measurements of fluid withdrawn at daily intervals show that the accumulation may frequently reach a liter a day.

The serous character of the exudate is maintained for only a short time: within from one to three days fibrin and leucocytes appear in such quantity that on standing a sediment is formed amounting to from one-tenth to one-fifth of the total volume. The supernatent fluid is yellow, brownish, or light

pink in color. At this time the pleural surfaces are covered with a deposit of fibrin, often of some thickness and sometimes interfering with aspiration. The fibrin soon becomes abundantly infiltrated with leucocytes and the fluid progressively more charged with these cells, becoming seropurulent and then purulent, until finally only a thin layer of clear serum appears at the top after the fluid has stood for many hours.

This description is based upon cases in which the empyema is due to the hemolytic streptococcus. Smears of the fluid, however, rarely reveal this organism in chains of any considerable length. Usually they appear as diplococci with the adjacent surfaces slightly flattened. From two to six of these may lie in a row forming very short streptococcal chains, but in view of the great number of isolated diplococci it is often difficult for the observer to convince himself that this arrangement may not be accidental. When cultivated in broth long chains develop. Very rarely chains of 80 or more diplococcal forms are found in the original freshly withdrawn exudate.

The occurrence of phagocytosis in the exudate is variable. In some cases it appears to be almost entirely absent, but in other cases it is marked and cells crowded with microorganisms are frequently seen. In some instances failure of the cell nuclei to stain as deeply in these cells as in neighboring leucocytes, while the organisms themselves stain deeply, gives the impression that the phagocytosis is not an effective protection against this infection; but in other instances the reverse is observed, the microorganisms within the cell taking the stain but faintly while the nuclei appear normal in this and other respects. In the majority of the leucocytes the nuclei are fragmented, from four to six clumps of nuclear material lying separated within the cytoplasm.

### DISSEMINATION OF INFECTION IN SURVIVING CASES.

That the dissemination of the infection in surviving cases was less extensive than in fatal cases is shown by the relatively small number in which the intrathoracic condition was bilateral, notwithstanding the fact that bronchopneumonia was prone to affect both lungs. Peritonitis is mentioned in only two cases which recovered. In one of these an investigation showed that the reported peritonitis was based on the following brief clinical memorandum made on the 835th day after admission to the hospital for a lobar pneumonia of the right lower lobe: "Local peritonitis over region of right kidney, symptoms of subphrenic abscess." The day before, this localized cavity had been drained by resecting a callus formed after the first resection of the eighth rib in the midaxillary line three months previously. The case offers no analogy to the acute general peritonitis so frequent in fatal cases. No details are available concerning the character of the other case in which peritonitis was noted, and the patient recovered.

Pericarditis has also been of low incidence in cases that survived. The diagnosis has usually been based upon the occurrence of a friction sound referred to the pericardium. In cases of pericarditis which subdivided, fibrous agglutination and ultimate adhesions sometimes resulted. A true infection of the pericardium, with abundant purulent exudate due to the streptococcus, was almost invariably fatal.

With respect to the extrathoracic infections, other than peritonitis and meningitis, there is but little percentage difference in incidence between cases that survived and those proving fatal.

Confining the compilation to data from camp base hospitals and excluding the chronic cases transferred from other hospitals, the occurrence of the most frequent infections complicating empyema is given in Tables 33, 34, and 35. These summaries are based upon the special emypema records and show the frequency of these complications as noted in those records in both fatal and surviving cases. Both the absolute numbers and percentages are given.

Nearly all of the cases of empyema in the Army that were recognized and survived received active treatment. This treatment varied from a single aspiration to extensive operations entailing decortication of the lung and collapse of the chest wall. It is therefore impossible to describe the course that would have been taken by the infection of the pleura had there been no surgical intervention. There are no records of autopsies made upon cases any considerable time after healing of the empyema. A knowledge of the ultimate results of empyema in the Army is dependent, therefore, upon the personal reports of the patients and on the results of physical and X-ray examinations. Since the character of these findings was determined by both the pathology and the treatment of each case, a consideration of the kinds and degrees of disability experienced by the patients with their probable explanations can best be deferred until the methods of treatment have been described. But there are certain pathological processes which must influence the ultimate outcome in every case. For example, it is evident that productive inflammatory processes must follow the damage wrought by the infections described in this chapter and that these will inevitably lead to the formation of cicatricial tissue tending to contract. Thus, adhesions and deformities are threatened in proportion to the extent and abundance of the granulation tissue within the lung or upon the pleural surfaces. Analogous to this is the new formation of bone from surviving periosteal tissues.

It should be the aim of the surgeon to first avert conditions threatening life, then to promote the well-being of his patient, and, finally, to reduce the ultimate disability to a minimum.

TABLE 33.[a]—*Association of the three chief classes of infecting organisms found in the pleural exudate with the more frequent complications—Based on 3,889 cases.*

| Line numbers. | Complications. | Bacteriology given. | | | | | | | | | | | | Bacteriology unknown. | | | Grand total. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Streptococcus. | | | Pneumococcus. | | | Staphylococcus. | | | Totals. | | | | | | | | |
| | | Lived. | Died. | Total. | Lived. | Died. | Total. | Lived. | Died. | Total. | Lived. | Died. | Total. | Lived. | Died. | Total. | Lived. | Died. | Total. |
| 1 | Bilateral pneumonia | 285 | 314 | 599 | 151 | 75 | 226 | 13 | 13 | 26 | 449 | 402 | 851 | 135 | 167 | 302 | 584 | 569 | 1,153 |
| | Per cent | | | 70.4 | | | 26.6 | | | 3.1 | | | 73.8 | | | 26.2 | | | 29.64 |
| 2 | Pulmonary abscess | 56 | 68 | 124 | 40 | 9 | 29 | 5 | 0 | 5 | 81 | 77 | 158 | 17 | 22 | 39 | 98 | 99 | 197 |
| | Per cent | | | 78.5 | | | 18.4 | | | 3.2 | | | 80.2 | | | 19.8 | | | 5.07 |
| 3 | Mediastinal infection | 0 | 44 | 44 | 0 | 3 | 3 | 0 | 0 | 0 | 0 | 47 | 47 | 0 | 7 | 7 | 0 | 54 | 54 |
| | Per cent | | | 93.6 | | | 6.4 | | | 0.0 | | | 87.0 | | | 13.0 | | | 1.40 |
| 4 | Pericarditis | 23 | 175 | 198 | 9 | 25 | 34 | 1 | 2 | 3 | 33 | 202 | 235 | 6 | 33 | 39 | 39 | 235 | 274 |
| | Per cent | | | 84.2 | | | 14.5 | | | 1.3 | | | 85.8 | | | 14.2 | | | 7.05 |
| 5 | Endocarditis | 0 | 13 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 13 | 0 | 6 | 6 | 0 | 19 | 19 |
| | Per cent | | | 100 | | | 0.0 | | | 0.0 | | | 68.4 | | | 31.6 | | | 0.49 |
| 6 | Peritonitis | 1 | 85 | 86 | 2 | 9 | 11 | 0 | 1 | 1 | 3 | 95 | 98 | 0 | 13 | 13 | 3 | 108 | 111 |
| | Per cent | | | 87.8 | | | 11.2 | | | 1.0 | | | 88.3 | | | 11.7 | | | 2.85 |
| 7 | Abscess of soft parts | 67 | 38 | 105 | 35 | 3 | 38 | 4 | 1 | 5 | 106 | 42 | 148 | 20 | 6 | 26 | 125 | 48 | 174 |
| | Per cent | | | 70.9 | | | 25.7 | | | 3.4 | | | 85.1 | | | 14.9 | | | 4.47 |
| 8 | Phlebitis | 6 | 4 | 10 | 5 | 0 | 5 | 2 | 0 | 2 | 13 | 4 | 17 | 2 | 2 | 4 | 15 | 6 | 21 |
| | Per cent | | | 58.8 | | | 29.4 | | | 11.8 | | | 81.0 | | | 19.0 | | | 0.54 |
| 9 | Erysipelas | 12 | 17 | 29 | 5 | 2 | 7 | 0 | 0 | 0 | 17 | 19 | 36 | 5 | 5 | 10 | 22 | 24 | 46 |
| | Per cent | | | 80.6 | | | 19.4 | | | 0.0 | | | 78.3 | | | 21.7 | | | 1.18 |
| 10 | Arthritis | 18 | 14 | 32 | 9 | 1 | 10 | 1 | 0 | 1 | 28 | 15 | 43 | 16 | 2 | 18 | 44 | 17 | 61 |
| | Per cent | | | 74.4 | | | 23.3 | | | 2.3 | | | 70.5 | | | 29.5 | | | 1.57 |
| 11 | Otitis media | 61 | 32 | 93 | 33 | 2 | 35 | 1 | 1 | 2 | 95 | 35 | 130 | 16 | 5 | 21 | 111 | 40 | 151 |
| | Per cent | | | 71.5 | | | 26.9 | | | 1.5 | | | 86.1 | | | 13.9 | | | 3.88 |
| 12 | Mastoiditis | 9 | 9 | 18 | 4 | 1 | 5 | 1 | 1 | 2 | 14 | 11 | 25 | 4 | 0 | 4 | 18 | 11 | 29 |
| | Per cent | | | 72.0 | | | 20.0 | | | 8.0 | | | 86.2 | | | 13.8 | | | 0.75 |
| 13 | Meningitis | 0 | 6 | 6 | 0 | 5 | 5 | 0 | 1 | 1 | 0 | 12 | 12 | 0 | 3 | 3 | 0 | 15 | 15 |
| | Per cent | | | 50.0 | | | 41.7 | | | 8.3 | | | 80.0 | | | 20.0 | | | 0.39 |
| 14 | Empyema, right side | 658 | 277 | 935 | 325 | 62 | 387 | 27 | 7 | 34 | 1,010 | 346 | 1,356 | 369 | 169 | 538 | 1,379 | 515 | 1,894 |
| | Per cent | | | 69.0 | | | 28.5 | | | 2.5 | | | 71.6 | | | 28.4 | | | 48.7 |
| 15 | Empyema, left side | 608 | 250 | 858 | 275 | 45 | 320 | 23 | 10 | 33 | 906 | 305 | 1,211 | 308 | 149 | 457 | 1,214 | 454 | 1,668 |
| | Per cent | | | 70.9 | | | 26.4 | | | 2.7 | | | 72.6 | | | 27.4 | | | 42.9 |
| 16 | Bilateral empyema | 19 | 166 | 185 | 12 | 47 | 59 | 0 | 9 | 9 | 31 | 222 | 253 | 5 | 69 | 74 | 36 | 291 | 327 |
| | Per cent | | | 73.1 | | | 23.3 | | | 3.6 | | | 77.4 | | | 22.6 | | | 8.41 |

[a] Source of information: Special empyema reports made to the Office of the Surgeon General.

TABLE 34.[a]—*Table of complications, with case mortalities.*[b]

| Total cases, 3,889. | | | | Died, 1,260 (32.4%). | | | | | | | | | | | | | Lived, 2,629 (67.6%). | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Column numbers. | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| | | | | | | | | | | | | | | | | | Empyema, right side. | | | | Empyema, left side. | | | | Bilateral empyema. | | | |
| | | | | | | | | | | | | | | | | | 1,379 (52.5%). | | | | 1,214 (46.2%). | | | | 36 (1.4%). | | | |
| Total cases, 3,889. | Line numbers. | Complications. | Cases. | Bilateral pneumonia. | Pulmonary abscess. | Mediastinal infection. | Pericarditis. | Endocarditis. | Peritonitis. | Abscess of soft parts. | Phlebitis. | Erysipelas. | Arthritis. | Otitis media. | Mastoiditis. | Meningitis. | S | p | Sa | ? | S | p | Sa | ? | S | p | Sa | ? |
| | | | 589 | 569 | 99 | 54 | 235 | 19 | 108 | 48 | 6 | 24 | 17 | 40 | 11 | 15 | 658 | 325 | 27 | 369 | 608 | 275 | 23 | 308 | 19 | 12 | 0 | 5 |
| | | | | 45.2% | 7.9% | 4.3% | 18.7% | 1.5% | 8.6% | 3.8% | 0.5% | 1.9% | 1.3% | 3.2% | 0.9% | 1.2% | 47.7% | 23.5% | 2.0% | 26.8% | 50.1% | 22.7% | 1.9% | 25.4% | 52.8% | 33.3% | 0.0% | 13.9% |
| Lived, 2,629 (67.6%). | 1 | Bilateral pneumonia | 584 | 49.4% | 44 | 50 | 186 | 13 | 76 | 28 | 5 | 16 | 10 | 24 | 4 | 7 | 160 | 69 | 10 | 69 | 131 | 72 | 3 | 62 | 14 | 10 | 0 | 4 |
| | | | 22.2% | 50.6% | 64.7% | 100% | 91.9% | 100% | 100% | 50.9% | 55.6% | 100% | 40.6% | 49.0% | 50.0% | 100% | 57.6% | 74.2% | 76.9% | 50.7% | 57.3% | 82.8% | 50.0% | 52.1% | 10.9% | 21.7% | 0.0% | 8.5% |
| | 2 | Pulmonary abscess | 98 | 24 | 50.3% | 6 | 17 | 2 | 7 | 6 | 0 | 1 | 1 | 3 | 1 | 2 | 32 | 14 | 4 | 12 | 24 | 5 | 1 | 5 | 0 | 1 | 0 | 0 |
| | | | 3.7% | 35.4% | 49.1% | 100% | 89.5% | 100% | 100% | 60.0% | 0.0% | 100% | 33.3% | 37.5% | 100% | 100% | 55.2% | 82.4% | 100% | 57.1% | 52.2% | 83.3% | 100% | 71.5% | 0.0% | 16.7% | 0.0% | 0.0% |
| | 3 | Mediastinal infection | 0 | 0 | 0 | 100% | 27 | 0 | 8 | 5 | 0 | 0 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | 0.0% | 0.0% | 0.0% | 0.0% | 100% | 0.0% | 100% | 100% | 0.0% | 0.0% | 100% | 100% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| | 4 | Pericarditis | 39 | 12 | 2 | 0 | 85.8% | 5 | 28 | 7 | 0 | 3 | 3 | 8 | 4 | 1 | 7 | 3 | 0 | 3 | 15 | 6 | 1 | 3 | 1 | 0 | 0 | 0 |
| | | | 1.5% | 6.1% | 10.5% | 0.0% | 14.2% | 100% | 100% | 87.5% | 0.0% | 100% | 100% | 72.7% | 100% | 100% | 15.9% | 30.0% | 0.0% | 23.1% | 23.8% | 60.0% | 100% | 25.0% | 1.1% | 0.0% | 0.0% | 0.0% |
| | 5 | Endocarditis | 0 | 0 | 0 | 0 | 0 | 100% | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100% | 100% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| | 6 | Peritonitis | 3 | 0 | 0 | 0 | 0 | 0 | 97.3% | 3 | 0 | 0 | 1 | 2 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | 0.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 2.7% | 83.3% | 0.0% | 0.0% | 100% | 100% | 100% | 100% | 4.3% | 50.0% | 0.0% | 0.0% | 0.0% | 25.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| | 7 | Abscess of soft parts | 126 | 27 | 4 | 0 | 1 | 0 | 1 | 27.6% | 0 | 1 | 2 | 4 | 2 | 0 | 41 | 23 | 3 | 11 | 25 | 12 | 1 | 9 | 1 | 0 | 0 | 0 |
| | | | 4.8% | 49.1% | 40.0% | 0.0% | 12.5% | 0.0% | 16.7% | 72.4% | 0.0% | 20.0% | 25.0% | 28.6% | 100% | 0.0% | 71.9% | 100% | 100% | 73.3% | 71.4% | 85.7% | 50.0% | 90.0% | 7.7% | 0.0% | 0.0% | 0.0% |
| | 8 | Phlebitis | 15 | 4 | 1 | 0 | 0 | 0 | 0 | 1 | 28.6% | 0 | 0 | 0 | 0 | 0 | 5 | 3 | 0 | 1 | 0 | 2 | 2 | 1 | 1 | 0 | 0 | 0 |
| | | | 0.0% | 44.4% | 100% | 0.0% | 0.0% | 0.0% | 0.0% | 100% | 71.4% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100% | 100% | 0.0% | 33.3% | 0.0% | 100% | 100% | 100% | 33.3% | 0.0% | 0.0% | 0.0% |
| | 9 | Erysipelas | 22 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 52.3% | 0 | 1 | 0 | 0 | 6 | 1 | 0 | 3 | 5 | 3 | 0 | 2 | 1 | 1 | 0 | 0 |
| | | | 0.8% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 80.0% | 0.0% | 47.8% | 0.0% | 33.3% | 0.0% | 0.0% | 40.0% | 33.3% | 0.0% | 50.0% | 50.0% | 100% | 0.0% | 50.0% | 25.0% | 100% | 0.0% | 0.0% |
| | 10 | Arthritis | 44 | 15 | 2 | 0 | 0 | 0 | 0 | 6 | 2 | 0 | 27.9% | 1 | 1 | 0 | 8 | 4 | 0 | 6 | 10 | 3 | 1 | 9 | 0 | 2 | 0 | 1 |
| | | | 1.7% | 60.0% | 66.7% | 0.0% | 0.0% | 0.0% | 0.0% | 75.0% | 100% | 0.0% | 72.1% | 33.3% | 100% | 0.0% | 80.0% | 100% | 0.0% | 100% | 66.7% | 75.0% | 100% | 100% | 0.0% | 100% | 0.0% | 33.3% |
| | 11 | Otitis media | 111 | 25 | 5 | 0 | 3 | 0 | 0 | 10 | 0 | 2 | 2 | 26.5% | 0 | 0 | 28 | 16 | 1 | 10 | 31 | 16 | 0 | 6 | 2 | 1 | 0 | 0 |
| | | | 4.2% | 51.0% | 62.5% | 0.0% | 27.3% | 0.0% | 0.0% | 71.4% | 0.0% | 66.7% | 66.7% | 73.5% | 0.0% | 0.0% | 66.7% | 94.1% | 100% | 83.3% | 70.5% | 94.1% | 0.0% | 85.7% | 28.6% | 100% | 0.0% | 0.0% |
| | 12 | Mastoiditis | 18 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 37.9% | 1 | 4 | 2 | 0 | 2 | 5 | 2 | 1 | 2 | 0 | 0 | 0 | 0 |
| | | | 0.7% | 50.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 62.1% | 100% | 44.4% | 100% | 0.0% | 100% | 83.3% | 66.7% | 50.0% | 100% | 0.0% | 0.0% | 0.0% | 0.0% |
| | 13 | Meningitis | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Died, 1,260 (32.4%). | 14 | Empyema, right side. | ∞ | 277 | 103 | 26 | 6 | 37 | 5 | 21 | 16 | 0 | 9 | 2 | 14 | 5 | 1 | | | | | | | | | | | |
| | | | | 53.8% | 42.4% | 44.8% | 100% | 84.1% | 100% | 95.5% | 28.1% | 0.0% | 60.0% | 20.0% | 33.3% | 55.6% | 100% | | | | | | | | | | | |
| | 15 | | p | 62 | 24 | 3 | 2 | 7 | 0 | 1 | 0 | 0 | 2 | 0 | 1 | 0 | 2 | | | | | | | | | | | |
| | | | | 12.0% | 25.9% | 17.6% | 100% | 70.0% | 0.0% | 50.0% | 0.0% | 0.0% | 66.7% | 0.0% | 5.9% | 0.0% | 100% | | | | | | | | | | | |
| | 16 | | Sa | 7 | 3 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | | | | | |
| | | | | 1.4% | 23.1% | 0.0% | 0.0% | 100% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | | | | | | | | | | | |
| | 17 | | ? | 169 | 67 | 9 | 1 | 10 | 1 | 5 | 4 | 2 | 3 | 0 | 2 | 0 | 2 | | | | | | | | | | | |
| | | | | 32.8% | 49.3% | 42.9% | 100% | 76.9% | 100% | 100% | 26.7% | 66.7% | 50.0% | 0.0% | 16.7% | 0.0% | 100% | | | | | | | | | | | |
| | 18 | Empyema, left side. | ∞ | 250 | 97 | 22 | 10 | 48 | 2 | 26 | 10 | 2 | 5 | 5 | 13 | 1 | 2 | | | | | | | | | | | |
| | | | | 55.1% | 42.5% | 47.8% | 100% | 76.1% | 100% | 100% | 28.6% | 100% | 50.0% | 33.3% | 29.6% | 16.7% | 100% | | | | | | | | | | | |
| | 19 | | p | 45 | 15 | 1 | 1 | 4 | 0 | 3 | 2 | 0 | 0 | 1 | 1 | 1 | 1 | | | | | | | | | | | |
| | | | | 9.9% | 17.2% | 1.7% | 100% | 40.0% | 0.0% | 75.0% | 14.3% | 0.0% | 0.0% | 25.0% | 5.9% | 33.3% | 100% | | | | | | | | | | | |
| | 20 | | Sa | 10 | 3 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | | | | | | | | | | | |
| | | | | 2.2% | 50.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100% | 50.0% | 0.0% | 0.0% | 0.0% | 0.0% | 50.0% | 100% | | | | | | | | | | | |
| | 21 | | ? | 149 | 57 | 2 | 1 | 9 | 2 | 3 | 1 | 0 | 2 | 0 | 1 | 0 | 0 | | | | | | | | | | | |
| | | | | 32.8% | 47.9% | 28.5% | 100% | 75.0% | 100% | 100% | 10.0% | 0.0% | 50.0% | 0.0% | 14.3% | 0.0% | 0.0% | | | | | | | | | | | |
| | 22 | Bilateral empyema. | ∞ | 166 | 114 | 20 | 28 | 90 | 6 | 38 | 12 | 2 | 3 | 7 | 5 | 3 | 3 | | | | | | | | | | | |
| | | | | 57.0% | 89.1% | 100% | 100% | 98.9% | 100% | 100% | 92.3% | 66.7% | 75.0% | 100% | 71.4% | 100% | 100% | | | | | | | | | | | |
| | 23 | | p | 47 | 36 | 5 | 0 | 14 | 0 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | | | | | | | | | | | |
| | | | | 16.2% | 78.3% | 83.3% | 0.0% | 100% | 0.0% | 100% | 100% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100% | | | | | | | | | | | |
| | 24 | | Sa | 9 | 7 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | | | | | | | | | | | |
| | | | | 3.1% | 100% | 0.0% | 0.0% | 100% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100% | 0.0% | 0.0% | | | | | | | | | | | |
| | 25 | | ? | 69 | 43 | 11 | 5 | 14 | 3 | 5 | 1 | 0 | 0 | 2 | 2 | 0 | 1 | | | | | | | | | | | |
| | | | | 23.7% | 91.5% | 100% | 100% | 100% | 100% | 100% | 100% | 0.0% | 0.0% | 66.7% | 100% | 0.0% | 100% | | | | | | | | | | | |

[a] Source of information: Special empyema reports made to the Office of the Surgeon General.

[b] For convenience the table has been divided into four large squares and subdivided again diagonally. The diagonal line separates the living from the dead, as has been indicated in the outer margins. This table may be used for the following correlations: (1) To determine the percentage and the number of cases among the living and the dead which were associated with any of the various complications. For example, in the upper left-hand margins under "Phlebitis," of 1,260 cases of empyema dying, 6, or 0.5 per cent, were associated with this complication, while of 2,629 living cases, 15, or 0.6 per cent, had a similar complication. (2) To determine the mortality of cases with two associated conditions. For example, at the intersection of column 1 and line 8, below the diagonal line in the upper left-hand square, the figure 4 indicates that four of the living cases showed this association of the complications indicated as complications. The percentage figure shows the percentage of the entire number of cases showing this association which lived. The intersection of the similar columns above the diagonal line indicates the number of cases, with these two associated conditions, which died, as well as the percentage mortality in cases of empyema associated with the two conditions indicated in the margins of the intersecting columns. (3) To determine the relationship of the type of empyema, whether right, left, or bilateral, the associated organism and the indicated complication. The intersecting squares give the number of cases falling in each category and the percentage mortality and the percentage of living cases. (4) To determine the total mortality according to the association of the conditions indicated in the margins of the intersecting columns. These percentages are given immediately above and below the heavy diagonal line at the intersection of similar columns.

TABLE 35.[a]—*Table of complications, with relative frequencies.*

Total cases, 3,889. Died, 1,260. Lived, 2,629.

| Total cases, 3,889. | Line numbers. | Complications. | | | Cases. | 1 Bilateral pneumonia. | 2 Pulmonary abscess. | 3 Mediastinal infection. | 4 Pericarditis. | 5 Endocarditis. | 6 Peritonitis. | 7 Abscess of soft parts. | 8 Phlebitis. | 9 Erysipelas. | 10 Arthritis. | 11 Otitis media. | 12 Mastoiditis. | 13 Meningitis. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Column numbers. | | | | | | | | | | | | | | | | |
| | | | | | | Died, 1,260. | | | | | | | | | | | | |
| Lived, 2,629. | 1 | Bilateral pneumonia | | | 584 | 45.2% / 22.2% | 44 / 44.4% | 50 / 92.6% | 186 / 79.2% | 13 / 68.4% | 76 / 70.3% | 28 / 58.3% | 5 / 83.3% | 16 / 66.7% | 10 / 58.8% | 24 / 60.0% | 4 / 36.4% | 7 / 46.7% |
| | 2 | Pulmonary abscess | | | 98 | 24 / 24.5% | 7.9% / 3.7% | 6 / 11.1% | 17 / 7.2% | 2 / 10.5% | 7 / 6.5% | 6 / 12.5% | 0 / 0.0% | 1 / 4.2% | 1 / 5.9% | 3 / 7.5% | 1 / 9.1% | 2 / 13.3% |
| | 3 | Mediastinal infection | | | 0 | 0 / 0.0% | 0 / 0.0% | 4.3% / 0.0% | 27 / 11.5% | 0 / 0.0% | 8 / 7.4% | 5 / 10.4% | 0 / 0.0% | 0 / 0.0% | 4 / 23.5% | 1 / 2.5% | 0 / 0.0% | 0 / 0.0% |
| | 4 | Pericarditis | | | 39 | 12 / 30.8% | 2 / 5.1% | 0 / 0.0% | 18.7% / 1.5% | 5 / 26.3% | 28 / 25.9% | 7 / 14.6% | 0 / 0.0% | 3 / 12.5% | 3 / 17.6% | 8 / 20.0% | 4 / 36.4% | 1 / 6.7% |
| | 5 | Endocarditis | | | 0 | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 1.3% / 0.0% | 1 / 0.9% | 3 / 6.25% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 1 / 6.7% |
| | 6 | Peritonitis | | | 3 | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 8.6% / 0.1% | 5 / 10.4% | 0 / 0.0% | 0 / 0.0% | 1 / 5.9% | 2 / 5.0% | 1 / 9.1% | 1 / 6.7% |
| | 7 | Abscess of soft parts | | | 125 | 27 / 21.4% | 4 / 3.2% | 0 / 0.0% | 1 / 0.8% | 0 / 0.0% | 1 / 0.8% | 3.8% / 4.8% | 0 / 0.0% | 1 / 4.2% | 2 / 11.8% | 4 / 10.0% | 2 / 18.2% | 0 / 0.0% |
| | 8 | Phlebitis | | | 15 | 4 / 26.7% | 1 / 6.7% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 1 / 6.7% | 0.5% / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% |
| | 9 | Erysipelas | | | 22 | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 4 / 18.2% | 0 / 0.0% | 1.9% / 0.8% | 0 / 0.0% | 1 / 2.5% | 0 / 0.0% | 0 / 0.0% |
| | 10 | Arthritis | | | 44 | 15 / 34.1% | 2 / 4.5% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 6 / 13.6% | 2 / 4.5% | 0 / 0.0% | 1.3% / 1.7% | 1 / 2.5% | 1 / 9.1% | 0 / 0.0% |
| | 11 | Otitis media | | | 111 | 25 / 22.5% | 5 / 4.5% | 0 / 0.0% | 3 / 2.7% | 0 / 0.0% | 0 / 0.0% | 10 / 9.0% | 0 / 0.0% | 2 / 1.8% | 2 / 1.8% | 3.2% / 1.2% | 0 / 0.0% | 0 / 0.0% |
| | 12 | Mastoiditis | | | 18 | 4 / 22.2% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0.9% / 0.7% | 1 / 6.7% |
| | 13 | Meningitis | | | 0 | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 1.2% / 0.0% |
| Died, 1,260. | 14 | Empyema, right side. | 315 | s | 277 | 103 / 37.2% | 26 / 9.4% | 6 / 2.2% | 37 / 13.4% | 5 / 1.8% | 21 / 7.6% | 16 / 5.8% | 0 / 0.0% | 9 / 3.2% | 2 / 0.7% | 14 / 5.1% | 5 / 1.8% | 1 / 0.4% |
| | 15 | | | p | 62 | 24 / 38.7% | 3 / 4.8% | 2 / 3.2% | 7 / 11.3% | 0 / 0.0% | 1 / 1.6% | 0 / 0.0% | 0 / 0.0% | 2 / 3.2% | 0 / 0.0% | 1 / 1.6% | 0 / 0.0% | 2 / 3.2% |
| | 16 | | | Sa | 7 | 3 / 42.9% | 0 / 0.0% | 0 / 0.0% | 1 / 14.3% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% |
| | 17 | | | ? | 169 | 67 / 39.6% | 9 / 5.3% | 1 / 0.6% | 10 / 5.9% | 1 / 0.6% | 5 / 3.0% | 4 / 2.4% | 2 / 1.2% | 3 / 1.8% | 0 / 0.0% | 2 / 1.2% | 0 / 0.0% | 2 / 1.2% |
| | 18 | Empyema, left side. | 454 | s | 250 | 97 / 38.8% | 22 / 8.8% | 10 / 4.0% | 48 / 19.2% | 2 / 0.8% | 26 / 10.4% | 10 / 4.0% | 2 / 0.8% | 5 / 2.0% | 5 / 2.0% | 13 / 5.2% | 1 / 0.4% | 2 / 0.8% |
| | 19 | | | p | 45 | 15 / 33.3% | 1 / 2.2% | 1 / 2.2% | 4 / 8.9% | 0 / 0.0% | 3 / 6.7% | 2 / 4.4% | 0 / 0.0% | 0 / 0.0% | 1 / 2.2% | 1 / 2.2% | 1 / 2.2% | 1 / 2.2% |
| | 20 | | | Sa | 10 | 3 / 30.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 1 / 10.0% | 1 / 10.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 1 / 10.0% | 1 / 10.0% |
| | 21 | | | ? | 149 | 57 / 38.3% | 2 / 1.3% | 1 / 0.7% | 9 / 6.0 | 2 / 1.3% | 3 / 2.0% | 1 / 0.7% | 0 / 0.0% | 2 / 1.3% | 0 / 0.0% | 1 / 0.7% | 0 / 0.0% | 0 / 0.0% |
| | 22 | Bilateral empyema. | 91 | s | 166 | 114 / 68.7% | 20 / 12.0% | 28 / 16.9% | 90 / 54.2% | 6 / 3.6% | 38 / 22.9% | 12 / 7.2% | 2 / 1.2% | 5 / 3.0% | 7 / 4.2% | 5 / 3.0% | 3 / 1.8% | 3 / 1.8% |
| | 23 | | | p | 47 | 36 / 76.6% | 5 / 10.6% | 0 / 0.0 | 14 / 29.8% | 0 / 0.0% | 5 / 10.6% | 1 / 2.1% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0 | 0 / 0.0% | 2 / 4.3% |
| | 24 | | | Sa | 9 | 7 / 77.8% | 0 / 0.0% | 0 / 0.0 | 1 / 11.1% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 1 / 11.1% | 0 / 0.0% | 0 / 0.0% |
| | 25 | | | ? | 69 | 43 / 62.3% | 11 / 15.9% | 5 / 7.2% | 14 / 20.3% | 3 / 4.3% | 5 / 7.2% | 1 / 1.5% | 0 / 0.0% | 0 / 0.0% | 2 / 2.9% | 2 / 2.9% | 0 / 0.0% | 1 / 1.5% |

| Total cases, 3,889. | Line numbers. | Complications. | | | Cases. | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Column numbers. | | | | Lived, 2,629. | | | | | | | | | | | |
| | | | | | | Empyema, right side. | | | | Empyema, left side. | | | | Bilateral empyema. | | | |
| | | | | | | 1,379 | | | | 1,214 | | | | 36 | | | |
| | | | | | | s | p | Sa | ? | s | p | Sa | ? | s | p | Sa | ? |
| | | | | | | 658 | 325 | 27 | 369 | 608 | 275 | 23 | 308 | 19 | 12 | 0 | 5 |
| Lived, 2,629. | 1 | Bilateral pneumonia | | | 584 | 140 / 21.3% | 69 / 21.2% | 10 / 37.0% | 69 / 18.7% | 131 / 21.5% | 72 / 26.2% | 3 / 13.0% | 62 / 20.1% | 14 / 73.7% | 10 / 83.3% | 0 / 0.0% | 4 / 80.0% |
| | 2 | Pulmonary abscess | | | 98 | 32 / 4.9% | 14 / 4.3% | 4 / 14.8% | 12 / 3.3% | 24 / 3.9% | 5 / 1.8% | 1 / 4.3% | 5 / 1.6% | 0 / 0.0% | 1 / 8.3% | 0 / 0.0% | 0 / 0.0% |
| | 3 | Mediastinal infection | | | 0 | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% |
| | 4 | Pericarditis | | | 39 | 7 / 1.1% | 3 / 0.9% | 0 / 0.0% | 3 / 0.8% | 15 / 2.5% | 6 / 2.2% | 1 / 4.3% | 3 / 1.0% | 1 / 5.3% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% |
| | 5 | Endocarditis | | | 0 | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% |
| | 6 | Peritonitis | | | 3 | 1 / 0.2% | 1 / 0.3% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 1 / 0.4% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% |
| | 7 | Abscess of soft parts | | | 125 | 41 / 6.2% | 23 / 7.1% | 3 / 11.1% | 11 / 3.0% | 25 / 4.1% | 12 / 4.4% | 1 / 4.3% | 9 / 2.9% | 1 / 5.3% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% |
| | 8 | Phlebitis | | | 15 | 5 / 0.8% | 3 / 0.9% | 0 / 0.0% | 1 / 0.3% | 0 / 0.0% | 2 / 0.7% | 2 / 8.7% | 1 / 0.3% | 1 / 5.3% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% |
| | 9 | Erysipelas | | | 22 | 6 / 0.9% | 1 / 0.3% | 0 / 0.0% | 3 / 0.8% | 5 / 0.8% | 3 / 1.1% | 0 / 0.0% | 2 / 0.6% | 1 / 5.3% | 1 / 8.3% | 0 / 0.0% | 0 / 0.0% |
| | 10 | Arthritis | | | 44 | 8 / 1.2% | 4 / 1.2% | 0 / 0.0% | 6 / 1.6% | 10 / 1.6% | 3 / 1.1% | 1 / 4.3% | 9 / 2.9% | 0 / 0.0% | 2 / 16.7% | 0 / 0.0% | 1 / 20.0% |
| | 11 | Otitis media | | | 111 | 29 / 4.3% | 16 / 4.9% | 1 / 3.7% | 10 / 2.7% | 31 / 5.1% | 16 / 5.8% | 0 / 0.0% | 6 / 1.9% | 2 / 10.5% | 1 / 8.3% | 0 / 0.0% | 0 / 0.0% |
| | 12 | Mastoiditis | | | 18 | 4 / 0.6% | 2 / 0.6% | 0 / 0.0% | 2 / 0.5% | 5 / 0.8% | 2 / 0.7% | 1 / 4.3% | 2 / 0.6% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% |
| | 13 | Meningitis | | | 0 | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% | 0 / 0.0% |
| Died, 1,260. | 14 | Empyema, right side. | 315 | s | 277 | 47.7% / 53.8% | | | | | | | | | | | |
| | 15 | | | p | 62 | | 23.3% / 12.0% | | | | | | | | | | |
| | 16 | | | Sa | 7 | | | 2.0% / 1.4% | | | | | | | | | |
| | 17 | | | ? | 169 | | | | 26.8% / 32.8% | | | | | | | | |
| | 18 | Empyema, left side. | 454 | s | 250 | | | | | 50.1% / 55.1% | | | | | | | |
| | 19 | | | p | 45 | | | | | | 22.7% / 9.9% | | | | | | |
| | 20 | | | Sa | 10 | | | | | | | 1.9% / 2.2% | | | | | |
| | 21 | | | ? | 149 | | | | | | | | 25.4% / 32.8% | | | | |
| | 22 | Bilateral empyema. | 91 | s | 166 | | | | | | | | | 52.8% / 57.0% | | | |
| | 23 | | | p | 47 | | | | | | | | | | 33.3% / 16.2% | | |
| | 24 | | | Sa | 9 | | | | | | | | | | | 0.0% / 3.1% | |
| | 25 | | | ? | 69 | | | | | | | | | | | | 13.9% / 23.7% |

[a] Source of information: Special empyema reports made to the Office of the Surgeon General.

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## CHAPTER IV.

# TREATMENT OF EMPYEMA CAVITIES WITH ANTISEPTIC SOLUTIONS.

### SOLUTIONS EMPLOYED.

Records of the experiences in the use of antiseptics in the treatment of empyema form one of the most interesting and valuable chapters in the history of this disease. There are few topics about which there have been such diversities of opinion. Many of the divergent views concerning the efficacy of antiseptics have been due to differences in the pathological conditions presented by the cases, in the choice of the antiseptic, and in the technical details of its application.

The antiseptic most frequently used was Dakin's neutral solution of sodium hypochlorite. A careful review of the special empyema records reveals 1,774 cases in which it was employed. These cases, however, do not form a homogeneous group. In some, this antiseptic was used only after the case had become chronic. In others, it was applied immediately after operation and used persistently until the wound closed. The mode of application was not uniform. There were cases in which the Carrel technique was carefully followed in detail, the wounds were irrigated daily at the time dressings were renewed, and Carrel tubes were inserted in all parts of the cavity. This technique permitted the instillation of the solution at intervals of from one to four hours, during the day and night, until the dressings were renewed on the following day. In other cases these frequent instillations were omitted and the application of the solution consisted only in a daily irrigation when the cases were dressed. In a relatively small number of cases there was an alternate application of Dakin's solution and some other antiseptic, either dichloramine–T or formalin. These divergencies in the time and method of using the antiseptic render the task of estimating its exact value one of considerable difficulty.

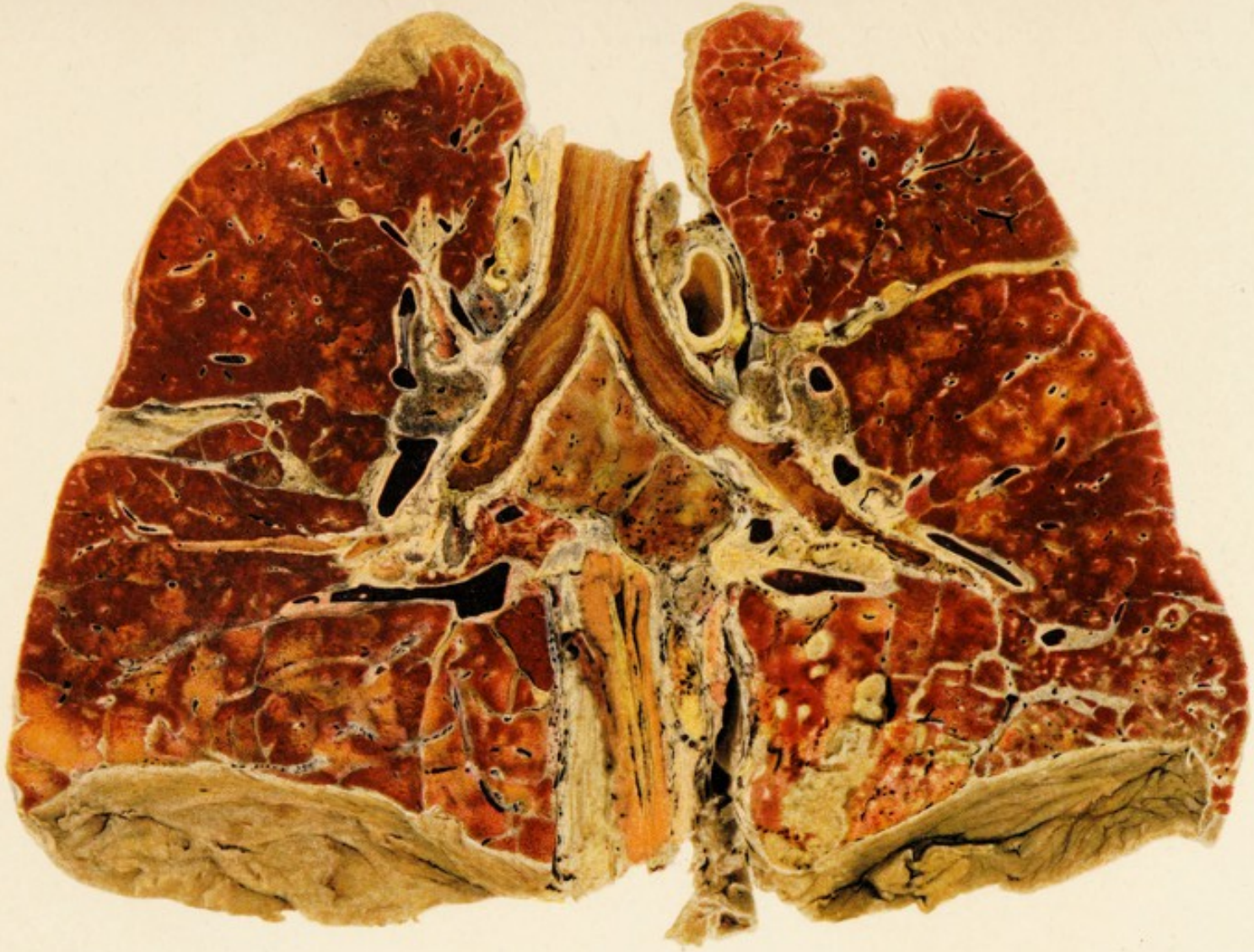
Other antiseptics noted in the special empyema records,[1] with the number of cases in which they were employed, are listed below:

| | Cases. |
|---|---|
| Formalin | 162 |
| Dichloramine–T | 73 |
| Bismuth | 65 |
| Boric acid | 14 |
| Chlorazene or chloramine–T | 11 |
| Cresol | 10 |
| Iodine | 7 |
| Mercuric chloride | 5 |
| Optochin | 3 |

| | Cases. |
|---|---|
| "B. I. P." (bismuth subnitrate, 1 part; iodoform, 2 parts; liquid paraffin oil, sufficient to make a thick paste) | 2 |
| Potassium permanganate | 2 |
| Aniline dyes | 2 |
| Hychlorite | 1 |
| Iodoform | 1 |
| Silver nitrate | 1 |
| Urotropin | 1 |
| Quinine | 1 |

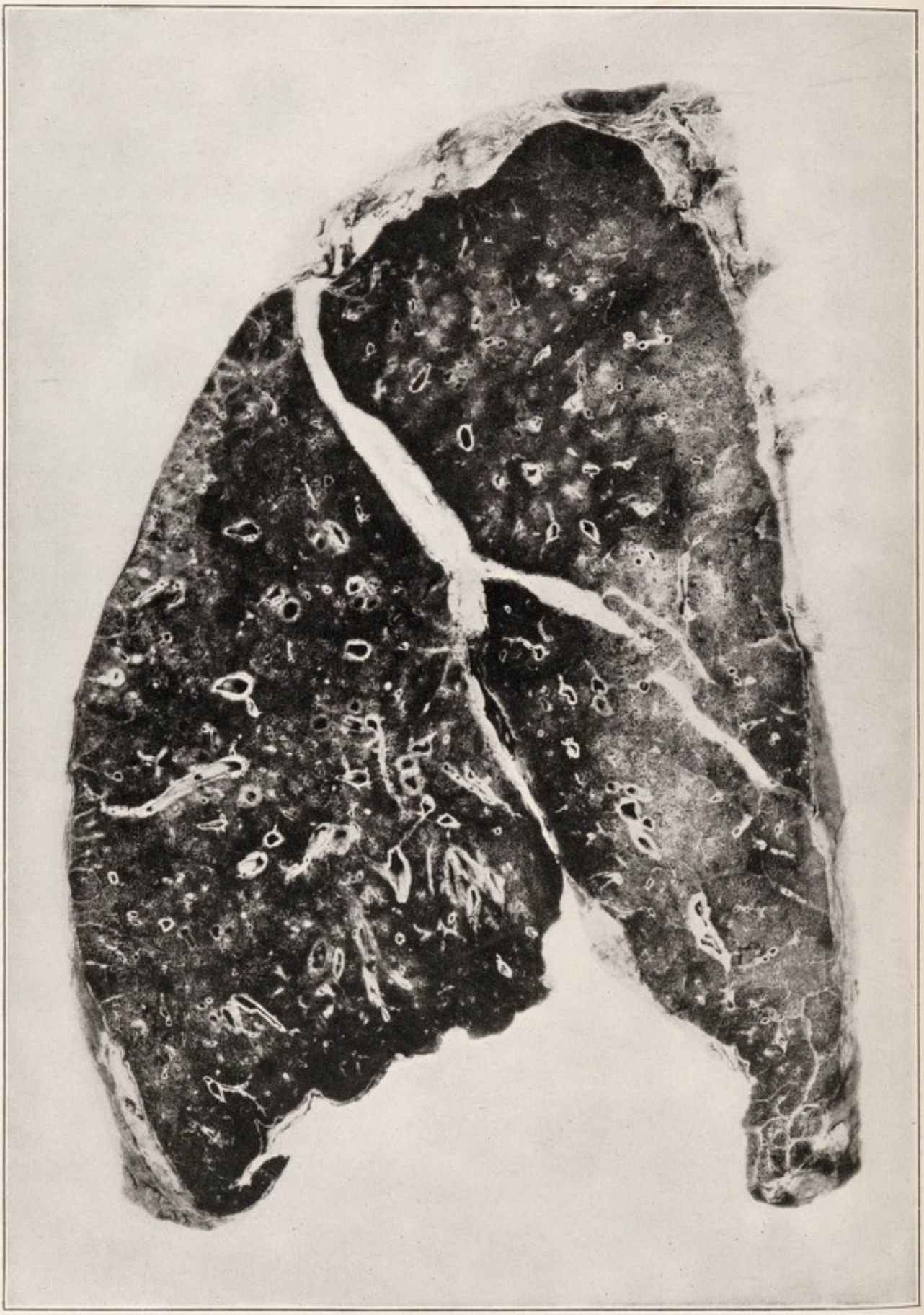
In 40 cases a 50 per cent solution of glucose was instilled into the cavity, and in 4 additional cases glucose was combined with formalin.

In none of the cases included in this list are there records of bacteriologic studies of the progress of disinfection which throw light upon the value of the



INTERSTITIAL BRONCHOPNEUMONIA WITH BILATERAL EMPYEMA AND FIBRINOUS PERICARDITIS DUE TO HEMOLYTIC STREPTOCOCCI. ACCESSION NUMBER 3,300. ARMY MEDICAL MUSEUM.

PLATE V.



AN ENCAPSULATED INTERLOBAR EMPYEMA DUE TO HEMOLYTIC STREPTOCOCCI. ARMY MEDICAL MUSEUM ACCESSION NO. 3106.

PNEUMONIA DUE TO AN INFECTION WITH HEMOLYTIC STREPTOCOCCI FOLLOWING INFLUENZA. ACCESSION NUMBER 3,133. ARMY MEDICAL MUSEUM.

antiseptics used. It is obvious, however, that the results did not encourage the extensive use of any antiseptics other than those belonging to the chlorine group.

A number of cases at Camp Pike and Camp Dodge were treated by the "closed method." An open thoracotomy was not done. The cavities in these cases were aspirated and irrigated with Dakin's solution and formalin through a catheter inserted through a puncture wound in the chest wall. For an evaluation of these two antiseptics and of the various methods employed in the treatment of empyema, a preliminary review of the difficulties met in the disinfection of the pleural cavity is necessary.

### CONDITIONS INFLUENCING STERILIZATION.

The first essential for successful disinfection is contact between the antiseptic and the organisms it is designed to destroy. A glance at the illustrations in the chapter on the pathology of empyema will reveal many of the conditions which render this difficult. It is at once apparent that the bacteria may be enmeshed in a fibrinopurulent exudate between two adjacent lobes of a lung, or that exudate may bind the lung to the costal wall or to some other portion of the parietal layer of the pleura. In addition there may be subpleural pulmonary abscesses which communicate with the pleural cavity through small fistulas. Furthermore, firm adhesions may divide the pleural space into pockets which are either completely isolated or which communicate with each other by narrow and possibly tortuous channels.

The clinical course, X-ray and bacteriologic examinations during life, as well as the post-mortem findings in fatal cases, show that empyemata differ to an extraordinary degree in the character and extent of the infection. There are cavities of simple conformation, confined to a relatively small part of the pleura, and infected by bacteria which succumb to protective reactions developed in the host. In the absence of untoward circumstances such cases are self-limited. Simple drainage and protection from secondary infection usually meet the indications for treatment. Post-mortem examination of the more complex cases shows that they are usually, if not always, associated with acute interstitial pneumonia, which was prevalent in certain camps. They are usually due to infection with hemolytic streptococci. The suppurative process is not confined to the pleura, but extends to the interlobular areolar tissue, and causes minute abscesses immediately beneath the pleural surface or deep within the lung parenchyma. The intrathoracic conditions in these complex cases are of such importance in the problem of disinfection that they must be studied in some detail. Cases of this character usually die early in the course of the disease with associated infections of other viscera. A small percentage of them live and tend to become chronic.

The interlobar agglutinations occurring in these cases are well illustrated in Plates V, VI, and VII. In Plate V a small abscess opens into the interlobar cleft. The interlobular connective tissue within the lung is so swollen by the exudate within its meshes that it forms broad lines which separate the lobules; in the normal lung these boundaries are inconspicuous.

The interlobar clefts are not, however, the only sites in which such adhesions occur. They may be found in any situation where the pleural surfaces were

in contact at the time infection occurred and were not separated immediately by an accumulation of fluid. A very instructive series of frozen sections (Figures 15 to 22) through the thorax of a cadaver in which there was a serofibrinous effusion into the right pleural cavity, shows the situations in which such a disruption of the fibrinous adhesions failed to take place when the cavity was filled with exudate.[a] After the body was frozen in the supine position, parallel transverse sections about 1 inch in thickness were made through the thorax and abdomen. Only those which include the pleurae are of importance here. There is no clinical record of this case, but it is evident that any pneumonia which may have preceded the pleuritis had undergone substantial resolution before death, since there is no evidence of pulmonary consolidation in the sections from which these photographs were taken. The areas in which the opposed pleural surfaces remain in contact, in spite of a massive effusion, include nearly the whole of the cavity anterior to the root of the lung. The lung appears to be in contact with the upper surface of the diaphragm as well. It is interesting that the diaphragm is normally higher on the right. It is not unlikely that this difference in levels is increased in this case by a relaxation of the muscles following the pleuritis on the affected side. A natural consequence of such a relaxation would be to deepen and narrow the sulcus between the diaphragm and thoracic wall below the inferior margin of the lung. This sulcus can be traced through at least four of these frozen sections below the level where they include portions of the lung. Had the fibrinous exudate been as abundant in this case as it was in many of the cases of empyema occurring in the Army, this sulcus would have been completely filled with a fibrinopurulent deposit which would have bound the two pleural surfaces together. It is in these regions where a deposit of fibrin holds the serous surfaces together that permanent fibrous adhesions are subsequently formed.

The conditions described above have a bearing on the results of attempts at disinfection by antiseptic solutions introduced into the portions of the pleural cavity made accessible by thoracotomy. Thin layers of infected fibrin lying between the lobes of a lung or between the visceral and parietal pleuræ prevent thorough contact of the antiseptic with organisms enmeshed throughout the whole extent of the fibrinous deposit. The contents of pus pockets within this fibrin or in subpleural or intrapleural abscesses are also well protected against antisepsis. An antiseptic must have either great power of penetration, or solvent properties adequate to remove the obstructing fibrin or dead tissue if it reach bacteria present under these conditions.

This brief exposition indicates some of the factors preventing thorough disinfection of empyema cavities. There is, however, one other condition that frequently prevents the introduction of fluid antiseptics in quantities sufficient to be of much value. If a peripheral abscess of the lung ruptures into the pleural space, a communication is often established which allows the flow of fluids from the pleural cavity into the bronchial tract. Such pleurobronchial communications were frequent in cases of empyema following streptococcus bronchopneumonia. Sometimes their presence was revealed only when irrigation of the cavity was first attempted. The introduction of the solution into

[a] These sections were made and photographed by Prof. Thomas Dwight and were available for use in this study through the courtesy of the anatomical department of the Harvard Medical School.

POSTERIOR SURFACE OF THE LUNG ILLUSTRATED IN PLATE VII.
ARMY MEDICAL MUSEUM ACCESSION NO. 3133.

45267°—24——12

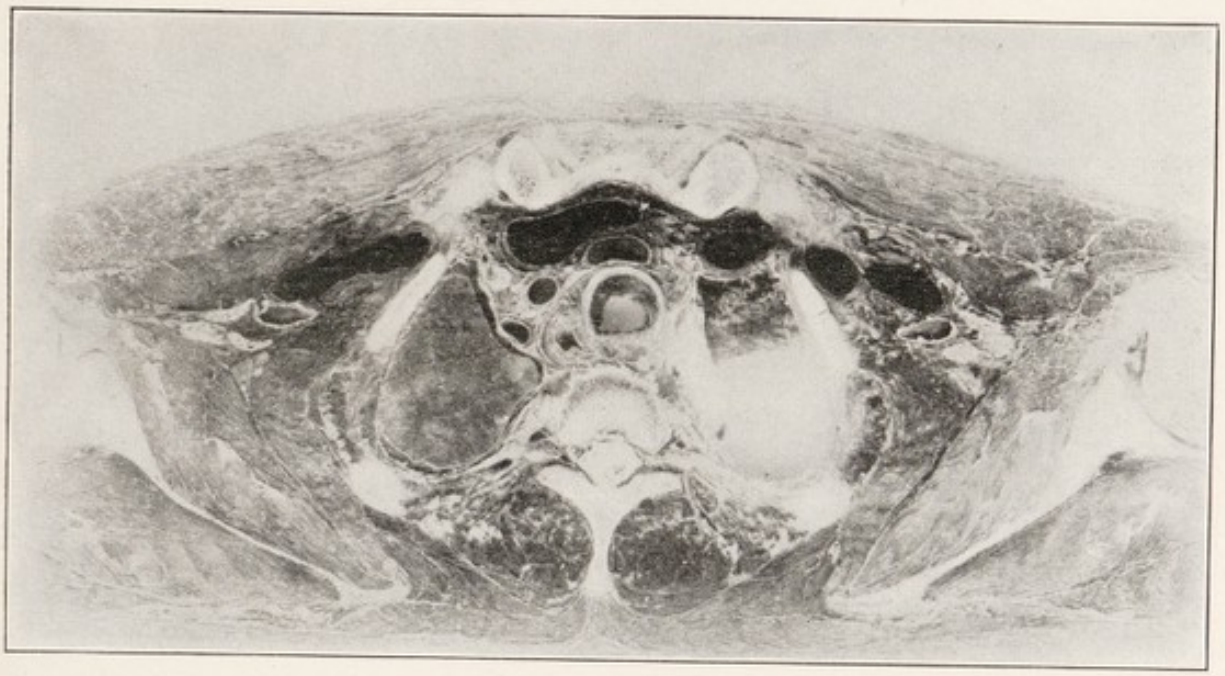


FIG. 15.—This and the following illustrations, to Fig. 22, represent a series of frozen sections through the thorax to demonstrate the position of a lung compressed by a large effusion.

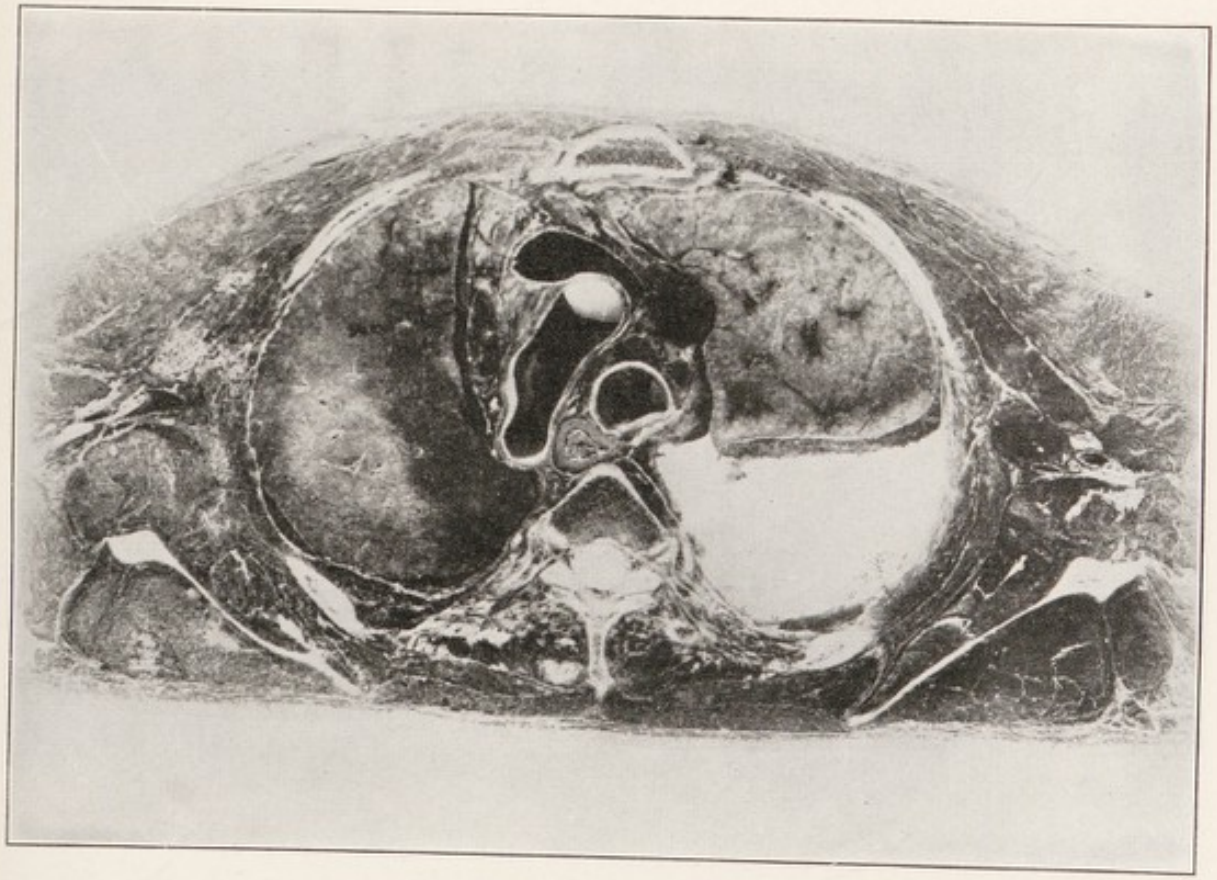


FIG. 16.

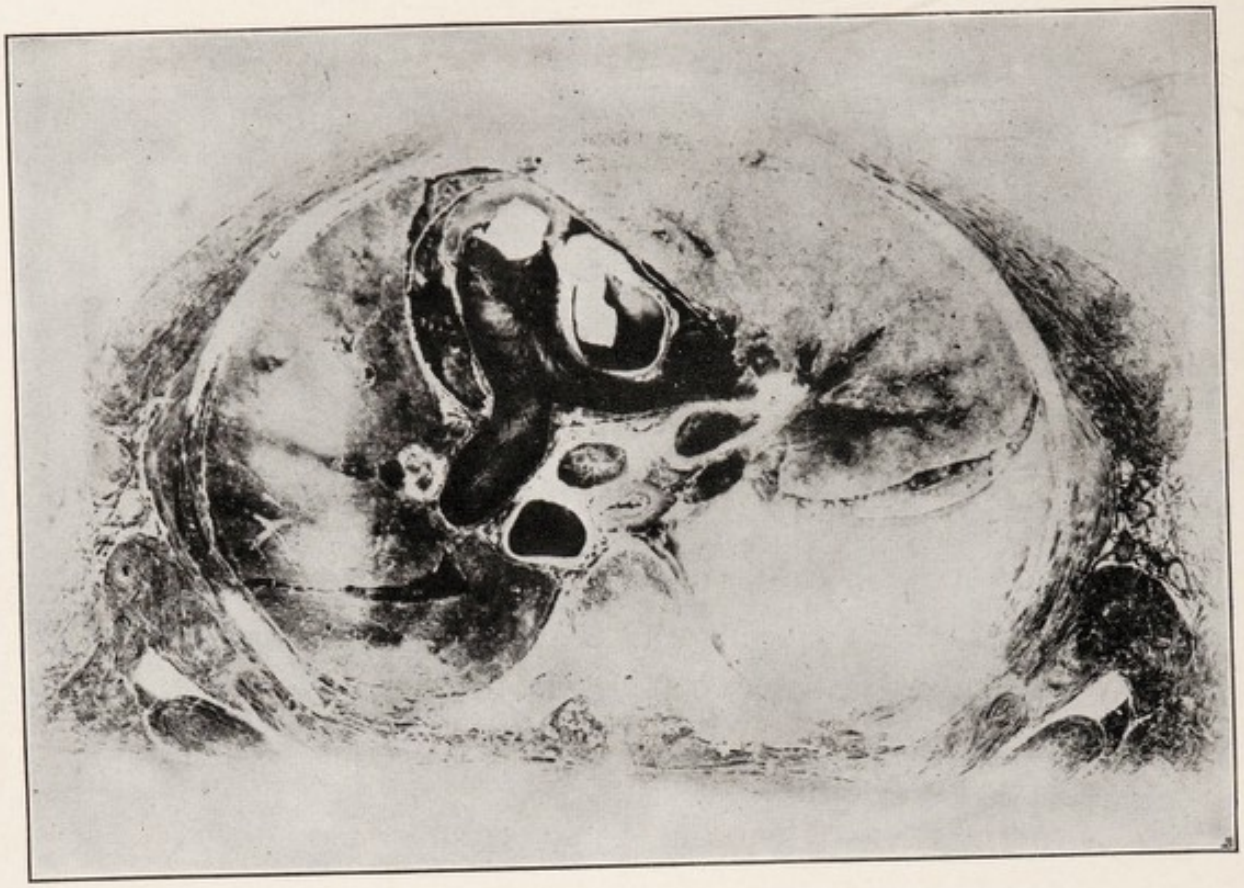


FIG. 17.

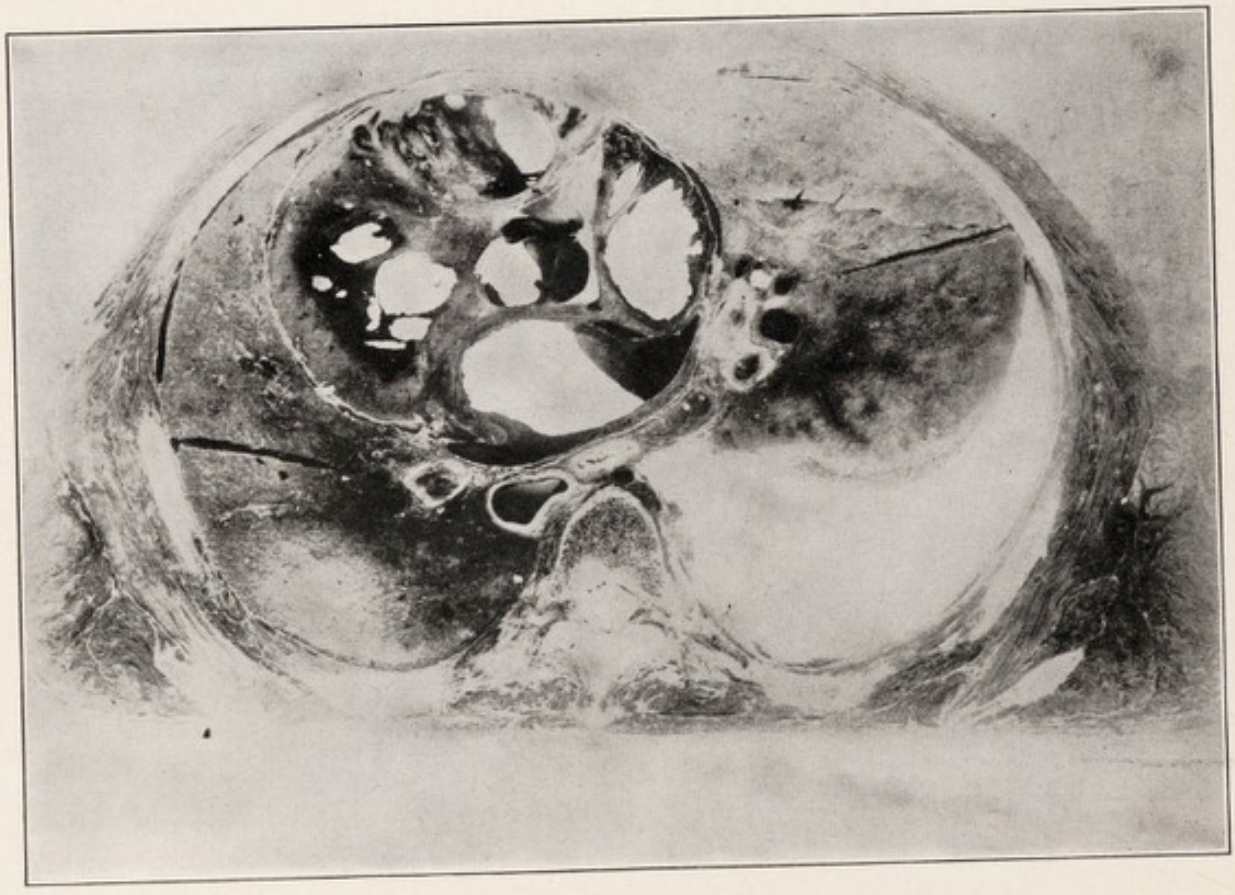


FIG. 18.

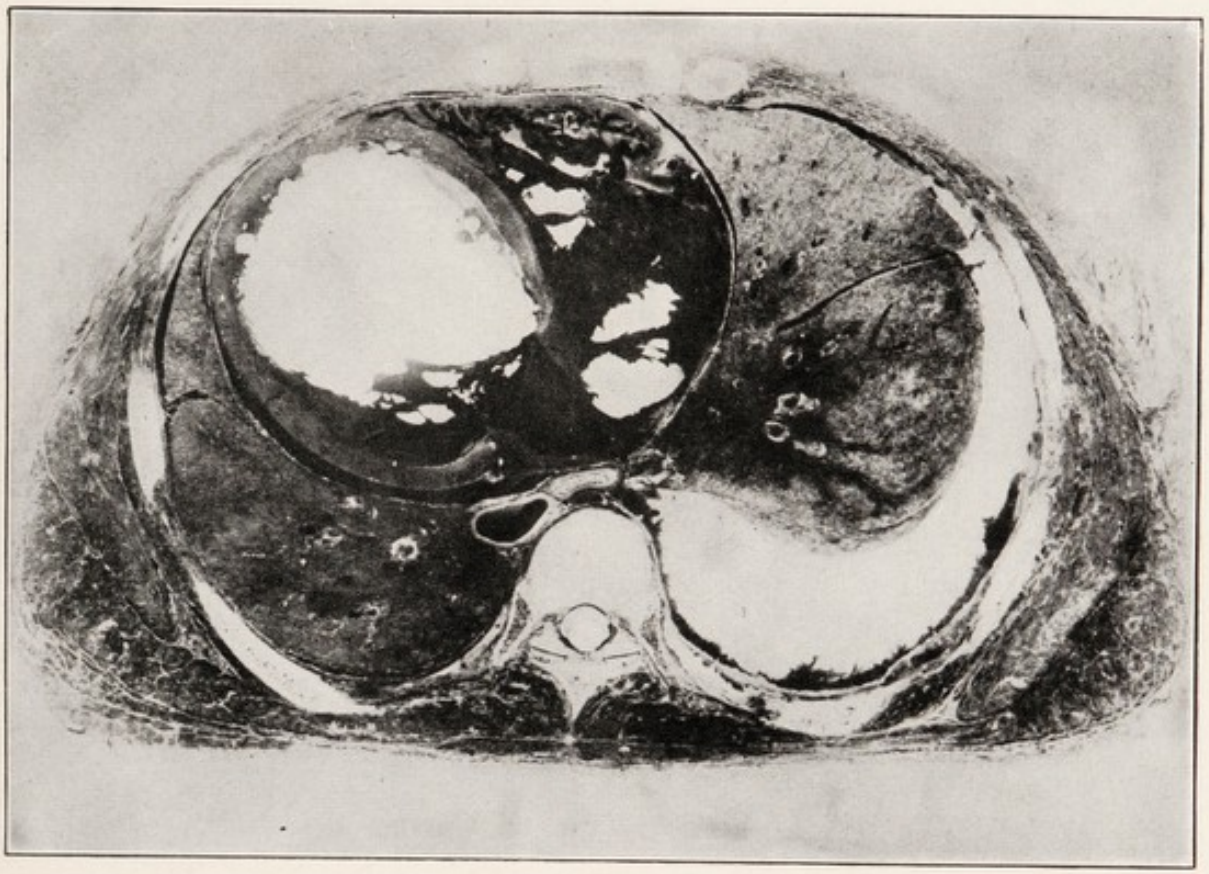


FIG. 19.

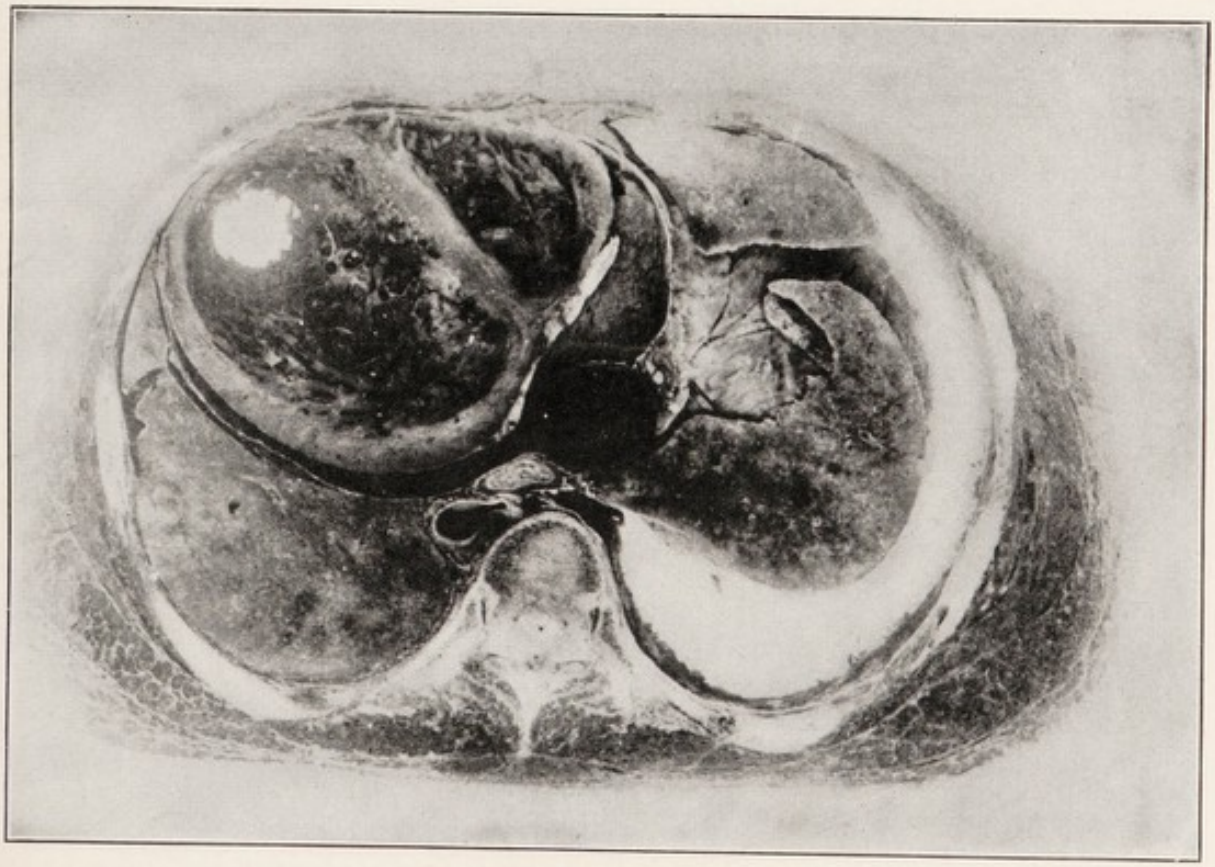


FIG. 20.

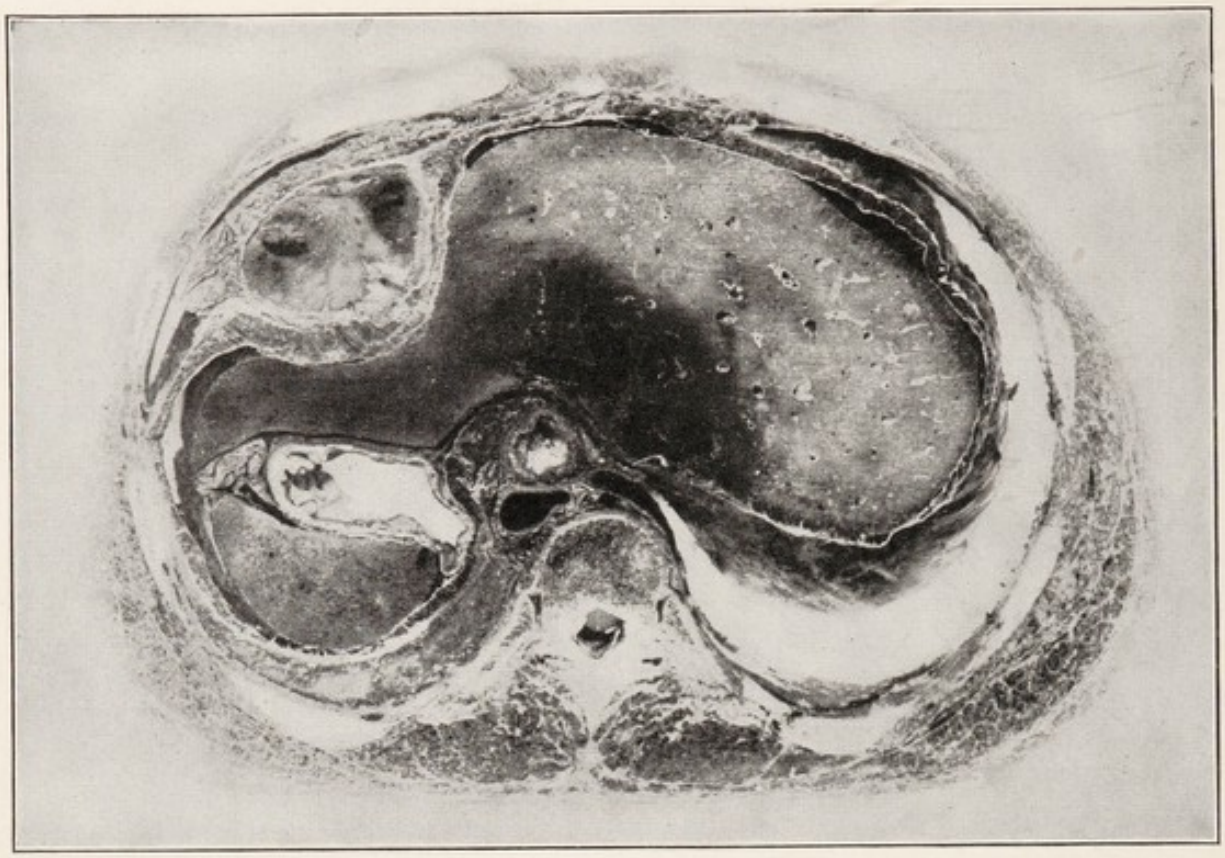


FIG. 21.

FIG. 22.

the cavity in these cases induced coughing. The patients could then taste the solution which had been used. In other cases there was no evidence of a pleuropulmonary fistula until frequent irrigations or instillations had been practiced for an extended period of time. In these instances the pleural opening was probably covered by fibrin which was later dissolved by the sodium hypochlorite, or the abscess had not ruptured when irrigation was first attempted. When these pleurobronchial communications were large and patent they prevented irrigation. In many cases the instillation of small amounts of solution was possible if the patients were placed in a position which did not allow fluid to enter the bronchi.

Hitherto only those impediments which are of a mechanical nature have been touched upon. There are, however, difficulties in which chemical factors play a great part. These, of course, must be overcome if successful disinfection of the entire cavity and its various ramifications is to be secured. Germicidal substances must be considered, not solely with reference to the bacteria which they are designed to destroy, but their reactions with the exudate and tissues must be understood. Many antiseptics act by coagulating proteins, and, if they are in sufficient concentration, kill animal as well as bacterial cells through a fixation of the cytoplasm. Other antiseptics, particularly those containing active chlorine, react with proteins by altering their chemical constitution. The products of the reactions induced by Dakin's solution are soluble on account of the active chlorine. In whatever class an antiseptic may belong, the reactions in which it takes part must reduce its potency as a germicide, since they reduce the concentration of available antiseptic. Substances in solution enter into these reactions more readily and promptly than those in particulate form, so that the antiseptic available for germicidal action may be greatly reduced in exudates containing large amounts of fibrin or soluble protein. The influence of these side reactions in reducing the efficiency of antiseptic applications must, therefore, be kept in mind in this form of treatment.

The surgical treatment of empyema differs from that of wounds of the soft parts in that the septic area can not be opened freely so that perfect drainage and irrigation can be obtained. It is not a simple matter to select a site for thoracotomy that will with certainty drain the most dependent part of the cavity. There is great danger in attempting to drain the cavity through the sulcus between the diaphragm and costal wall, for instances are on record in which the diaphragm was perforated at operation, with subsequent infection of the peritoneum. In some of these cases the site of operation was as high as the seventh intercostal space in the midaxillary line. It is doubtful if thorough drainage of this sulcus is secured by thoracotomy at the level at which the incision is usually made.

The difficulty experienced in completely draining the cavity has been mentioned because it is a factor which greatly influences the success of attempted disinfection. Residual quantities of exudate always reduce the germicidal potency of antiseptics, but especially of antiseptics of high reactivity, such as those of the chlorine group. These highly reactive antiseptics, however, are precisely the ones which offer the greatest promise of success, because they are strongly bactericidal in concentrations which will not destroy living tissues.

Even when drainage is perfect, the secretions are often formed so rapidly and in such large quantities that the concentration of the antiseptic solution is reduced by simple dilution. For this reason antiseptics which act almost instantaneously are the most potent.

In view of all the adverse factors enumerated, the sterilization of an empyema cavity might well appear a hopeless task. In many instances this has proved the case. It is possible, however, to sterilize a very high percentage of cases after persistent effort if certain facts are constantly kept in mind. Based on this review of the difficulties encountered, the following definite conclusions may be drawn. All foci of infection must be made accessible to the disinfectant; the secretions formed within the cavity must be evacuated as completely as possible; and an antiseptic of rapid action must be chosen when the secretions are abundant. It appears, then, that the choice of an appropriate antiseptic and a proper mode of application are of prime importance. The neutral solution of sodium hypochlorite, which has been so extensively used in the treatment of septic wounds, has met these conditions more perfectly than any other antiseptic and, in consequence, has been most frequently used in the postoperative treatment of empyema.

There are two methods of using the data available in determining the value of Dakin's solution in the treatment of empyema. One of these is the bacteriologic study of the progress of disinfection in individual cases. The other is a comparison of the results of that treatment with those following other procedures. In either of these methods difficulties of interpretation are encountered because of variations in the bacteriology and pathology of the cases. Post-mortem examinations of fatal cases, and the clinical histories of those surviving, reveal such great variations in the course of the infection that it is impossible to select groups of cases which present common salient features for study. In some individual cases it is evident that undiscovered foci of infection have prevented successful sterilization of cavities for periods of months.

Since cases can not be compared individually in respect to the intrathoracic conditions, it is necessary to consider them in large groups in order to eliminate possible individual differences. The study then becomes purely statistical and definite criteria must be selected for comparison of the groups. Two quite different criteria have been selected for this comparison. The first is the length of time which elapsed between the first open operation and the closure of the thoracic wound. The second is based upon replies to follow-up letters,[2] and refers to the ability to work, the presence of dyspnea, pain, persistent cough, and cardiac symptoms. These criteria are both objective and subjective. The closure of the wound is an objective event noted by a surgeon in charge of the case. The replies received from the men after discharge from the Army are largely subjective.[2] The evidence bearing upon the efficiency of antiseptic treatment with Dakin's solution is, therefore, varied in character.

The study of these data has required a consideration of all the available material en masse and further study of a few individual groups of cases which were under more careful observation by a commission established by the Surgeon General of the Army.[3] This has been necessary on account of the character of the treatment which was altered from time to time throughout all the Army camps as the methods of sterilization were improved. Without the data

on these more intensely studied cases a general survey of the entire situation would be grossly misleading. For this reason the statistical study has been subdivided under headings which are intended to present the effects of treatment on all the cases for which suitable records are available and to clarify more points raised by this general survey. Various other descriptive data have been appended as a matter of record.

### THE EFFECT OF ANTISEPSIS WITH NEUTRAL SOLUTION OF SODIUM HYPOCHLORITE ON THE HEALING OF THORACOTOMY WOUNDS.

From the entire group of cases which were treated by open drainage, 1,113 have been selected as a basis for study. Obviously, the most important fact which could be gleaned from such a group of cases would be the effect of irrigation on the length of the drainage period. No discrimination was employed in the selection, but all cases in which the data were accurate in regard to the date of operation, the application of Dakin's solution, and the final closure of the wound were used for study. With these three definite points in mind these cases were divided into smaller groups for comparison. These smaller groups have been termed "simple drainage," "Dakin-part,"and "Dakin-full."

In the first group the clinical history mentions no antiseptic treatment, and the postoperative care is designated as "simple dressings," or "drainage." This group of cases, numbering 510, is designated by the term "simple drainage." In the other two groups Dakin's solution was used at some stage in the course of the postoperative treatment. The technique followed in the application of this solution was not uniformly the same, nor were irrigations always continued throughout the course of the postoperative care up to the time of wound closure. In some instances the only reference to Dakin's solution is the statement that it was used for daily irrigation at the time dressings were renewed. Since the antiseptic action of the hypochlorite is transitory, a single application at daily intervals can not be regarded as an efficient utilization of this solution for attaining sterilization of the pleural cavity. These cases have therefore been collected to form a second and a third group, "Dakin-full," in which the records specify that Dakin's solution was instilled at intervals of from one to three hours during the day and at less frequent intervals during the night, and "Dakin-part," in which treatment was not so persistent. These two groups aggregate 603 cases, of which 455 fall into the "Dakin-part" series and 148 into the "Dakin-full."

The first step in the analysis of each of these individual groups of cases has been a rearrangement of each series based on the interval of time which elapsed between the operation and the perfect closure of the wound. Such an arrangement permits the construction of a curve for each group. When the curves for all of these groups are charted to illustrate the percentages of cases healed at different intervals of time after the first open operation the results of the three methods of treatment can be compared in graphic form. The manner in which this chart was constructed necessitates an explanation.

There were 510 cases treated by simple drainage. The intervals between operation and wound closure in these cases ranged from 13 to 389 days. If the total number of days, made up of the sum of the intervals in all these cases, is divided by the number of cases studied the mean interval for the whole

series would be 84.547 days. In other words, this was the average healing time. The majority of the cases, however, healed before this number of days had elapsed. As a matter of fact 297 healed within this period and 213 healed later. The mean closure time for the 297 cases was 55.714 days. Again, 140 cases healed in less than this interval and 157 healed between 55.714 days and 84.547 days, which is the mean period for the entire group. Taking in turn the mean time of healing for the 140 earlier cases it is found to be 39.014 days, with 65 of the cases healing prior to that interval and 75 cases between this and the secondary mean of 55.714 days. In like manner, these 65 cases fall into two groups of 30 to 35, respectively. The mean of the 30 cases is 22 days, and that of the 35 cases 33.97 days.

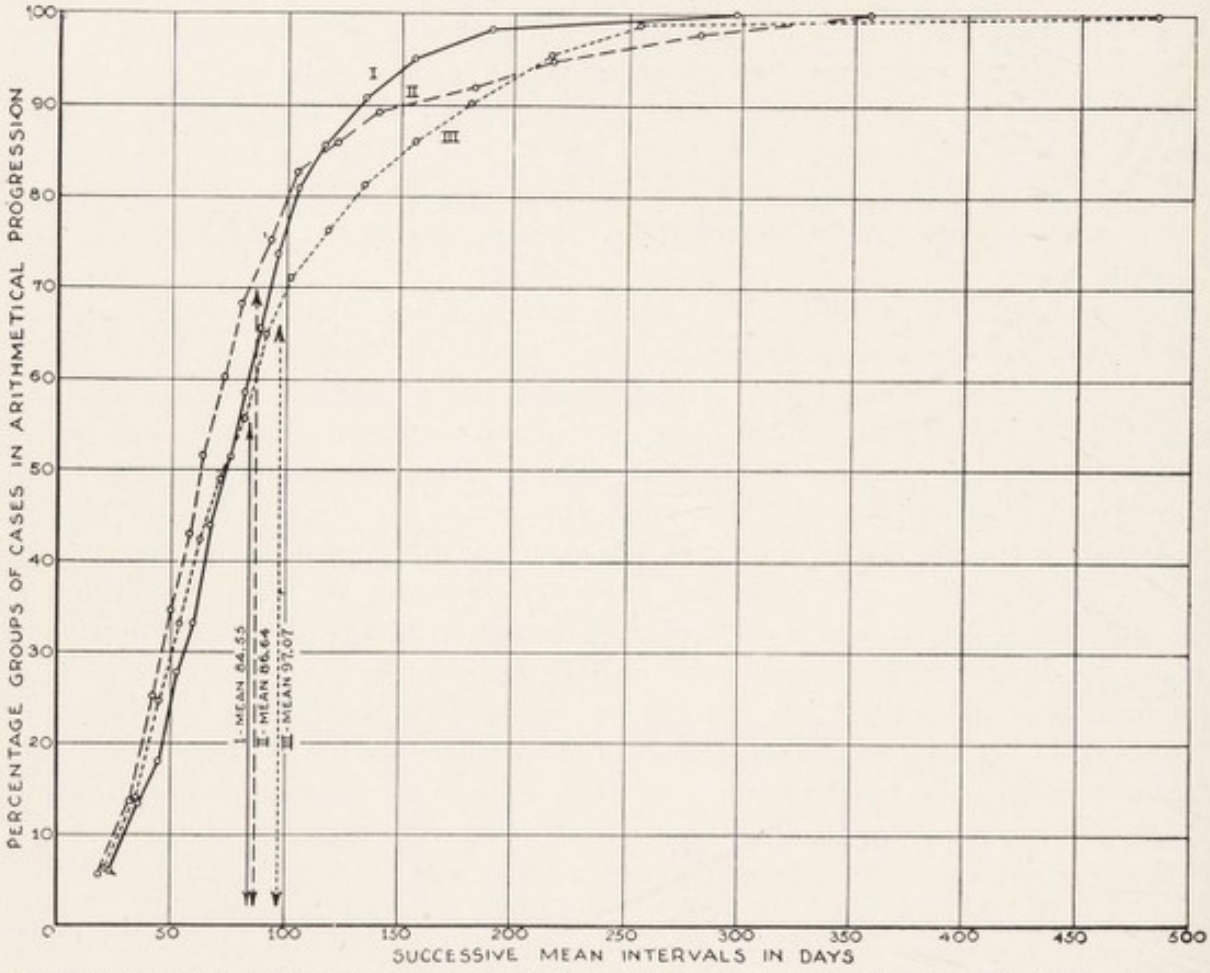



CHART LVIII.—Intervals between first operation and closure of the thoracic wound. Curve I, simple drainage (see Table 36). Curve II, Carrel-Dakin, full technique (see Table 38). Curve III, Carrel-Dakin, part technique (see Table 37).

In this way, by determining the successive means of the first, second, third, and fourth orders, the whole series was divided into 16 groups. The number of cases falling within each group was determined and the percentage ratio which this number bore to the total number in the series was obtained. When these percentages were successively added together they gave the percentage of cases which had healed at successive intervals after operation. These intervals were the mean closure periods for each of the 16 groups. The sums of the percentages were plotted as ordinates over abscissæ which represent the sums of corresponding mean times of closure. The calculations on each of the three large groups of cases have been appended in Tables 36, 37, and 38. Chart LVIII is a combination of the three curves constructed from these tables.

TABLE 36.[a]—*Wound closure after first operation—Distribution of cases among successive mean periods—Postoperative treatment, simple drainage.*

| Distribution. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Cases. | | | | | | Mean periods in days. | | | | |
| Total number. | Successive groups. | | | | Per cent of total in fourth group. | Successive groups. | | | | Average mean period. |
| | First. | Second. | Third. | Fourth. | | Fourth. | Third. | Second. | First. | |
| 510 | 297 | 140 | 65 | 30 | 5.882 | 22.00 | 28.45 | 39.01 | 55.71 | 84.55 |
| | | | | 35 | 6.863 | 33.97 | | | | |
| | | | 75 | 30 | 5.882 | 43.60 | 47.13 | | | |
| | | | | 45 | 8.824 | 51.58 | | | | |
| | | 157 | 84 | 27 | 5.294 | 58.70 | 61.24 | 70.50 | | |
| | | | | 57 | 11.176 | 65.95 | | | | |
| | | | 73 | 36 | 7.059 | 75.06 | 78.43 | | | |
| | | | | 37 | 7.255 | 81.70 | | | | |
| | 213 | 140 | 79 | 37 | 7.255 | 88.51 | 92.48 | 100.3 | 124.8 | |
| | | | | 42 | 8.235 | 95.98 | | | | |
| | | | 61 | 35 | 6.863 | 105.5 | 110.5 | | | |
| | | | | 26 | 5.098 | 117.1 | | | | |
| | | 73 | 48 | 25 | 4.902 | 134.1 | 144.3 | 171.6 | | |
| | | | | 23 | 4.510 | 155.4 | | | | |
| | | | 25 | 17 | 3.333 | 189.6 | 224.0 | | | |
| | | | | 8 | 1.569 | 297.1 | | | | |

[a] Source of information: Special empyema reports made to the Office of the Surgeon General.

TABLE 37.[a]—*Wound closure after first operation—Distribution of cases among successive mean periods—Postoperative treatment, Dakin-part.*

| Distribution. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Cases. | | | | | | Mean periods in days. | | | | |
| Total number. | Successive groups. | | | | Per cent of total in fourth group. | Successive groups. | | | | Average mean period. |
| | First. | Second. | Third. | Fourth. | | Fourth. | Third. | Second. | First. | |
| 455 | 295 | 150 | 62 | 28 | 6.154 | 20.32 | 27.87 | 38.77 | 58.08 | 97.07 |
| | | | | 34 | 7.473 | 34.09 | | | | |
| | | | 88 | 49 | 10.770 | 44.50 | 48.27 | | | |
| | | | | 39 | 8.571 | 53.44 | | | | |
| | | 145 | 70 | 42 | 9.231 | 62.40 | 66.06 | 76.81 | | |
| | | | | 28 | 6.154 | 71.54 | | | | |
| | | | 75 | 33 | 7.253 | 81.12 | 86.85 | | | |
| | | | | 42 | 9.321 | 91.35 | | | | |
| | 160 | 96 | 51 | 27 | 5.934 | 102.6 | 110.9 | 126.4 | 168.9 | |
| | | | | 24 | 5.275 | 118.3 | | | | |
| | | | 45 | 23 | 5.055 | 133.5 | 145.0 | | | |
| | | | | 22 | 4.835 | 156.8 | | | | |
| | | 64 | 43 | 19 | 4.176 | 180.8 | 200.5 | 232.8 | | |
| | | | | 24 | 5.275 | 216.0 | | | | |
| | | | 21 | 17 | 3.736 | 255.3 | 298.9 | | | |
| | | | | 4 | 0.879 | 483.5 | | | | |

[a] Source of information: Special empyema reports made to the Office of the Surgeon General.

TABLE 38.[a]—*Wound closure after first operation—Distribution of cases among successive mean periods—Postoperative treatment, Carrel-Dakin technique.*

| Distribution. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Cases. | | | | | | Mean periods in days. | | | | |
| Total number. | Successive groups. | | | | Per cent of total in fourth group. | Successive groups. | | | | Average mean period. |
| | First. | Second. | Third. | Fourth. | | Fourth. | Third. | Second. | First. | |
| 148 | 101 | 51 | 20 | 8 | 5.405 | 18.63 | 26.90 | 38.31 | 53.46 | 86.64 |
| | | | | 12 | 8.108 | 32.42 | | | | |
| | | | 31 | 16 | 10.811 | 41.69 | 45.68 | | | |
| | | | | 15 | 10.135 | 49.93 | | | | |
| | | 50 | 25 | 12 | 8.108 | 57.41 | 60.67 | 68.90 | | |
| | | | | 13 | 8.784 | 63.85 | | | | |
| | | | 25 | 13 | 8.784 | 73.39 | 77.04 | | | |
| | | | | 12 | 8.108 | 81.00 | | | | |
| | 47 | 31 | 21 | 10 | 6.757 | 94.00 | 99.95 | 110.1 | 157.9 | |
| | | | | 11 | 7.432 | 105.4 | | | | |
| | | | 10 | 5 | 3.378 | 122.5 | 131.3 | | | |
| | | | | 5 | 3.378 | 140.0 | | | | |
| | | 16 | 9 | 4 | 2.703 | 182.5 | 207.5 | 250.7 | | |
| | | | | 5 | 3.378 | 217.0 | | | | |
| | | | 7 | 4 | 2.703 | 281.5 | 313.7 | | | |
| | | | | 3 | 2.027 | 356.7 | | | | |

[a] Source of information: Special empyema reports made to the Office of the Surgeon General.

There are many circumstances to be taken into consideration in attempting to interpret the relations between the curves, which could not be illustrated in this chart. Chief among these is the fact that the cases were not uniformly distributed throughout the epidemiologic periods. Since Dakin's solution was not used in the treatment of empyema, except in a few isolated instances, until March or April, 1918, the curve for simple drainage is made mostly from cases which occurred early in the epidemic. Before this time few antiseptic measures were employed because it was deemed hazardous to irrigate empyema cavities with even bland solutions. This lack of synchronism in the curves introduces an element of uncertainty as to whether the cases included under simple drainage were of the same character as those upon which the other curves are based. The curves resulting from this method of analysis are sufficiently well defined, however, to permit a comparison of the three groups of cases. These curves show the same general character, with a fairly steep and nearly uniform gradient that comprises about 70 per cent of all cases. The remaining 30 per cent show a gradually increasing tendency toward chronicity, which is least marked in the cases treated by simple drainage.

Based entirely upon the relations of these curves, the conclusion might be reached that cases treated by simple drainage progressed more favorably than those in which Dakin's solution was used, but that full Carrel-Dakin technique was more effective than less intensive treatment of the cases. Such a conclu-

sion would be paradoxical, of course, and would indicate that some factor not hitherto considered enters into the distribution of the cases grouped according to the various modes of treatment. The obvious conclusion would be that those which were treated by simple drainage were in general less refractory than those receiving antiseptic treatment. There is no basis, however, for such a conclusion, since the mortality from empyema and the pathology of the cases indicate that the disease was probably more severe when simple drainage was the common mode of treatment than later when antisepsis was in vogue.

Neither of these conclusions would be wholly correct. Many of the most refractory cases occurred in the latter part of 1917 and the first two or three months of 1918, when the morbidity was high. The mortality in this period of high incidence was at its maximum, and many of the cases that survived ran a very protracted course before healing. Few of these protracted cases, however, were treated throughout their course by simple drainage. If they failed to heal under that treatment within a period of three or four months after the first operation they were either transferred to hospitals where Dakin's solution was employed, or the Carrel-Dakin technique was introduced into the wards of the hospital where they were being treated. In the construction of these curves it was not feasible to separate the cases into groups on the basis of these transfers or changes of treatment. All the cases which were treated with Dakin's solution, irrespective of the antecedent history, were included in one or the other of the curves. This grouping was necessitated by the general lack of specific information concerning the date on which chlorine antiseptics were first used. This information is available only in a limited group of cases, which will be referred to presently.

From the above considerations it would appear that the curve for simple drainage is unduly favorable to this mode of treatment when compared with the use of Dakin's solution. Without more precise data concerning the individual cases, it would be unprofitable to attempt a closer analysis of these three groups.

While these curves can not be considered as strictly accurate, they furnish a means for comparing the three methods of postoperative treatment which can be accepted as reasonably satisfactory. This is particularly true of the two curves representing cases treated with Dakin's solution, for with certain exceptions these fall within the same epidemiological period of time, and the character of the majority of the cases was presumably similar in the two groups.

It may be pointed out that in 50 per cent of the cases treated with the full Carrel-Dakin technique the wounds closed in approximately 63 days, while 50 per cent of those treated less efficiently required about 74 days for healing. This is a saving of 11 days, or nearly 15 per cent of the time required for the more chronic cases. In like manner, it is observed that 70 per cent of the Dakin-full cases healed in 85 days, in contrast to 101 days for the Dakin-part cases. This is a difference of 16 days, nearly 16 per cent of the time required by the cases in the latter group.

The foregoing figures refer only to the time which elapsed between the first operation and the closure of the wounds. It is pertinent to inquire into the percentage of these cases in which the closure was permanent. While it was possible to limit the cases to those included in the three groups just studied,

it was advisable to enlarge these groups by the addition of certain cases in which definite data were lacking concerning the date of wound closure. Many of the recurrences at the site of operation were at long intervals after the onset of the empyema and necessitated follow-up letters over an extended period. They have been reported at an interval as long as 1,100 days after the onset of the infection.

Among 1,043 cases in which simple drainage was the only postoperative treatment, follow-up letters were returned by 713, or 68.35 per cent.[2] Recurrences of the empyema were reported in 82 (7.86 per cent) of the total 1,043; 11 occurred after return to quarters before discharge from the Army, and 71 after discharge. Of these 82 recurrent cases, 5 died subsequently. One of the deaths followed pulmonary tuberculosis, and the four others were associated with tuberculosis in advanced stages. Twenty-two were receiving compensation for temporary partial disability, 1 for permanent partial disability (15 per cent), 11 for temporary total, and 1 for permanent total (tuberculosis). Nine of the 82 cases were receiving vocational training; 10 were incapacitated for any work; 23 were doing light work; 6 stated that they were able to work though hampered by dyspnea, pain or symptoms referred to the heart. It is evident that these men were in poor condition and that in the majority of cases the recurrence was not a trivial matter.

There were 489 follow-up replies [2] from the 723 cases in which the postoperative treatment was irrigation with Dakin's solution (partial technique); that is, 67.50 per cent responded to inquiries as compared with 68.36 per cent of those treated by simple drainage. There were 44 recurrences among the 723 cases, or 6.08 per cent. Twenty-five occurred after discharge from the Army; 13 after return to quarters, but before discharge; and the remaining 6 were still in the service, but no note was made of the date when these men left the hospital; 1 case died of unknown cause after discharge from the Army; 5 of the recurrent cases were tuberculous. Thirteen of the 44 cases received compensation for temporary partial disability, 2 for permanent partial, 8 for temporary total (1 tuberculous), and 3 for permanent total (1 noted as tuberculous). Nine cases received vocational training. Five of the men reported that they were unable to work, 8 were doing light work, and 10 full work.

Of the 252 cases in which the complete Carrel-Dakin technique was used after operation, 167 replied to inquiries [2] concerning their condition. This is 66.27 per cent, a somewhat smaller proportion than in the other two groups. There were 13 recurrences, 5.16 per cent. Of these, 9 occurred after discharge from the Army, 1 after return to quarters before discharge, and 3 were still in the service, though the time when they left the hospital is not recorded. Those receiving compensation for disabilities were rated as follows: Temporary partial, 5; temporary total, 4; 5 received vocational training. None was reported as tuberculous, though there is some doubt as to whether all the cases rated for temporary total disability were not tuberculous.

These data are too incomplete for tabulation. They give only a general idea of the conditions presented by cases that suffered a relapse. There is no clear indication that the infecting organism originally found in the pleural exudate, or the nature of the disease preceding empyema, had any influence in determining a recurrence. There are no data concerning the organisms present n the fluid after relapse.

## THE BACTERIOLOGICAL STUDY OF THE PROGRESS OF DISINFECTION AT CAMP LEE.

Before it is possible to analyze the smaller group of cases mentioned in the preceding section, the methods of study must be considered in detail. The most complete data relative to the action of solutions of sodium hypochlorite in the sterilization of empyema wounds are from Camp Lee. Here many of the cases were treated throughout by irrigation, and others, which had not healed under simple drainage within three or four months, were transferred to Carrel-Dakin technique. The purpose of the bacteriological study was to determine the number of viable bacteria in the same amount of pleural exudate at intervals during the period of antiseptic treatment. The method which was employed has been described by Garbat, who continued this study on the cases of empyema that were transferred from Camp Lee to General Hospital No. 12 on June 31, 1918.[4]

Samples of exudate were obtained at frequent intervals when cases were dressed. These samples were collected by filling standard-sized platinum loops which were capable of holding approximately 0.02 gram. Each sample of exudate was immediately mixed with about 1 c. c. of a sterile 1 per cent solution of sodium thiosulphate, which neutralized any chlorine antiseptic which might remain in the sample from the previous irrigation. These procedures were carried out at the bedside immediately after the dressings and the tubes inserted in the cavity had been removed, but before the cavity was irrigated.

The samples were then taken to the laboratory and thoroughly mixed in a Petri dish with defibrinated blood and melted agar. After the agar had solidified, the plates were incubated for 24 hours at 37° C.

As far as possible, the walls of the sinus were avoided and the secretion was taken from the cavity. This precaution was necessary, particularly in cases which had been under treatment for a considerable length of time. In these cases the tissues of the thoracic wall fitted closely around the tubes so that the secretions between the tubes and walls of this sinus were protected from the antiseptic except at the time the cavities were irrigated, with the drainage tubes removed. These secretions usually contained bacteria which had invaded the sinus in spite of rigid antisepsis during the dressing of the wounds. These bacteria had been free to multiply until swept away or destroyed at the next irrigation. Samples of this material could not give a true picture of the bacteriologic flora of the main part of the draining tract.

When disinfection had proceeded to a point where sterility was nearly or fully attained, the secretions within the cavity were often so scanty that the wire loop used for securing the sample could not be completely filled. Under these circumstances the number of bacteria could only be approximated, but a sufficient quantity of secretion could always be obtained to verify or disprove sterility.

In all the cases studied in this way at Camp Lee, the primary infections were due to hemolytic streptococci.[5] The use of blood-agar as a culture medium made it possible, therefore, not merely to enumerate the total number of colonies upon the plate, but also to distinguish and estimate the number of these bacteria present. The counting was done either with the unaided eye or a hand glass, or under the low power lens of the microscope; a series of frac-

tional areas of the plate were averaged and multiplied by the proper factor, thus giving the approximate number for the entire plate.

In some of the cases studied in this way the application of Dakin's solution was carried out immediately after thoracotomy. In other instances a considerable period of simple drainage had intervened between the operation and the institution of this treatment. The data concerning these changes in treatment, the time when hemolytic streptococci were eliminated from the pleural exudate, and the time of wound closure or healing are given later in Tables 45, 46, and 47, and in Chart LXII.

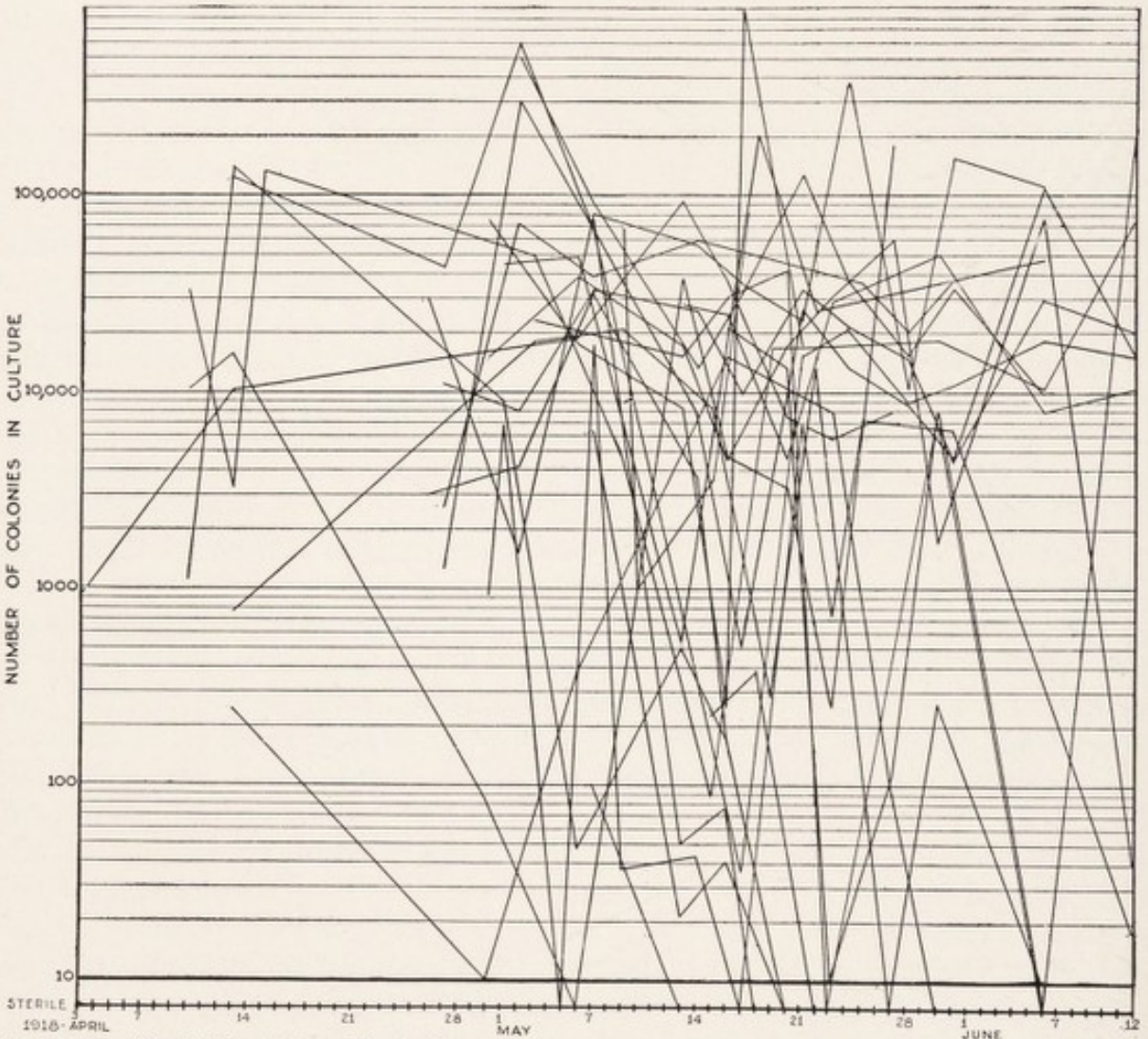



CHART LIX.—Graphic illustration of the total number of colonies on plates made at intervals during the disinfection of cavities, Camp Lee, Va.

These data must be supplemented by following the fluctuations in the number of viable organisms present in the exudate from time to time during the period of antiseptic treatment. These fluctuations in 24 cases picked at random are shown in Chart LIX. The dates on which the exudate was sampled are used as the abscissæ, and the number of colonies on the plated cultures taken for the ordinates. These are plotted on a logarithmic scale, with an arbitrary line at the bottom indicating a sterile culture. The definite ordinates range between 10 colonies on the plate to 900,000. By using this logarithmic scale great differences in the number of colonies can be included on a chart of reasonable proportions.

At first glance, the lines upon this chart appear to form a tangled skein lying between 1,000 and 100,000. Some of the lines never leave this zone of a fairly constant infection, but occasionally a line descends sharply, indicating a rapid decrease in the number of organisms in the exudate. In a few instances this descending line reaches the level which indicates sterility. In some in-

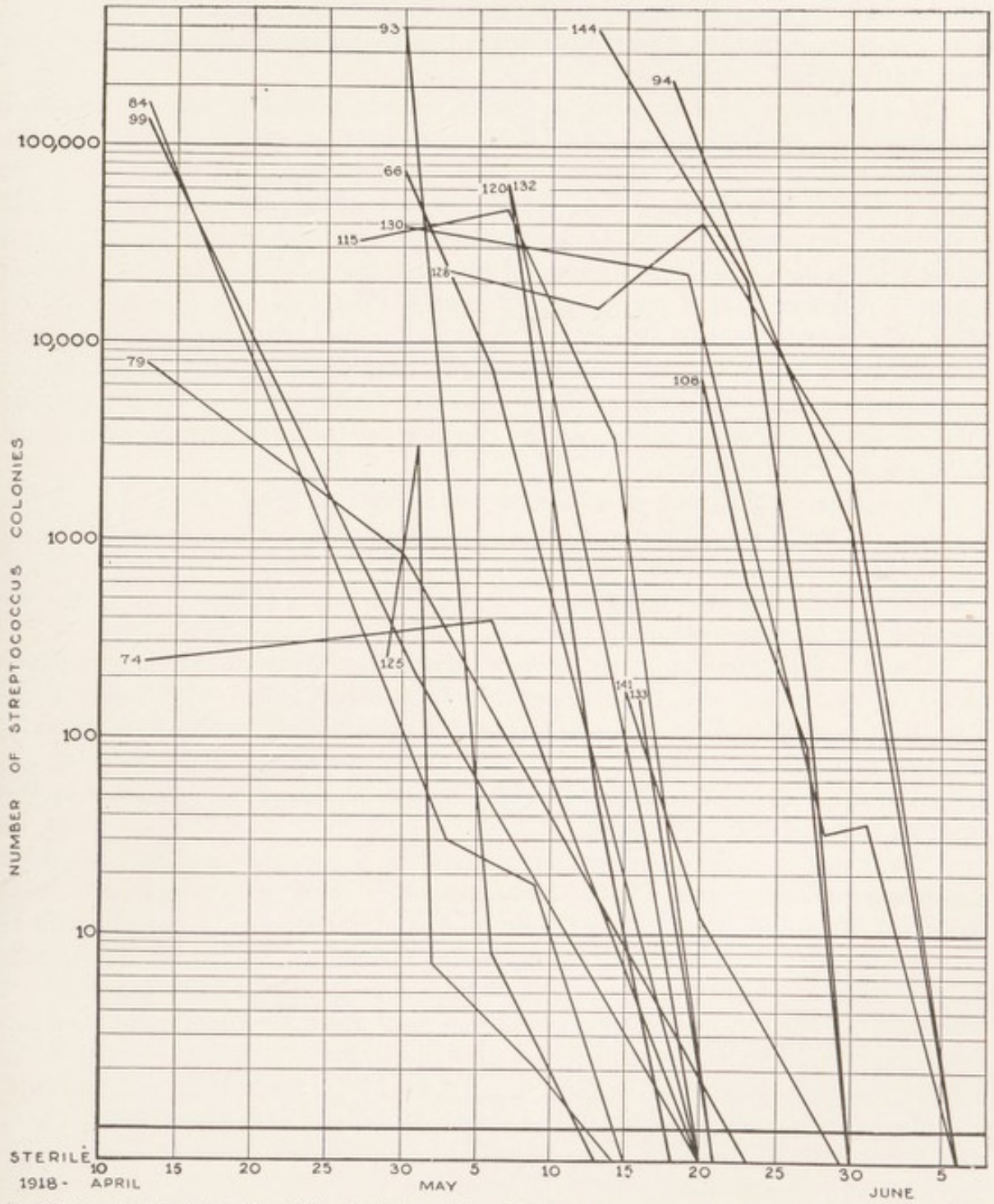



CHART LX.—Graphic illustration of the elimination of hemolytic streptococcus from empyema cavities during disinfection with Dakin's solution at Camp Lee, Va.

stances after sterility was apparently attained, the bacteria were again found in numbers even larger than those obtained on any previous examinations.

Notwithstanding the apparent confusion of the lines in this chart, it is instructive to note that the general slope of the descending lines does not vary to any considerable extent. It is equally evident, however, that the course of

disinfection was far from uniform in the majority of these cases, since there are great variations in most of the curves. There are many possible explanations of these wide fluctuations. One is undoubtedly concerned with the bacteriological technique employed in the study. Some of the samples were unquestionably contaminated with secretions retained between the drainage tube and sinus wall where they were protected from the action of Dakin's solution. It was extremely difficult to avoid this secretion when the sinuses were long, narrow, and tortuous.

There are numerous ways, of course, in which disinfection may be retarded or thwarted. Some of these have been mentioned in the early part of this chapter. Occasionally foreign bodies, such as drainage tubes, pieces of rubber dam, or other bits of dressings, have nullified attempts at disinfection by harboring organisms in places inaccessible to the antiseptic. Necrosis and osteomyelitis of a rib have discharged infected material into cavities, causing repeated reinfections of cases which would otherwise progress favorably. Some of the wide fluctuations in the chart were due to the rupture of a small encapsulation which was not drained at the time of the operation. This has occurred frequently after the cavities were practically sterile. Apparently the solution of the fibrinous linings of the cavities by Dakin's solution opened up the secondary pus pockets.

The chart which has been under consideration gives the totals of the colonies on the plates. Since the bacteria responsible for the infection in all the cases at Camp Lee were hemolytic streptococci, it is important to study the effect of antiseptic treatment on these bacteria. Chart LX has been prepared for this purpose.

Chart LX includes only those cases in which the streptococci were eliminated before the patients were transferred from Camp Lee. They were, therefore, continously under the same care and subjected to a uniform method of study. The figures associated with the curves are the case numbers of the patients, and serve as references to the condensed tables (45, 46, 47) of the cases at the end of this chapter.

The chart is much less confusing than the preceding one, because these cases were selected and chance contaminations with stray organisms were ignored. Attention was directed only to the streptococcus. The chart is of interest because it demonstrates that under favorable conditions the surgeon may expect to sterilize the cavities within a reasonably short interval. A corollary to such a conclusion would be that when disinfection is not accomplished readily, some condition within the thorax or in the chest wall or some error in the technique employed in the use of the antiseptic is responsible.

From this point of view, Carrel-Dakin technique serves not merely as a useful measure to promote cure, but if it be controlled by quantitative bacteriological examinations may call attention to complications which might otherwise be overlooked. Failure to attain sterilization of the cavity within a reasonable period of time should lead to a study of the case in order to discover the conditions causing the constant reinfection.

## THE RELATION BETWEEN STERILIZATION AND WOUND CLOSURE.

The preceding review of the bacteriological methods leads to a consideration of the application of these methods to a study of disinfection and wound closure. In the section on the effects of sodium hypochlorite antisepsis on healing, reference was made to a smaller yet more intensively studied group of cases. This smaller group includes 102 cases studied at Camp Lee.[6] They were treated in the same manner as the larger series but are subject to more careful analysis since the requisite data are complete. Careful bacteriological studies were made in all cases in which Dakin's solution was used for irrigation, so that the progress of disinfection can be followed in each case from the beginning of this treatment until the wound had healed. The methods of analysis are similar to those employed in the larger series, and the cases have been grouped according to the treatment. The intervals between the operations and the final healing of the wounds have been determined and the mean successive intervals estimated for each group. These intervals have been charted in Chart LXI, so that they may be compared with those in the previous series.

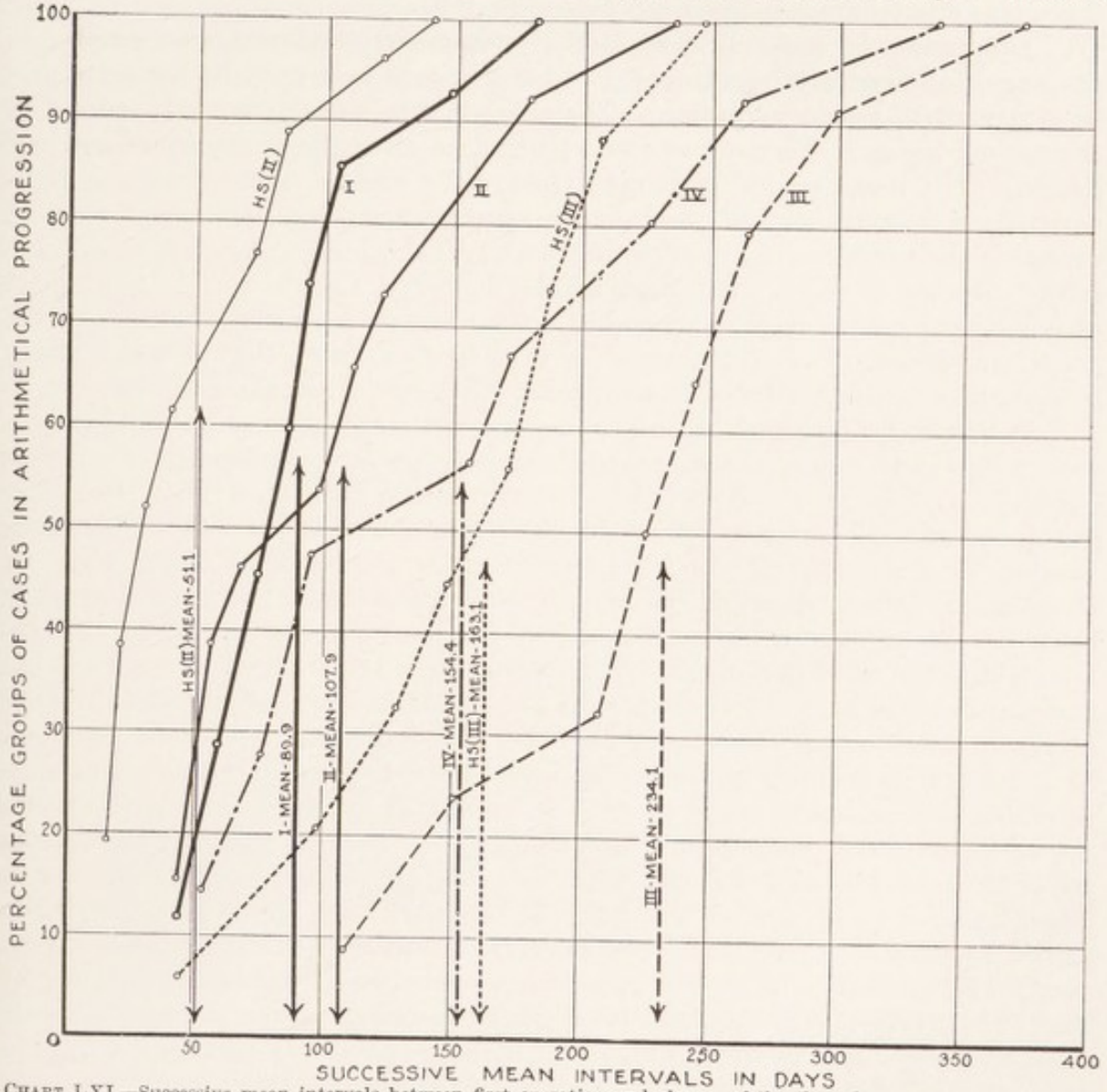



CHART LXI.—Successive mean intervals between first operation and closure of the thoracic wound, Camp Lee, Va. Curve I, simple drainage (see Table 39). Curve II, prompt treatment with Dakin (see Table 40). Curve III, delayed treatment with Dakin (see Table 42). Curve IV, simple drainage, including subsequent treatment with Dakin; this curve is a composite of Curves I and III (see Table 44). Curve HS (II), hemolytic streptococci eliminated among II (see Table 41). Curve HS (III), hemolytic streptococci eliminated among III (see Table 43).

The first group (Curve I) contains 42 cases in which no antisepsis was applied during the postoperative care. Among these there were three recurrences appearing a considerable time after the wound healed. The second group (Curve II) includes 26 cases in which Dakin's solution was used for irrigation at the time dressings were changed, and also for intermittent instillations between dressings at intervals of from one to three hours. This treatment was begun within a short time after the first operation. In this group there was one recurrence after the wound had closed. The third group (Curve III) comprises 34 cases in which the postoperative treatment was simple drainage, followed after an interval of from one to four months by antiseptic treatment with Dakin's solution. The procedure was the same as that used in the second group. There were two recurrences after the thoracic wound had healed. The mean period of wound closure for each of these groups is indicated by a vertical line on each of the respective curves. Curves I and II resemble the corresponding curves in Chart LVIII which was based on a much larger number of cases. In Chart LVIII, however, Curves I and II intersect at a shorter interval after operation at a time when a smaller percentage of the cases had healed. It is the intersection of these two curves that demands study in seeking an explanation of the apparent efficiency of simple drainage.

If the whole series of 102 cases is again reviewed, it may be divided into two groups. In one of these groups Dakin's solution was promptly used after operation. This group of 26 cases is represented by Curve II. The other group includes those cases, 76 in number, that were, at least for some time, treated by simple drainage. This second group is shown as Curve IV. Of these cases, 25 healed within 90 days, or before the time after operation when cases usually pass from the more acute to the more chronic condition. Seventeen additional cases had progressed to a point where the cavity was obliterated and the thoracic wound had contracted to a small sinus not adjudged to require energetic treatment. There were 34 cases that had not made such progress. They were still draining profusely and presented cavities of varying but considerable size. These cases were then treated with Dakin's solution of sodium hypochlorite. This change in treatment and the time at which it took place are of such importance that the data have been presented in graphic form in Chart LXII. Here it is shown that the transfers were most frequent in the period between 60 to 90 days after operation, and that in 27 of the 34 cases, nearly 80 per cent, simple drainage had preceded antiseptic treatment for at least two months. The mean interval after operation when antiseptic treatment was begun was 90 days, whereas in the cases promptly treated it was nine days. The 90-day interval closely approximates that at which empyema cases become chronic, that is, when the production of healthy granulation tissue is checked by cicatricial changes, and the healing process becomes indolent. The contractions of the newly formed tissues at this stage militate against free drainage of any considerable cavity that may persist, and also restrict the thoroughness with which antiseptic treatment can be applied. It is not surprising, therefore, to find that, taken collectively, these transferred cases proved more refractory than those that did well under simple drainage or that received a more prompt antiseptic treatment.

It should be stated that in many of the transferred cases the adverse conditions following a protracted septic inflammation had to be corrected by a dilatation of the sinus or a second operation, before treatment of the cavity with Dakin's solution could be efficiently carried out.

To return to a further consideration of Chart LXI, Curve IV necessarily lies between Curves I and III, since it is based on the cases represented in these curves. Curve IV, which lies considerably to the right of Curve II, represents the cases promptly treated with Dakin's solution. In the aggregate, the cases that received prompt Dakin treatment closed in a shorter period of time than those in which this treatment was delayed or entirely omitted.

Since the purpose of antiseptic treatment is the elimination of the infecting organisms, bacteriological studies relative to the progress of disinfection become

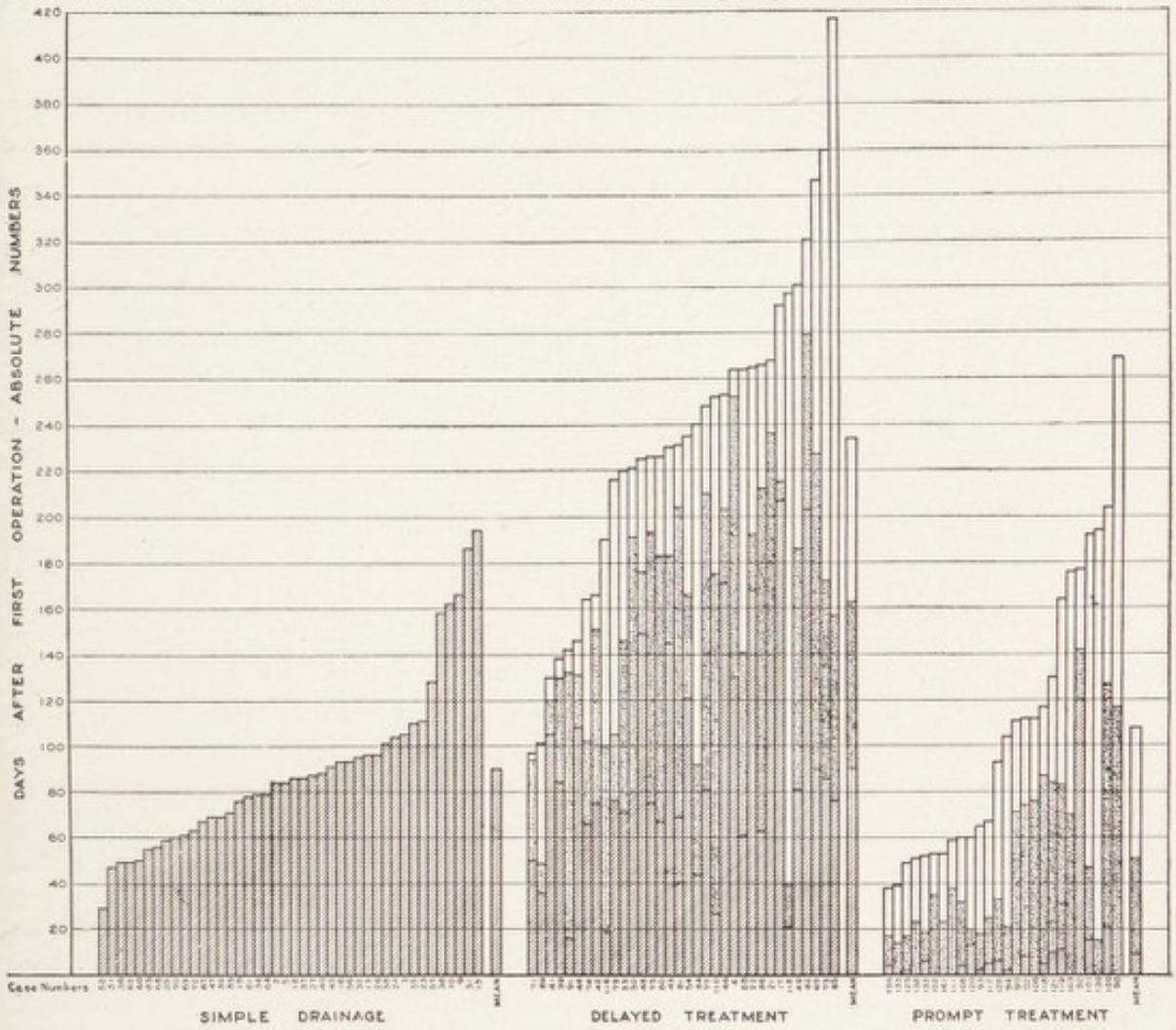



CHART LXII.—Graphic illustration of Camp Lee cases showing the effect of antisepsis with neutral solution of sodium hypochlorite on the healing of empyema wounds after the first operation. The height of the upright columns indicates the number of days which elapsed in each case before complete and final closure of the wound. At the extreme left is a series of 42 cases which healed under simple tube drainage without antisepsis (see Table 47). In the center is a series of 34 cases first treated by simple drainage and subsequently transferred to irrigations with Dakin's solution (see Table 45). The time of simple drainage is represented by the cross-hatched portion of the column after which the cases were transferred to antisepsis. The time which elapsed before healing by antisepsis is represented by the dotted and white portion, the dotted part representing the interval when streptococci were still present and the white part when they were no longer found in the cultures of the wounds. At the extreme right is a series of 26 cases treated throughout their course by irrigations (see Table 46). The average mean period is represented by the column at the right of each series.

of importance in the further analysis of these cases. There are no such data on the cases treated solely by simple drainage. Of the 42 cases in this group there are no bacteriological data for 18. Of the remaining 24, three showed pneumococci, and the rest hemolytic streptococci.

Bacteriological data are available for the two groups treated with Dakin's solution. Without exception they were associated with hemolytic streptococcf.

In addition to these data the approximate dates on which the streptococci were finally eliminated from the cavities are known. The distribution of the

intervals between the operations and the elimination of the streptococci from the wounds in the cases represented in Curves II and III has been charted. These curves are marked "HS" and the mean intervals indicated by vertical lines.

It is of practical interest to note that the mean intervals of time between the elimination of the hemolytic streptococcus and closure of the wound in the two groups in which Dakin's solution was used show a difference of only two weeks, notwithstanding a difference of approximately four months in the respective mean intervals of wound closure. In the Dakin-prompt cases the mean time for streptococcus elimination was 51.1 days; for wound closure 107.9 days. The difference between these is 56.8 days. The mean time for the elimination of streptococci in the Dakin-delayed cases was 163.1 days; for wound closure 233.8 days. Here the difference is 70.7 days.

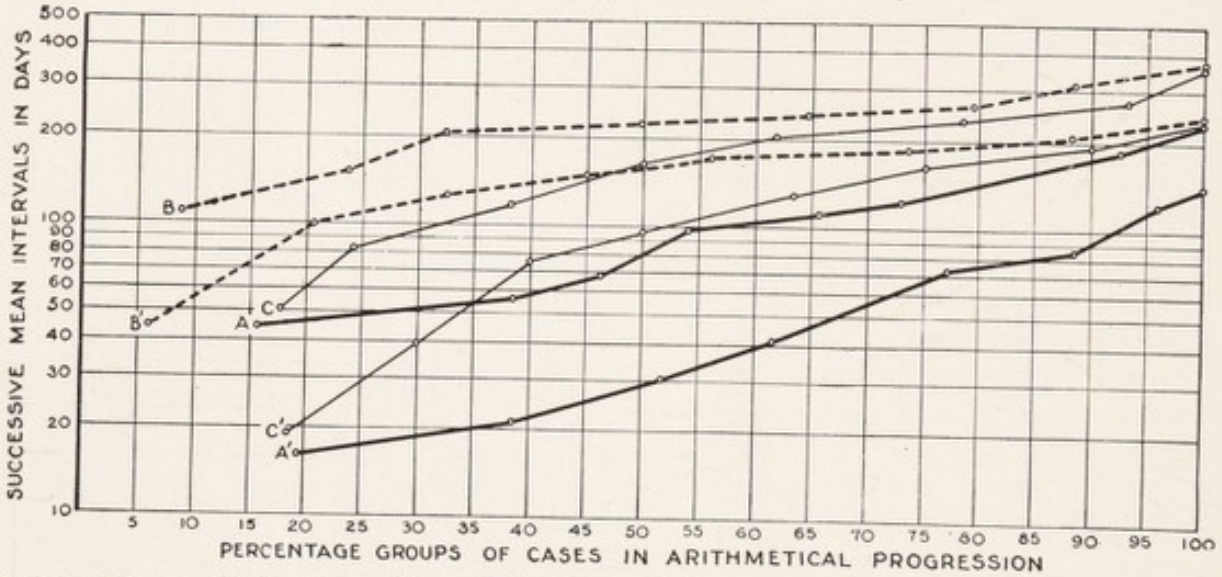



CHART LXIII.—Graphic illustration of the parallelism between the disappearance of hemolytic streptococci from wounds and closure of the cavities of cases at Camp Lee, Va. Curves A, B, and C are for wound closure and A′, B′, C′ for elimination of hemolytic streptococci. Curves A and A′ represent the effect of prompt treatment with Dakin's solution of sodium hypochlorite. Curves B and B′ delayed treatment, and curves C and C′ all cases. The successive mean intervals are drawn on a logarithmic scale.

From these data it appears justifiable to conclude that the chief hindrance to closure of the wound was a persistent infection with streptococci, and that the use of Dakin's solution was markedly helpful in overcoming this infection.

There remains for consideration the question as to whether this relation between the mean intervals for the elimination of the streptococcus and wound closure, which are so nearly identical after the use of Dakin's solution in these two groups, expresses the relation which exists between the intervals throughout the series of cases. Chart LXIII has been prepared on a logarithmic scale to illustrate the ratios between these intervals throughout the series.

There is a very close parallelism between the curves representing the elimination of the streptococcus and wound closure. This is most striking in the curves for delayed treatment, but is clearly evident in those for prompt treatment in spite of a slight lag in the first half of the cases. This chart shows that this relation between sterilization and wound closure is nearly uniform and that it is justifiable to extend the deductions based upon a comparison of the means to all parts of the series.

The figures upon which the curves in Charts LXI, LXII, and LXIII, are based are given in Tables 39 to 47.

It will be noticed that in grouping the cases at Camp Lee into those in which treatment was prompt and those in which it was delayed, a few cases appear to be misplaced. The decision in these cases was based on the character of the operation. Those cases in which the operation was done with a view to the introduction of Carrel tubes distributed to all parts of the cavity are included in the Dakin-prompt class even when the antiseptic applications did not immediately follow the operation. The number of these exceptional cases is not large enough to greatly influence the deductions which may be drawn from the data taken collectively.

TABLE 39.[a]—*Wound closure after the first operation among cases treated by simple drainage, distributed according to the successive mean periods—Camp Lee, Va.*

| Distribution. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Cases. | | | | | Mean periods in days. | | | |
| Total number. | Successive groups. | | | Per cent of total in third group. | Successive groups. | | | Average mean period. |
| | First. | Second. | Third. | | Third. | Second. | First. | |
| 42 | 25 | 12 | 5 | 11.90 | 44.0 | 54.25 | 67.48 | 89.9 |
| | | | 7 | 16.67 | 59.1 | | | |
| | | 13 | 7 | 16.67 | 74.7 | 79.70 | | |
| | | | 6 | 14.29 | 85.8 | | | |
| | 17 | 11 | 6 | 14.29 | 94.0 | 99.55 | 122.9 | |
| | | | 5 | 11.90 | 106 | | | |
| | | 6 | 3 | 7.14 | 149 | 165.7 | | |
| | | | 3 | 7.14 | 182 | | | |

[a] Source of information: Special empyema reports made to the Office of the Surgeon General.

TABLE 40.[a]—*Wound closure after first operation among cases promptly treated with neutral solution of sodium hypochlorite, distributed according to the successive mean periods—Camp Lee, Va.*

| Distribution. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Cases. | | | | | Mean periods in days. | | | |
| Total number. | Successive groups. | | | Per cent of total in third group | Successive groups. | | | Average mean period. |
| | First. | Second. | Third. | | Third. | Second. | First. | |
| 26 | 14 | 10 | 4 | 15.4 | 44.3 | 51.4 | 60.5 | 107.9 |
| | | | 6 | 23.1 | 56.2 | | | |
| | | 4 | 2 | 7.7 | 68.0 | 83.3 | | |
| | | | 2 | 7.7 | 98.5 | | | |
| | 12 | 5 | 3 | 11.5 | 111.7 | 116.4 | 163.2 | |
| | | | 2 | 7.7 | 123.5 | | | |
| | | 7 | 5 | 19.2 | 180.6 | 196.6 | | |
| | | | 2 | 7.7 | 236.5 | | | |

[a] Source of information: Special empyema reports made to the Office of the Surgeon General.

TABLE 41.[a]—*Elimination of hemolytic streptococci after the first operation among cases promptly treated with neutral solution of sodium hypochlorite, distributed according to the successive mean periods—Camp Lee, Va.*

| Distribution. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Cases. | | | | | Mean periods in days. | | | |
| Total number. | Successive groups. | | | Per cent of total in third group. | Successive groups. | | | Average mean period. |
| | First. | Second. | Third. | | Third. | Second. | First. | |
| 26 | 16 | 10 | 5 | 19.2 | 16.2 | 18.7 | 24.8 | 51.1 |
| | | | 5 | 19.2 | 21.2 | | | |
| | | 6 | 3.5 | 13.5 | 30.7 | 35.0 | | |
| | | | 2.5 | 9.6 | 41.0 | | | |
| | 10 | 7 | 4 | 15.4 | 73.0 | 78.0 | 93.2 | |
| | | | 3 | 11.5 | 84.7 | | | |
| | | 3 | 2 | 7.7 | 122 | 129 | | |
| | | | 1 | 3.9 | 142 | | | |

[a] Source of information: Special empyema reports made to the Office of the Surgeon General.

TABLE 42.[a]—*Wound closure after the first operation among cases treated with neutral solution of sodium hypochlorite after a period of simple drainage, distributed according to the successive mean periods—Camp Lee, Va.*

| Distribution. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Cases. | | | | | Mean periods in days. | | | |
| Total number. | Successive groups. | | | Per cent of total in third group. | Successive groups. | | | Average mean period. |
| | First. | Second. | Third. | | Third. | Second. | First. | |
| 34 | 17 | 8 | 3 | 8.8 | 109.3 | 135.5 | 180.5 | 234.1 |
| | | | 5 | 14.7 | 151.2 | | | |
| | | 9 | 3 | 8.8 | 208.7 | 220.6 | | |
| | | | 6 | 17.6 | 226.5 | | | |
| | 17 | 10 | 5 | 14.7 | 245.6 | 255.5 | 287.7 | |
| | | | 5 | 14.7 | 265.4 | | | |
| | | 7 | 4 | 11.8 | 302.8 | 333.6 | | |
| | | | 3 | 8.8 | 374.7 | | | |

[a] Source of information: Special empyema reports made to the Office of the Surgeon General.

TABLE 43.[a]—*Elimination of hemolytic streptococci after the first operation among cases treated with Dakin's solution of sodium hypochlorite, after a period of simple drainage, distributed according to the successive mean periods—Camp Lee, Va.*

| Distribution. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Cases. | | | | | Mean periods in days. | | | |
| Total number. | Successive groups. | | | Per cent of total in third group. | Successive groups. | | | Average mean period. |
| | First. | Second. | Third. | | Third. | Second. | First. | |
| 34 | 15 | 7 | 2 | 5.9 | 44.5 | 83.1 | 112.7 | 163.1 |
| | | | 5 | 14.7 | 98.6 | | | |
| | | 8 | 4 | 11.8 | 128.3 | 138.5 | | |
| | | | 4 | 11.8 | 148.8 | | | |
| | 19 | 10 | 4 | 11.8 | 172.3 | 181.7 | 202.9 | |
| | | | 6 | 17.6 | 188.0 | | | |
| | | 9 | 5 | 14.7 | 208.8 | 226.4 | | |
| | | | 4 | 11.8 | 248.5 | | | |

[a] Source of information: Special empyema reports made to the Office of the Surgeon General.

TABLE 44.[a]—*Wound closure after the first operation among cases treated by simple drainage, and including those subsequently receiving Carrel-Dakin treatment, distributed according to the successive mean periods.—A composite table of cases in Tables 39 and 42—Camp Lee, Va.*

| Distribution. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Cases. | | | | | Mean periods in days. | | | |
| Total number. | Successive groups. | | | Per cent of total in third group. | Successive groups. | | | Average mean period. |
| | First. | Second. | Third. | | Third. | Second. | First. | |
| 76 | 43 | 21 | 11 | 14.5 | 53.1 | 63.8 | 85.2 | 154.4 |
| | | | 10 | 13.2 | 75.6 | | | |
| | | 22 | 15 | 19.7 | 94.6 | 105.6 | | |
| | | | 7 | 9.2 | 157.9 | | | |
| | 33 | 18 | 8 | 10.5 | 173.3 | 203.1 | 244.6 | |
| | | | 10 | 13.2 | 227.0 | | | |
| | | 15 | 9 | 11.8 | 263.6 | 294.3 | | |
| | | | 6 | 7.9 | 340.5 | | | |

[a] Source of information: Special empyema reports made to the Office of the Surgeon General.

TABLE 45.[a]—*Camp Lee cases (total, 34) treated with Dakin's solution of sodium hypochlorite following a period of simple drainage.*

[The table shows the intervals between the operation, the beginning of antisepsis, the sterilization of the wounds, and final healing. The data are used directly without modification in Chart LXII.]

| Case No.[b] | First operation. | Antisepsis begun. | | Hemolytic streptococci absent. | | Wound closed. | | |
|---|---|---|---|---|---|---|---|---|
| | 1918 | 1918 | Days after operation. | 1918 | Days after operation.[c] | 1918–19 | Days after operation.[d] | |
| 4 | Jan. 3 | May 13 | 130 | Sept. 12 | 252 | Sept. 24 | 264 | |
| 17 | Jan. 18 | Aug. 13 | 207 | Aug. 21 | 215 | Nov. 6 | 292 | |
| 21 | Jan. 3 | May 23 | 140 | Aug. 27 | 236 | Sept. 28 | 268 | |
| 22 | Jan. 5 | June 22 | 168 | July 16 | 192 | Sept. 27 | 265 | |
| 30 | Jan. 18 | Apr. 8 | 80 | July 23 | 191 | Aug. 27 | 221 | |
| 33 | Feb. 14 | Apr. 26 | 71 | July 11 | 146 | Sept. 22 | 220 | |
| 39 | Feb. 2 | Apr. 27 | 84 | June 12 | 130 | June 20 | 138 | |
| 41 | Jan. 15 | Apr. 30 | 105 | May 15 | 120 | May 25 | 130 | |
| 42 | Jan. 26 | Apr. 11 | 75 | June 27 | 151 | July 11 | 166 | |
| 43 | Jan. 9 | June 3 | 145 | July 11 | 183 | Aug. 27 | 230 | |
| 44 | Jan. 10 | Apr. 28 | 108 | May 21 | 131 | June 6 | 146 | |
| 46 | Jan. 15 | July 5 | 171 | Aug. 6 | 203 | Sept. 25 | 253 | |
| 48 | Jan. 14 | June 12 | 149 | July 11 | 176 | Aug. 27 | 225 | |
| 49 | Jan. 18 | Apr. 9 | 81 | July 25 | 186 | Nov. 15 | 301 | |
| 54 | Jan. 31 | June 3 | 121 | July 16 | 166 | Sept. 23 | 235 | |
| 65 | Feb. 12 | Apr. 29 | 76 | July 19 | 157 | Apr. 5 | 417 | |
| 69 | Jan. 28 | Apr. 25 | 90 | Sept. 22 | 227 | Dec. 26 | 347 | |
| 71 | Feb. 7 | Mar. 29 | 50 | May 12 | 94 | May 15 | 97 | |
| 73 | Feb. 1 | Apr. 28 | 86 | July 24 | 172 | [e]Jan. 26 | 360 | |
| 74 | Feb. 7 | Apr. 14 | 66 | May 20 | 102 | July 21 | 164 | |
| 75 | Feb. 9 | Apr. 25 | 75 | Aug. 21 | 193 | Sept. 24 | 226 | |
| 77 | Feb. 5 | Apr. 27 | 81 | Sept. 3 | 210 | Oct. 11 | 248 | |
| 79 | Feb. 7 | Apr. 24 | 76 | May 23 | 105 | Sept. 11 | 216 | |
| 80 | Feb. 19 | Apr. 27 | 67 | Aug. 21 | 183 | Oct. 3 | 226 | |
| 81 | Feb. 20 | Apr. 30 | 69 | Sept. 12 | 204 | Oct. 9 | 231 R | |
| 82 | Feb. 12 | Sept. 3 | 203 | Nov. 18 | 279 | [e]Jan. 7 | 321 | |
| 84 | ...do.... | Mar. 28 | 44 | May 15 | 92 | Oct. 10 | 240 | |
| 86 | Feb. 25 | Apr. 27 | 63 | Sept. 23 | 212 | Nov. 16 | 266 R | |
| 88 | ...do.... | ...do.... | 61 | July 16 | 141 | ...do.... | 264 | |
| 89 | Mar. 1 | Apr. 6 | 36 | Apr. 18 | 49 | July 11 | 101 | |
| 91 | Mar. 9 | Mar. 25 | 16 | July 19 | 132 | July 29 | 142 | |
| 110 | Mar. 31 | Apr. 27 | 27 | Sept. 22 | 175 | Dec. 8 | 252 | |
| 115 | Apr. 6 | ...do.... | 21 | May 16 | 40 | [e]Jan. 8 | 297 | |
| 116 | Apr. 8 | ...do.... | 19 | July 17 | 100 | Oct. 15 | 190 | |
| Average mean | ..... | ..... | 90.0 | ..... | 163.1 | ..... | 234.1 | |

[a] Source of information: Special empyema reports made to the Office of the Surgeon General.
[b] The cases are listed chronologically according to the dates af admission to the base hospital.
[c] These intervals have been used to compute the successive mean periods in Table 43.
[d] These intervals have been used to compute the successive mean periods in Table 42.
[e] 1919.
R = Recurrence after healing.

TABLE 46.[a]—*Camp Lee cases (total, 26) treated promptly by neutral solution of sodium hypochlorite.*

[This table gives the dates of the operations, the day on which antisepsis was begun, the dates of sterilization, and the day on which the wounds were considered healed. The intervals have been calculated. The time intervals have been used directly in the preparation of Chart LXII.]

| Case No.[b] | First operation. | Antisepsis begun. | | Hemolytic streptococci absent. | | Wound closed. | | |
|---|---|---|---|---|---|---|---|---|
| | 1918 | 1918 | Days after operation. | 1918 | Days after operation.[c] | 1918 | Days after operation.[d] | |
| 92[e] | Mar. 3 | July 1 | 120 | July 23 | 142 | Aug. 27 | 177 | |
| 93 | Apr. 25 | Apr. 27 | 2 | May 13 | 18 | July 1 | 67 | |
| 94 | May 16 | May 18 | 2 | June 6 | 21 | July 29 | 104 | |
| 97 | Mar. 7 | Mar. 15 | 8 | May 20 | 74 | July 27 | 112 | |
| 98 | Mar. 21 | Mar. 21 | 0 | July 16 | 117 | Dec. 15 | 269 | |
| 99 | Mar. 9 | Mar. 9 | 0 | May 20 | 71 | June 29 | 111 | |
| 100 | Mar. 11 | Apr. 1 | 21 | July 16 | 127 | Oct. 1 | 204 | |
| 101 | Mar. 23 | Apr. 7 | 15 | May 9 | 47 | ...do.... | 192 | |
| 102 | Mar. 22 | Mar. 22 | 0 | Apr. 26 | 35 | May 14 | 53 | |
| 103 | Mar. 14 | Mar. 14 | 0 | May 23 | 70 | Sept. 6 | 176 | |
| 106 | June 6 | June 6 | 0 | Aug. 21 | 76 | Sept. 27 | 112 | |
| 108 | Apr. 28 | May 2 | 4 | June 6 | 32 | June 27 | 60 | |
| 111 | Apr. 12 | Apr. 12 | 0 | May 20 | 38 | June 10 | 59 | |
| 118 | May 7 | May 12 | 5 | Aug. 2 | 87 | Aug. 27 | 117 | |
| 117 | ...do.... | ...do.... | 5 | June 1 | 25 | July 15 | 69 | |
| 119 | Apr. 29 | May 10 | 11 | July 21 | 83 | Oct. 10 | 164 | |
| 120 | Apr. 28 | May 11 | 13 | May 18 | 20 | June 27 | 60 | R |
| 121 | May 7 | May 17 | 10 | July 30 | 84 | Sept. 14 | 130 | |
| 125[f] | Apr. 27 | Apr. 29 | 2 | May 14 | 17 | June 15 | 49 | |
| 128 | May 4 | May 10 | 6 | June 6 | 33 | Aug. 5 | 93 | |
| 130 | May 22 | May 22 | 0 | ...do.... | 15 | Dec. 22 | 194 | |
| 132 | May 1 | May 7 | 6 | May 20 | 19 | June 22 | 52 | |
| 133 | May 7 | ...do.... | 0 | May 21 | 14 | June 15 | 39 | |
| 136 | May 3 | ...do.... | 4 | May 24 | 17 | June 10 | 38 | |
| 138 | May 14 | May 14 | 0 | June 6 | 23 | July 4 | 51 | |
| 141 | May 6 | May 6 | 0 | May 29 | 23 | June 28 | 53 | |
| Average mean... | ..... | ..... | 9.0 | ..... | 51.1 | ..... | 107.9 | |

[a] Source of information: Special empyema reports made to the Office of the Surgeon General.
[b] The cases are listed chronologically according to the dates of admission to the base hospital.
[c] These intervals have been used to compute the successive mean periods in Table 41.
[d] These intervals have been used to compute the successive mean periods in Table 40
[e] Treatment with Dakin's solution was attempted at intervals, beginning soon after the operation, but had to be stopped because of a large pleurobronchial communication. The treatment could not be used intensively until 120 days after the first operation.
[f] Treated with dichloramine-T, 5 per cent in chlorcosane, throughout, except for an occasional irrigation with Dakin's solution at the time dressings were changed.
R = Recurrence after healing.

TABLE 47.[a]—*Camp Lee cases (total, 42) treated by simple drainage without antisepsis.*

[This table gives the interval in days before wound closure. Chart LXII shows these intervals graphically.]

| Case No.[b] | First operation. | Wound closed. | | Case No.[b] | First operation. | Wound closed. | |
|---|---|---|---|---|---|---|---|
| | 1918 | 1918 | Days after first operation.[c] | | 1918 | 1918 | Days after first operation.[c] |
| 2 | Jan. 1 | Mar. 26 | 84 | 45 | Jan. 14 | Apr. 15 | 91 |
| 3 | ...do.... | Apr. 16 | 105 | 47 | Jan. 18 | Mar. 28 | 69 |
| 5 | Jan. 16 | Apr. 10 | 84 | 50 | Jan. 15 | Mar. 25 | 69 |
| 9 | Jan. 5 | June 26 | 166 | 51 | Jan. 28 | Mar. 16 | 47 |
| 10 | Jan. 4 | June 15 | 162 | 52 | Jan. 14 | Feb. 12 | 29 |
| 13 | Jan. 10 | Apr. 16 | 96 | 53 | Jan. 13 | Mar. 25 | 71 |
| 15 | Jan. 5 | July 19 | 194 | 55 | Feb. 4 | May 25 | 110 |
| 16 | Jan. 7 | Apr. 5 | 93 | 56 | Jan. 17 | Apr. 20 | 93 R |
| 18 | Jan. 5 | Mar. 27 | 86 | 57 | Feb. 23 | July 1 | 128 |
| 19 | Jan. 15 | May 1 | 76 | 58 | Jan. 19 | Apr. 30 | 101 |
| 23 | Jan. 5 | Apr. 26 | 111 | 60 | Jan. 26 | Mar. 19 | 52 |
| 24 | Jan. 2 | May 16 | 104 | 61 | Feb. 7 | Apr. 26 | 78 |
| 25 | Jan. 9 | Mar. 9 | 59 | 62 | Feb. 13 | Apr. 5 | 51 |
| 26 | Jan. 1 | Apr. 7 | 96 | 63 | Feb. 20 | Apr. 22 | 61 |
| 27 | Jan. 2 | Mar. 30 | 87 | 64 | Jan. 29 | Apr. 18 | 79 |
| 31 | ...do.... | July 6 | 186 R | 67 | Feb. 7 | Apr. 15 | 67 |
| 32 | Jan. 14 | Apr. 19 | 95 | 68 | Feb. 13 | Apr. 10 | 56 |
| 34 | Jan. 23 | Apr. 12 | 79 | 70 | Feb. 11 | Apr. 12 | 60 |
| 36 | Feb. 23 | Apr. 15 | 51 | 72 | ...do.... | Apr. 15 | 63 |
| 37 | Jan. 14 | Apr. 10 | 86 | 83 | Feb. 20 | Apr. 16 | 55 |
| 38 | Jan. 22 | June 30 | 158 | | | | |
| 40 | Jan. 23 | Apr. 21 | 88 R | Average mean | ..... | ..... | 89.9 |

[a] Source of information: Special empyema reports made to the Office of the Surgeon General.
[b] The cases are listed chronologically according to the dates of admission to the base hospital.
[c] These intervals have been used to compute the successive mean periods in Table 39.
R = Recurrence after healing.

## THE EFFECTS OF ANTISEPSIS WITH NEUTRAL SOLUTION OF SODIUM HYPOCHLORITE ON THE FINAL CONDITION OF PATIENTS AFTER DISCHARGE.

At the beginning of this section reference was made to a statistical study of cases based upon the replies to follow-up letters. These replies give information concerning ability to work, dyspnea, pain, persistent cough, and symptoms referred to the heart by the man himself. The reports upon work may be divided into the following three classes: Heavy work, light work, and no work. These, together with the four symptoms, make seven simple categories. They may, however, be associated in pairs, in threes, fours, or even fives. For example, a man may report that he is doing heavy work, but has pain, or pain and dyspnea, or pain, dyspnea and cough. He may state that he has pain, dyspnea, a persistent cough, palpitation of the heart, and is unable to work.

When the possible permutations of these data have been listed and the number of cases under each heading ascertained in respect of two or more groups of cases, selected because of some specified difference in the histories, it is possible to calculate the probabilities as to whether the divergences revealed by the aggregate of follow-up data depart in any marked degree from that which would have resulted had the selection been made at random. The method which has been used to calculate these probabilities is known as the chi-square test. This mode of mathematical analysis has been applied to the three groups of cases already studied regarding wound closure, namely, (1) those in which the postoperative treatment was simple drainage, (2) those in which Dakin's solution was used with a partial Carrel technique, and (3) those in which the full technique was followed.[a]

Applying this test to a comparison of simple drainage with partial Dakin treatment in so far as work and symptoms are concerned, the equations $X^2 - 83.98$ and $P = 0.007$ were obtained. This means that the data as submitted would have arisen on the basis of chance seven times in 1,000 trials. In other words, the partial Dakin treatment gave significantly better results in so far as work and symptoms were concerned than simple drainage.

Comparing in the same way simple drainage with full Dakin treatment, the expressions were $X^2 = 88.02$, $P = 0.0005$. This again means that this antiseptic treatment was significantly better than simple drainage.

A comparison of the partial with the full Dakin treatment, also regarding work and symptoms, gave: $X^2 - 66.74$, $P - 0.08$. Here the results favor the full technique, but the degree of superiority is of a somewhat lower order than that revealed in the previous comparisons.

From these results it appears safe to conclude that Dakin's solution when used with the full Carrel technique gave better ultimate results than when it was used less intensively and that either use of the solution was followed by a better condition of the patient than when simple drainage without antisepsis was the postoperative treatment.

The comparisons were carried further, with the following results: Partial Dakin treatment gave better results than simple drainage regarding work, pain and probably, though not quite certainly, dyspnea. In so far as cough and heart symptoms were concerned, there was no significant difference.

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a The actual calculations were kindly undertaken by Prof. Raymond Pearl, of the Johns Hopkins University.

Full Carrel-Dakin treatment gave better results than simple drainage regarding dyspnea and probably, though not quite certainly, work, pain, cough, and heart symptoms.

It will be recalled that preceding studies have shown that many of the cases which eventually received treatment with Dakin's solution were of a more refractory nature than those which, when simply drained, healed within a reasonable length of time. It would be of value to know whether this difference in the readiness with which cases healed was associated with differences in the pathology of the cases as indicated by the diseases preceding empyema and the organisms present in the pleural exudate. The actual data bearing on this question will be found in tables at the end of this chapter. But these data also were submitted to the chi-square test, because this made it possible to study permutations which would obscure the meaning if presented in tabular form only and would yield very complex charts.

The antecedent diseases chosen for this purpose were measles, influenza, lobar pneumonia, and bronchopneumonia. These embrace practically all of the cases. The infecting organisms were classed as pneumococci, diplococci, streptococci, staphylococci, and "unknown." In this problem the data were considered only in pairs, for there was for each case but a single antecedent disease and a single infecting organism. In some instances there were too few of a given combination to have statistical significance; for example, there was no case of empyema following lobar pneumonia and treated with Dakin-full technique in which staphylococci were found in the exudate. There were, however, 16 useful categories into which the data concerning antecedent diseases and infecting organisms could be grouped under the headings of simple drainage, Dakin-part, and Dakin-full treatment.

Applying the chi-square test to these data, it resulted in showing a marked degree of selection. The expressions indicating this were as follows: Simple drainage compared with partial Dakin, $X^2 = 111.975$, $P = 0$; simple drainage compared with Dakin-full technique, $X^2 = 26.523$, $P = 0.022$; Dakin-part compared with Dakin-full, $X^2 = 31.90$, $P = 0.003$.

This method of statistical analysis does not offer any medical interpretation of the results, but merely shows that the distribution of the cases in respect to the mode of treatment was not fortuitous but was influenced in the aggregate by the pathology of the cases.

As a final summing up of all the foregoing studies it is reasonable to conclude that the more complex and refractory cases were the ones which eventually came under antiseptic treatment with Dakin's solution, and that this treatment proved of very marked benefit.

TABLE 48.[a]—*Data on symptoms used in applying the chi-square test.*

| | Simple drainage. | Dakin-part. | Dakin-full. | | Simple drainage. | Dakin-part. | Dakin-full. | | Simple drainage. | Dakin-part. | Dakin-full. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| w | 94 | 88 | 24 | lw-d-p | 67 | 36 | 13 | w-d-p-c-h | 0 | 0 | 0 |
| lw | 36 | 16 | 11 | lw-d-c | 8 | 4 | 1 | lw-d-p-c-h | 2 | 0 | 3 |
| Ow | 7 | 9 | 2 | lw-d-h | 4 | 4 | 1 | Ow-d-p-c-h | 1 | 2 | 0 |
| d | 6 | 8 | 6 | Ow-d-p | 8 | 8 | 3 | w-d-c-h | 2 | 0 | 2 |
| p | 9 | 9 | 8 | Ow-d-c | 0 | 3 | 0 | lw-d-c-h | 0 | 1 | 0 |
| c | 0 | 3 | 1 | Ow-d-h | 2 | 0 | 0 | Ow-d-c-h | 1 | 0 | 0 |
| h | 7 | 6 | 3 | w-p-c | 16 | 6 | 3 | lw-p-c-h | 1 | 0 | 0 |
| w-d | 22 | 19 | 8 | w-p-h | 3 | 3 | 0 | Ow-p-c-h | 0 | 1 | 0 |
| w-p | 83 | 55 | 14 | lw-p-c | 28 | 12 | 3 | d-p | 8 | 18 | 7 |
| w-c | 6 | 8 | 0 | lw-p-h | 13 | 10 | 2 | d-c | 2 | 2 | 1 |
| w-h | 0 | 1 | 0 | Ow-p-c | 4 | 2 | 0 | d-h | 0 | 0 | 1 |
| lw-d | 22 | 11 | 1 | Ow-p-h | 2 | 1 | 0 | p-c | 9 | 5 | 0 |
| lw-p | 85 | 35 | 15 | w-c-h | 0 | 0 | 0 | p-h | 2 | 2 | 0 |
| lw-c | 6 | 3 | 0 | lw-c-h | 0 | 1 | 0 | c-h | 0 | 0 | 0 |
| lw-h | 5 | 0 | 0 | Ow-c-h | 0 | 0 | 0 | d-p-c | 2 | 10 | 2 |
| Ow-d | 4 | 6 | 0 | w-d-p-c | 10 | 3 | 2 | d-p-h | 1 | 1 | 2 |
| Ow-p | 13 | 10 | 3 | w-d-p-h | 3 | 1 | 0 | d-c-h | 0 | 1 | 0 |
| Ow-c | 0 | 1 | 0 | lw-d-p-c | 25 | 12 | 0 | d-p-c-h | 0 | 0 | 0 |
| Ow-h | 2 | 1 | 1 | lw-d-p-h | 10 | 5 | 3 | p-c-h | 1 | 1 | 2 |
| w-d-p | 34 | 34 | 13 | Ow-d-p-c | 3 | 5 | 2 | | | | |
| w-d-c | 3 | 6 | 1 | Ow-d-p-h | 1 | 1 | 0 | | 684 | 488 | 166 |
| w-d-h | 1 | 0 | 2 | | | | | | | | |

[a] Source of information: Special empyema reports made to the Office of the Surgeon General.
w, heavy work; lw, light or limited work; Ow, no work; d, dyspnea; p, pain; c, persistent cough; h, heart symptoms.

TABLE 49[a].—*Data on antecedent diseases and associated microorganisms used in applying the chi-square test.*

| | Simple drainage. | Dakin-part. | Dakin-full. | | Simple drainage. | Dakin-part. | Dakin-full. | | Simple drainage. | Dakin-part. | Dakin-full. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| P-S | 226 | 185 | 58 | B-i | 0 | 0 | 0 | M-p | 12 | 1 | 4 |
| P-p | 160 | 72 | 25 | B-? | 35 | 25 | 14 | M-dp | e 5 | e 4 | e 1 |
| P-dp | a 13 | a 4 | a 4 | I-S | 110 | 90 | 31 | M-Sa | e 3 | e 1 | e 0 |
| P-Sa | a 8 | a 4 | a 0 | I-p | 56 | 74 | 26 | M-i | 0 | 0 | 0 |
| P-i | b 0 | b 1 | b 0 | I-dp | 4 | 8 | 1 | M-? | 52 | 9 | 8 |
| P-? | b 172 | b 54 | b 30 | I-Sa | d 6 | d 1 | d 0 | ?-S | 3 | 1 | 1 |
| B-S | 60 | 91 | 19 | I-i | d 0 | d 1 | d 0 | ?-p | 1 | 1 | 0 |
| B-p | c 26 | c 12 | c 11 | I-? | 38 | 48 | 12 | | | | |
| B-dp | c 4 | c 3 | c 0 | M-S | 54 | 40 | 7 | | 1,050 | 731 | 252 |
| B-Sa | c 2 | c 1 | c 0 | | | | | | | | |

[a] Source of information: Special empyema reports made to the Office of the Surgeon General.
P, lobar pneumonia; B, bronchopneumonia; I, influenza, M, measles; S, streptococcus; p, pneumococcus; dp, "diplococcus"; Sa, staphylococcus; i, influenza bacillus.
a, a, b, b, etc., indicate that the figures in these were combined, respectively, in using these data for making the chi-square test.

## A COMPARISON OF THE CLOSED AND OPEN METHODS IN THE TREATMENT OF EMPYEMA.

Following the institution of aspiration in the treatment of empyema as the immediate remedial measure to be followed by a subsequent thoracotomy, various modifications in treatment were adopted. Chief among these was the instillation of either Dakin's solution, formalin uncombined or in combination with glycerin, or a combination of all of these, through a catheter inserted in a punctured wound in the chest wall. The exudate was aspirated through the catheter and the antispetic was introduced into the cavity. When exudate was no longer formed in large quantities and cultures of the cavity were sterile the catheter was removed and the puncture wound was allowed to heal.

Similar methods of treatment had been attempted previous to the war and had been found untrustworthy. Attempts to treat cases of empyema by simple aspiration had resulted in cure in a small number of cases, but the percentage of permanent cures had been so small that the method never gained

great favor. It must be remembered, however, that these cavities were irrigated in only a few instances and that the treatment was essentially equivalent to open drainage through a small and inadequate thoracotomy wound. With the development of antiseptic solutions which could be used for irrigation, the possibilities of this method were greatly increased. The use of the method was revived at Camp Pike and underwent numerous modifications in the hands of the base hospital staff at that place.[7] Before March 15, 1918, all the cases of empyema which occurred at Camp Pike were treated by rib resection and simple tube drainage without irrigation. On account of the great quantities of pus which drained from the wounds, the dressings were constantly saturated with exudate. Tubes of small caliber were inserted through the wound to the bottom of the cavity and the exudate was aspirated frequently. This obviated the necessity of changing the dressings several times during the day. The mortality among these cases was 42.3 per cent.

Dakin's solution was next employed to irrigate the cavities. After April 15, 1918, a radical change was made in the method of drainage. Diederich [7] suggested that the cavities be aspirated and irrigated through a catheter introduced through a stab wound in the chest wall. The operation was still further modified by the use of a trocar and canula to facilitate the introduction of the catheter.[7] The catheter was introduced after a preliminary diagnostic aspiration, and when the pus had been removed Dakin's solution was intermittently injected into the cavity. The frequent instillations of this antiseptic dissolved the fibrin, and since the catheter did not allow the admission of air the pleural surfaces were held in contact and the lung was kept expanded. The method was further developed by Mozingo,[8] who injected 2 per cent formalin in glycerin in the cavities to obtain final sterility before removing the catheter. The mortality in a series of 113 cases treated in this manner was 7 per cent. This mortality is slightly higher than that at Camp Lee in a series of cases which were treated by aspiration and subsequent thoracotomy, so that a comparison of this method with open drainage after preliminary thoracotomy gives no preference to either with respect to mortality.[6] Both of the methods accomplished a similar purpose; that is, to tide the patient over the critical period of the pulmonary infection. Both series of cases covered a period after April 15, 1918, when the virulence of the infection was subsiding.

Accurate data covering a large number of cases treated by the closed method have not been obtained. A number of the cases recurred and others required secondary operations to bring about healing. In a small percentage sterile pus was found after the catheter had been removed for several weeks. A few of these exudates showed streptococci on culture. An analysis of such data as could be obtained has been attempted in Tables 50 and 51. The analysis comprises a comparison of some antiseptics previously mentioned so that the results of the treatment regarding the number of recurrences, the number of secondary operations required, and the final condition of the patient (his symptoms and his ability to work) may be studied.

In so far as the secondary operations, recurrences, and the length of time required for wound closure are concerned, the closed method gives slightly more favorable results; but when dyspnea, pain, and cough are referred to, the open method of drainage appears preferable. In general, a greater per-

centage of the patients treated by open drainage were able to do heavy work than were those treated by the closed method. In either event, where Dakin's solution was used, regardless of the method of treatment, the results have been better with reference to symptoms and work than among those treated by simple drainage without irrigation or by the closed method with formalin. In either case, Dakin's solution gave better results than the other antiseptics. Bismuth paste was the poorest form of antisepsis.

TABLE 50.[a]—*Operations required after various types of treatment and antisepsis.*

| Treatment. | Operation. | | | | | | | | | | | Recurrence, percentage. | Final wound closure, average days. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | First. | | Second. | | | Third. | | | Fourth. | | | | |
| | Cases. | Interval before operation. | Cases. | Percentage. | Interval before operation. | Cases. | Percentage. | Interval before operation. | Cases. | Percentage. | Interval before operation. | | |
| Dakin-full [b] | 252 | 9.2 | 55 | 21.8 | 132 | 15 | 6.0 | 248 | 6 | 2.4 | 361 | 5.16 | 86.64 |
| Dakin-part [b] | 723 | 8.4 | 175 | 24.2 | 137 | 56 | 7.6 | 249 | 19 | 2.6 | 318 | 6.08 | 97.07 |
| Bismuth [b] | 47 | 8.2 | 20 | 41.7 | 185 | 10 | 21.0 | 365 | 2 | 4.2 | 224 | 16.71 | 99.0 |
| Simple drainage [b] | 1,043 | 6.6 | 190 | 18.2 | 126 | 59 | 5.6 | 244 | 12 | 11.4 | 329 | 7.86 | 84.55 |
| Simple drainage with suction | 69 | 6.9 | 15 | 21.9 | 151 | 15 | 5.6 | 237 | ..... | ..... | ..... | 3.3 | 66.2 |
| Catheter drainage: | | | | | | | | | | | | | |
| *a*. Formalin and glycerin | 18 | ..... | 1 | 5.5 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 5.5 | ..... |
| *b*. Dakin's solution and glycerin | 39 | ..... | 3 | 7.6 | ..... | 2 | 5.1 | ..... | ..... | ..... | ..... | 5.5 | 41.5 |
| *c*. Dakin's solution | 72 | ..... | 13 | 18.0 | ..... | 5 | 6.9 | ..... | ..... | ..... | ..... | 5.5 | 66.0 |

[a] Source of information: Special empyema reports made to the Office of the Surgeon General.
[b] These figures are subject to the same interpretation regarding transfers of cases from simple drainage to treatment with sodium hypochlorite solution as are the figures in the tables for the intervals of wound closure.

TABLE 51.[a]—*Symptoms and ability of patients to work after various types of treatment and antisepsis.*

| Treatment. | Dyspnea, percentage. | Pain, percentage. | Cough, percentage. | Cardiac symptoms, percentage. | Heavy work, percentage. | Light work, percentage. | No work, percentage. |
|---|---|---|---|---|---|---|---|
| Dakin-full [b] | 29.4 | 39.7 | 9.1 | 9.1 | 50.0 | 40.9 | 9.1 |
| Dakin-part [b] | 27.4 | 39.2 | 12.7 | 6.5 | 52.6 | 35.5 | 11.9 |
| Bismuth [b] | 31.3 | 39.6 | 12.5 | 12.5 | 54.1 | 16.68 | 29.15 |
| Simple drainage [b] | 49.9 | 81.0 | 20.1 | 22.0 | 45.0 | 35.7 | 8.0 |
| Simple drainage with suction | 17.5 | 34.9 | 8.9 | 6.3 | 50.74 | 36.92 | 12.32 |
| No operation | 19.4 | 35.8 | 8.5 | 6.7 | 63.6 | 35.42 | 9.9 |
| Catheter drainage: | | | | | | | |
| *a*. Formalin and glycerin | 64.29 | 57.14 | 28.57 | 7.1 | 28.57 | 42.86 | 28.57 |
| *b*. Dakin's solution and glycerin | 41.38 | 51.71 | 20.69 | 13.79 | 51.76 | 41.40 | 6.90 |
| *c*. Dakin's solution | 29.10 | 45.80 | 20.80 | 12.00 | 45.00 | 50.00 | 5.00 |

[a] Sources of information: Reports of sick and wounded made to the Office of the Surgeon General and special empyema reports made to the Office of the Surgeon General.
[b] These figures are subject to the same interpretation in regard to transfers of cases from simple drainage to treatment with sodium hypochlorite solution as are the figures in the tables for the intervals of wound closure.

## THE PREPARATION AND ACTION OF NEUTRAL SOLUTION OF SODIUM HYPOCHLORITE (DAKIN'S SOLUTION).

Neutral solution of sodium hypochlorite was used so extensively in the treatment of infected wounds throughout the war that it seems proper to introduce a description of the methods used in the preparation of the solution and a brief résumé of the manner in which it acts on bacteria and on living tissue. Three methods were used. The choice of the method depended, of course, on the facilities available at the base hospital where the solution was prepared. The formulæ followed in preparing the solutions have been transcribed as a matter of record.

1. PREPARATION FROM BLEACHING POWDER, WASHING SODA, AND BORIC ACID.

This is the original formula for making the neutral solution of sodium hypochlorite devised by Dakin.[9] The boric acid rendered the solution neutral when it was first prepared and maintained essential neutrality when it was used. This acid, being polybasic, formed a variety of salts which, through shifts in their relative proportions, tended to preserve the equilibrium in reaction.

To make 10 liters of the solution, 400 grams of washing soda (crystals) or 140 grams of dry sodium carbonate were dissolved in that amount of water; 200 grams of bleaching powder (the "Chloride of lime" or chlorinated lime of commerce) containing from 24 to 28 per cent of available chlorine were added. The mixture was shaken thoroughly to promote contact and to render the calcium carbonate, which was at first precipitated as a white cloud, granular, so that it could be removed by filtration. Ultimately, it was a saving of time to devote as much as 10 minutes to this constant agitation of the mixture, so it was most convenient to use a well-corked bottle for making the solution. After shaking, the mixture was allowed to stand for half an hour or longer. When the precipitate had settled the clear supernatant liquid was siphoned off and filtered through paper or a cotton plug inserted in the neck of a funnel. Forty grams of boric acid were dissolved in this clear filtrate, which was then ready for use.

If the bleaching powder contained 25 per cent of available chlorine and all of it entered into the reaction with the sodium carbonate, the resulting solution would contain 0.5 per cent of sodium hypochlorite.

The reaction taking place between calcium hypochlorite and sodium carbonate is expressed by the equation:

$$(1)\quad Ca(OCl)_2 + Na_2CO_3 = CaCO_3 + 2NaOCl.^a$$

But bleaching powder contains not only calcium hypochlorite, but several other constituents. Among these are calcium chloride and calcium hydrate which also react with sodium carbonate:

$$(2)\quad CaCl_2 + Na_2CO_3 = CaCO_3 + 2NaCl.$$

$$(3)\quad Ca(OH)_2 + Na_2CO_3 = CaCO_3 + 2NaOH.$$

The third reaction results in the formation of sodium hydrate. It was chiefly to neutralize this sodium hydrate that the boric acid was added. Inasmuch as the amount of calcium hydrate in bleaching powder varied considerably, it was important to determine whether the amount of boric acid used was actually sufficient to effect neutralization with the particular lot of bleaching powder. This was determined readily by sprinkling a few particles of solid phenolphthalein upon the surface of the solution. If the solution was alkaline, a pink color was developed. In this case more boric acid was added. If the particles did not become pink, an adequate amount of boric acid had been added. An excess of boric acid reduced the keeping qualities of the hypochlorite solution.

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[a] The active or available chlorine in bleaching powder is sometimes assumed to be combined with calcium in conjunction with chlorine in the inactive state. On this assumption the reaction with sodium carbonate is expressed by an equation intermediate between (1) and (2): $Ca\begin{matrix}Cl\\O-Cl\end{matrix} + Na_2CO_3 = CaCO_3 + NaCl + NaOCl.$

2. THE PREPARATION FROM BLEACHING POWDER WITHOUT THE USE OF BORIC ACID.

This formula was proposed by Daufresne.[10] The idea upon which it was based was the use of carbonic acid in place of boric acid to secure neutrality. The requisite amount of carbonic acid was supplied by substituting an appropriate amount of sodium bicarbonate for a part of the sodium carbonate in Dakin's original formula. The proportion of sodium carbonate to sodium bicarbonate required to attain this result depended upon the composition of the bleaching powder, and particularly upon the amount of calcium hydrate it contained.

For the ordinary brands of bleaching powder the following proportions gave good results: Two hundred grams of bleaching powder containing from 24 to 28 per cent available chlorine were dissolved in 5 liters of water. The solution was allowed to stand for an hour. Ninety-four grams of dry sodium carbonate (or 265 grams washing soda in crystals) and 86 grams of sodium bicarbonate were dissolved in 5 liters of cold water in a separate container. These solutions were mixed and thoroughly shaken. When the granular calcium carbonate had settled the supernatant fluid was siphoned off and filtered.

If the solution prepared in this way were alkaline when tested with solid phenolphthalein, it was neutralized with boric acid, or carbon-dioxide gas was passed into the solution until there was no reaction with phenolphthalein. When this neutralization was necessary, the amount of bicarbonate was increased and the carbonate correspondingly reduced until the proportion suiting the particular bleaching powder used was found.

3. THE PREPARATION WITH SODIUM CARBONATE AND CHLORINE GAS.[11]

Chlorine gas was passed into a solution containing 15 grams of dry sodium carbonate (17.6 grams of the monohydrate or 40 grams of washing soda) to the liter, 4.8 grams (about 1,700 c. c.) of the gas were required for each liter of the solution. The reaction which takes place between the sodium carbonate and chlorine may be divided into two stages:

$$(1)\quad 2Na_2CO_3 + 2Cl + H_2O = NaOCl + 2NaHCO_3.$$

$$(2)\quad 2NaHCO_3 + 2Cl = NaOCl + NaCl + 2CO_2 + H_2O.$$

The final products are sodium hypochlorite, sodium chloride, and carbon dioxide.

This method of preparing sodium hypochlorite was expeditious and simple in every respect except for the determination of the amount of chlorine necessary. The chlorine was furnished in liquid form, in steel cylinders. A chlorine meter adapted for use with these cylinders was supplied to the base hospitals. A tube ending in an unglazed porcelain diffuser was used to pass the chlorine into the solution. It was necessary to test the solution with great care to make sure that the requisite amount of chlorine and no excess was retained. There are, of course, sources of error in estimating the weight of chlorine by measuring its volume, because the latter is affected by changes in both pressure

and temperature. If the correct volume was once determined according to the meter and the conditions were kept uniform these errors were eliminated.

The sodium hypochlorite solution prepared in this way lacked the "buffer salts" contained in solutions made according to the original formula. The convenience of the method and the rapidity with which large volumes of the solution could be prepared occasioned its wide use in the military hospitals where from 60 to 80 liters were required each day.

### 4. TESTING THE STRENGTH OF DAKIN'S SOLUTION.

As a result of experimental and clinical observations it was concluded that the satisfactory action of the solution as a surgical antiseptic depended chiefly upon the concentration of available chlorine and the reaction. The reaction was approximately neutral, and the hypochlorite content was not less than 0.4 per cent and not more than 0.5 per cent. Later experience confirmed these conclusions. If the hypochlorite content of the solution was below 0.4 per cent, its efficiency as a germicide was very greatly reduced; if the concentration was above 0.5 per cent, the solution was unduly irritating. These limits were so narrow that in view of the variations in strength likely to occur in the preparation of the solution because of differences in the composition of the materials used or in the manipulations, it was necessary to determine the strength of the solution when it was first prepared. The liability of deterioration after a few days made these tests necessary if solutions were not used immediately after preparation.

The determination of hypochlorite concentration was made by titrating, with a decinormal solution of sodium thiosulphate (24.82 grams of the crystallized salt ($Na_2S_2O_3$ $5H_2O$) dissolved in 1,000 c. c. of distilled water). One cubic centimeter of this thiosulphate solution (N/10) is equivalent to:

0.0127 gram iodine.
0.00354 gram chlorine.
0.00262 gram hypochlorous acid, HOCl.
0.00372 gram sodium hypochlorite, NaOCl.
0.01407 gram chloramine-T, $CH_3$, $C_6H_4$, $SO_2NaNCl$.
0.006 gram dichloramine-T, $CH_3$, $C_6H_4$, $SO_2NCl_2$.

In addition to the standard solution of sodium thiosulphate, the reagents required were a 10 per cent solution of potassium iodide; pure acetic acid, 10 per cent; and starch paste, prepared by boiling about 0.1 gram of starch with 100 c. c. of water.

The titration was made in the following manner: Five c. c. of the iodide and acetic acid solutions were added to 10 c. c. of solution. This mixture at once turned brown on account of the liberation of iodine. The decinormal thiosulphate solution was dropped from a graduated burette until the brown color nearly disappeared. A few drops of the starch paste were added and the titration was continued until the mixture was colorless. The number of cubic centimeters of standard thiosulphate solution, required to complete this reaction, multiplied by the factor 0.00372 (see above) gave the weight of sodium hypochlorite in the 10 c. c. of Dakin's solution taken for the determination. This multiplied by 10 gave the percentage strength.

## TESTING THE REACTION OF DAKIN'S SOLUTION.

If the solution was too alkaline it was unduly irritating to the tissues; if too acid it deteriorated rapidly. Solutions were prepared which did redden particles of solid phenolphthalein sprinkled upon the surface. An empirical test for undue acidity consisted in expressing about 0.5 c. c. of one per cent alcoholic solution of phenophthalein from a medicine dropper into about 5 c. c. of the solution to be tested. Solutions of the proper alkalinity showed a momentary flash of red. If there was not at least a momentary flash of red, the alkalinity of the solution was not sufficient to prevent rapid loss in hypochlorite content.

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## CHAPTER V.

## THE RÔLE OF THE ROENTGEN-RAY LABORATORY IN THE STUDY AND TREATMENT OF EMPYEMA.

The Roentgen-ray laboratory was utilized probably more generally throughout the Army camps than any other laboratory which was designed to assist the clinician and surgeon in diagnosis. In the first place, it furnished evidence of organic lesions which could be preserved as a definite record of the condition at the time the exposures were made, and these records could be compared with those obtained at later stages of the disease; second, it was not time consuming and might be used to confirm diagnoses which could not be made with certainty by physical examination alone; third, it very largely eliminated personal opinion because of the objective character of the evidence it gave. Although the elimination of personal opinion in regard to the clinical aspects of disease is not usually to be desired, it was necessary in many instances on account of the time which might be saved by turning to the roentgenologist for a diagnosis. More evidence was often secured in a brief time than could be gleaned from an extended clinical study. This was true in surgical conditions which were the result of injury when immediate diagnosis was necessary. No delay was warranted. In medical diagnosis, however, more time might be spent in clinical study, and the Roentgen ray was then used as a confirmatory method. In unusual conditions or in cases of doubtful diagnosis it aided the internist immeasurably.

This indebtedness to the radiographer was particularly great in the diagnosis and care of the numerous cases of pleuritis which occurred in America during the mobilization and training of the Army. Similar epidemics had been encountered in previous wars, but the knowledge and experience acquired then were not abreast of the modern methods in medicine, and the records made at these times were correspondingly incomplete on many aspects of the disease. The first clear conception of these fulminating pulmonary infections came from the post-mortem evidence of their pathology. On account of the errors which the clinician was frequently led to make, both because of his inexperience with the disease and the unreliability of the physical signs in many of the cases, it then became customary to follow pneumonia radioscopically from the onset of the infection. The aid rendered in the diagnosis of pneumonia and pleuritis was invaluable, especially because it was not only applicable during the acute stages of the disease but assisted the surgeon after the case had come under his care. Since the great preponderance of disease among the personnel of the Army was respiratory (there was not only the epidemic of measles and streptococcus pneumonia, but in addition a wave of influenza of unparalleled severity), the rôle played by the roentgenologist may easily be imagined.

Previous to the war the roentgenologist had attained a high degree of efficiency in the study of pulmonary tuberculosis. Much of this work was done in conjunction with the clinician, or the physician who was especially

interested in thoracic medicine interpreted his own radiograms. Although it was possible to maintain a sympathetic association such as this in the Army hospitals, circumstances frequently made it impracticable from both the technical and the administrative standpoints. As a result there was a tendency for each department to carry on its allotted function without sufficient correlation with the other branches of the hospital service. When the epidemic of pneumonia swept the cantonments in the eastern part of the United States in 1917 and 1918, the diagnostic value of fluoroscopic examinations and of roentgenograms was quickly realized, and the impetus given the study of acute respiratory diseases was remarkable. The necessity for accurate diagnosis was impressed on every Army physician. The attempt to lessen the mortality by a more thorough knowledge of the disease led to a free interchange of ideas between the roentgenologist and the ward surgeon. As empyema developed and cases came to operation, the surgeon again strengthened this intercourse. Plates were often essential in locating encapsulated pockets of pus. They were necessary in the intelligent treatment of chronic cavities and sinuses when large decortications or constructive surgery were indicated, because there was no other means by which the extent and location of these cavities could be determined so accurately. Hence the surgeon often depended on stereoscopic plates of the injected cavities to assure himself of the necessity for interference or of the extent and character of the operation required. In these ways, on account of the fact that the roentgenologists had facts to offer which could not be supplied by clinical experience and judgment alone, the bond between the ward, the operating room and the X-ray laboratory of a necessity became more firm.

The equipment found to be necessary followed the demand made by these cases. During 1917 and the early months of 1918 the hospitals were equipped with stationary radiographic apparatus. Since there were no portable sets at that time, it was necessary to carry patients to the laboratory. Frequently, even when examinations were much needed, it was undesirable to move those who were critically ill, so bedside units were introduced to obviate this circumstance. These bedside units were perfectly serviceable for the confirmation of the diagnosis of pneumonia or the detection of fluid, and in some respects, particularly because the record was permanent, they were superior to the fluoroscope, which gave no advantageous technical detail and involved moving the patient. In examinations for the localization of encapsulations or for the study of cavities after operation, they were not as valuable as the standard tables and stands, since they did not afford facilities for stereoscopic plates.

The important functions of the Roentgen-ray laboratory during the drainage period were the study of the chronic cavities and the detection of pus pockets. Stereoscopic plates were always more valuable for these purposes. When the wounds were healed there was often some difficulty in excluding the presence of an active tuberculous lesion unless stereoscopic plates were made. These plates showed greater detail, but definite diagnosis was at times impossible. In general there was no great improvement in the type of apparatus employed in thoracic work aside from the development of the portable bedside units and the application of tubes which could be operated successfully at a low amperage.

The methods utilized in the study of pneumonia and empyema were modified to some extent when it was found that there was need for improvement in the technique employed. Previous to the war it had been the custom with many roentgenologists to expose chest plates with a relatively high amperage and to correspondingly shorten the time of exposure. Greater detail was secured in this manner when stereoscopic plates were desired, since it was possible to eliminate some of the respiratory movement by the shortened exposure. After the spring of 1918, however, the maximum milliamperage was limited to 45 by an order from the Surgeon General's Office.[1] This memorandum was issued with the idea that the time during which Coolidge tubes were serviceable could be lengthened when a low amperage was used. This limited amperage did not affect the routine examinations, but if patients were especially dyspneic a milliamperage of 60, with an exposure of one or two seconds, at times resulted in clearer roentgenograms. The methods used in the study of cavities and sinuses were improved in some instances to secure more accurate roentgenograms, but the modifications were slight. The chief developments were in the direction of keener interpretation, the greater utilization of available modes of study, and the dissemination of the acquired experience among the physicians in the Army at the time.

Cases of empyema pass through three stages. These stages are a formative period, which includes the interval between the onset of the effusion and the time at which surgical drainage is instituted; the period of drainage proper, either by an open or closed method; and the period of convalescence after actual healing of the external wound. Although a division which is based on the method of treatment and the therapeutic requirements of the patient might be considered somewhat unsound, since it is not primarily pathological in its inception, it nevertheless affords an actual working basis for a consecutive consideration of the various applications of the Roentgen ray, as the objects and purposes for which it was employed during these periods were distinctly different. With this division in mind, the following text has been written in three parts.

## THE FORMATIVE OR PREOPERATIVE STAGE.

### RELATION BETWEEN PNEUMONIA AND EMPYEMA, AS SHOWN BY ROENTGEN-RAY STUDIES.

The occurrence of empyema is so intimately associated with pneumonia that it is difficult to consider the two separately with precision. Since one follows the other, such a separation is possible in typical lobar pneumonia and the subsequent empyema, but is difficult in streptococcus infections because the effusions occur in all stages and degrees of lung infection, and can less frequently be considered postpneumonic. When streptococcus infections were common, in 1917 and 1918, it was not an unusual thing to discover a large effusion when there had been no previous clinical evidence of parenchymal lung involvement. To demonstrate an actual pneumonia under these conditions, examinations were necessary before the physical signs were obscured or modified by the presence of fluid. It is noteworthy that it was as frequently impossible to discover consolidation by roentgenograms when the early clinical symptoms pointed to a pleuropulmonary infection. There is no reason to suppose that

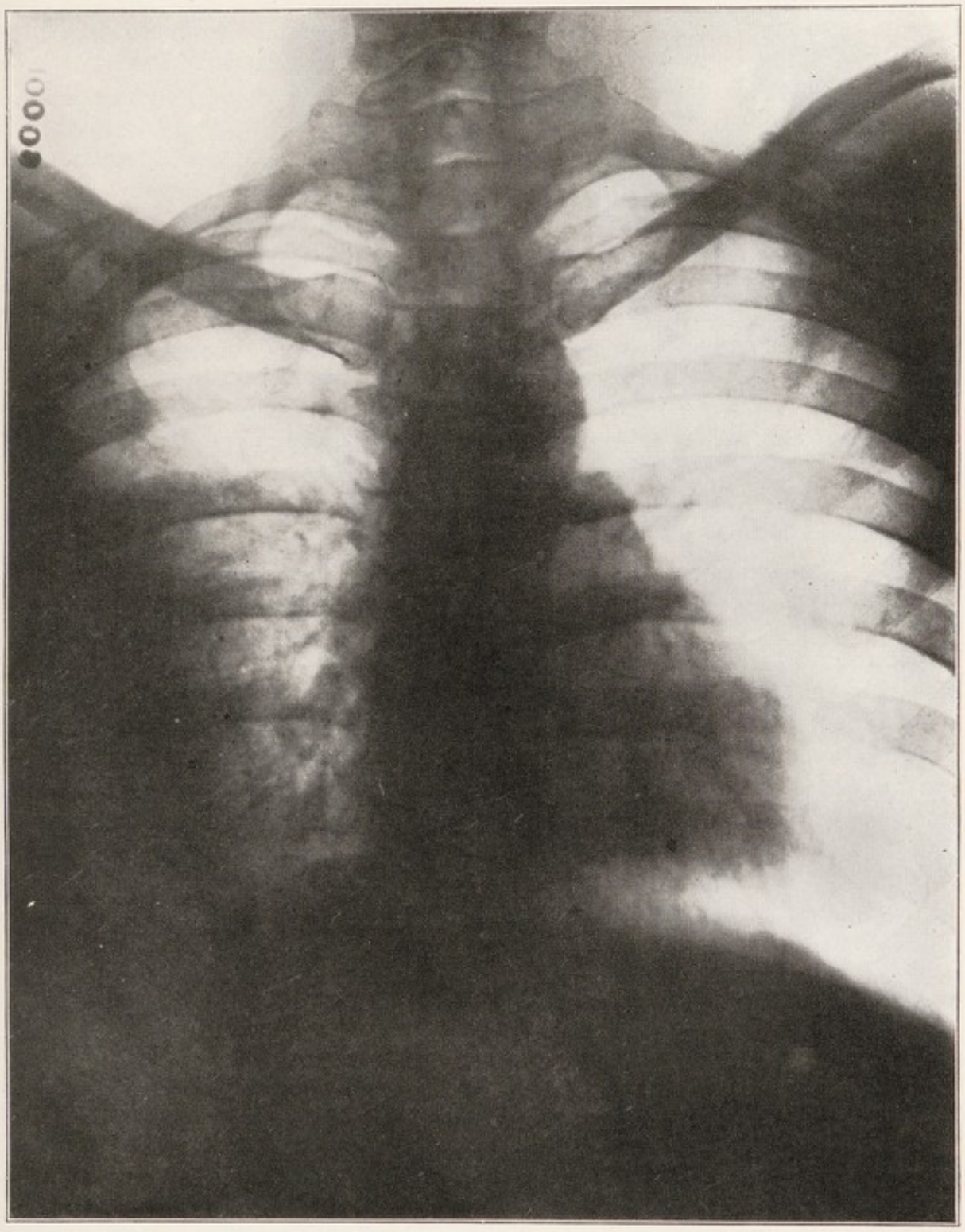

FIG. 23.—Roentgenogram illustrating an encapsulated empyema following lobar pneumonia.

in these streptococcus cases there was not an actual involvement of the lung antedating the effusion, but before there was sufficient consolidation, apparent either by percussion or in roentgenograms, the affected half of the chest was so filled with fluid that all lung detail was obscured. It was in cases of this type that the later clinical findings were so confusing as to cause difficulty in distinguishing between massive pleuritis and consolidation. It was always possible to make a decision with the fluoroscope or a single plate.

Later when effusion occurred, after evidence was definitely established pointing to a lobar pneumonia type of consolidation, or to an irregular diffuse bronchopneumonic type of consolidation, the transitional stages in the pneumonic shadows were easily followed. The type of lobar pneumonia most frequently encountered first gave a sharply limited shadow of varying density, which increased with the degree of consolidation and was less and less marked as resolution progressed. When empyema followed the pneumonia, especially if it had been confined to a part of the lung at some distance from the diaphragm, so that the shadow was discrete and distinct, the lung detail was obscured by the more even diffuse shadow of the exudate, which did not clear within the period of seven or eight days normally required for resolution. When the pneumonia was at the base of the lung and the axillary margin was involved, the fluid often obliterated the diaphragmatic angle. More frequently there was only a dense shadow posteriorly over the lower lobe.

The bronchopneumonia which was prevalent was a generalized patchy involvement of several lobes with a tendency to become confluent in various areas. The plates were perfectly distinctive in that they showed the irregular distribution of the consolidation. The effusions which occurred in these cases were either free or encapsulated, but in either case they were of greater density than the areas of consolidation. Wherever fluid accumulated, the lung structure and the patchy appearance of the bronchopneumonia were obscured by the dense homogeneous shadow of the exudate. Ordinarily, plates at intervals of two or three days showed the lungs resuming their normal density, while the shadows of the encapsulations persisted. Resolution was occasionally so slow that small encapsulations were not easily detected on account of the similarity between the appearance of small pus pockets, with considerable parenchymal involvement of the adjacent lung tissue, and the patchy shadow of an early bronchiectasis, with considerable peribronchial infiltration which sometimes supplanted the shadow of the bronchopneumonia.

The shadow of the empyema following lobar pneumonia occurred where the lung had previously shown the greatest involvement. Although it was not always sharply limited in the roentgenograms to that part of the lung surface which had appeared consolidated, the location was approximately that of the pleura which had been involved by the pneumonia. Lobar pneumonia was most frequent in the lower lobes and the shadow of the subsequent empyema was most intense over the lower posterior or lateral pleural surface corresponding to the area of consolidation. This is shown in Figure 23.[a] Under varying conditions there were other areas where the first lung changes incident to the infection were observed. One of the commonest sites during the influ-

[a] The roentgenograms used to illustrate this chapter were obtained from Base Hospital, Camp Lee, Va., General Hospital No. 12, Biltmore, N. C., and Walter Reed General Hospital, Washington, D. C. They were photographed at the Army Medical Museum.

enza epidemic was just lateral to the hilus of the lung.[2] Pneumonia, following influenza, although caused by pneumococci in most instances, was secondary and can not be classed as typically lobar; but when the pneumococcus was found to be the predominating organism in the sputum and the pleural fluid, the shadows of the pneumonia and the empyema usually occupied successively the same area of the pleural surface. There was not always the sharp coincidence found in the lobar type of distribution, but probably this may be explained by the fact that influenzal pneumonia had a bronchopneumonic type of distribution. The pus in all of the pneumococcus cases was apparently so surrounded by adhesions and was produced in such minor quantities that it did not invade the entire pleural cavity, consequently shifting of the fluid shadow could seldom be demonstrated. A consideration of the pathology of the pleuritis complicating pneumococcus pneumonia, which comprises a gradual infiltration of the fibrinous pleural exudate overlaying the pneumonia with leucocytes and pneumococci, accounts for the course followed by these cases.

### THE FLUID SHADOW AND THE EFFECTS OF THE ACCUMULATED EXUDATE.

The effusions containing hemolytic streptococci were usually large in amount. This was especially true of those which occurred early in the pneumonia or developed before there was roentgenologic or clinical evidence of consolidation. Since the chest was very quickly filled with fluid, once effusion had begun, opportunity was afforded for a study of the displacement of the mediastinal structures and variations in the aeration of the lung due to the accumulation of exudate before and after drainage. The course of these cases was especially instructive when followed from the beginning of the effusion in conjunction with the roentgenologist.

For the first examination of these cases of fulminating pleurisy either a single plate or the fluoroscope was found satisfactory. The fluoroscope showed disturbed function which could not be demonstrated readily with plates, but on the other hand plates often aided in the localization of small consolidated areas which might be overlooked on the screen. Immediately following the onset of these infections which were at first predominantly pleural, fluoroscopic examination showed a distinct limitation of motion on the affected side before any great amount of fluid had developed. Apparently this limitation of motion was largely voluntary at this stage and resulted from an effort on the part of the patient to lessen the pain. The diaphragm was practically immobile and the chest wall was fixed in a degree of partial expansion. That this was largely a reflex effort was evident from a few observations on patients who developed fluid so slowly that the visceral and parietal pleuræ in the axillary region were at first scarcely separated, and examinations were possible after the pain had partly subsided, yet the chest had not filled with sufficient fluid to hinder the respiratory excursion. As soon as the pain had subsided the spasm was relieved. The fixation of the chest wall with the lung partly expanded was probably due to the greater relief afforded the patient when this position was maintained, since it permitted a greater degree of unilateral fixation of the chest wall than was possible when the lung on that side was either fully

expanded or contracted. The relief afforded was always greatest when the affected lung was slightly expanded. Increase in the effusion, and later consolidation and adhesions, account for the limited respiratory movements which were observed during the pneumonia and after the drainage of the empyema.

When one was fortunate to secure roentgenograms of an early diffuse pleuritis, the fluid shadow was first observed in the lower axilla, but when considerable fluid had developed this shadow was most dense above the dome of the diaphragm. The fact that the fluid causing the lung to be separated from the chest wall as the costophrenic angle was filled was first apparent in the axilla, does not indicate necessarily that the exudate formed a thicker layer there than over any other part of the lung. It does indicate, however, that a small amount of fluid, spread evenly over the axillary and posterolateral surfaces of the lower lobe, is capable of obstructing the ray to a greater extent in this region. This is due to the greater depth of fluid through which the roentgen rays must pass when the chest is viewed in the anteroposterior position. The shadow first filled the costophrenic angle, then as the exudate increased, the axillary region acquired a density nearly equal to that of the rest of the lower chest, while the lung which was compressed into the upper part of the pleural cavity left a clear area near the apex.

Expansion following drainage could not be observed as satisfactorily as the compression of the lung by the fluid. When the exudate was removed through a catheter so that air was not admitted to the cavity, the expanding lung showed the reverse of the picture just described. The pleura by this time was covered by a layer of fibrin which cast a moderate shadow after the cavity had been emptied as completely as was possible. After the exudate was aspirated there was greater penetration of the upper thorax, while shadows due to the pleura at the base and near the drainage site persisted. Frequently these parts of the chest did not clear entirely until long after the drainage wound had healed. The fluoroscope or single plates were useful during the period of aspiration to indicate the frequency with which the exudate should be removed.

The radioscopic study of large exudates offered evidence which confirmed certain established principles in regard to the aeration of the lungs and the displacement of the mediastinal organs. The displacement of the mediastinal structures which occurs with large unencapsulated effusions has been an important diagnostic sign of fluid from the standpoint of physical diagnosis and of the interpretation of plates. There are changes in the aeration of the lungs accompanying this displacement which are apparently a result of the pressure exerted by the fluid within the cavity. It is obvious that with fluid in one of the pleural cavities sufficient to displace the mediastinal tissues there must be a change in the pressure to which the lungs are subjected. With the increasing pressure in one side of the thorax due to an influx of fluid the heart and other structures are pushed toward the opposite side. At first the lung on the side which contains the fluid is found compressed in the upper part of the chest with but slight displacement of the heart and the tracheal shadows. If fluoroscopic examinations are made at this time the opposite lung is found to undergo complete aeration, but after further displacement of the mediastinal shadow

by larger amounts of fluid, the aeration of the healthy lung is impeded by the pressure. According to the work of Graham and Bell,[3] one should suspect that approximately equal pressures would be maintained on the opposite sides. This would account for the diminished aeration of the healthy lung, since the negative pressure which exists in the healthy pleural cavity would be diminished by an influx of fluid on the opposite side. There is a point in this connection which indicates that the mediastinal structures may bear part of the increased pressure of the fluid and so maintain a pressure on the healthy side which more nearly approaches normal. The study of a number of chests with massive unilateral effusions has shown that the displacement is not always proportional to the amount of fluid in the pleural cavity. The lung on the affected side has been forced so firmly into the upper part of the pleural cavity and is so surrounded by fluid that the chest was of nearly uniform density with but little mediastinal displacement, while roentgenograms of similar chests have shown great displacement of the midthoracic organs. The only explanation which might account for this variation is that the mediastinum had different degrees of mobility, so that similar pressures in different individuals caused greater displacement in some than in others. When the pressure was relieved by the removal of fluid without the admission of air into the pleural cavity, the healthy lung acquired its original density. This can be explained either by the relaxation of the lung when the cubic contents of the pleural cavity were increased as the mediastinum returned to its normal position, or by the readjustment of the intrathoracic pressures. The mediastinal shadow, however, did not assume the normal position at once, but returned to the midline gradually. It is possible that the elasticity of the tissues separating the pleural cavities had been temporarily diminished by the tension to which they had been subjected, and furthermore, that sufficient fluid could not be removed by aspiration to reestablish normal pleural pressures immediately.

Three roentgenograms illustrating the effects of a unilateral effusion have been introduced into this chapter. Figures 24 and 25 were made at short intervals before the pleural cavity was drained, and Figure 26 immediately after the fluid had been withdrawn through a snugly fitted catheter. In Figure 24 the left cavity is obscured by the shadow of a massive effusion which is of sufficient density to obscure the rib shadows except at the apex and in the lower axilla. The heart and trachea are found moderately displaced. This displacement is more marked in Figure 25, in which the increasing effusion has still further obscured the shadows of the ribs and forced the mediastinal organs farther into the opposite cavity, resulting in a decreased aeration of the healthy lung. In Figure 26, obtained on the day following drainage, there is increased penetration of both lungs, indicating that on the left side the removal of the fluid has allowed the lung to expand and on the right that the lung is no longer compressed by the displaced mediastinal organs. The shadows show that although the trachea and upper mediastinum have returned to their normal positions the heart is still displaced. These illustrations show the characteristic changes accompanying the fulminating streptococcus effusions mentioned in the preceding paragraphs.

FIG. 21.—Roentgenogram illustrating a large pleural effusion complicating a streptococcus bronchopneumonia.

FIG. 25.—Roentgenogram illustrating the displacement of the mediastinal and heart shadows. This exposure was made two days after the one reproduced in Fig. 24.

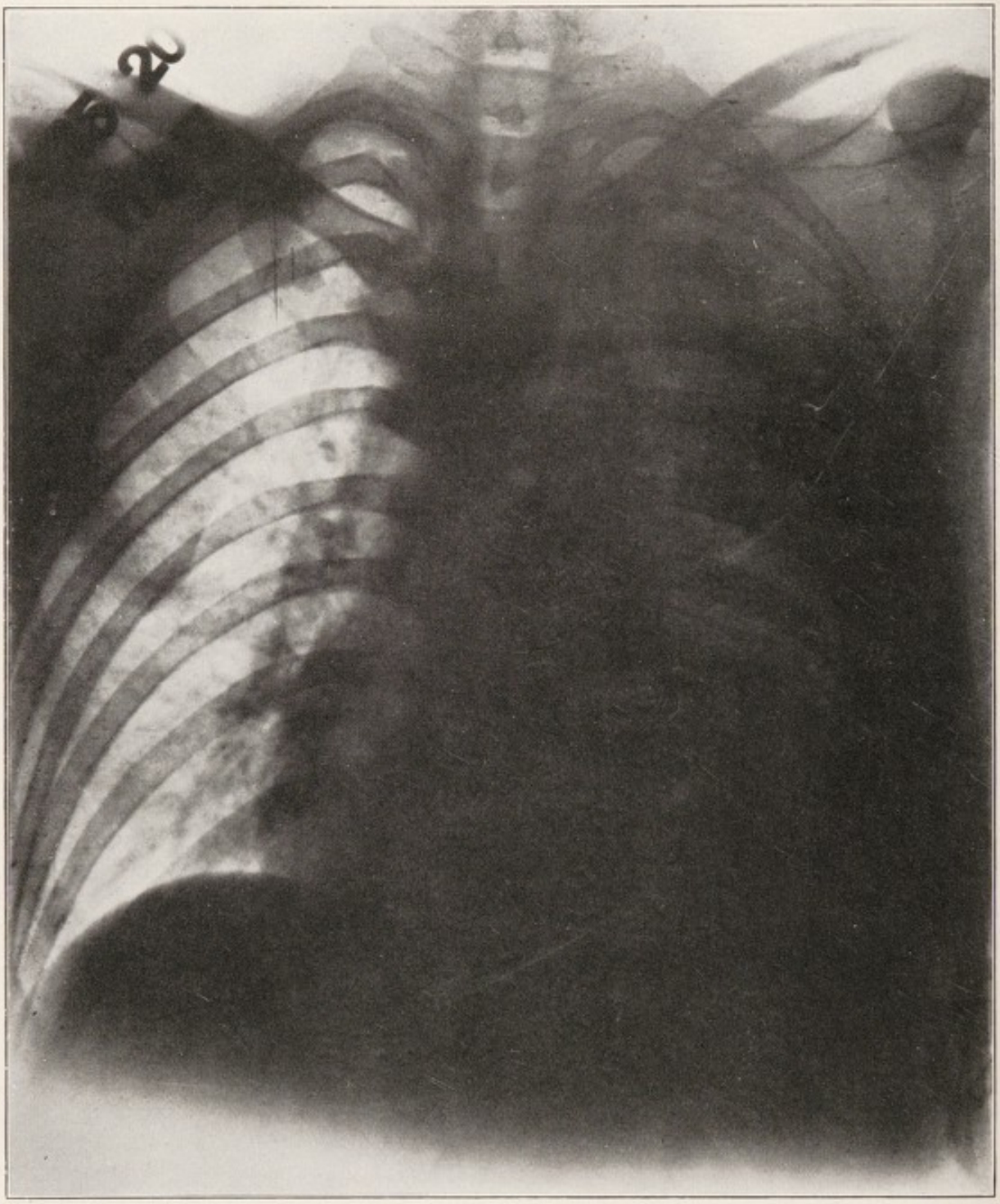

FIG. 26.—Roentgenogram showing the effect of catheter drainage (closed method of treatment) on the effusion illustrated in Figs. 24 and 25.

## ENCAPSULATIONS AND LUNG ABSCESSES.

Encapsulations of pus were not unusual in streptococcus infections but were often so obscured by large free effusions or by consolidated lung that they were not discovered until after drainage, or after resolution of the pneumonia. They were most frequent where the parietal and visceral pleuræ had been in contact along the anterior lappet of the lung, between the lung and the pericardium, or between the lobes. It was not infrequent to find an encapsulation anterior or lateral to the apex where the lung had been floated against the chest wall by a large exudate. These encapsulations occasionally occurred behind the hilus near the vertebræ, where they were not easily detected because of the difficulty in distinguishing the shadow from that of the root of the lung.

The pus pockets which were formed during the acute inflammation of the pleura and the accumulation of a large exudate were usually anterior, between the lobes, or paravertebral. These locations were the regions in which the visceral and parietal pleuræ were held together by the buoyant effects of the fluid and in which encapsulation occurred when part of the free exudate was surrounded by adhesions. In many instances when empyema occurred after the bronchopneumonic process was well developed, the effusions were small and were not free in the pleural cavity; they resembled the empyema occurring after lobar pneumonia, in so far as they were limited to the surface of lung areas which had shown the greatest consolidation. Due to the irregular distribution of the areas of consolidation these encapsulations were often multiple.

Exudates limited to the interlobar cleft originated either in a pleuritis which developed soon after the onset of the infection or were subsequent to pneumonia involving the adjacent parts of the lung. On account of the oblique position of the interlobar fissure the appearance of these infections varied in roentgenograms taken in the anteroposterior position according to the type and extent of the inflammation. The localized pleuritis appeared either as a narrow line extending outward from the hilus toward the periphery, or as a cone-shaped shadow with its base situated at the margin of the lung.

The narrow shadows occurred with greatest frequency among the cases which did not require subsequent operation, so that it was assumed they represented a localized fibrinous pleuritis involving but a small part of the pleura between the lobes. The wider shadows were more often associated with purulent exudates which necessitated drainage. From the post-mortem pathology it is probable that in many instances abscesses were an intermediary factor between the pneumonia and the infection of the interlobar pleura, but it was impossible to demonstrate them by roentgenograms. Very often after an interlobar pleuritis had resolved without surgical interference the shadow of the thickened pleura persisted as long as the case could be followed.

Pockets of pus between the pericardium and lung or between the lung and vertebræ were difficult to diagnose when the pus was spread over the pericardial shadow. Further consideration of these cases, however, shows that the heart shadow was not increased in all directions except by a pericardial effusion or an acute cardial dilatation. It is true that some of the encapsulations between the left lung and the pericardium were so large that the right heart border was occasionally displaced, but in these cases the outline along the left border

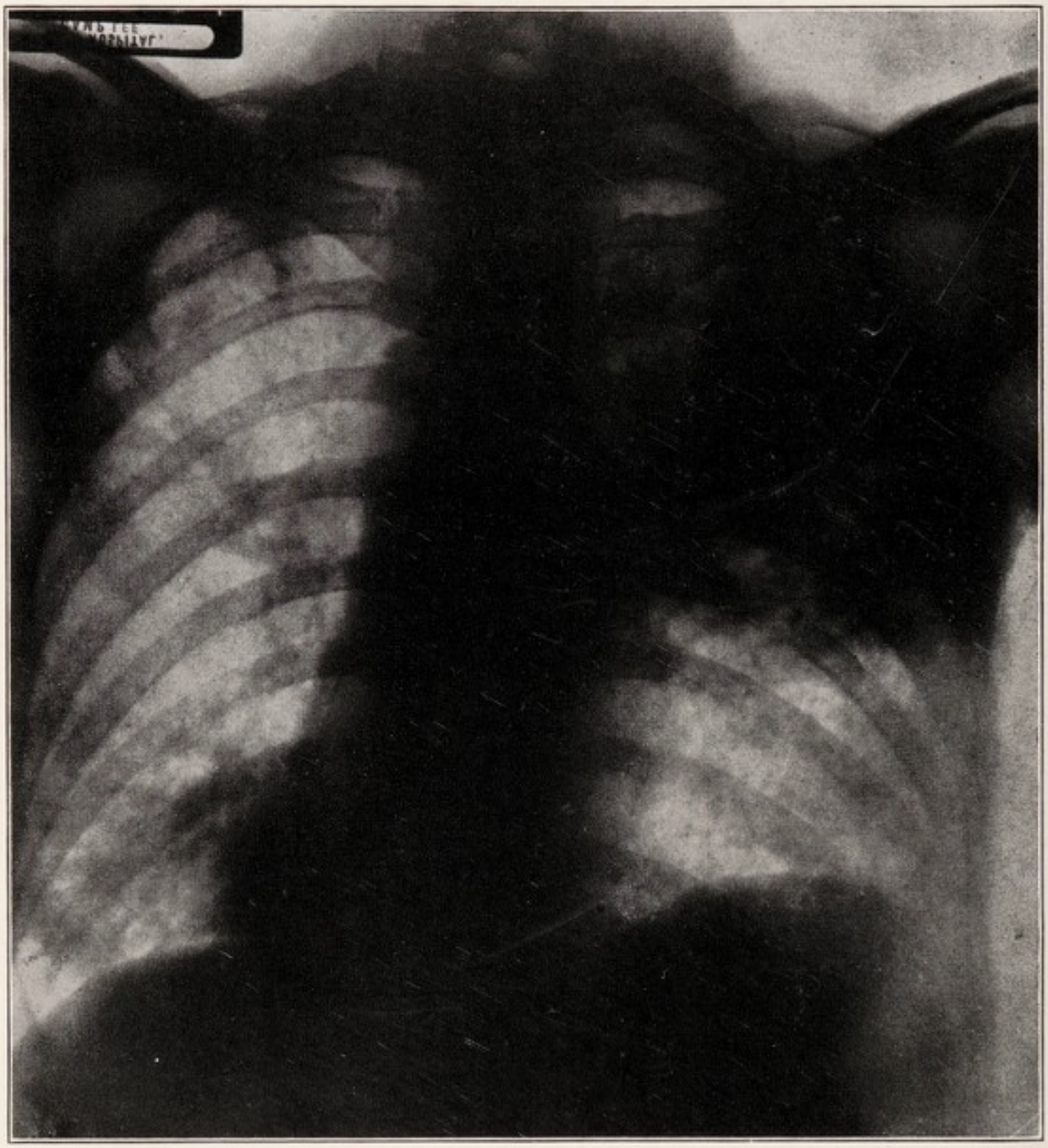

FIG. 27.—Roentgenogram of an empyema of the interlobar cleft, with an adjacent resolving pneumonia.

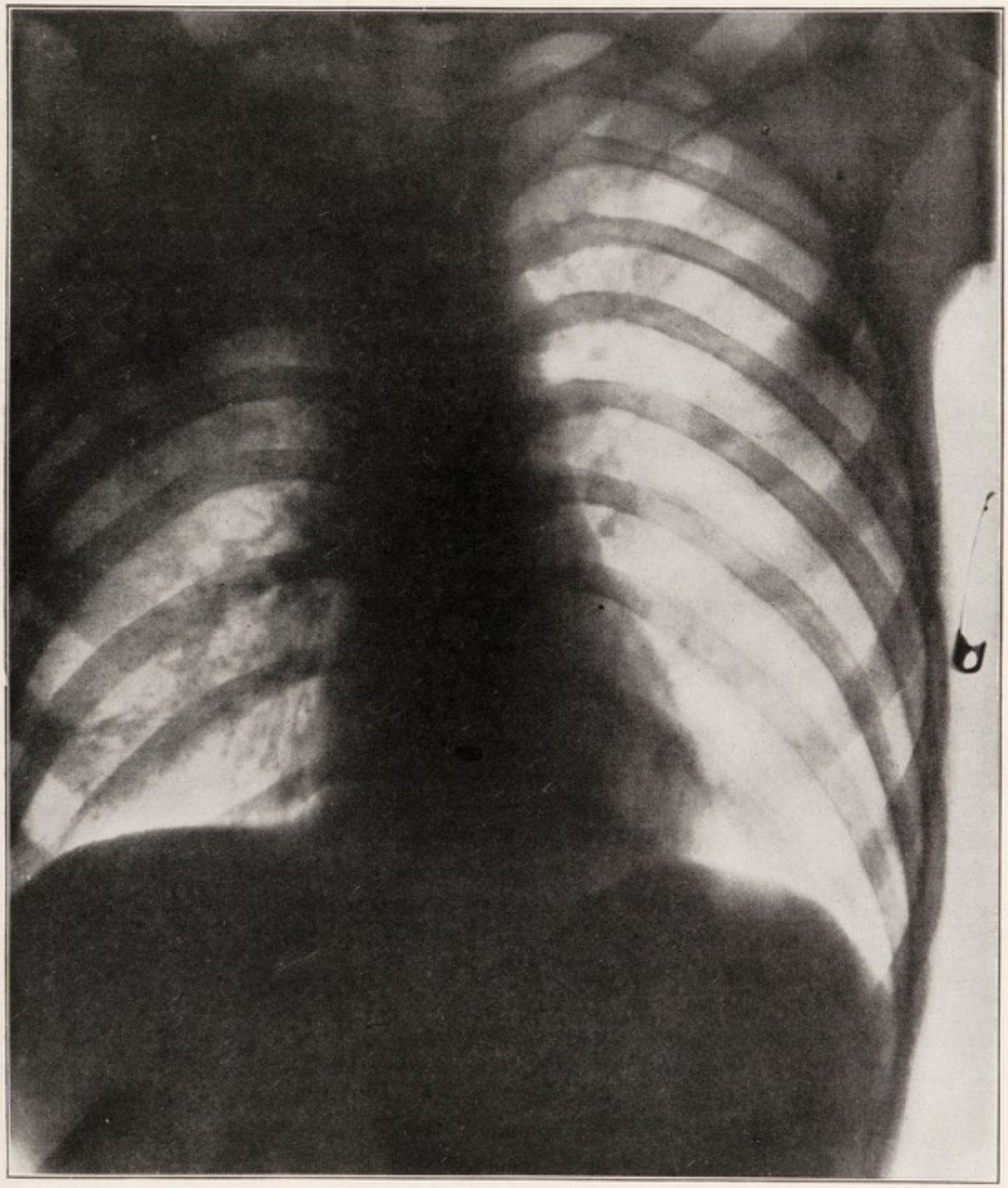

FIG. 28.—Encapsulated empyema at the right apex.

of the encapsulation did not have the convexity which we have learned to associate with pericardial effusion. Accumulations of pus along the right of the heart caused but little displacement of the apex to the left and presented a straighter line than the rounded curved right border of a distended pericardium. In rare cases pericardial effusions were so pocketed that the pericardium appeared irregularly distended. Then they could not be differentiated from paracardial encapsulations. It was always possible, of course, to aspirate, but on account of the danger of infecting an otherwise healthy pericardium some surgeons considered that the Roentgen ray afforded the only safe method for diagnosis and preferred to explore rather than attempt a diagnostic aspiration.

Pockets posterior to the root of the lung were usually detected after the acute pneumonic process had subsided. The area in which they occurred rendered detection difficult on account of the conflicting shadows of the vertebræ, heart, and bronchi. Even when plates were made in the oblique position the spinal gutter was often obscured by the bodies of the vertebræ. After the pus had been encapsulated for several days the adjacent parts of the posterior lobe reacted to the absorption of the exudate, the septa became thickened and the bronchi prominent, so that the picture was similar in many respects to that of a localized purulent bronchitis. The actual shadow of the encapsulated fluid was not often seen. If there was a large amount of pus it cast a dense paravertebral shadow with a straight lateral border, but in many instances the reaction in the lung was the only evidence of the smaller encapsulations.

Abscesses occurred frequently, and serial plates afforded some opportunity to observe the changes which took place in the lung as they developed. In the majority of instances in which a single abscess large enough to be detected occurred early, the infected area was the site of a slowly resolving pneumonia. Resolution had not progressed far, however, before it was apparent that the lung became mottled and striated. Rarely the pus was discharged into the air passages and the cavity which it had previously occupied could be seen in plates; more often, especially when hemolytic streptococci were responsible for small abscesses, the lung surrounding the infected areas became striated, but the nidus of the inflammation could not be detected. The striæ were more prominent in plates at later intervals and appeared as reasonably dense lines radiating from the point of infection.

When the pleura was involved in the inflammatory process around an abscess it cast a hazy shadow which became heavier as the reaction to the inflammation increased. It was not possible to obtain serial plates of abscesses with a fluid line to illustrate their formation. At times small pleural pockets showing both air and fluid were observed just after the pus had been partially evacuated into a bronchus, but these did not resemble the large cavities, measuring several centimeters in diameter, which occurred in the peripheral part of the lung and which were accompanied by considerable destruction of lung substance. They may have been formed by the rupture of a large peripheral lung abscess into the air passages, or they may have followed a pleuropulmonary fistula communicating with an encapsulated empyema. Relatively little acute reaction existed in the lung tissue adjacent to these large abscesses, and since the

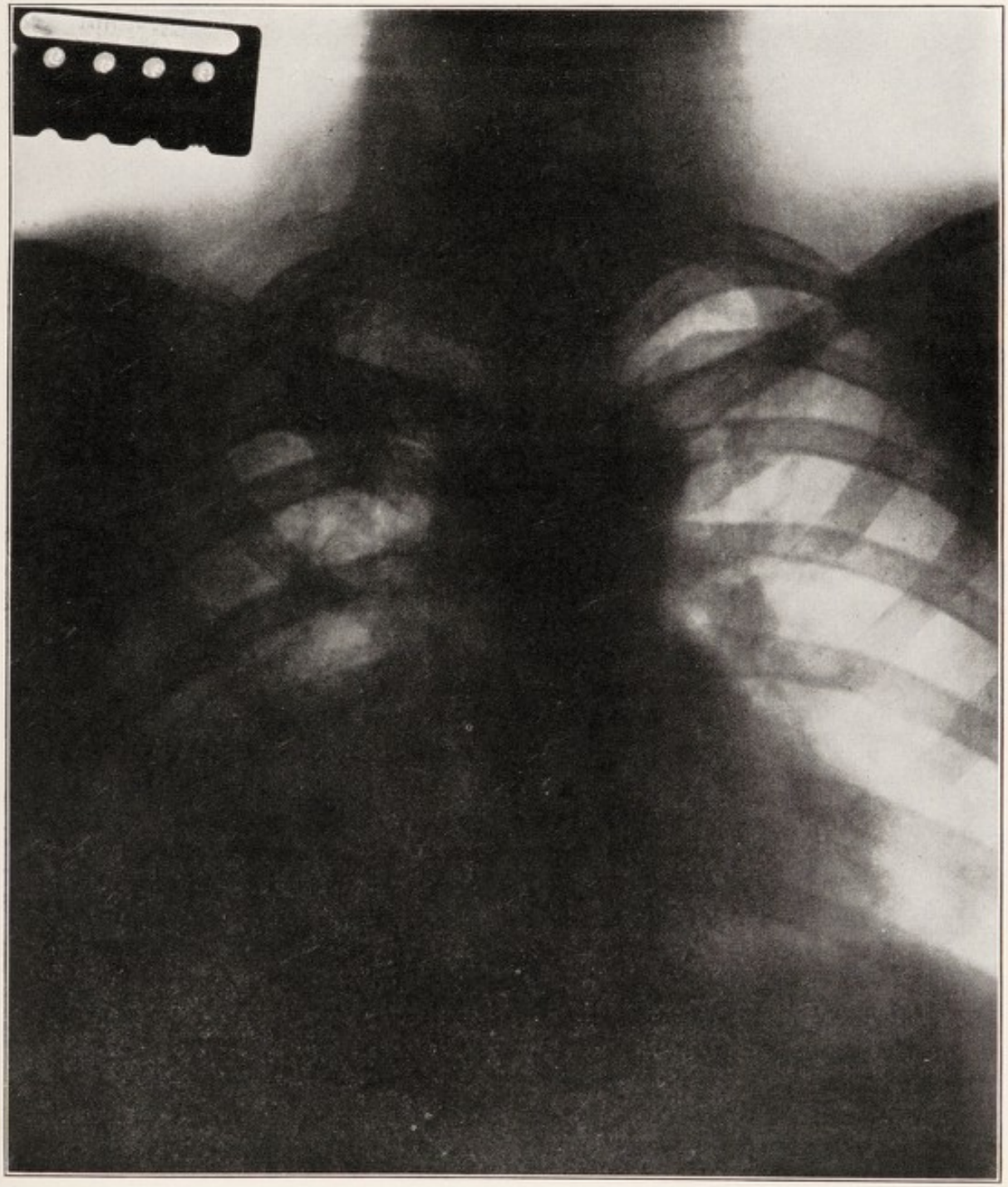

FIG. 29.—Abscess of the apex of the right upper lobe.

walls cast a dense shadow we may assume they were of long standing when they were first observed; in fact, they were seldom seen until several weeks after the pneumonia. On account of the frequency of pyopneumothorax in the early cases and the high percentage of pleuropulmonary fistulæ occurring after drainage of streptococcus effusions, it is probable that many of these large abscesses were of pleural origin and began as encapsulated empyemata. It was not possible to determine from stereoscopic plates whether the pleuræ formed the abscess walls or the abscesses lay entirely within the lung. Usually they appeared to be situated immediately beneath the chest wall without intervening lung tissue. A point of value to the surgeon was the fact that the fluid line shifted with the changed position of the patient. It was possible, by making stereoscopic exposures in various positions of the patient, to discover the lower limits of the cavity which appeared distinctly against the dense tissue of the wall when the fluid was allowed to gravitate away from the lower parts and was displaced by air. This procedure enabled the surgeon to determine the point of election for drainage in the cases in which the lowermost parts of the wall were so thick that it was difficult to determine the lowest point at which an incision would accomplish complete drainage. In cavities in which the fluid was found to shift slowly or only partially, considerable desiccation of the contents was found at operation.

Abscesses of the glands at the hilus were occasionally anticipated on account of the inflammatory reaction in the surrounding lung. Although it was not possible to make a positive diagnosis, because the bronchi overshadowed this area, the radial thickening of the septa about these abscesses could be depended on with a fair degree of certainty. Diagnoses which were made on these findings were confirmed in numerous instances by subsequent operation.

After the resolution of the pneumonia one of the most interesting and practical phases of Roentgen-ray study was terminated. In cases of typical lobar pneumonia the opinion of the roentgenologist was not required as frequently as in bronchopneumonia, which terminated by lysis and in which there was usually some doubt about the condition of the lung and pleura. In some camp base hospitals it was considered advisable to examine all respiratory cases before discharge on account of the insidious nature of these infections. Although this was not necessary in most instances, the pathology which was frequently discovered more than justified the effort.

### THE STUDY OF CHRONIC CAVITIES AND SINUSES.

After thoracotomy the surgeon was concerned chiefly with the contraction of the sinus walls, with the shape of the cavity during the acute and chronic stages, and with the thoroughness of the irrigation and drainage. This knowledge was essential for the proper and intelligent care of the patient. The cases which were treated throughout their course by the canula and catheter method of drainage did not, of course, require such frequent roentgenologic examinations, since the visceral and parietal pleuræ were held in approximation as long as the catheter fitted tightly and air was excluded. When drainage was continuous, as in cases where constant moderate suction was applied to the pleural cavity, the only object in obtaining roentgenograms was to exclude the possibility of abscesses or multiple pleural pus pockets. Many of the empyemata treated in this manner did not resolve, unfortunately, so it became necessary

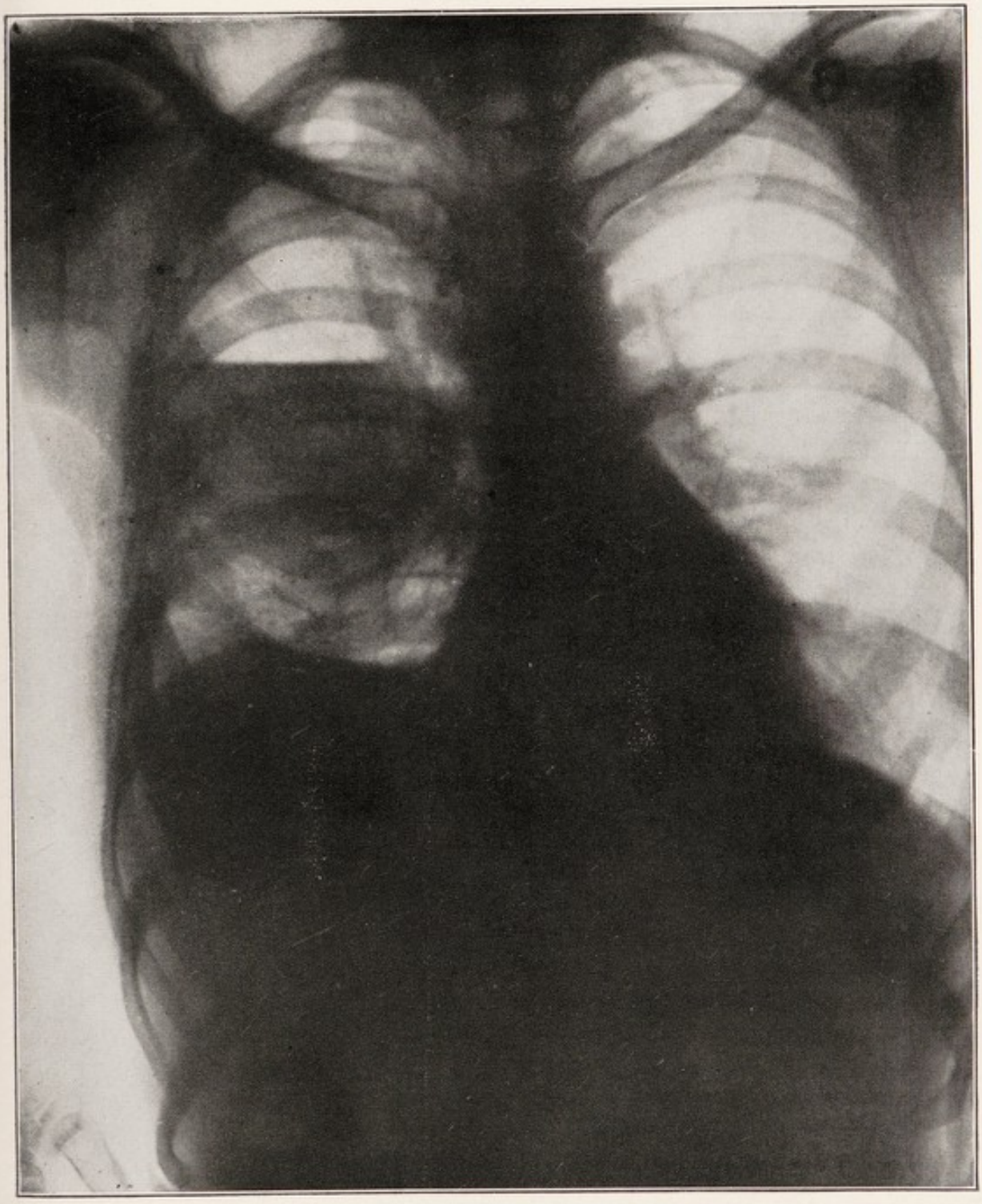

FIG. 30.—An encapsulated pleural abscess with fluid line.

at some later time to resect part of a rib to secure conditions which would permit a permanent closure of the wound. Undoubtedly this treatment was distinctly advantageous even though it did not permanently heal the empyema, because examinations of these cavities after resection showed that they were uniformly smaller than those resulting from any other method of drainage which was attempted in large effusions. In other respects they resembled cavities occurring after immediate surgical drainage or after a series of "medical" aspirations.

Two methods of study were available. In early cases or in those in which there was a very large cavity it was always possible to distinguish the areas of pneumothorax in roentgenograms made in the anteroposterior position. Later, when the cavities were chronic and had contracted so that the axillary part of the chest was filled by the expanded lung, the outline of the lung surface could not be seen, so it was necessary to fill the cavities with bismuth suspension before an accurate idea of their shape and size could be obtained. It was equally important to obtain stereoscopic plates of these injected cavities, a point emphasized by Beck, who found these methods helpful in the study of empyema and in the localization of foreign bodies in cases of purulent pleural effusion after injury.

In addition to the method of treatment employed, the nature of the infecting organism caused considerable variation in the size and location of these draining cavities, not through activity in the pleura, but rather by reason of the type of pneumonia with which the particular organism was most frequently associated. As mentioned in previous paragraphs, the pneumococcus did not produce large, free effusions even when the consolidation had a lobular type of distribution, but rather a circumscribed collection of pus in the exudate overlaying the inflamed lung. Roentgenograms of the thorax, following operations on such empyemata, showed that the cavities were smaller than the majority of those occurring after streptococcus pneumonia and that they were most frequent in the region below the scapula or in the lower axilla. They were also much less chronic and showed less thickening of the pleura. The streptococcus cases, however, presented a variety of pictures. Some of them resulted in small cavities which, except for their chronicity and the remarkable thickening of the pleural layers so characteristic of streptococcus pleuritis, resembled empyemata following pneumococcus infections. There was a greater tendency for them to occur over the anterior parts of the chest, due probably to the lobular distribution of the pneumonia. Then there were large cavities occurring after massive exudates which extended from the angles of the ribs to the midclavicular line. Since it was possible to aspirate these large exudates for several days and allow the pleuræ to become adherent, they were modified by treatment more than any other type; and because they were most often drained through a posterolateral incision, the sinus which resulted from the expansion of the lung and the contraction of the walls extended upward from the wound below the angle of the scapula toward the apex of the lung. The roentgenograms of these cases were the source of considerable information regarding the factors entering into the obliteration of the cavity and the causes of encapsulation and imperfect drainage.

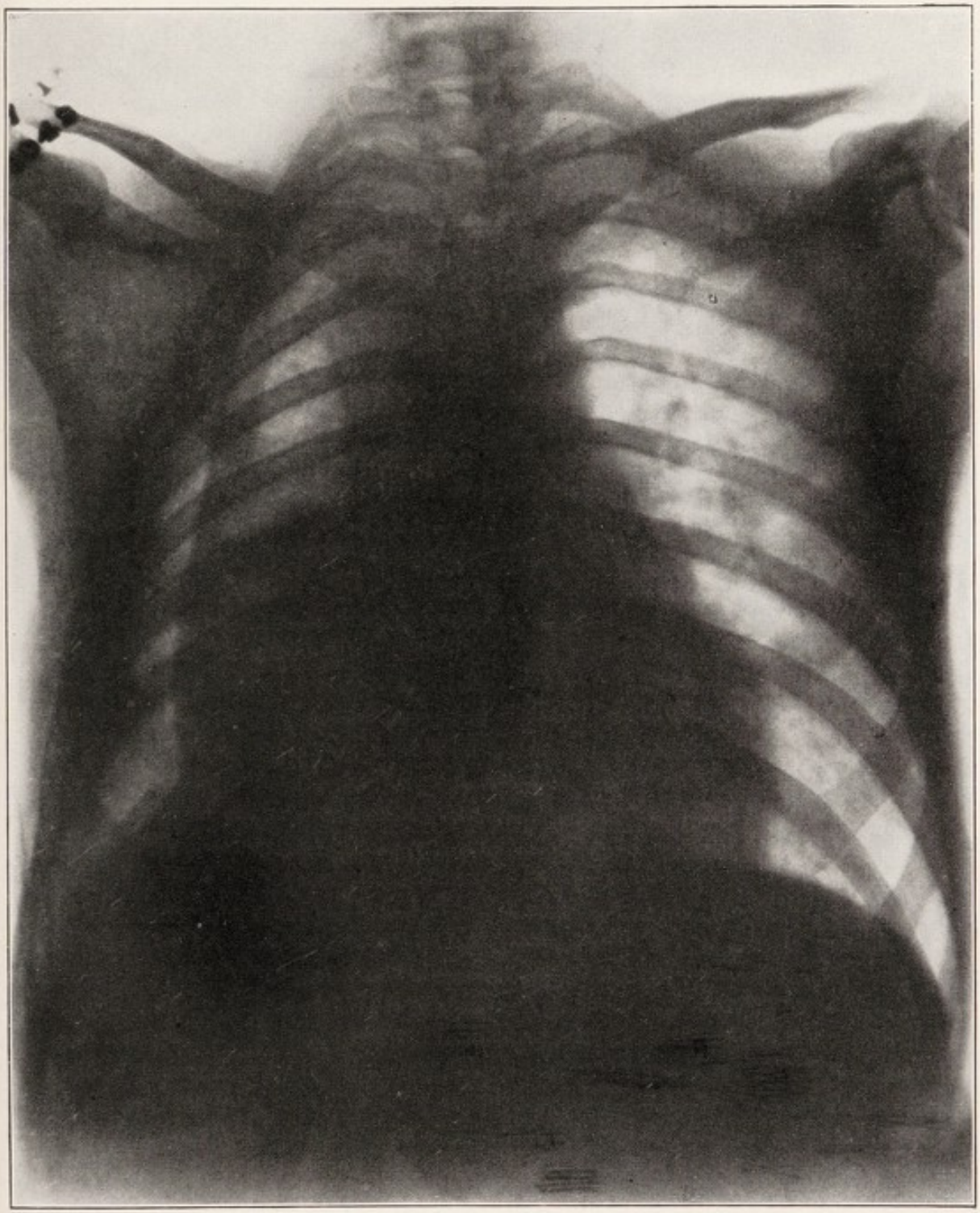

FIG. 31.—Roentgenogram of a chronic empyema cavity. There are adhesions to the diaphragm below.

## THE EXPANSION OF THE LUNG AND THE OBLITERATION OF THE CAVITY.

A study of roentgenograms made subsequent to the operation has led to the conclusion that the obliteration of the cavity can be accounted for by three processes which, although they are interdependent, are not equally effective in bringing about cohesion of the pleura in different stages of healing. The expansion of the lung is probably the most important single factor, and according to the roentgenograms could be brought about by aspiration or catheter drainage up to the time of operation. After operation the lung was held more fully expanded through the application of various types of drainage valves which were designed to augment the negative pressure in the cavity and bring the pleuræ in closer contact through increased aeration of the diseased lung. The second factor, the formation of adhesions, appears to be directly dependent on the ability of the lung to expand and fill the thorax, so that the margins of the cavity can be obliterated gradually where the lung is in contact with the chest wall. The third and last mechanical process is the contraction of the cicatricial tissue composing the sinus wall. This has been found to be the only factor which enters into the closure of chronic empyemata in which the lung has apparently reached the possible limits of expansion under the abnormal pleural conditions which exist and in which the pleura is so thick and sluggish that adhesions are no longer produced.

In 1918 Homans [4] reported a series of cases in which he attempted to correlate the data furnished by roentgenograms of pleural empyemata and various clinical observations regarding the time required for the expansion of the lung and closure of the wound. He concluded that the conformation of the surface of the part of the lung which formed the inner wall of the cavity was an important index to prognosis, since the period of convalescence was shorter when this surface was concave than when it was already rounded out to fill the cavity. He reasoned that with a concave surface there was more often sufficient lung tissue between the points at which the lung was adherent to the chest wall to fill the cavity when the lung was expanded than in those instances when the lung presented a convex surface outward and was apparently expanding but was under tension on account of adhesions. While this tenet appears to be true in the early cases, there are some points which must be considered before the principle can be applied to the chronic cases as well.

The surface of the lung in the cases observed immediately after thoracotomy is usually concave, especially when the margin of the lung is adherent to the diaphragm near the costophrenic angle and the apex is held in its normal location. It has not been infrequent, however, to find the margin bound firmly to the upper surface of the diaphragm at a point some distance from its costal origin. In these cases the surface is often convex because the lower parts of the lung are held away from the chest wall, so that the lung is partly compressed and its costal surface must eventually be called upon to cover a greater area if the lung expands to fill the cavity than it would under normal conditions. The second type of convex surface is illustrated in Figure 32. It occurs where the under surface of the lower lobe is partly adherent to the diaphragm but the margin projects freely into the cavity. It has been found that cases of the first type mentioned, in which the surface is concave and is not hampered by adhesions, heal more quickly than do those of the convex type.

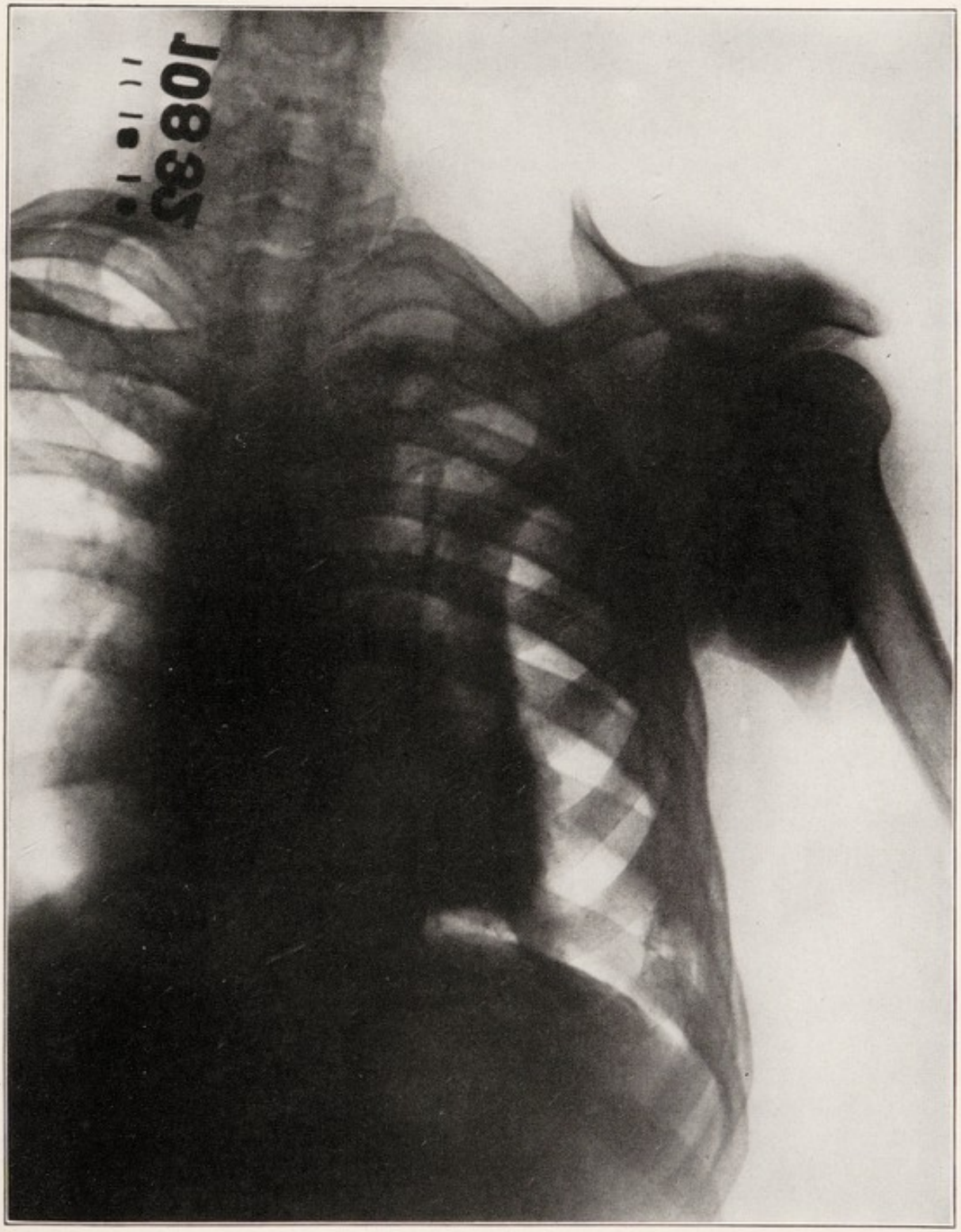

FIG. 32.—A chronic cavity with adhesions over the surface of the lower lobe preventing lung expansion.

Fluoroscopic examinations of healing cases have further demonstrated that not all concave lung surfaces are capable of expansion sufficient to fill the cavities. This has been found true especially in chronic empyema when the visceral pleura has been converted into dense contracted cicatricial tissue which is capable of holding the lung away from the chest wall. Cavities of this type are similar to the healed empyema with a pneumothorax. While they have been found to resemble those earlier cavities which have offered the best prognosis on cursory examination, fluoroscopy has shown that the lung is often incapable of expansion and is under such tension that it does not expand on forced expiration or even when expiration is impeded by closing the mouth and nares. It appears, then, that fluoroscopic examination is of more value in determining the actual expansibility of the lung than the study of antero-posterior roentgenograms.

The fluoroscopic examination of many of these healing cases demonstrated the fact that, ordinarily, the lung surface was much more convex in the antero-posterior direction than along a line from the apex to the adherent margin; furthermore, it was found that healing proceeded more rapidly in this direction so that the chronic cavity or sinus finally assumed an elongated shape due to the gradual obliteration of the anterior and posterior margins by adhesions. A study of these margins showed that they were formed by the convex lung surface and costal pleura which converged in almost parallel planes, so that an acute angle was formed at the point of contact. This condition was evidently the most favorable for the formation of adhesions since the lung and parietal pleuræ were brought into contact in these areas and became adherent. The ability of the lung to expand was, of course, always the primary consideration because the production of these adhesions along the margins of the cavity was hindered if the lung surface was under tension and was not closely approximated to the chest wall. While the study of the lung surface was most important early after operation, the condition of the margins was valuable in the more chronic stages. It was apparent that the actual concavity or convexity of the surface was of prognostic value only insofar as it might indicate the ability of the lung to expand and fill the cavity, and that adhesions were formed much more rapidly when this surface was partially rounded and expanded so as to bring the pleuræ in contact more closely at the margins.

The transition between the stage when the cavity is being obliterated rapidly and the period in which the cicatrix gradually contracts to form the chronic sinus is illustrated in Figures 31 and 33. These roentgenograms were made at an interval of three months. In the earlier illustration the margin of the lung is adherent to the surface of the diaphragm while the apex is held in the upper part of the pleural cavity. The lung surface is convex on account of these basal adhesions and from the density of the shadow which it casts is probably covered by a dense layer of cicatricial tissue. The angle at the upper margin is acute, since it is formed by the lung and costal surfaces converging in nearly parallel planes. In the later illustration, Figure 33, the cavity has diminished in size. The obliteration has taken place at this upper margin and along the costodiaphragmatic angle, but there has been no further adhesion between the lung and diaphragm. The roentgenograms not only exemplify the steps in the healing of a cavity of this type, but illustrate the changes which

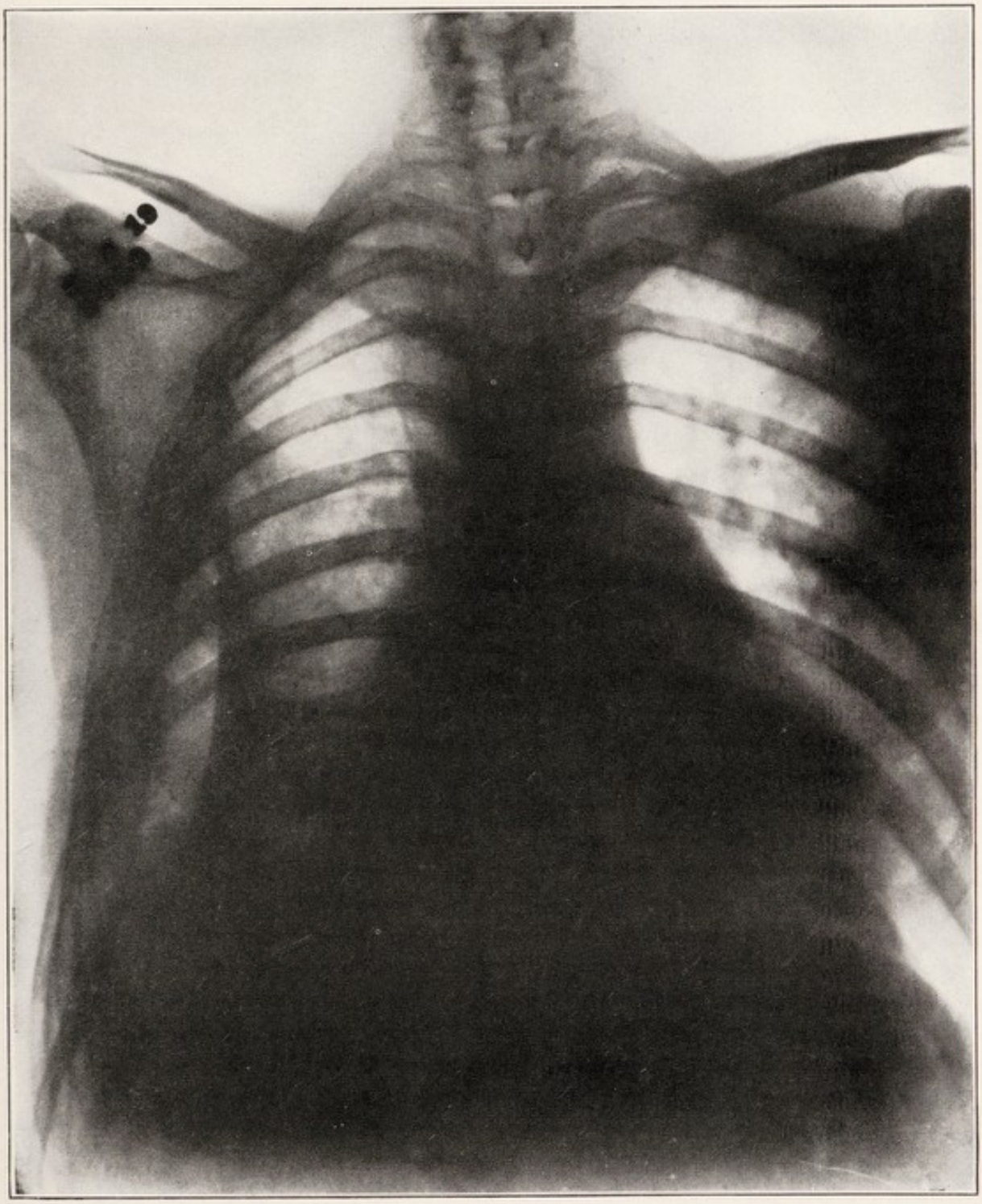

FIG. 33.—Roentgenogram of the cavity illustrated in Fig. 31 after an interval of two months. The cavity has been reduced in size, but the cicatrix over the surface of the lung prevents full expansion.

take place in conformation of the cavity as it becomes more chronic. The upper margin is less acute, the surface is concave, and there is a dense cicatricial shadow over the lung and the parietal wall. In the still more chronic stages, the scar tissue is so dense that adhesions are no longer formed and the margins are rounded so that approximation of the surfaces is no longer possible. Such cavities contract slowly and usually necessitate thoracoplasty.

The other factors which have been observed to enter into the closure of the empyema cavity are concerned with changes in the conformation of the pleural cavity. There are usually a slight scoliosis, an approximation of the ribs on the affected side and an elevation of the diaphragm, all of which tend to lessen the volume of the diseased pleural cavity so that it is never necessary for the lung to attain its former capacity.

## BISMUTH SUSPENSIONS IN THE STUDY OF CAVITIES.

Observation of the early cavities was continued until the entire anterior surface of the lung was adherent to the chest wall. When this stage was reached it was impossible to study the cavities unless they were filled with material opaque to the Roentgen ray, because they were usually posterior and were obscured by the expanded lung. Methods which had been used previously in the study of cavities were found unsatisfactory. Roentgenograms which were made when probes, drainage tubes, or Carrel-Dakin tubes were placed in the cavities did not permit a study of the actual shape and depth. Attempts were made to obtain roentgenograms with bromide, iodide or thorium solutions, but the plates were unsatisfactory and severe local and general reactions sometimes occurred. Roentgenologists who were using a mixture of bismuth and petrolatum, prepared according to a formula devised by Beck,[5] were able to obtain excellent pictures of small cavities, but if the cavity was large and irregular in shape it was often impossible to fill it completely so that small ramifications could be studied. Because it was so difficult to fill the cavities perfectly, the surgeon was occasionally led astray in his estimation of the size of cavities, injected for radiograms just prior to operation. The method was modified by substituting cottonseed oil for petrolatum as a vehicle for the bismuth subnitrate. The cavities were filled by allowing this bismuth-oil mixture to run into the sinus so slowly that the air was displaced from the deepest recesses, then the opening was packed tightly with a gauze strip which had been dipped in a warmed mixture of petrolatum, wax, and bismuth. Stereoscopic exposures were made with the cavity filled and immediately after it had been allowed to empty. After the exposures it was considered advisable to irrigate the cavity with Dakin's solution to remove all traces of bismuth.

The advantages of this procedure over the use of pastes in the study of empyema cavities were mainly due to the liquid character of the vehicle. It was easily removed in cases in which there was perfect drainage and could always be flushed out except where there were sacculations which required secondary operations before the sinus would heal. These instances were rare and where retention of bismuth did occur on account of some irregularity of the sinus wall, the operation revealed pus retention as well. For this reason it was especially valuable in chronic cases for it served as an index to the

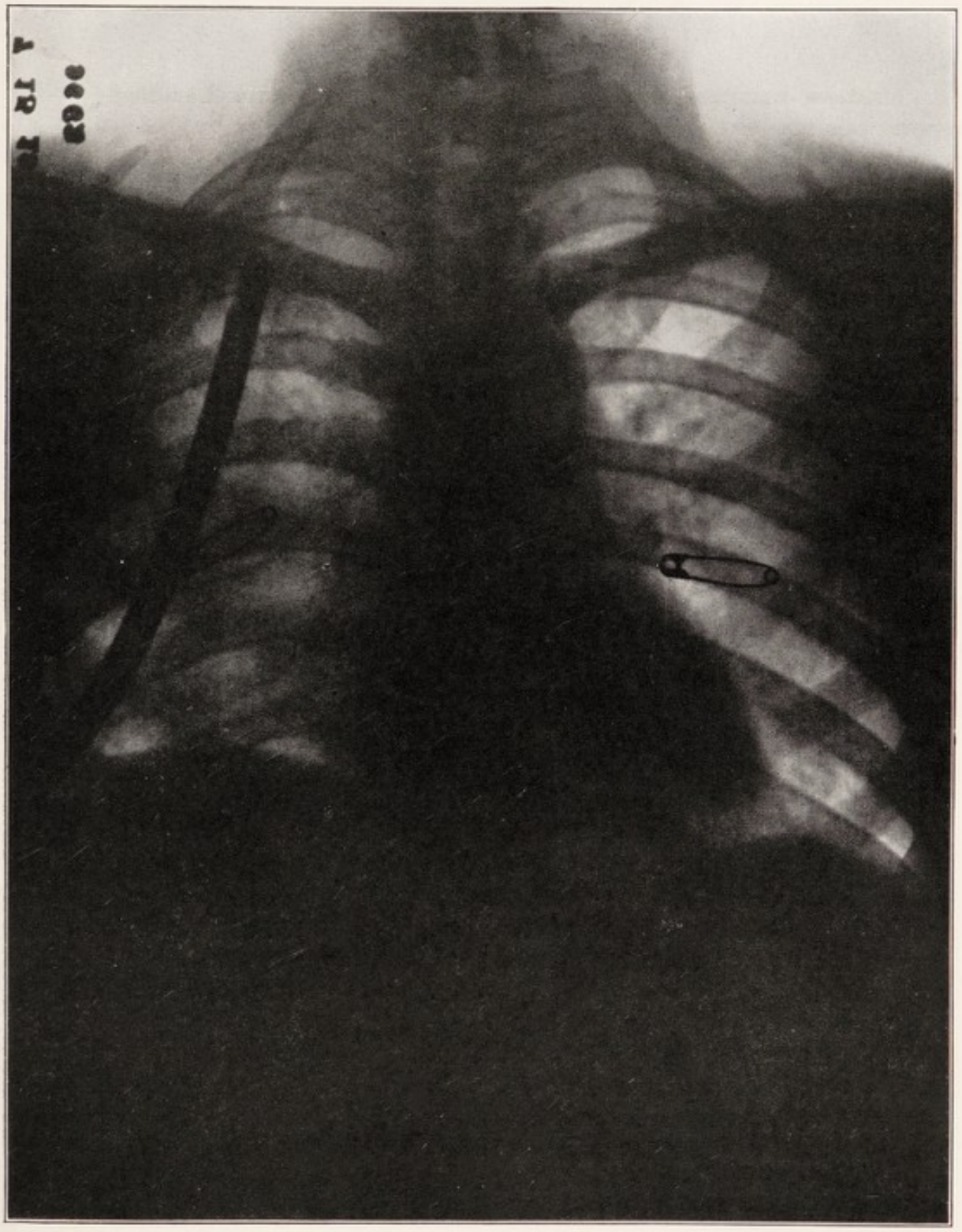

FIG. 34.—A chronic cavity with a single large drainage tube.

completeness with which the cavity was being drained and irrigated. It was never retained in any instance in which an operation was not necessary for the proper treatment of the case.

Stewart[6] studied a series of cases in which he employed all of the methods which have been mentioned. He concluded that it was inadvisable to undertake the injection of large cavities for roentgenographic purposes, but found that small sinuses could be studied profitably after they had been filled with a bismuth paste. In shallow cavities a paste is certainly more easily handled because liquid suspensions are retained with difficulty unless the cavity holds a considerable amount of the mixture. It does not seem, however, that there is any valid objection to filling large cavities with oil suspensions of bismuth subnitrate since several hundred cases were profitably studied in this manner at Walter Reed General Hospital and at General Hospital No. 12.[7] Stewart reported one case of poisoning following roentgenography. This is the only case discoverable. From a consideration of the roentgenological studies made with oil and bismuth suspension it appears that the percentage of poisoning has been lower in patients in whom oil was used as a vehicle than among those in whom pastes were introduced into the cavity.

### CONFORMATION OF THE CHRONIC CAVITY AND THE RELATION TO DRAINAGE AND HEALING.

Bismuth studies have shown such variations in the size and shape of the cavities, which followed the empyemata occurring in 1918 and 1919, that it has been difficult to draw any general conclusions in regard to the prognosis of these cases from such data alone. It was obvious, both clinically and from observations made in the laboratory, that, although large cavities would heal under irrigation if they were not chronic, when they reached a chronic stage they often required a collapse of the chest wall or a decortication to effect permanent healing. Aside from this fact, the study of the peculiarities of the individual case was the only criterion upon which judgment might be based, because roentgenology permitted the study of one of the factors only, the conformation of the cavity, which entered into the proper condition for the healing of the wound. The second factor, the bacterial flora and the degree of sterility which might be obtained, depended usually on pathology which could not be discovered in roentgenograms. In some instances bismuth studies of the cavities showed mechanical obstructions to drainage, which would account for the chronicity of the discharge and the difficulty experienced in sterilization.

A large percentage of the chronic cavities resulted from the drainage of massive streptococcus pleurisies. The cavities following the open drainage of pneumococcus empyemata were never as chronic and, because the pus was less in amount and sharply encapsulated, they were usually smaller and more varied regarding the location of the thoracotomy wound. However, it has been pointed out that pneumococcus empyema was most frequently posterior over the lower lobes, and, as a result, the majority of the thoracotomies were in this region. With the larger streptococcus effusions, more latitude was possible in the selection of the drainage site because the exudate could be drained if the incision were made at any point between the anterior axillary line and the inner border of the scapula, as the entire posterior half of the pleural cavity

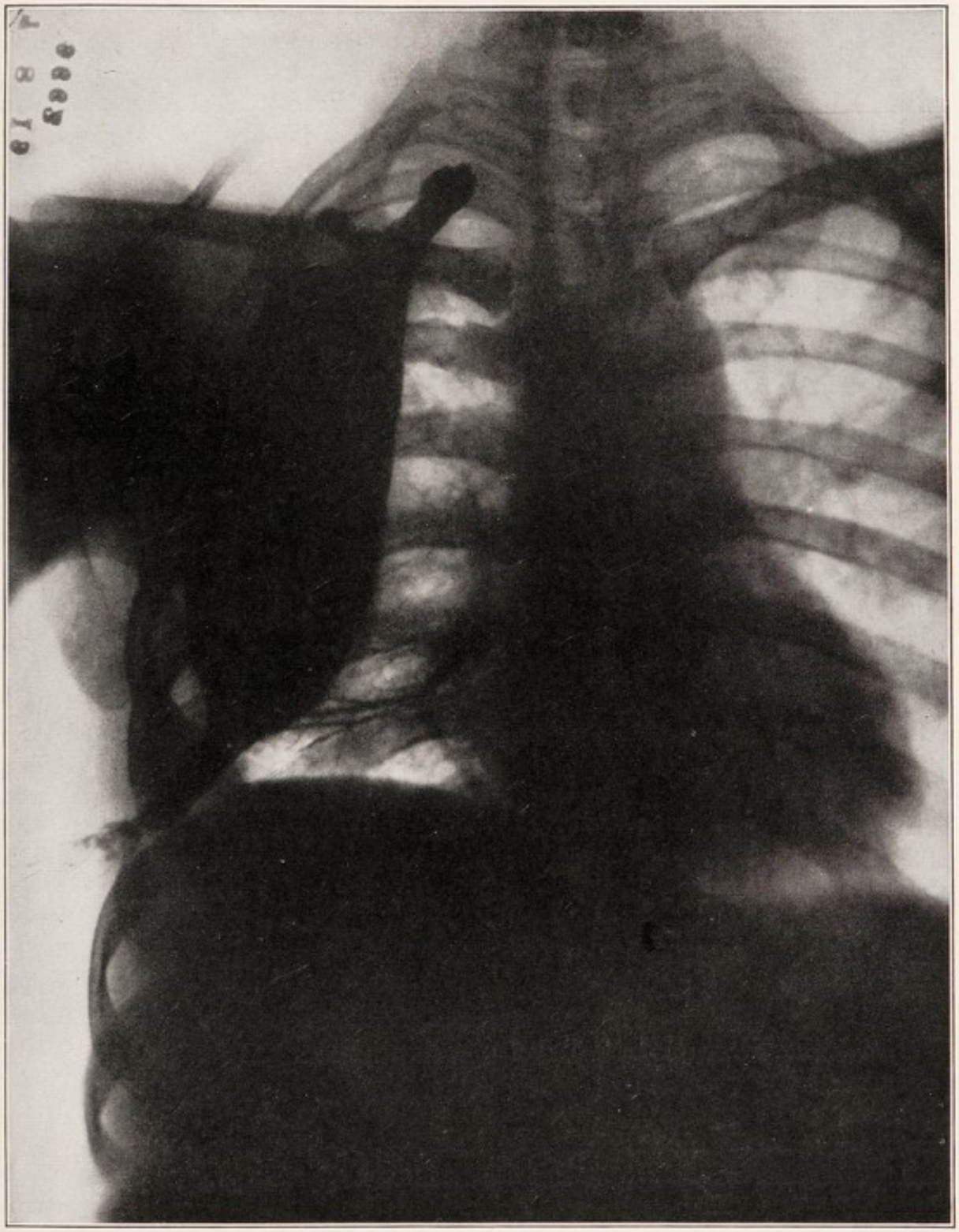

FIG. 35.—The cavity illustrated in Fig. 34 after it had been filled with a suspension of bismuth in oil. The cavity communicated with the bronchi through small pleuropulmonary fistula.

was usually filled with fluid. Regardless of the location of the wound, whether it was anterior or well posterior, the greater part of the chronic cavity was always in the posterior part of the thorax. In those instances in which anterior drainage had been done, the main part of the cavity was in the scapular region and extended forward to the wound through a narrow sinus.

The majority of these cavities finally assumed an elongated shape in the region of the posterior axillary line. Bismuth injections have shown such a variety of shapes that it is hardly possible to attempt a useful classification on this basis. Sixty per cent extended from the thoracotomy wound toward the apex of the lung along a longitudinal axis which deviated slightly toward the spine in the upper part of the thorax. The distance between the lung and the chest wall was usually 1 and 2 cm., but the anteroposterior diameter was variable, because some of the cavities had contracted until they were mere sinuses while others reached from the midaxillary line to the inner border of the scapula. Ten per cent were similar in every respect to those just mentioned except that they reached below the thoracotomy wound, as shown in Figure 37. An additional 10 per cent reached even to the diaphragm, so that the base was broad and the lung was held away from the chest wall by adhesions to the diaphragm, as illustrated in Figure 32. The remainder were irregularly shaped, varying from sinuses extending between the lobes of the lung to large lobulated cavities overlying a large part of the lung surface.

When the cavities were of many months' standing, bismuth studies were valuable only in so far as they might indicate the extent of any surgical procedure which might be undertaken; but in the earlier stages, when marginal adhesions were being formed and the cavity was diminishing rapidly in size, the shape of the cavity often indicated the probable outcome of the case. The majority of the cases, which were easily sterilized and closed permanently within a few months after the operation, were of the posterior, elongated type which resulted from low, posterior drainage. It was never possible to determine definitely which cavities would heal and which would become chronic sinuses, but the prognosis was always better in the posterior elongated type because of the greater ease with which they could be sterilized. The high percentage of chronic, refractory cavities and sinuses, which fall in this class, is due to the great number of early cavities which assumed this shape before they healed. The favorable results in the early cases can be accounted for by the regularity of the walls and the mechanical perfection of drainage which allowed better irrigation than was possible when adhesions had prevented the proper expansion of the lung and had caused the cavity to be irregular or to drain poorly.

In a previous paragraph it was noted that about 60 per cent of the chronic sinuses were posterior and extended upward from the wound toward a point just posterior to the apex of the lung, and that a large majority of the cavities which healed early had assumed this position before healing. A study of cases during various stages of healing indicated that there were several factors which might cause the cavity to assume this position. The first factor was the location of the empyemata. This was over the posterior and lateral aspects of the lower lobe. This common location of the empyemata did not account for the position of the sinus following generalized, streptococcus

FIG. 36.—A chronic sinus over the posterior surface of the lung. Bismuth-oil injection.

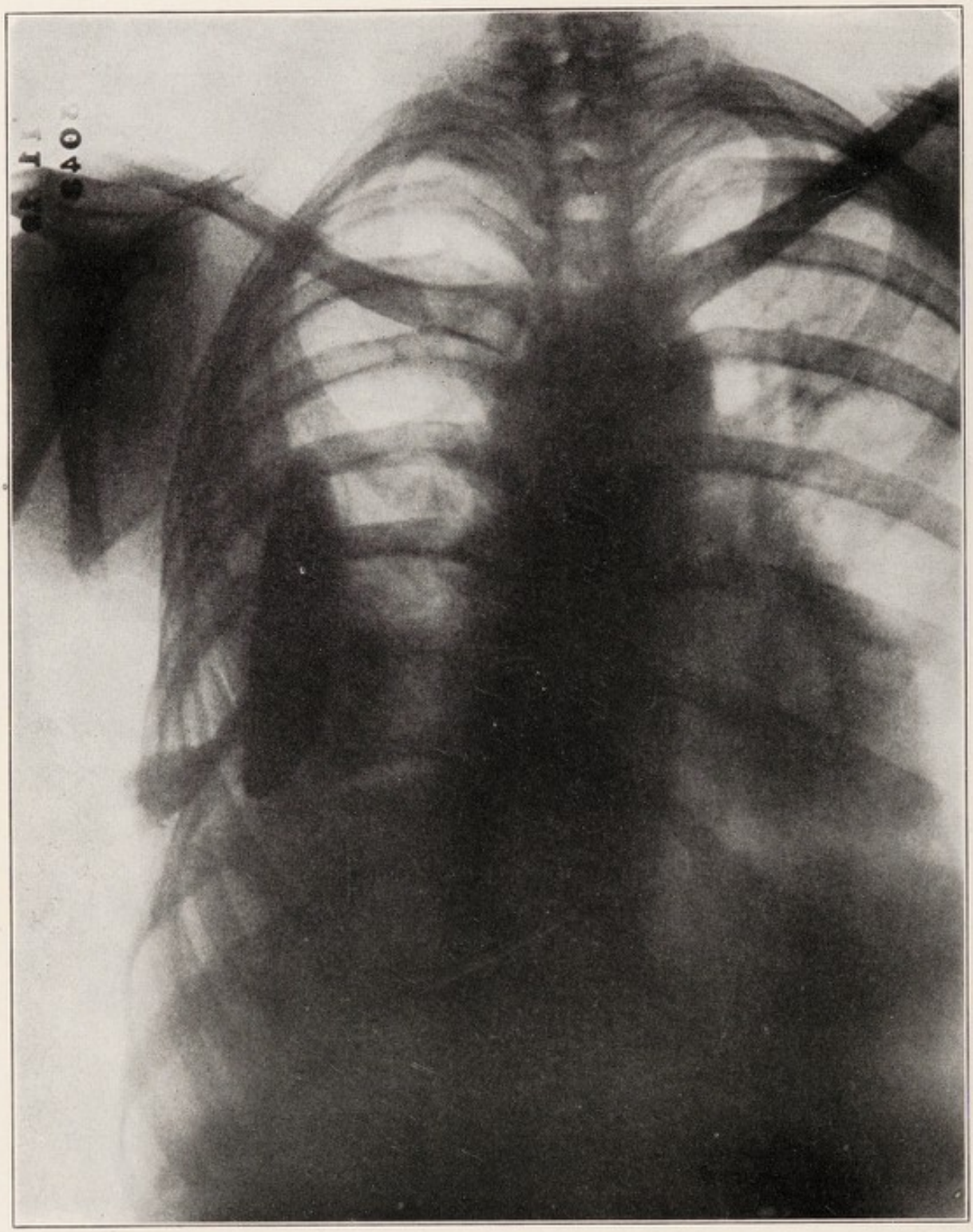

FIG. 37.—A chronic sinus over the posterior surface of the lung. Bismuth-oil injection.

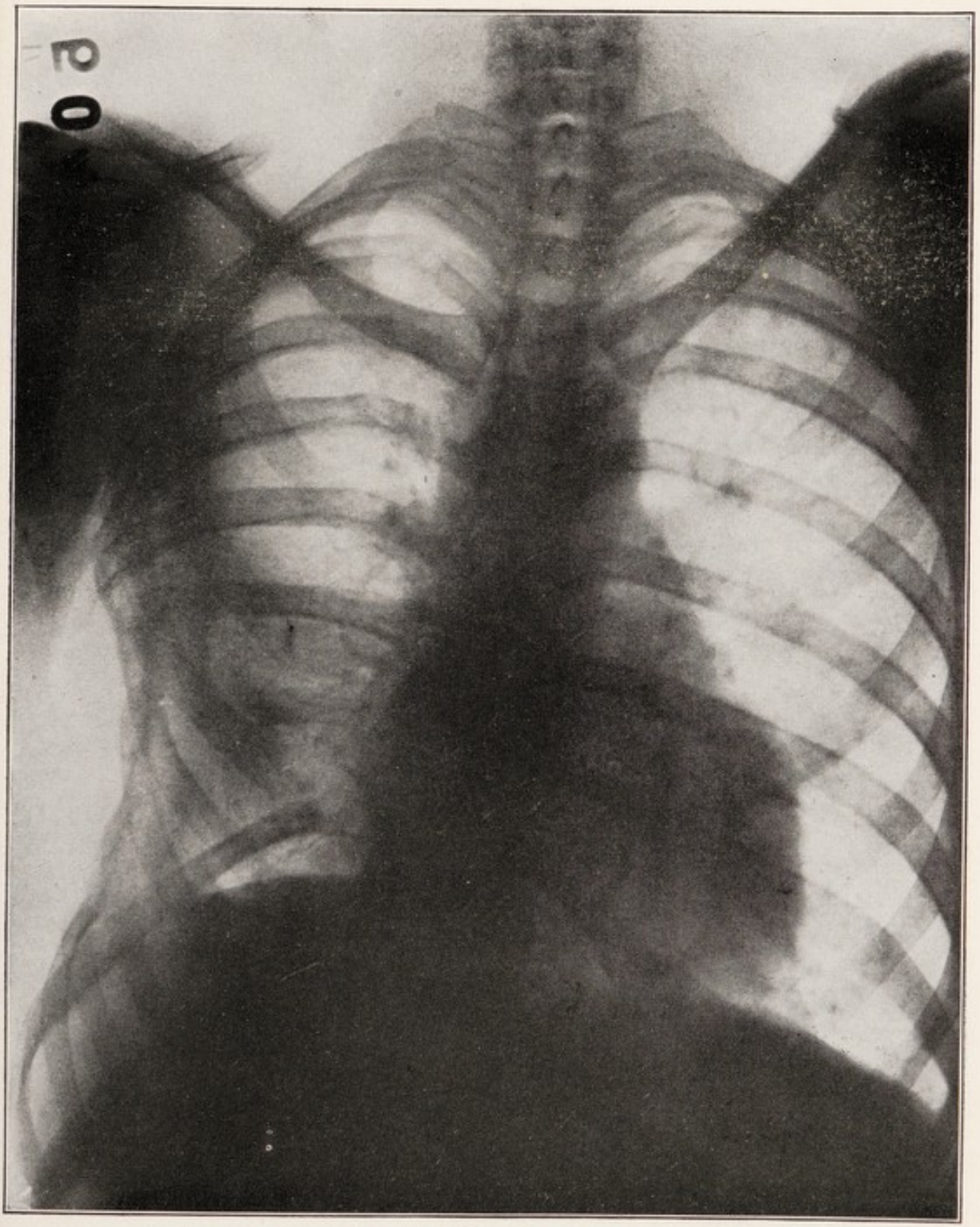

FIG. 38.—The result of a thoracoplastic operation on the cavity illustrated in Fig. 37.

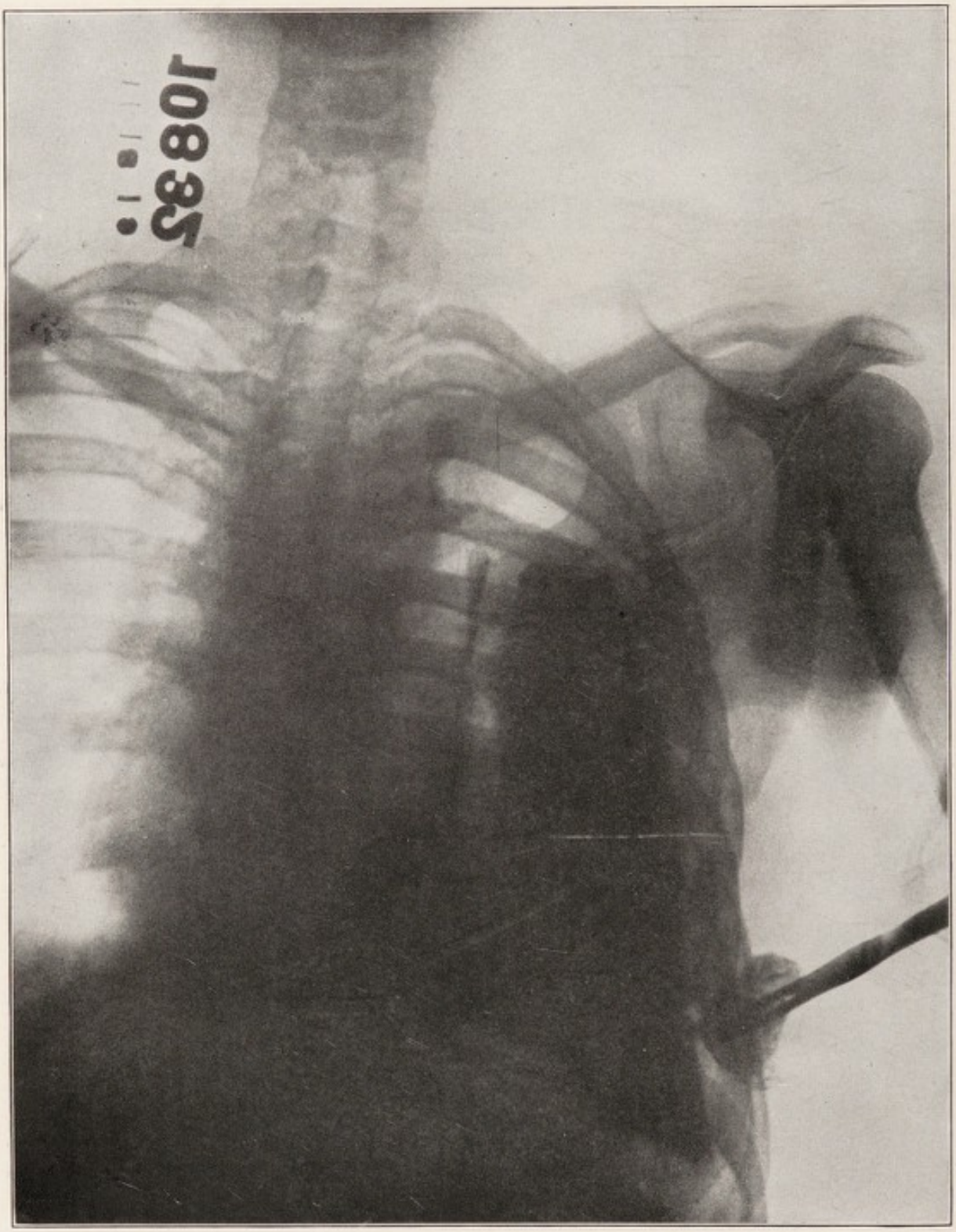


FIG. 39.—The cavity illustrated in Fig. 32 filled with a suspension of bismuth in oil.

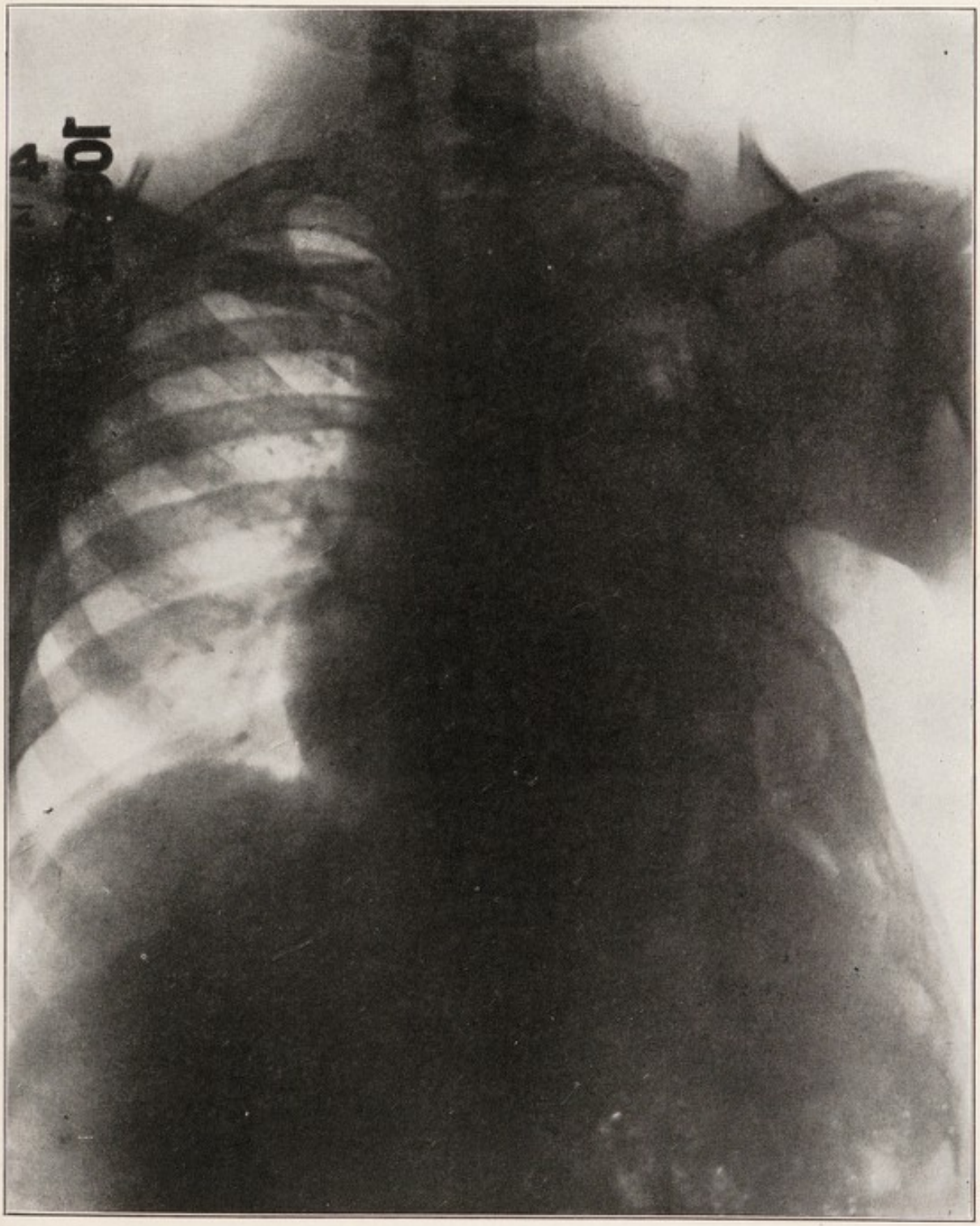

FIG. 40.—The result of a thoracoplastic operation on the cavity illustrated in Figs. 32 and 39.

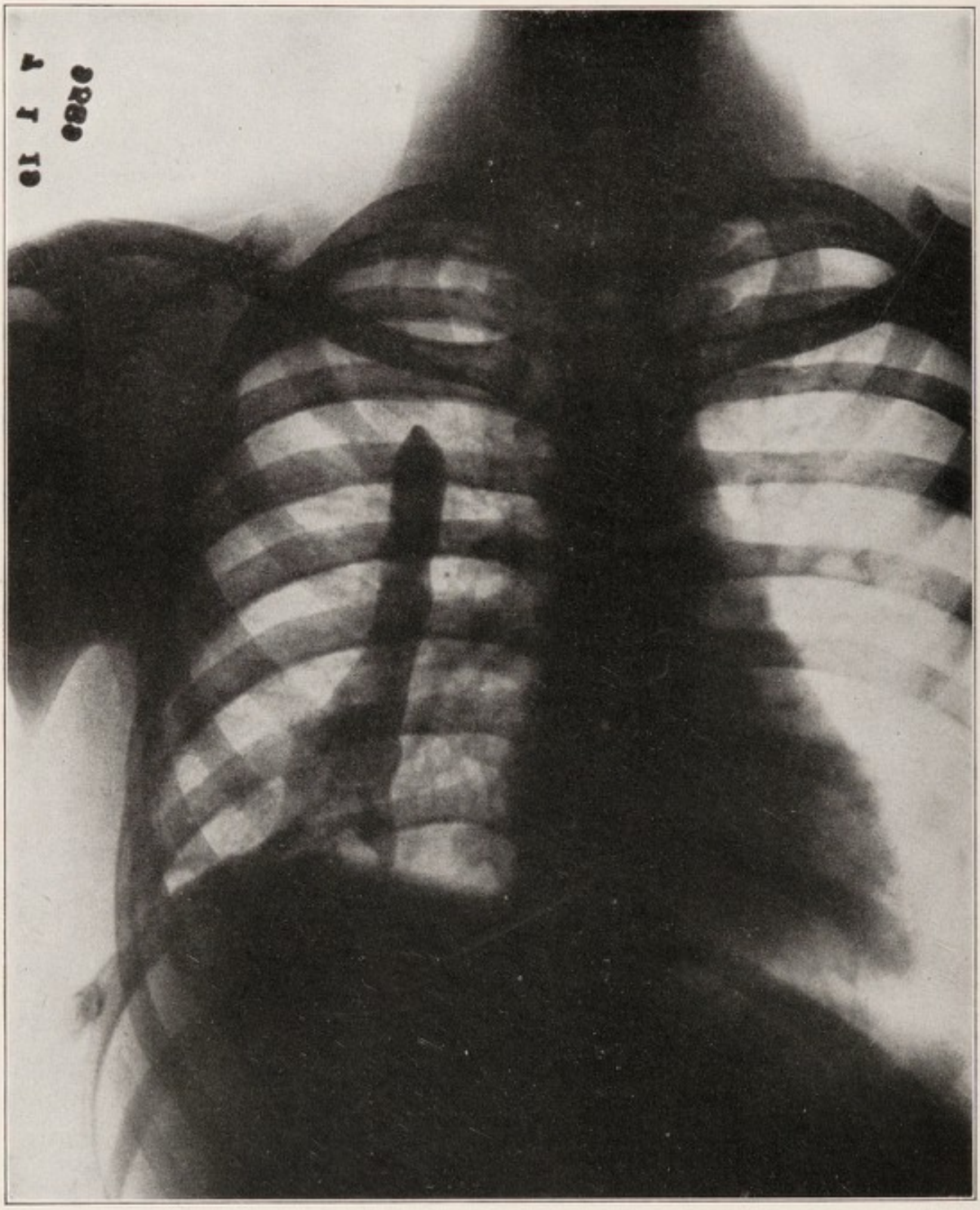

FIG. 41.—A shallow cavity over the posterior surface of the lung. Bismuth-oil injection.

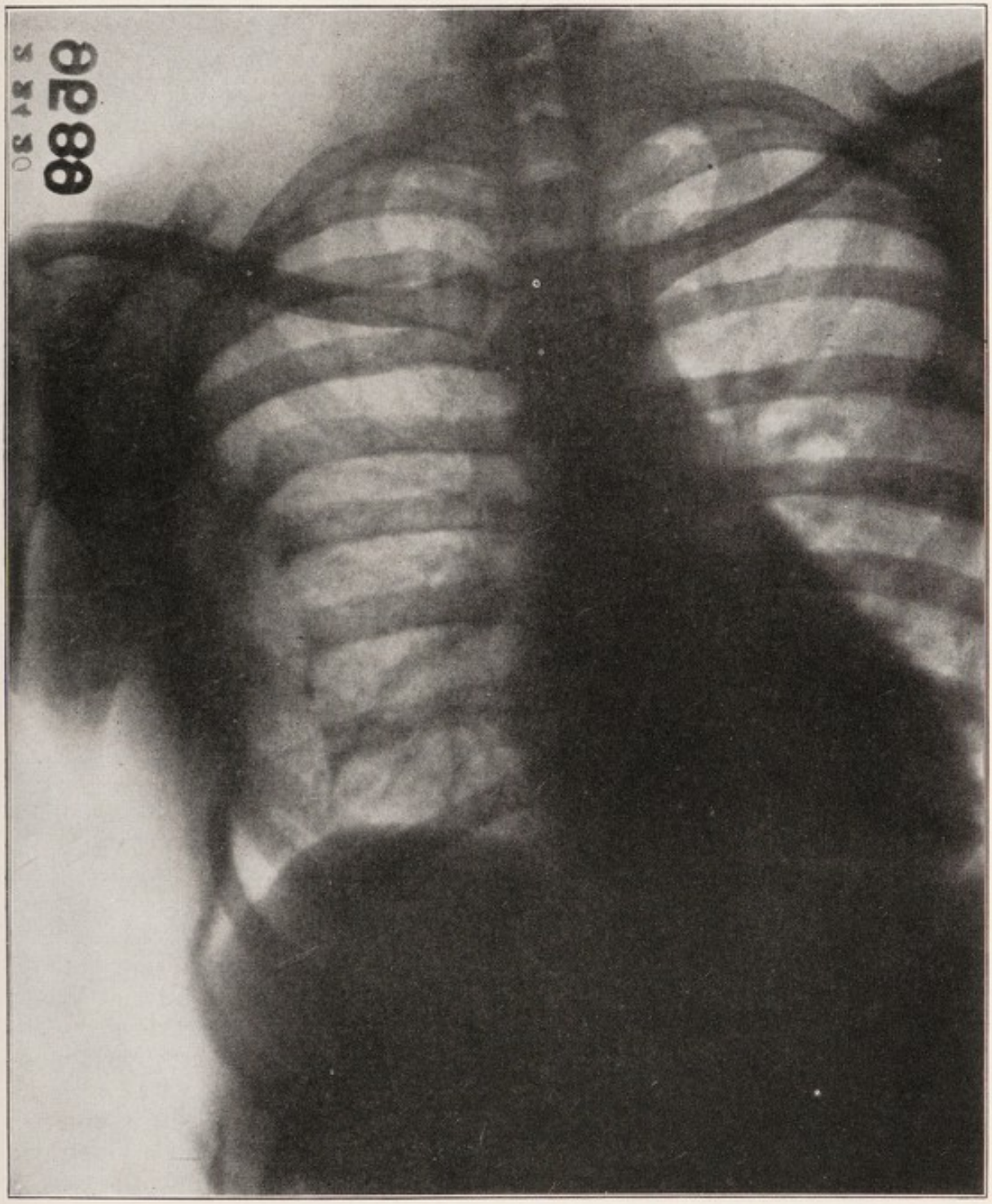


FIG. 42.—The result of a thoracoplastic operation on the cavity illustrated in Fig. 41.

pleuritis, except that the greatest accumulation of fluid was in the lower posterior thorax in these cases. The selection of this site for thoracotomy tended toward the localization of the sinus in this area, but did not explain the fact that after drainage in the anterior axillary line the anterior part of the cavity healed rapidly while the posterior part persisted to form the chronic sinus. This could be explained in the first place by the accumulation of exudate in this region which resulted in thicker, cicatricial layers, and in the second place, by the tendency of the lung to adhere more quickly to the chest wall over its anterior surface.

The remaining 40 per cent of the chronic cavities showed either adhesions which prevented expansion, or such irregularities in shape that there was continual pus retention. This retention of pus was always associated with difficulty in sterilization and was often due to mechanical factors which were the result of adhesions and the contraction of the cicatrix during the obliteration of the cavity. Since the bismuth mixture used was of a consistence similar to the discharge from the cavities, it was possible to determine the causes of retention and poor drainage from the roentgenograms made immediately after the mass was drained out, because it collected in various parts of the cavity in considerable amounts when drainage was obstructed. Three main causes of pus retention were discovered in this manner. These were a poorly chosen operative site, a contraction of a cicatrized sinus which was long and sinuous and opened into a large cavity, and lobulation of the cavity by contraction of the scar tissue until areas were practically separated from the rest of the cavity and tended to form encapsulated pleural abscesses. In practically all of these instances in which bismuth was retained it was easily removed by flushing even though there was some obstruction to its free egress. In rare instances where part of the cavity had been separated by the pleural cicatrix it was removed with greater difficulty; a secondary thoracotomy was occasionally necessary before the partially encapsulated pus pockets could be emptied of the retained bismuth and purulent exudate.

Imperfect drainage due to the site of the operation occurred when resection had been done in the anterior axillary line or high in the posterior axillary line for the drainage of a large free exudate filling the posterior part of the pleural cavity. In these instances the bismuth collected in the cul-de-sac below the level of the drainage wound as shown in Figure 37. Flushing was sufficient to remove the bismuth; but on account of the improved drainage it afforded, a properly placed thoracotomy opening hastened healing. Occasionally these cavities would heal readily without secondary operations if they were relatively recent and if thorough dakinization was carried out. The obliteration of the cul-de-sac was brought about by costodiaphragmatic adhesions. The second type of pus retention occurred where there was no irregularity in the shape of the cavity but the sinus had been allowed to contract before the discharge had ceased. These cases, a type of which is illustrated in Figure 43, responded to dilatation of the sinus. The third type of retention due to adhesions within the cavity will be mentioned in the succeeding paragraphs. It is sufficient to state here that it was rare in pneumococcus empyemata or in thoroughly irrigated cavities. While it was possible to ensure spontaneous healing in these cases if the faulty drainage was corrected early, when the cavity was very chronic and refractory this seldom resulted in much change in size, though it was possible to sterilize a certain number by intense irrigation.

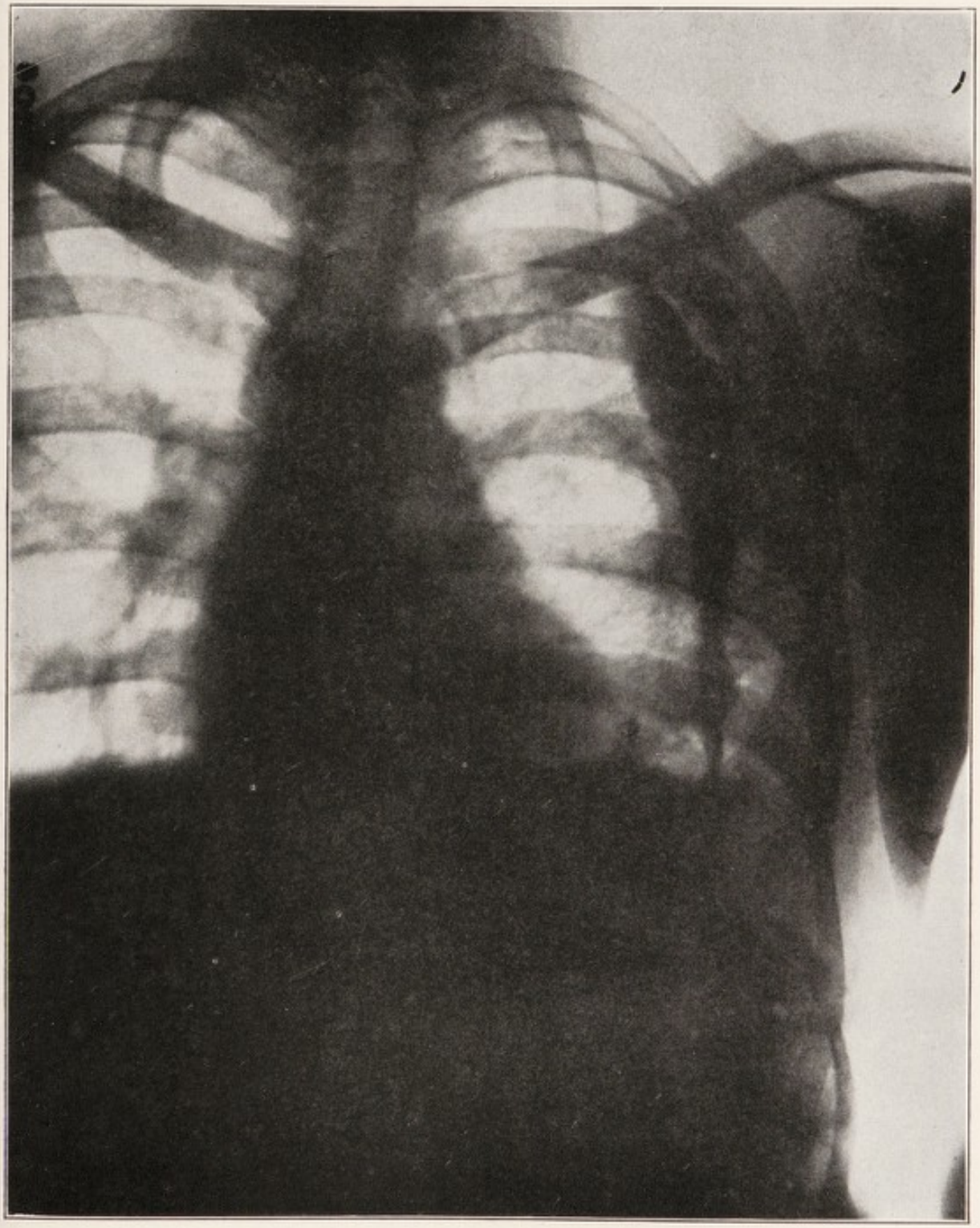

FIG. 43.—A cavity with a narrow, contracted sinus. On account of the narrow opening the bismuth and oil could not be removed without the insertion of a catheter. This exposure was made before the cavity had been irrigated to remove the retained suspension of bismuth.

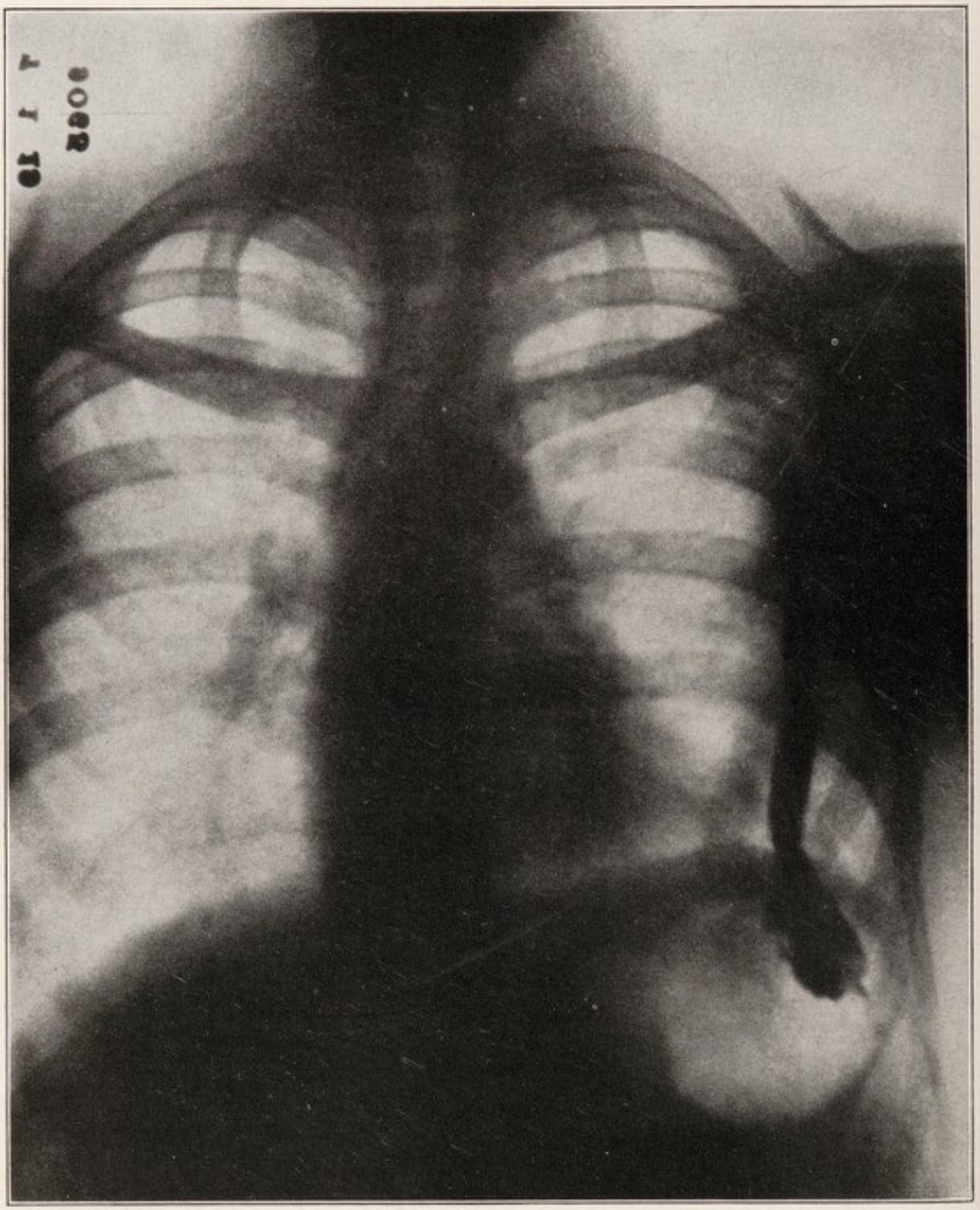

FIG. 44.—The cavity illustrated in Fig. 43 after dilatation of the sinus and irrigation with sodium hypochlorite. This exposure, made after an interval of three months, demonstrates the obliteration of the main part of the cavity under this treatment.

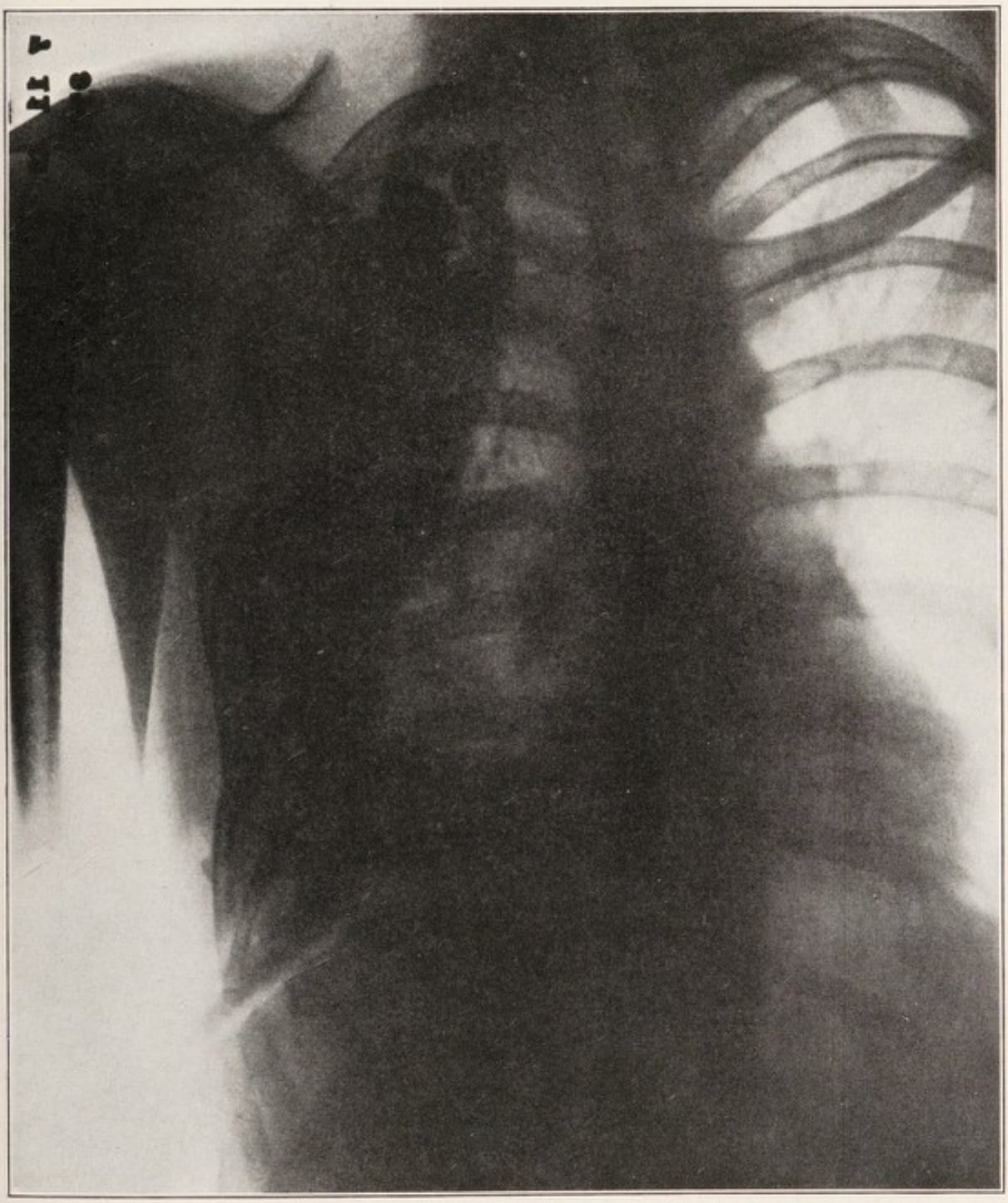

Fig. 45.—An irrgularly shaped chronic cavity filled with a suspension of bismuth in oil.

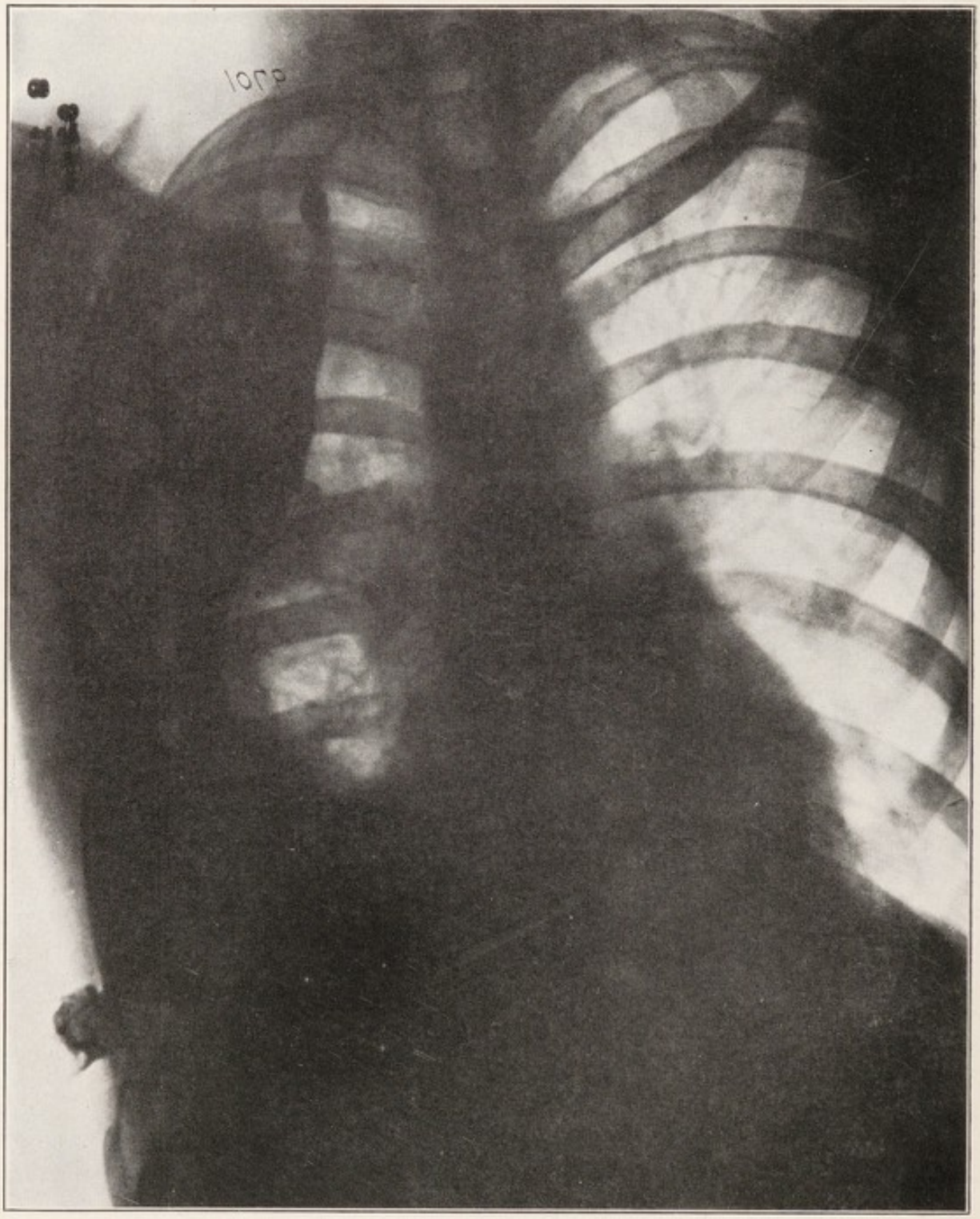

FIG. 46.—The cavity illustrated in Fig. 45, after an interval of one month. The cavity had been irrigated with sodium hypochlorite solution during this time. There was an obliteration of the cavity in all its diameters.

When the drainage and irrigation were improved, cavities which had become practically stationary usually diminished in size. This was noted especially in the very narrow sinuses which extended several centimeters through dense parietal cicatrix and then opened into a bulbous cavity higher in the thorax. The walls of the cavity were either rounded or irregular and shallow. When the sinus was dilated and Carrel-Dakin treatment assiduously carried out, roentgenograms of the injected cavities showed that there was considerable decrease in size after an interval of a few weeks. Small irregular lobulated parts of the cavity were the first to be obliterated by adhesions. In general, the prognosis in so far as the obliteration of the cavity was concerned, was best in cases which were not exceedingly chronic and in which the anterior and posterior margins were thin and slightly irregular. Margins of this character could be studied in stereoscopic roentgenograms of the bismuth-filled cavities. They usually indicated that the visceral and parietal pleuræ were still closely in contact in those areas and that adhesion was still occurring. When the walls had become thoroughly cicatrized these margins appeared rounded or obtuse on account of the gradual contraction of the scar tissue which exerted tension on the lung and tended to separate the lung surface and chest wall along the edges of the cavity. When these margins were so modified the majority of the cavities were practically stationary and there was but slight change in size even after long intervals.

In spite of careful examinations during the drainage period a certain number of encapsulated pus pockets were found late in convalescence. The majority proved to be abscesses within the parenchyma of the lung or pleural pockets some distance from the draining tract. These abscesses were probably formed during the acute inflammation of the pleura, and had been overlooked in the early roentgenograms because they were obscured by the thickened pleura and by the reaction in the lung tissue adjacent to the cavity. Abscesses and encapsulations did occur, however, in cases where the previous examinations left no doubt concerning the absence of pathology aside from the draining cavity. Many of these encapsulations were near the draining tract and in parts of the chest which had been previously occupied by cavity, so their origin could be explained only by assuming that they had been formed through the sequestration of a part of the tract by adhesions or by the contraction of cicatricial tissue. Occasionally, cases were found in which series of roentgenograms at frequent intervals demonstrated that irregular and lobulated cavities were at times divided in this way so that the sequestration of pus actually occurred. When the sequestra were small, thorough irrigation before the connecting sinus had completely closed was usually sufficient to cause sterilization and healing of the pocket. Large sequestra required secondary thoracotomy. Roentgenograms of massive effusions have shown the lung floated against the upper anterior chest wall by the accumulation of exudate in the lower posterior part of the pleural cavity. Autopsies on cases which died within the first few days of the infection indicate that adhesions are first formed over the anterior surface of the upper lobe where the lung and the parietal pleuræ are in contact; when the exudate has been partly removed or has not been sufficiently large to compress the lung into the apex of the pleural cavity, the adhesions have occurred over correspondingly greater areas of lung surface and along the rounded spinal margin. Especially have adhesions been found along the line formed by the upper border of the exudate. With the gradual withdrawal or absorption of fluid,

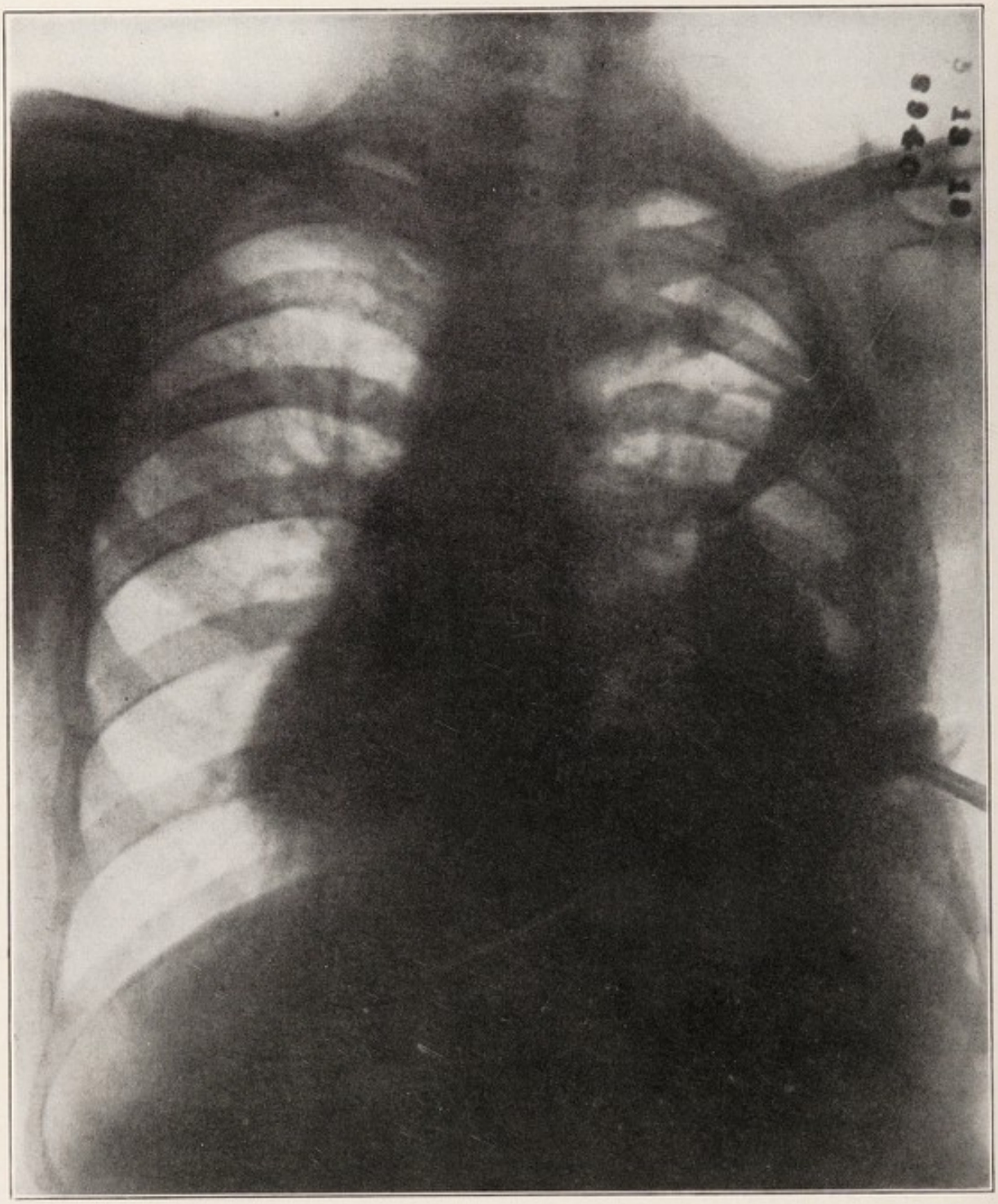

FIG. 47.—A chronic cavity with lobulation. Bismuth-oil injection.

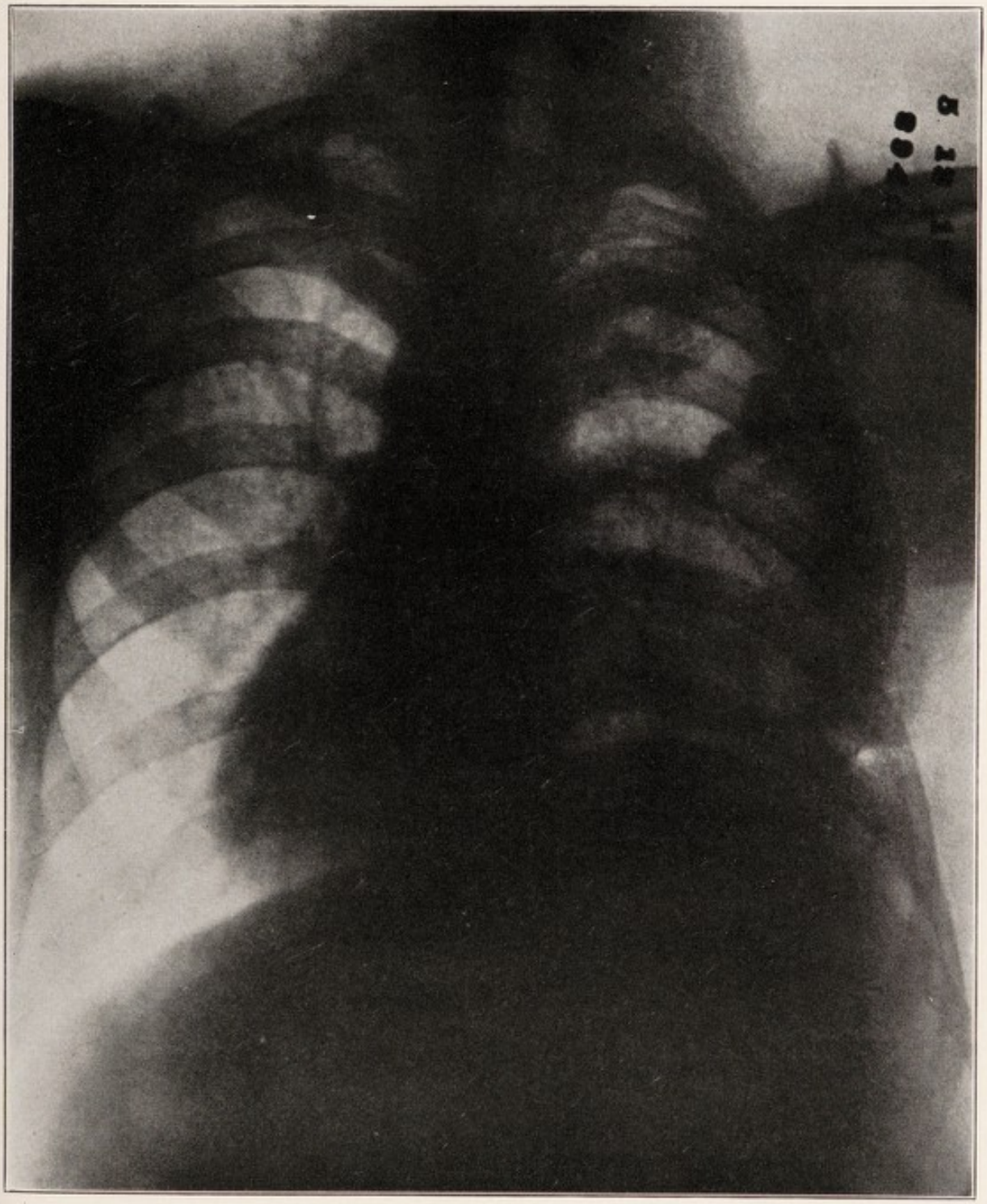

FIG. 48.—The cavity illustrated in Fig. 47, immediately after the bismuth mass had been allowed to escape. There was retention in the lobulation. This showed imperfect drainage.

adhesions have occurred along this receding line where the lung and chest wall come into contact. As the fluid always accumulated in greater amounts over posterior and lateral surfaces of the lower lobe, these surfaces were the last to become adherent. After thoracotomy the cavity naturally corresponded to the part of the thorax from which the residual fluid was removed at operation.

The majority of the cases appear to have been drained surgically while there was still considerable exudate in the pleural cavity, so the parietal pneumothorax produced by the collapse of the part of the lung which was not yet adherent prevented further contact of the pleuræ in this region. By filling these cavities with bismuth suspension the directions along which adhesions were formed could be determined by the rapidity with which the cavity diminished in size in a series of roentgenograms. Certain parts of the lung surface were usually adherent when the first roentgenograms were obtained following the operation. The lung between the angles of the ribs and the vertebræ, as well as the apex and that portion of the anterior surface near the mediastinum, were found to be bound to the chest wall in a large majority of these early cases. It appears that adhesions were then formed most rapidly along the circumference of the lung surfaces which were most convex and which were capable of the greatest expansion, because the anteroposterior dimension of the cavity diminished more rapidly than obliteration took place from the apex of the lung in the direction toward the thoracotomy wound. As a result of this difference in the rapidity with which adhesions were formed in these two directions, the chronic sinus assumed the elongated shape previously mentioned. Adhesions were formed much more slowly along the posterior than along the anterior margin, so the anterior and axillary lung surfaces were soon adherent, leaving a posteriorly located cavity or sinus.

The direction of the chronic sinus has been referred to frequently in the preceding paragraphs. It was noted, in every instance where the lung had expanded and had not been impeded along the lower margin by adhesions to the diaphragm which held the surface away from the parietal wall, that these sinuses were directed posteriorly rather than anteriorly from the thoracotomy wound. This was accounted for by the position of the angles of the ribs and the increase in the circumference of the lung at successively lower levels from the apex to the diaphragm. Adhesions were formed early over the posterior surface as far as the costal angles, so there was a tendency for the lower part of the posterior margin of the cavity to be situated more anteriorly than portions of this margin which were nearer the apex. Furthermore, since the apex was adherent early, the upper, anterior parts of the cavity were obliterated by advance of the adhesions around the lesser apical circumference, while the anteroinferior parts were not closed by adhesions so quickly because of the greater extent of the pleural surface over this greater lung circumference. The combination of these two factors, together with the sluggish formation of adhesions from the apex directly toward the thoracotomy wound, accounts for the oblique direction over the posterior surface of the lung and the elongated shape of the sinuses.

### PLEUROPULMONARY FISTULA.

Pleuropulmonary fistula was a common cause of delayed healing. These fistulae occurred with the greatest frequency in cases of chronic streptococcus empyema, and because the fistulæ were continual sources of contamination, cavities so complicated were difficult to sterilize. Fistulæ were usually

FIG. 49.—A shallow posterior empyema cavity filled with bismuth suspension.

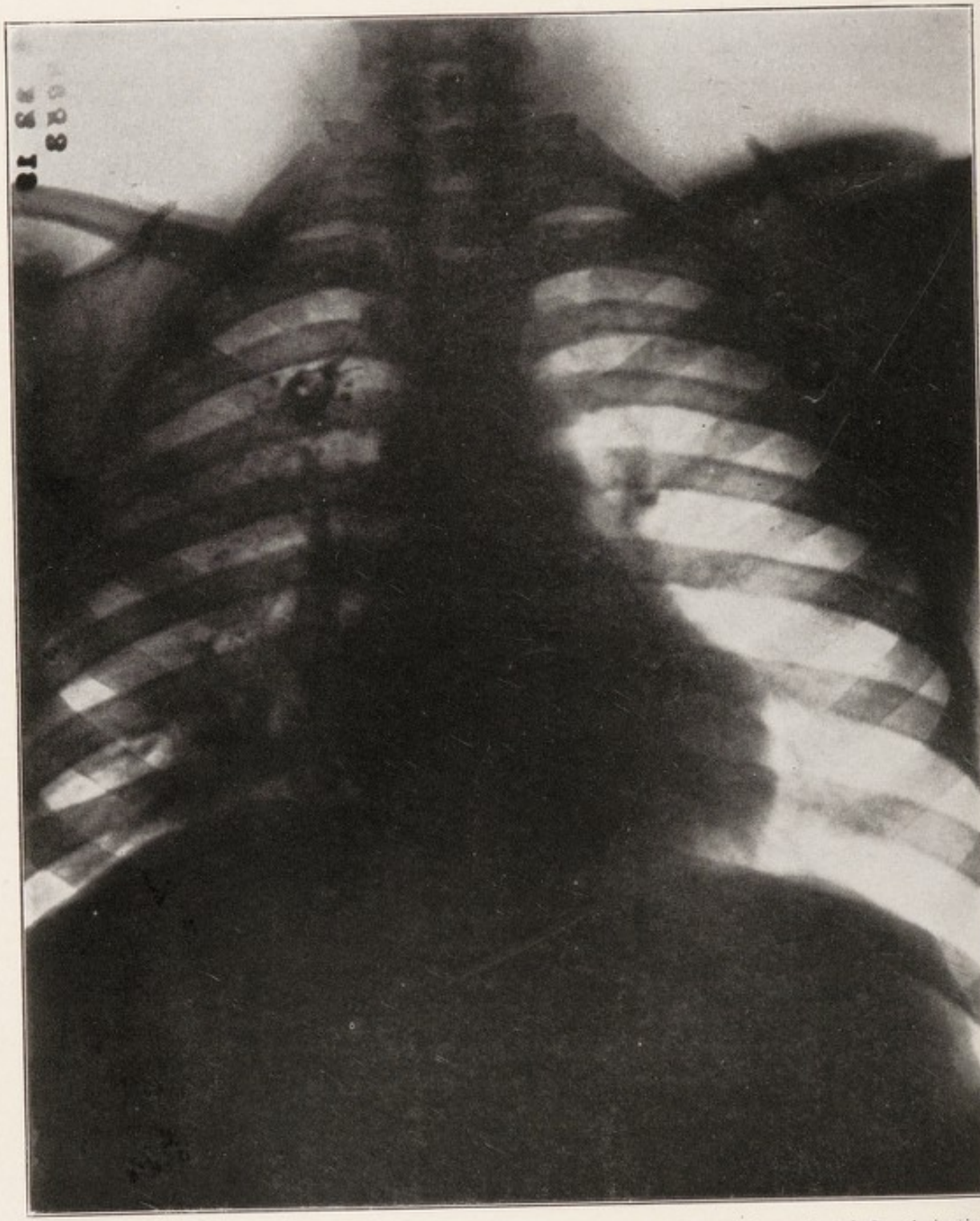

FIG. 50.—The cavity illustrated in Fig. 49 after the bismuth suspension had drained out, but before irrigation.

suspected because of the severe cough and the expectoration of Dakin's solution during irrigation. It was believed that bismuth-oil injections should not be undertaken when the cavity communicated with the bronchial tree, but in some instances, as shown in Figure 35, the bronchi leading from the fistulæ were found filled with bismuth when there had been no previous indication that a communication existed. The bismuth either outlined the bronchi clearly or was disseminated throughout the affected lung; there were no untoward effects from the procedure. Pastes were also employed with highly satisfactory results for the localization of fistulæ because they were not scattered throughout the lung as frequently as the oily suspensions, but, in view of a number of cases which showed considerable amounts of opaque material in the lung parenchyma at long intervals after the cavity was injected, it was considered inadvisable to employ this procedure as a routine diagnostic measure. Beck has emphasized the precautions which should be observed in cases where pleurobronchial communications are known to exist.[8]

Early healing of cases beginning with a pneumococcus infection was more frequent than among those following hemolytic streptococcus pneumonia. The streptococcus cases went through a chronic period of drainage and contraction which lasted several months. Many of them finally formed a small sinus; others reached a stationary stage when they were still comparatively large, so that a fair percentage required thoracoplastic operations. When it was decided that surgical interference was the only means of treatment and that it would involve the removal of parts of several ribs, stereoscopic plates of the bismuth-filled cavities gave an accurate idea of the location of the cavities and supplied information as to the extent and character of the operation that would be necessary to bring about approximation of the chest wall and lung surface. The difficulty frequently experienced in localizing points within the thorax in relation to the body surface was obviated very largely by stereoscopic roentgenograms or by fixing a coarse wire screen to the chest wall in a manner described by Beck.

### THE STUDY OF CONVALESCENT PATIENTS.

Roentgenograms obtained after the wounds were healed served a manifold purpose. They were necessary in many cases because physical examination was not conclusive in regard to the nature of the pathology which existed in the thorax, because the thickness of the pleura rendered physical examination difficult. This thickening of the pleura resulted in dullness and diminished fremitus at the base and near the site of thoracotomy. To distinguish between such pleural thickening and an accumulation of fluid in the closed sinus by physical examination alone was frequently impossible unless the fluid was purulent and the condition was accompanied by elevation of temperature and other systemic reactions. While the roentgenograms were not always decisive as to the nature of the existent pathology it was possible to choose the site for exploratory thoracentesis more intelligently after stereoscopic study.

Reaccumulations of pus often occurred in the healed sinus tract and usually were clinically evident from the local reaction and the bulging of the scar. When the sinus was small the roentgenograms did not show an increase in the shadow when compared with those made at previous exposures because there was usually much cicatricial tissue which obscured the small accumulation of fluid.

The reaccumulations in the larger sinuses were accompanied by less local reaction. The dullness and decreased fremitus which occurred over the old cavity were often diagnostic, of course, especially if the temperature were elevated. Roentgenograms of these large recurrences showed dense shadows with sharply defined margins which did not resemble the diffuse shadow of moderate density found with pleural adhesions and cicatrization alone. Futhermore, shadows due to adhesions usually increased in density toward the diaphragm, while those due to fluid were practically always in the upper parts of the thorax and corresponded to the sinus in direction and location. Roentgenograms of the unhealed cavity filled with bismuth and those obtained immediately after the wound had healed were valuable for comparison.

In nearly every healed empyema there was a remnant of the sinus which formed a blind closed pocket, so that it may be said that healing, in so far as it can be applied to these empyemata, signified that the sinus or cavity had been sterilized, or the discharge had so diminished that it was possible for the wound to close. The small sinuses extended only through the parietal wall and could not be discerned in roentgenograms. The larger sinus tracts were indistinguishable unless they were air-containing or were filled with exudate. Those containing air, which was retained on account of the wide separation of the visceral and parietal surfaces at the time the drainage tubes were removed, when the external wound was allowed to close, pursued one of two courses. Usually the air was gradually absorbed and after many months the lung was approximated to the chest wall. The second possibility, which was in fact a rather rare occurrence, was that the closed, air-containing cavity communicated with the bronchial tree and instead of decreasing in size appeared larger in later roentgenograms. Occasionally such cavities were reinfected through the fistulous communication and, if exudate accumulated, showed a shifting fluid line. When fluid occurred, differentiation between serous and purulent exudates was impossible without exploratory thoracentesis. Serous fluids were absorbed and did not accumulate after having been once aspirated.

The roentgenograms of these closed cavities were interesting in respect to the character of the cicatrix over the lung surface and on the parietal wall. In roentgenograms obtained during the drainage of the cavities the parietal pleura was always several times thicker than that over the lung and, although it cast a moderate shadow, this shadow was never as dense as that of the cicatrix over the lung surface. Later, when the cavity had healed, this parietal layer was very frequently so transparent that on cursory examination it resembled an air-containing cavity. These pleural shadows differed in certain respects from an encapsulated pneumothorax so that in stereo-roentgenograms differentiation was always possible. The semitransparent area was always wedge-shaped with the base near the diaphragm and the apex of the wedge near the apex of the lung; furthermore, the density of the shadow was found to be similar to that of the tissue between the ribs and was not as clear as that of a pneumothorax. No explanation was found which might account for the transparency of the thick parietal pleura.

Roentgenograms following pneumococcus infections showed a normal lung parenchyma, but those obtained after hemolytic streptococcus bronchopneumonia and empyema indicate that there is a residual thickening of the septa

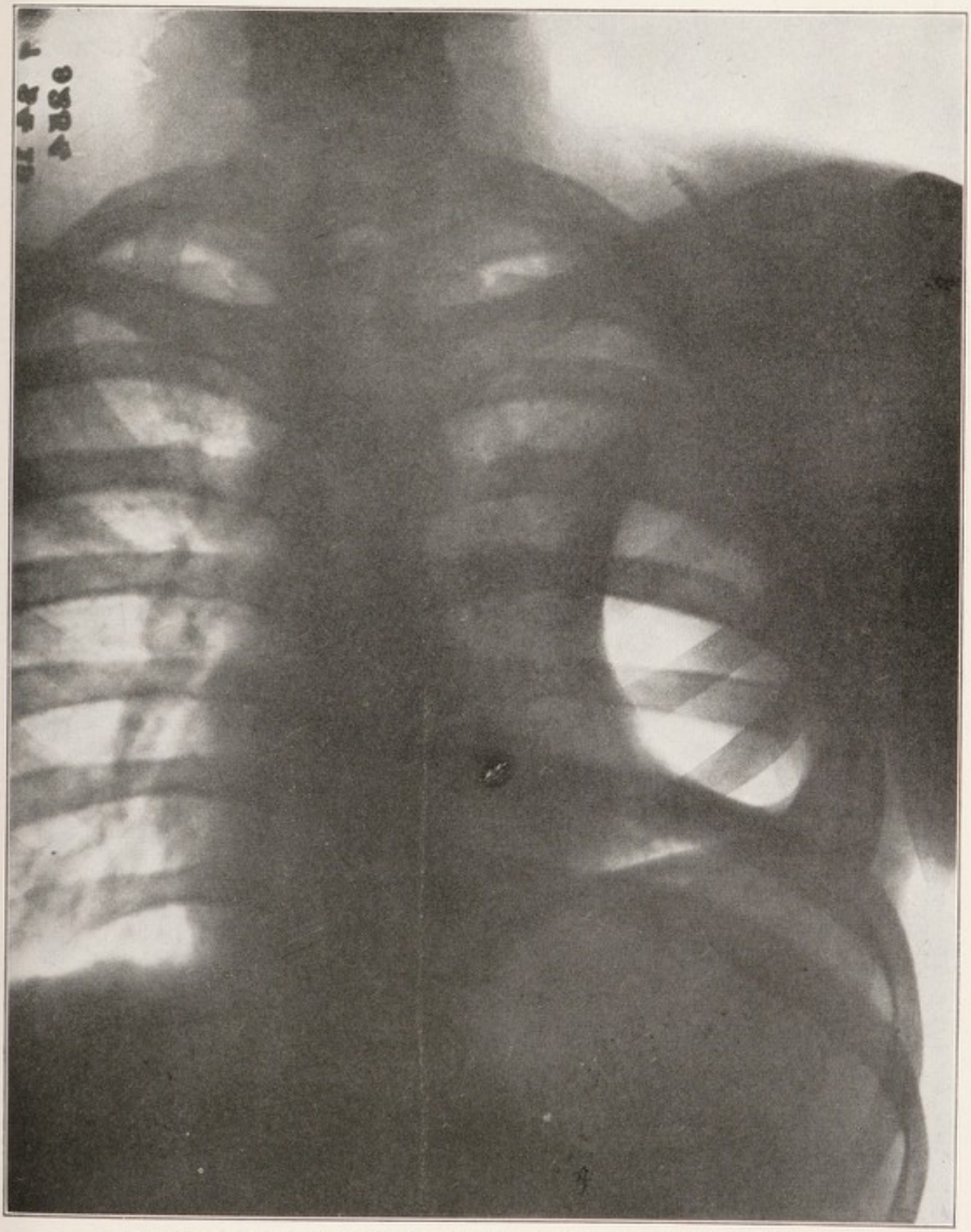

FIG. 51.—A healed pneumothorax due to a patent pleuropulmonary communication.

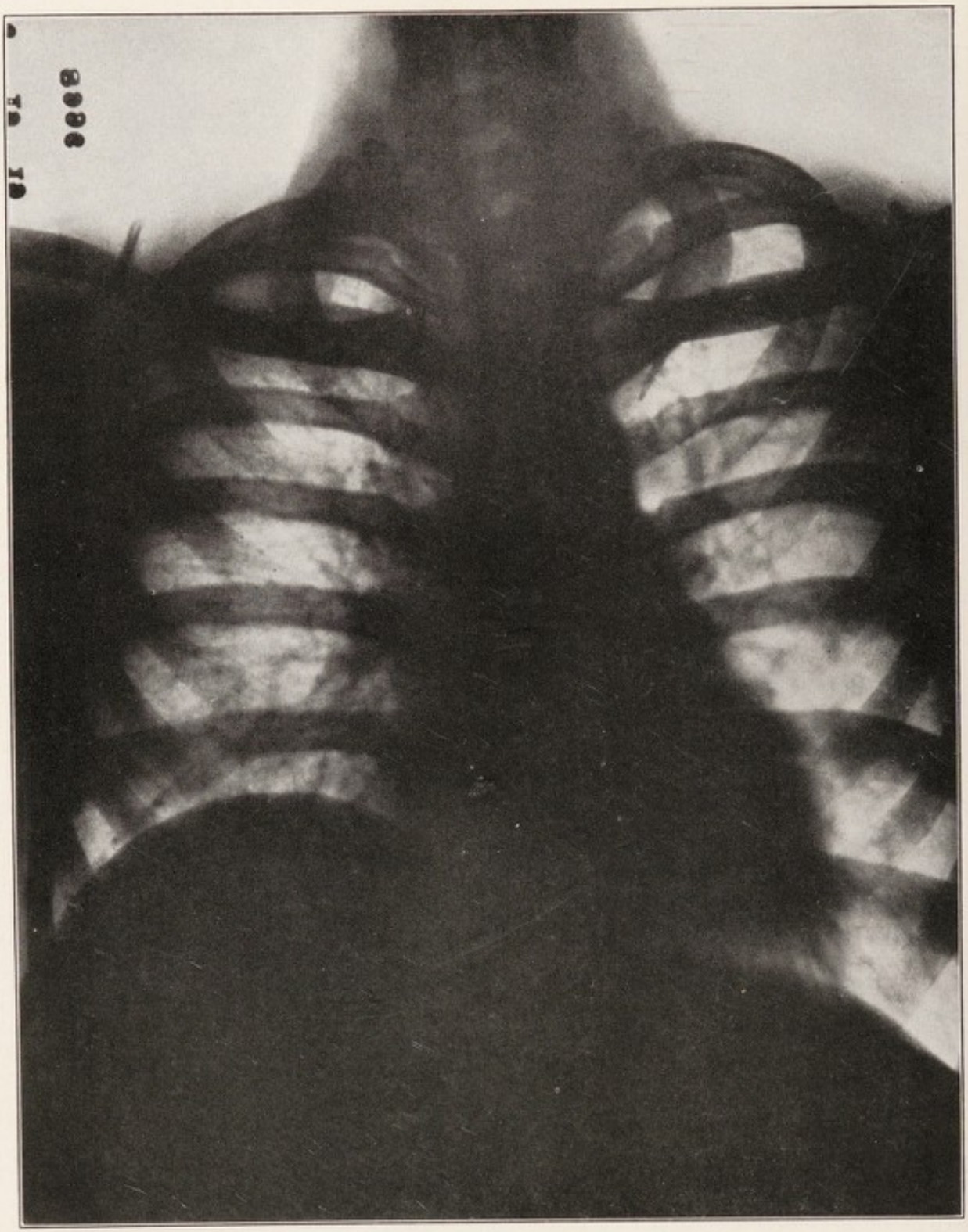

FIG. 52.—Healed empyema showing a moderate elevation of the diaphragm on the affected side, and compensatory expansion of the opposite lung.

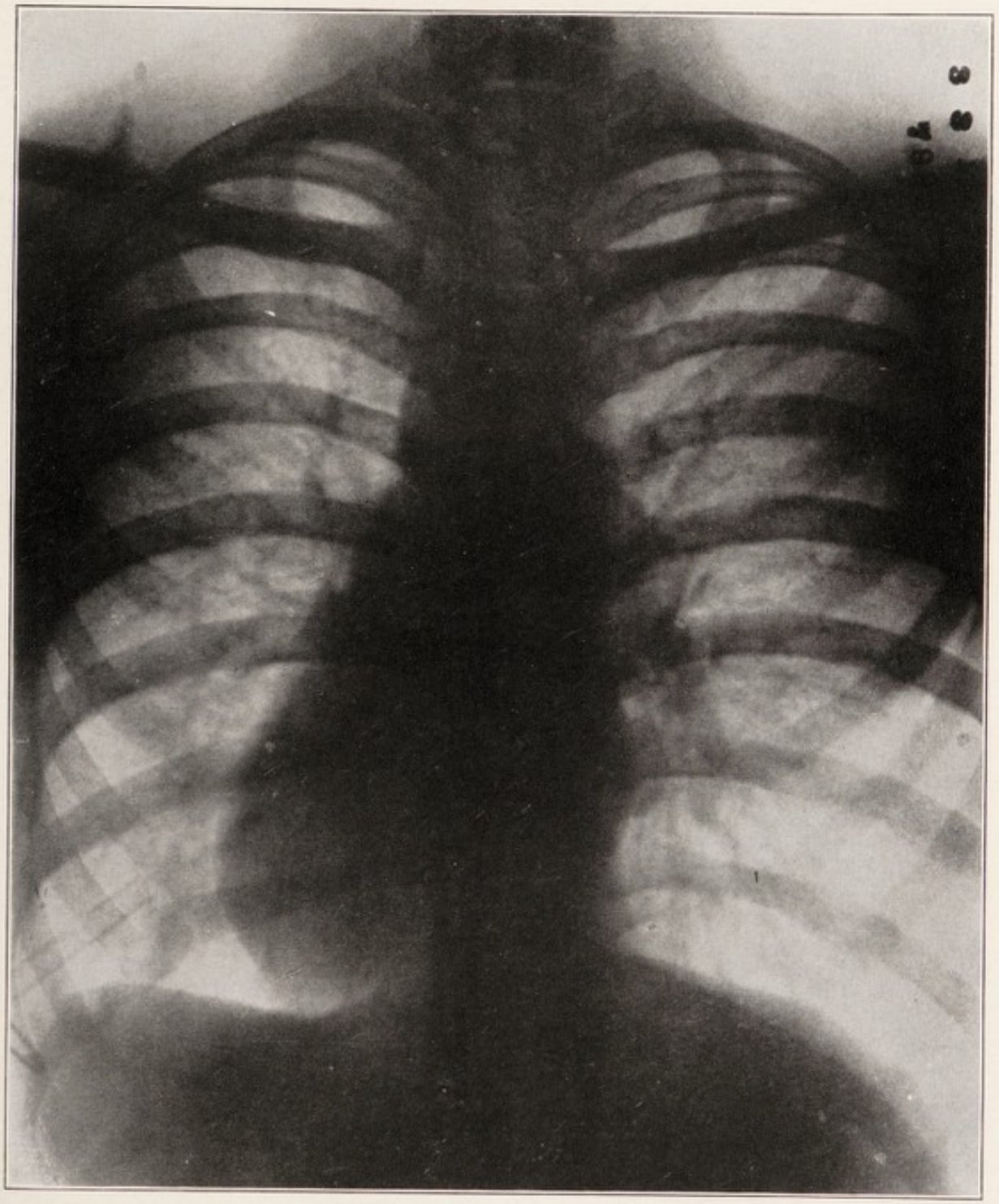

FIG. 53.—Postoperative empyema following streptococcus pneumonia, showing the characteristic lung markings following the infection.

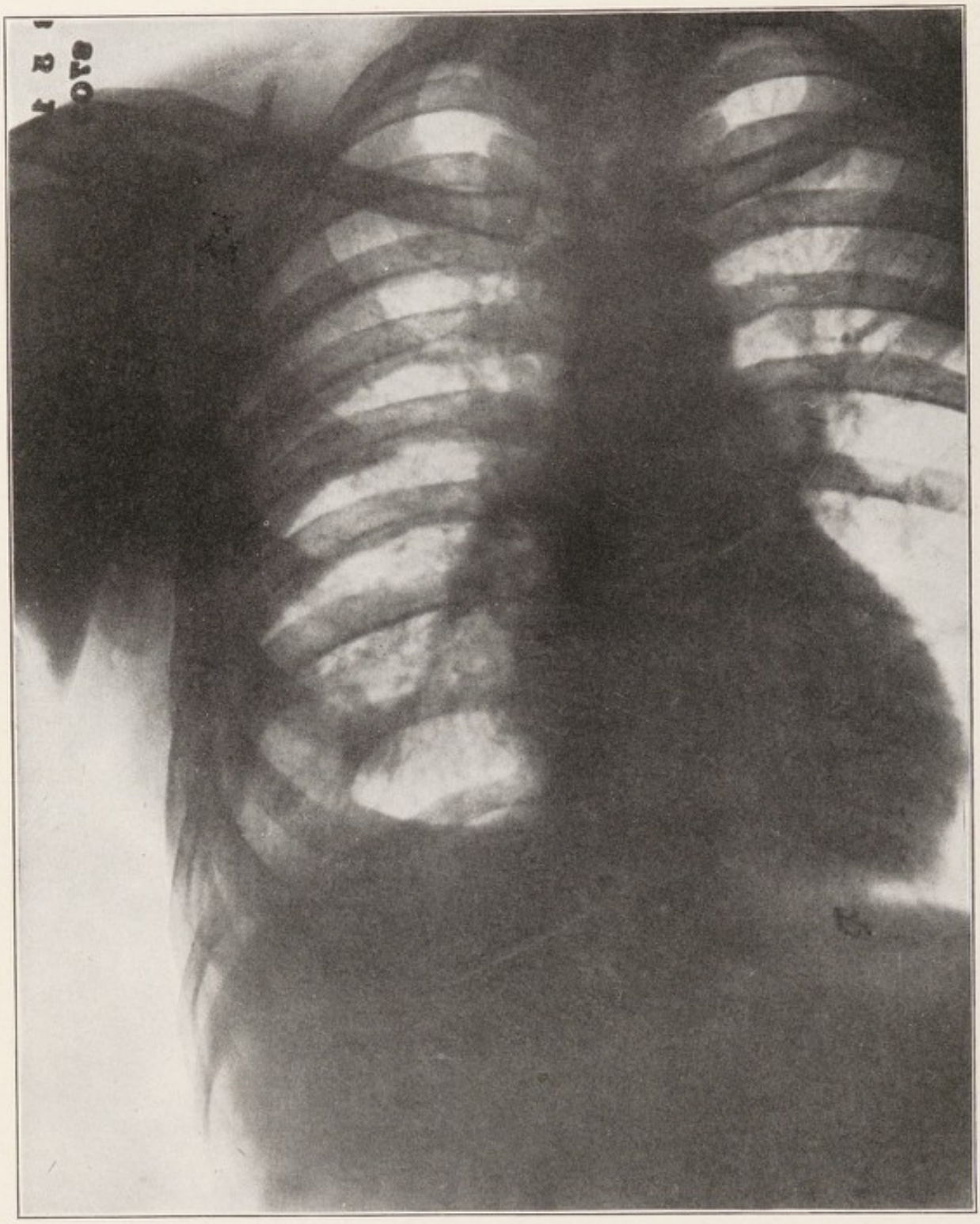

FIG. 54.—Healed empyema with an adherent diaphragm and dilated bronchi at the site of the healed wound.

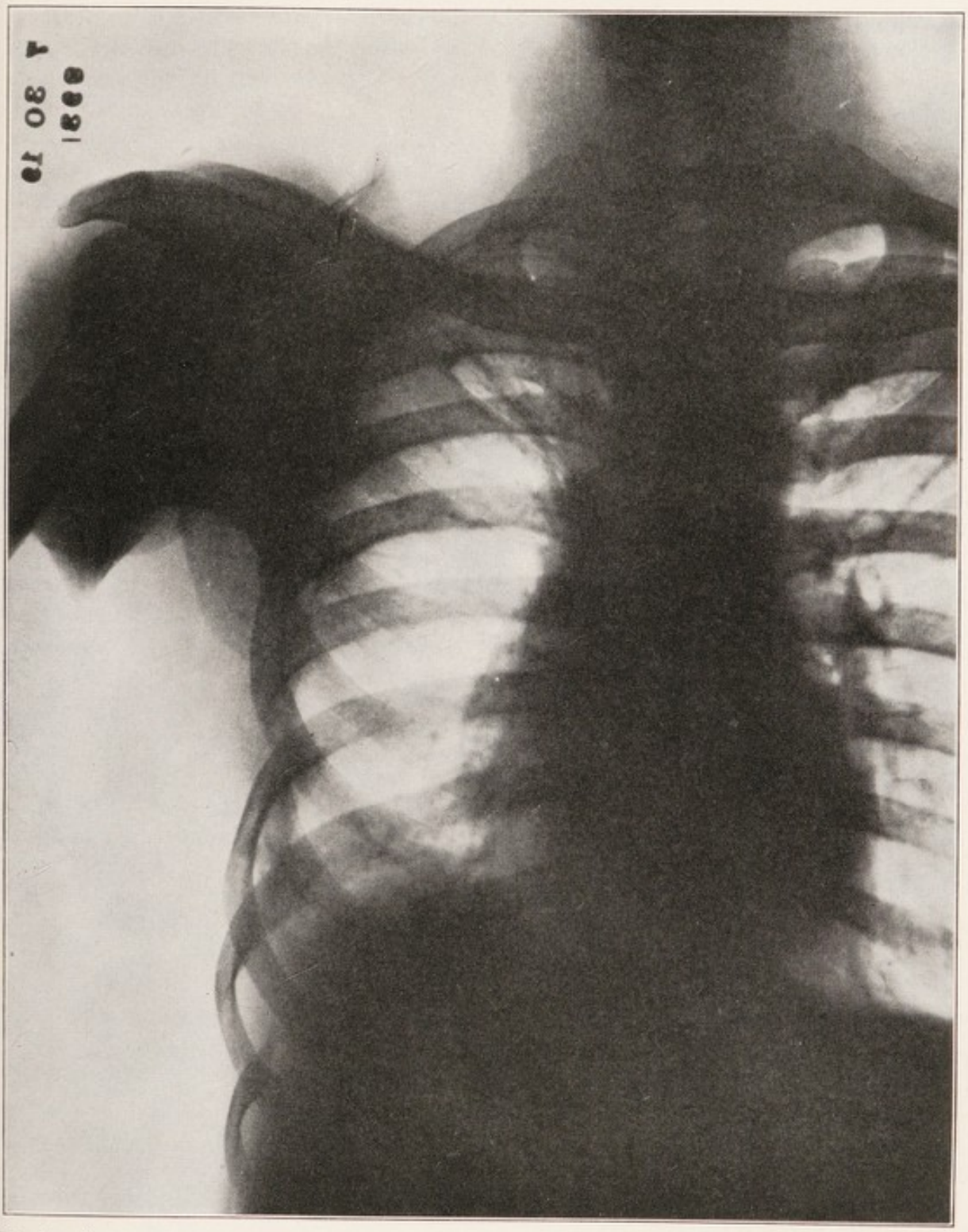

FIG. 55.—Postoperative empyema with a thickened interlobar septum, thickened pleura, and an active tuberculous lesion at the right apex.

and interstitial tissues which persist as long as it is practicable to follow the cases. After intervals of one or two years, the septa could be traced from the bronchi outward to the margin of the lung. They were always more prominent in the affected lung. These markings differed from the delicate fan-like apical lesions of tuberculosis or the patchy mottled appearance of a tuberculous bronchopneumonia in that their distribution was throughout the whole lung area, and the lines were discrete and fine and radiated outward through perfectly aerated lung. No change has been found to occur in radiograms taken at various intervals during convalesence. Dense nodules have been found along the course of these markings in a large percentage of the cases with greater frequency than they have occurred in the lungs of patients without a history of streptococcus pneumonia. Unfortunately it was impossible to obtain plates of these men taken before the pneumonia, so it can not be said definitely that they did not exist prior to the infection. In the absence of a tuberculous history, both before and after the pneumonia, it was believed that they might represent interstitial changes in the glands and lung parenchyma incident to the pneumonia.

A diffuse, basal bronchiectasis with markedly thickened bronchi was observed after many of the infections. It was usually confined to the lower lobe after a combined infection with hemolytic streptococcus and Pfeiffer's bacillus. The bronchi and smaller air passages appeared thickened and could be traced out to the lung margin through the shadow of the lung substance, while the adjacent lung appeared mottled and patchy. This lesion was especially common in roentgenograms of patients convalescent from bronchopneumonia secondary to influenza. It was frequently confused with tuberculosis or with the inflammatory reaction surrounding abscesses or paravertebral pus pockets. In rare instances tuberculosis developed in these bronchiectatic areas after intervals of two or three years without modifying the picture in such a way that the diagnosis could be made until the process was well advanced. Apical bronchiectatic lesions have occurred in postinfluenzal cases, but since these lesions were not roentgenologically distinctive they were considered tuberculous.

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## CHAPTER VI.

# CLINICAL ASPECTS OF STREPTOCOCCUS PNEUMONIA AND EMPYEMA.

### EPIDEMIOLOGIC CONDITIONS PREDISPOSING TO INFECTION WITH HEMOLYTIC STREPTOCOCCI.

Although empyema occurred in a small percentage of the military personnel before the induction of men fresh from civil life to make up the National Army, it was not until these recruits were gathered together in the camps that the morbidity and mortality rates for empyema were markedly increased. The empyema which had been common in civil life was usually due to pneumococci. The morbidity and mortality rates for pneumococcus infections were low, but as soon as the camps were filled with new men, infections with hemolytic streptococci were most common. This type of infection had occurred before during military operations. It was prevalent during the War of 1812, and, according to MacCallum,[1] probably occurred as a sequela of measles during the Civil War. In civil life hemolytic streptococcus pneumonia-empyema was recognized as a frequent and much feared complication of measles in children. At times it had been epidemic in parts of the United States. It appears that immediately before the mobilization of the Army these minor epidemics were more common than they had been in previous years.

Cases of hemolytic streptococcus pneumonia and pleuritis probably occurred in the Regular Army before the last few months of 1917, but it was not until late in that year that they were sufficiently numerous to attract general attention.[2] Pleuritis of unusual severity was observed along the Mexican border among troops of the Regular Army and the National Guard. This was before the World War. The pneumonia and pleural infections were so severe in these cases that the operative risk was great. Early in 1917 aspiration was adopted as a routine measure preliminary to operation. This method of treatment was suggested at that time by Keller[3] on account of the high mortality rate following surgical drainage of the pleural cavity during the first few days of illness. From the descriptions of these cases it is probable that they were similar in every respect to the cases which were observed later in the military camps during the mobilization of the National Army.

The first camps in which any great number of cases of empyema occurred were Beauregard and Wheeler. These camps were composed largely of men drafted from the rural districts of the Southern States. The epidemics of pneumonia in these camps were preceded in each instance by an epidemic of measles, and as pneumonia became more prevalent the incidence of empyema increased. In many of these cases empyema followed lobar pneumonia but the majority of them were secondary to hemolytic streptococcus bronchopneumonia. The first cases of streptococcus infection which occurred were apparently as severe as those which occurred two or three months after the epidemic began when the morbidity rate per thousand men had reached its highest peak. Later, in the spring of 1918, a few cases occurred in the northern camps, but, except in a few instances, they were scattered and the disease did not assume epidemic proportions.

In those camps in which streptococcus pneumonia was prevalent diseases of the upper respiratory tract were common and the plotted curves of the ratios (Chap. II) of the pulmonary and common respiratory diseases per 1,000 men show that pulmonary and common respiratory infections had the same seasonal variations and that the ratios of their incidence were practically parallel during various periods of the year. In a few isolated instances bacteriologic surveys showed that hemolytic streptococci were responsible for a fair percentage of the cases under this heading.

On account of the statistics from camps such as Camp Custer, where measles apparently played a very subordinate part as a factor predisposing to infection with hemolytic streptococci, and from camps such as Camp Dodge, where the cases were more equally distributed in regard to the predisposing infection—that is, between measles and other common respiratory diseases—it is evident that measles was not the only factor in the dissemination of hemolytic streptococcus infection. It does appear, however, that the majority of the first cases in the southern camps followed this exanthem and it is probable that on account of the large number of cases which developed, the virulence of the streptococci was enhanced and that the number of carriers was markedly increased in these localities.

The increased number of carriers undoubtedly had a great influence on the number of new cases. When the epidemic first began the infection was probably direct, in the sense that cases of respiratory disease were placed side by side in the wards of the hospital, and, on account of the ease with which streptococci pass from one individual to another, a case of streptococcus tonsillitis could be responsible for the direct infection of several other individuals. In the same way, a single streptococcus bronchopneumonia in a measles ward might result in the infection of several other patients. Cases once infected were prone to carry the bacteria in their throats for a lengthy period. The most rigid antiseptic treatment of the fauces was of little avail in terminating the carrier state.[4] These carriers were sources of infection and distributed the bacteria among normal patients as well as among patients with the simpler, common respiratory diseases. A vicious circle was established by this constant association of healthy men, carriers, and infected patients. Patients with the mildest respiratory diseases were constantly in contact with sources of streptococcus infection, and pneumonia was naturally more common on account of these contacts. The rôle which the increasing virulence of the bacteria may have played can not be determined.

Bacteriologic surveys of wards during the winter of 1917 and 1918 showed that streptococci could be disseminated throughout a ward from a single infected case. This was not only true for wards of patients in which there were streptococcus lung infections, but it was equally true for wards of patients in which there were carriers of streptococci only. These surveys showed that when carriers or cases of bronchopneumonia due to hemolytic streptococci were admitted to wards previously free from streptococcus infection, within a few days streptococci could be found in the throats of the majority of the other patients. When this occurred in measles wards, cases of pulmonary infection subsequently developed. The practical application of this observation was carried out at Fort Sam Houston during February, March, and April

of 1918. All cases of the exanthemata were held in an observation ward until the diagnosis was made. During the 24 or 48 hours that the patients were under observation for diagnosis, throat cultures were made to determine the cases already infected with streptococci. Those not infected with streptococci were isolated from those who were already carriers. The pulmonary complications following rubella were so infrequent that segregation of the carriers was not necessary. This simple precaution resulted in a definite decrease in the number of secondary complications after measles. The results of these surveys have been published by Cole and MacCallum,[5] and by Clendenning.[6]

The percentage of carriers among the personnel of the camps and hospitals varied according to the season and according to the local prevalence of streptococcus infections. No general surveys were made during the winter of 1917 and 1918, but during the epidemic of influenza in 1918 and 1919 a survey which illustrates some of these variations was carried out at Walter Reed General Hospital in Washington, D. C.[7] There were two waves of influenza at this hospital. The first wave occurred during October and November, 1918, and the second during January, February, and March, 1919. There were few streptococcus infections previous to January, but during the latter half of this month and during February, infections with hemolytic streptococci were common. These infections were not confined to pulmonary conditions but included primary surgical infections and secondary infections of wounds. Such a circumstance would be expected only if there were an increase in the number of carriers as all infected cases were carefully isolated. The survey for throat carriers was begun at a time when influenza was on the decline, yet pulmonary streptococcus infections were at their height. Surprisingly enough the number of carriers among the normal individuals selected for study increased until the last of April when there was a sharp decline in the percentage. During the time that the percentage of normal throat carriers was increasing, influenza had practically died out and there were but occasional cases of bronchopneumonia, but there were numerous instances of infections with streptoccoci of primarily surgical nature. While it is impossible to draw too rigid conclusions from a single survey of this kind, certain facts stand out preeminently. First, it is apparent that the streptococci were unable to invade the lungs in the absence of a predisposing respiratory infection. This is evident, since during April, 1918, there were more normal carriers than at any previous period, but few cases of bronchopneumonia occurred. There was practically no influenza and little upper respiratory disease at this time. Second, the number of carriers was increased by contact between carriers and normal individuals not previously infected.

It would appear from the preceding considerations that the carriers and upper respiratory infections were responsible in a great measure for the epidemics of bronchopneumonia and that a study of these factors and their relations would explain the epidemiologic variations found in different camps. Previous experience in civil life had demonstrated the close association between measles and hemolytic streptococcus pneumonia, so that in camps in the Southern States where the two appeared almost simultaneously there is every reason to believe that, since measles was directly responsible for a large number of cases, it was the most important epidemiologic factor. The increase in the number

of carriers following such a widespread infection, together with the prevalence of other respiratory diseases, could account for the fact that streptococcus bronchopneumonia was not confined to cases of measles but followed other bronchial infections and occurred long after the epidemics of measles had subsided. In some of the northern cantonments there were but few cases of measles. In these camps the epidemic of streptococcus pneumonia began later than in camps where measles was the predominant primary infection. This situation can be compared to that at Walter Reed General Hospital where influenza was the primary respiratory disease. Pneumococcus infections were the most common but during the latter part of the epidemic there were numerous cases of streptococcus bronchopneumonia. It was a universal observation that measles predisposed to an early epidemic of streptococcus pneumonia,

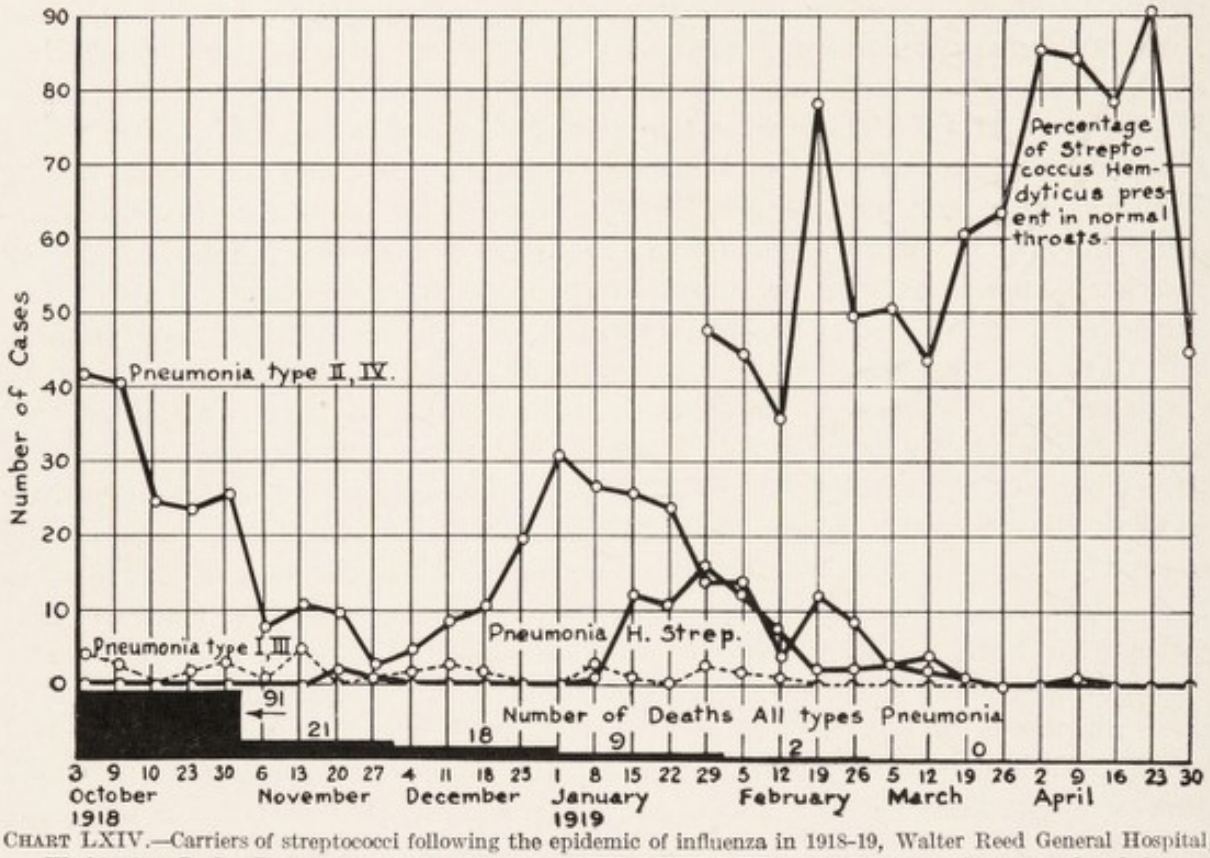


CHART LXIV.—Carriers of streptococci following the epidemic of influenza in 1918-19, Walter Reed General Hospital, Washington, D. C. This chart, as well as Charts LXVIII, LXIX, LXX, and LXXI, have been reproduced through the courtesy of the *Journal of the American Medical Association*.

while epidemics of other bronchial infections might or might not be accompanied by the disease. If it occurred it came late in the epidemic.

### SYMPTOMATOLOGY AND PHYSICAL SIGNS.

Streptococcus bronchopneumonia and pleuritis were usually secondary in the sense that they followed a primary upper respiratory infection. In some camps the majority of the infections followed measles while in others tonsillitis, bronchitis, and pharyngitis preceded most of the cases. In many instances it was difficult to elicit a history of respiratory disease. The patients often gave a history of cough, headache, and malaise for a few days preceding the onset of the pneumonia. Nosebleed was common in this type of infection. In some cases the onset was sudden, with intense pleural pain and fever, but a careful study of the cases showed that there had been predisposing respiratory disease.

The symptoms at the time of onset varied according to the localization of the infection. There were, in fact, two types of cases. In one type the pleura was predominantly involved throughout the course of the disease. In the second type the pneumonia was the most striking feature. Cases with evidence of early pleural irritation were most common after tonsillitis, bronchitis, pharyngitis, or mumps. They even occurred without a history of a preceding respiratory disease. There were pleural pain, fever, nausea, and vomiting. The onset was occasionally accompanied by chill, but less frequently than in lobar pneumonia. The exudate usually developed early and occurred in large quantities. Cases of the second type began with an aggravation of the symptoms of the preceding infection. When the pneumonia followed measles a secondary rise in temperature was observed between the third and the seventh days after the rash appeared. These infections were most frequently seen when the measles had been accompanied by a severe bronchitis. The bronchitis became more severe with the rise in temperature, the râles over the bases were more numerous and liquid, and the cough was aggravated. Chills were not frequent in this type of case and pleural pain was not a striking feature. While the majority of the cases belonged distinctly to one of these types, cases were observed in which both the pneumonia and pleuritis were severe in the first few days of the infection.

When the pneumonia was fully developed the respiratory distress was the most striking feature of the disease. Respiratory embarrassment was not marked when the pneumonia was not extensive and the infection was confined mostly to the pleura. The respirations were always shallow at the onset when there was much pleural irritation, but as soon as the pain subsided they assumed a more normal character. When the pneumonia was extensive in both lungs the respiration was rapid, shallow, and labored. The patients were restless and anxious. There was marked inspiratory and expiratory embarrassment, so that the accessory muscles of respiration were brought into play and the alæ nasi contracted sharply with each inspiration. The respirations were usually 40 to 60 per minute. There was constant, exhausting productive cough with large amounts of frothy mucopurulent sputum. After a severe paroxysm of coughing, the patient was drenched with sweat, the respirations were shallow and rapid and the face was flushed or cyanotic. Cyanosis was common during the later stages of the disease.

During the first two weeks of the disease, the temperature in the majority of the cases averaged 102° to 104° F. When the infection was predominantly pleural it was usually continuous for the first few days after the onset, with daily variations of only one-half to one degree. As soon as the pneumonia was fully developed the differences between the morning and evening readings were more marked, and they were frequently as great as 3°. In certain cases the pneumonia was never extensive but there were large quantities of pleural exudate. In these instances the temperature was usually highest at the time the exudate was first formed. After each aspiration it would fall 1° to 3°, but would rise again as more fluid was produced. This irregular temperature curve continued until the time of operation.

These daily variations in temperature were usually most extreme when the patients were expectorating large quantities of mucopurulent sputum.

Occasionally there were drenching sweats, and after these sweats the temperature might be normal for several hours, but true crises were not observed in the streptococcus infections. The high fever persisted in the majority of cases from three to four weeks. During the third week the morning temperature might be normal, but evening elevations occurred for several weeks after the empyema had been drained and the bronchopneumonia had resolved.

The pulse was rapid and weak. Herpes occurred at times but was not seen as frequently as it was observed in lobar pneumonia. Vomiting and nausea were common during the first few days but seldom persisted beyond the first week. Abdominal distention was infrequent. The liver and spleen were seldom palpable. Jaundice, usually associated with tenderness over the liver, was observed both early in the course of the bronchopneumonia and immediately before death.

In cases of bronchopneumonia which were not complicated by an effusion at the onset there was moderate dullness over the consolidated lung. The râles were usually confined to the dull area and were at first fine and crepitant, but after the second or third day they were coarse and bubbling. In the cases following an acute bronchitis or measles several such areas were often observed on the first or second day of the pneumonia. As the pneumonia advanced these areas of dullness became confluent and râles were heard over the entire chest. The percussion note elicited was never as flat as that elicited over the consolidation of lobar pneumonia. The breath sounds were bronchovesicular or bronchial and they were often suppressed at the onset of the pneumonia. Tactile fremitus was diminished at first, but later was normal or slightly increased.

When a massive pleural effusion developed within the first few hours after the initial symptoms of cough and pleural pain the physical signs were often similar to those found in extensive lobar pneumonia. The percussion note over the affected lung was flat; the tactile fremitus was either increased or normal, rather than diminished, as would be expected with a large effusion; the breath sounds were either suppressed or bronchovesicular. Harsh bronchial breathing never occurred over massive effusions. There were, however, several signs which could be depended on in the majority of cases as differential points between consolidation and fluid. The most valuable sign was the cardiac displacement, which was extreme in these cases. This cardiac displacement was observed occasionally with complete consolidation of one lung, but in such cases was never more than 3 or 4 cm. The second differential sign was a tympanitic and hyperresonant percussion note below the clavicle on the side of the effusion. Hyperresonance occurred at the apex of the lung with consolidation of a lower lobe, but the percussion note was never tympanitic.

The signs associated with large effusions were usually less confusing than were those occurring when small amounts of fluid were encapsulated at the apex or at the base of the lung near the large bronchi. Collections of exudate in these regions usually gave increased tactile fremitus, dullness, and harsh bronchial breathing. Fluoroscopic examination or Roentgen-ray plates were valuable, but aspiration was the only positive means of diagnosis. Diagnosis was especially difficult when the exudate occurred late in the pneumonia, because the pus was often pocketed between the lobes of the lung, between the lung

and the pericardium, or along the mediastinal wall. Roentgen-ray examinations were essential in locating these encapsulations before diagnostic aspiration was attempted.

The sputum was usually thick, mucopurulent, and tenacious, and at times was blood streaked. It was especially copious in the cases of extensive bronchopneumonia secondary to the bronchitis of measles. In cases with a predominant pleural infection there was little sputum during the first week of the illness. The quantity of sputum was usually an index of the extent of the pneumonic process. When the patients developed bronchiectasis, a lung abscess, or, when pus was encapsulated in some obscure pocket, the cough and sputum were prominent features of convalescence. From the washed sputum of the convalescent patients having these complications pure cultures of hemolytic streptococci were commonly obtained.

In practically every case of empyema there was a leucocytosis of from 15,000 to 30,000. The polymorphonuclear neutrophiles were usually increased to about 80 to 85 per cent, and the small mononuclears averaged 5 to 15 per cent. In cases following measles 10 to 15 per cent of transitionals and large mononuclears were frequently observed. The leucocyte count was usually 12,000 to 15,000 in those cases in which pus had been present for some time. The differential count was often normal. Occasionally normal counts were observed in febrile patients with undiscovered pleural pockets of pus. When streptococcus bronchopneumonia and empyema followed influenza a leucopenia was the rule. In severe cases of influenza in which the leucocyte count was low (2,000 to 3,000) before the pneumonia developed the count was not usually influenced by the secondary infection of the lung. Occasionally during the second week of the pneumonia the leucocytes would reach 8,000 to 12,000. The count seldom exceeded 15,000. The differential count was either normal or there was a decided lymphocytosis (40 to 60 per cent). Anemia was never a prominent feature of the acute cases, but was common in long continued cases with undiscovered pleural foci.

The urine was small in amount during the height of the fever. There were usually traces of albumin and a few hyaline and granular casts. Red cells were found occasionally.

### CONDITIONS ASSOCIATED WITH EMPYEMA.

In the chapter on pathology a study of the available autopsy material showed that, in the majority of the fatal cases, the infection had extended beyond the lung and pleura affected at the onset and that multiple foci occurred throughout the body. It would hardly be proper to speak of these secondary infections as complications of the pleuritis, since the pleuritis was in fact secondary to the pneumonia and was but an expression of the avidity with which the bacteria spread from the lung to the adjacent tissues. Since the pneumonia was the primary focus from which the bacteria were disseminated, infections of the pericardium, peritoneum, and viscera have been termed "conditions associated with empyema." In rare instances the pericardium was probably infected by a direct extension from the pleura overlying the pericardial sac. When the infection took place by this route the pericarditis was in the strictest sense secondary to the pleuritis. Exceptions such as this, however, occurred

only when viscera immediately contiguous to the pleural surface were invaded. In some instances resolution of the pneumonia was undoubtedly delayed on account of the pleural infection and secondary foci developed late during the course of the disease.

Bilateral pneumonia and empyema were associated in 29.64 per cent of all the cases with a resultant mortality of 49.4 per cent. The association of these conditions was most common during the first four weeks of the disease. It occurred in approximately 70 per cent of the fatal cases dying within this period, 40 per cent of which were associated with a unilateral empyema. In the remaining 60 per cent both pleural cavities were infected. The mortality was much higher in the cases with streptococcus pneumonia. Of the cases which had bilateral pneumonia and unilateral empyema due to streptococci 42.2 per cent died. When both pleurae were involved the mortality was 89.1 per cent. Unilateral empyema and bilateral lobar (pneumococcus) pneumonia had a mortality of 21.6 per cent. When the empyema was bilateral the mortality was 78.3 per cent. Bilateral staphylococcus pneumonia-empyema was invariably fatal.[8]

There were two types of cases with these associated conditions. In the first type of infection the process was so rapid that both lungs and pleuræ were involved within the first four days after the onset of the pneumonia. This course was rather to be expected among the cases which began with intense pleural pain and an audible friction sound. The exudate in the pleural cavity first affected was usually large and measured from 1 to 3 liters. The opposite cavity contained smaller amounts because the blood stream was usually invaded and death occurred before large quantities were produced. Pericarditis occurred frequently, but the diagnosis was not always made because the effusions were small and the inflammatory reaction often did not progress beyond the serofibrinous stage. Occasionally a friction rub, synchronous with the heart beat, was audible over the precordium. The patients complained of intense precordial or abdominal pain. In the second type of case the course was not as rapid, and, especially when the bronchopneumonia was secondary to measles or influenza, extension proceeded in a more leisurely manner. Both lungs were often affected before the exudate was formed, the pneumonia being recognizable in the beginning by patches of râles, consolidation, and bronchial breathing. These patches coalesced, the dullness over the involved areas increased and the breath sounds became distant. The pleural cavities were not involved simultaneously. Aspiration often yielded only a few hundred cubic centimeters of seropurulent fluid. While the prognosis was exceedingly poor in bilateral pneumonia and empyema when both cavities were infected, the later type of case, in which there was an interval of several days between the time that the first cavity was infected and the opposite cavity was involved, offered a better opportunity for treatment. The pus was aspirated until the pneumonia had subsided. The closed method of aspiration through a stab wound was especially valuable, as this method offered an opportunity for frequently emptying the cavities without disturbing the patient. The lungs could be kept expanded to their fullest capacity if the fluid was withdrawn at intervals of four or five hours.

Bilateral empyema was most common during the fifth week of the pneumonia. It was always associated with an active pulmonary process in both

lungs in those cases in which the two pleural cavities were infected within a period of a few days. When the interval between the beginning of the infections on the two sides was greater than two weeks the pneumonia on the side primarily affected had usually resolved before the second empyema occurred. The incidence of these bilateral infections was much lower after the fifth week. Bilateral infections occurred in about 1.3 per cent of the cases which recovered and in 23 per cent of the fatal infections. The mortality was 89.7, 79.7, and 100 per cent, respectively, among the streptococcus, pneumococcus, and staphylococcus cases.

Pericarditis was especially common among the cases which died after the first few days of the disease. It occurred in 1.5 per cent of the living cases and in 18.7 per cent of those dying before the eighth week after the onset of the pneumonia. The mortality was 85.8 per cent among the cases in which it occurred. It was associated most commonly with a bilateral streptococcus pneumonia and empyema. Peculiarly enough, pericarditis was rare before the fourth or fifth day of the infection. Apparently, even in the most fulminating cases with bilateral pneumonia and empyema, which developed with great rapidity, the extension of the infection was not sufficiently rapid to reach the pericardium before the patients died. After the first week pericarditis was increasingly frequent. The symptoms were often masked by the pneumonia and the presence of fluid so that a diagnosis was difficult, but the one outstanding symptom was precordial pain, which occurred in a majority of these patients and was associated with a pericardial rub. This rub was of a to-and-fro character and in most instances it was transient, but if it persisted for several days the prognosis was better than when it was heard only at the onset of the pericarditis. It would seem that in the instances in which the pericardial infection did not progress beyond the fibrinous stage the process was self-limited, but when exudate was formed in amounts which would render the rub inaudible the process went on to pus formation. The blood cultures were usually positive in these cases. In some instances the pericardium was infected before the blood stream had been invaded. The pericardial exudates were small and in the majority of instances the condition of the patients did not warrant surgical drainage. In a limited number of cases, in which the pericarditis occurred so late in the course of the infection that the pneumonia had resolved, the sac was drained through a wide apical incision. A few of these cases recovered from the infection but died after an interval of several months from cardiac dilatation and insufficiency.

Although peritonitis was found at autopsy in fully 20 per cent of the cases, it occurred in only 2.8 per cent of the total number of empyema cases. The peritoneum was invariably infected after the pneumonia had extended to both lungs and there was clinical evidence of a pericarditis. It was uncommon before the fourth day of the disease. The symptoms and physical findings were inconstant. When the patients were not moribund they complained of abdominal pain which was often definitely localized in the upper quadrants of the abdomen; audible friction rubs were common over the liver and spleen; and there were rigidity and tenderness. The mortality was 97.3 per cent among the cases in which this complication occurred. The blood cultures were always positive.

The thoracic conditions associated with empyema were, of course, more common than the conditions involving other viscera. Aside from peritonitis, extrathoracic complications were infrequent. Endocarditis, erysipelas, arthritis, phlebitis, multiple abscesses, mastoiditis, otitis media, and meningitis were observed in a small percentage of the cases. Endocarditis and meningitis were always fatal. The remainder of the complications mentioned were found as frequently among the cases which survived as among those which died, and so can not be considered as conditions directly responsible for death.

One of the most common of the extrathoracic conditions was the tendency to multiple streptococcus abscesses of the muscles and fasciæ. The abscesses were most common in the epigastrium in the sheath of the rectus muscle, and were seen less frequently in the pectoral muscles or in the subcutaneous tissues. They usually occurred in the course of streptococcus pneumonia, but repeated blood cultures on these cases failed to demonstrate a bacteriemia. They were not confined, however, to cases of empyema and pneumonia, but were observed, at times, in septicemia following a primary phlegmon due to hemolytic streptococci.

## GENERAL CONSIDERATIONS OF TREATMENT.

The treatment of these cases of bronchopneumonia and empyema was modified to a great extent during the spring of 1918. Until that time no distinction had been made between the treatment of empyema following lobar pneumonia and that occurring during the course of a streptococcus bronchopneumonia. The same principle had been followed in either case; and, regardless of the fact that the two conditions were pathologically and clinically distinct entities requiring different procedures, all the cases were surgically drained by thoracotomy or rib resection as soon as the diagnosis of empyema was made. The infections differed in two respects. First, the course of streptococcus bronchopneumonia extended over weeks while the acute stage of the pneumococcus infections was limited to a period of several days and was terminated in most instances by a crisis. After the crises the patients could be operated on without danger. Second, the streptococcus effusions were large and occurred during the height of the pulmonary infection; while those due to pneumococci were small, were encapsulated, and were diagnosed after the crisis in at least 80 per cent of the cases.

On account of the severity of the infection and the high mortality among cases of bronchopneumonia it was felt that palliative measures might bridge over the acute stage of the pneumonia until a time when the patients would be better operative risks, and that the risk would then be no greater than that taken when cases of empyema following lobar pneumonia were operated on within two or three days after the crisis. In 1917, Keller[3] had suggested that if the effusions were aspirated for several days the shock at operation might be less severe. He carried out this procedure in a few cases with excellent results. Aspiration was again attempted at Camp Dodge early in 1918. In April, 1918, a commission was appointed by the Surgeon General of the Army to study the question of treatment.[9] This commission found, however, that other measures were required in addition to those already suggested. The results of the study, which was carried out at Camp Lee, Va.,

were published during the summer of 1918 and served as a guide for the treatment of the cases occurring after that time. The material in this report has been used freely in the following paragraphs.

### ASPIRATION OF INFECTED PLEURAL EFFUSIONS.

When streptococcus pneumonia and empyema first occurred in the Army camps it was customary to drain the effusions immediately the diagnosis was made. An operation undertaken at this time meant that the patients must be subjected to the shock of operation at a time when they were not fit surgical risks. They were poor risks for several reasons. First, the pleuritis occurred either at the onset of the pulmonary infection or during the course of an extensive bronchopneumonia when the majority of the patients were dyspneic and cyanotic. The cyanosis and the dyspnea were always most striking in those cases in which there was an extensive parenchymal lung infection. In addition, the effusions were usually large and the adhesions between the lung and parietal wall were not sufficient during the first few days of the disease to prevent the collapse of the lung when the pleural cavity was opened. The collapse of the lung at operation still further diminished the already embarrassed pulmonary ventilation. This chain of circumstances, the extensive pneumonia, the large free effusion, and the collapse of the lung, was often immediately fatal. Second, the fever was usually at its maximum when the exudate was formed; in fact in many cases an elevation of one or two degrees was observed just at this time. The patients were sometimes delirious, and refused to take fluids by mouth. When the effusions were drained during this intensive toxemia, the delirium was often more marked and all nourishment and fluids were refused for the following two or three days. The increased dyspnea and the diminished food and fluid intake augmented the toxemia, so that no immediate benefit was derived from the operation. When the operations were delayed until the second or third week after the onset of the pneumonia, however, the condition of the patient was so much improved that drainage could be accomplished with less danger.

During the interval between the time that the pleuritis was first diagnosed and the time that the patient was in condition to withstand an operation the effusions were removed by aspiration. For this procedure a Potain apparatus was used. Three or four aspirations were usually required at intervals of one or two days. After the third or fourth aspiration the exudate, which was at first serous and straw colored, became thick, creamy, and purulent, and at times it could not be drawn through the needle. The quantities of fluid aspirated varied, the greatest quantities being usually obtained in each case at the second or third aspiration. The effusions were usually largest in cases in which the onset of the pleuritis was during the first week of the pneumonia. The amounts which were obtained often varied greatly on different days, because adhesions and encapsulations would be so formed that parts of the cavity could not be emptied. The quantities of exudate and the intervals between aspirations in 10 typical cases are shown in Chart LXV. The intervals are reckoned from the onset of the pneumonia. In some of these cases it can be seen that aspiration was not always successful, and that when the effusions were small, dry taps were common. Occasionally only a few cubic centimeters could be obtained.

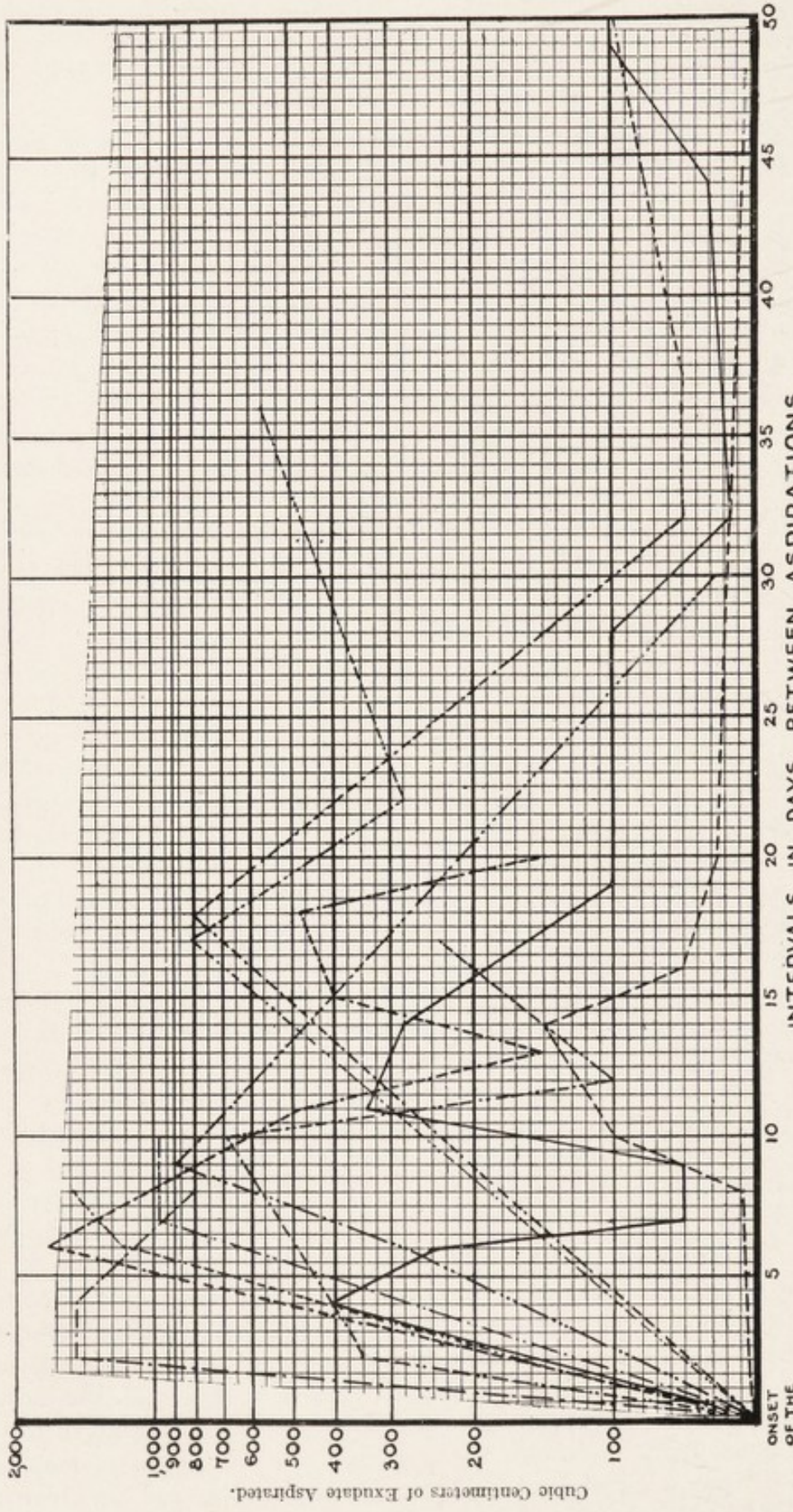


CHART LXV.—Aspiration of 10 typical cases of streptococcus pleuritis.

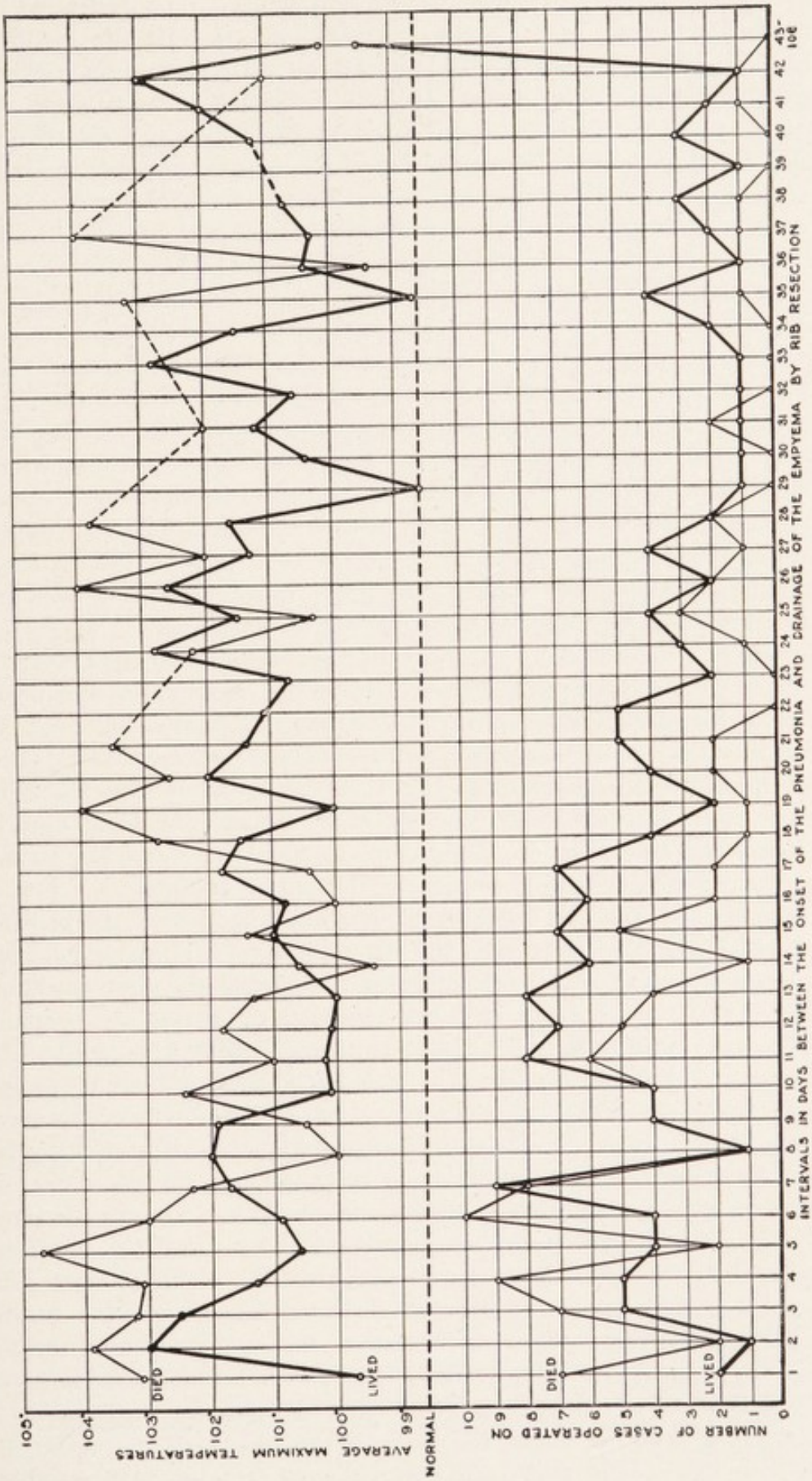


CHART LXVI.—Mortality following rib resection at varying intervals after onset of pneumonia.

Naturally the most important question was in regard to the time which was best suited for the surgical drainage of the empyema. This depended on the condition of the patient and on the character of the exudate obtained at aspiration. The patient was judged to be in fit condition for an operation when the bronchopneumonia was no longer active. From the physical signs alone it was impossible to be certain that the pneumonia was resolving, because dullness and coarse râles persisted in some cases for several weeks. The temperature, respirations, and pulse rate were the most reliable guides. When they showed a definite trend toward normal and the patients were no longer toxic, surgical drainage was usually carried out at once. The second criterion in regard to the time for operation was the character of the exudate. Operation was usually delayed until the exudate was no longer serous or serosanguineous, but was purulent and contained numerous fibrin flakes. It was thought from a study of the autopsies that when the fluid was purulent and contained numerous flakes of fibrin, adhesions had been formed between the visceral and parietal pleuræ which would prevent the collapse of the lung when the pleural cavity was opened. One of the indications for immediate operation was pyopneumothorax with symptoms of cardiac embarrassment. Frequently patients with pyopneumothorax were seen with cyanosis of the extremities, and an almost imperceptible pulse. In these cases aspiration was not as effective as immediate drainage for the relief of the symptoms.

A statistical study of cases of empyema which came to operation shows that the end of the second week after the onset of the pneumonia was probably most favorable for surgical intervention. A series of 264 cases has been chosen for this study. One hundred and two of the cases died within a few days after the operation, while the remaining 162 recovered. Since the mortality is about 40 per cent (approximately the mortality among the total number of cases of pneumonia associated with empyema in the Army), it is fair to assume that these cases represent a fair section of the entire epidemic. When these cases are charted according to the interval between the onset of the pneumonia and the drainage of the empyema by rib resection, it is observed that the majority of the patients who were operated on during the first week of the disease died, while the majority of those operated on during the second and third weeks lived. The highest point of the mortality curve falls on the seventh day, while the highest point for the living cases occurs at the end of the second week. Now, if the mortality following operation is compared with the average temperatures on the days the operations were done several interesting points are at once apparent. First, the average temperatures on the days of the operations were higher among the patients who died than among the patients who lived. Second, the maximum mortality and the peak of the temperature curve fall about the seventh day of the pneumonia. Third, the lowest average temperatures occurred about 14 days after the disease, when the mortality after operation was lowest. The conclusions to be reached from these points are obvious. The temperatures indicate that the infections were most acute during the first week of the disease and that operations were most often fatal during this interval when the high fever indicated an active pneumonia. During the second and third weeks the lower temperatures indicated

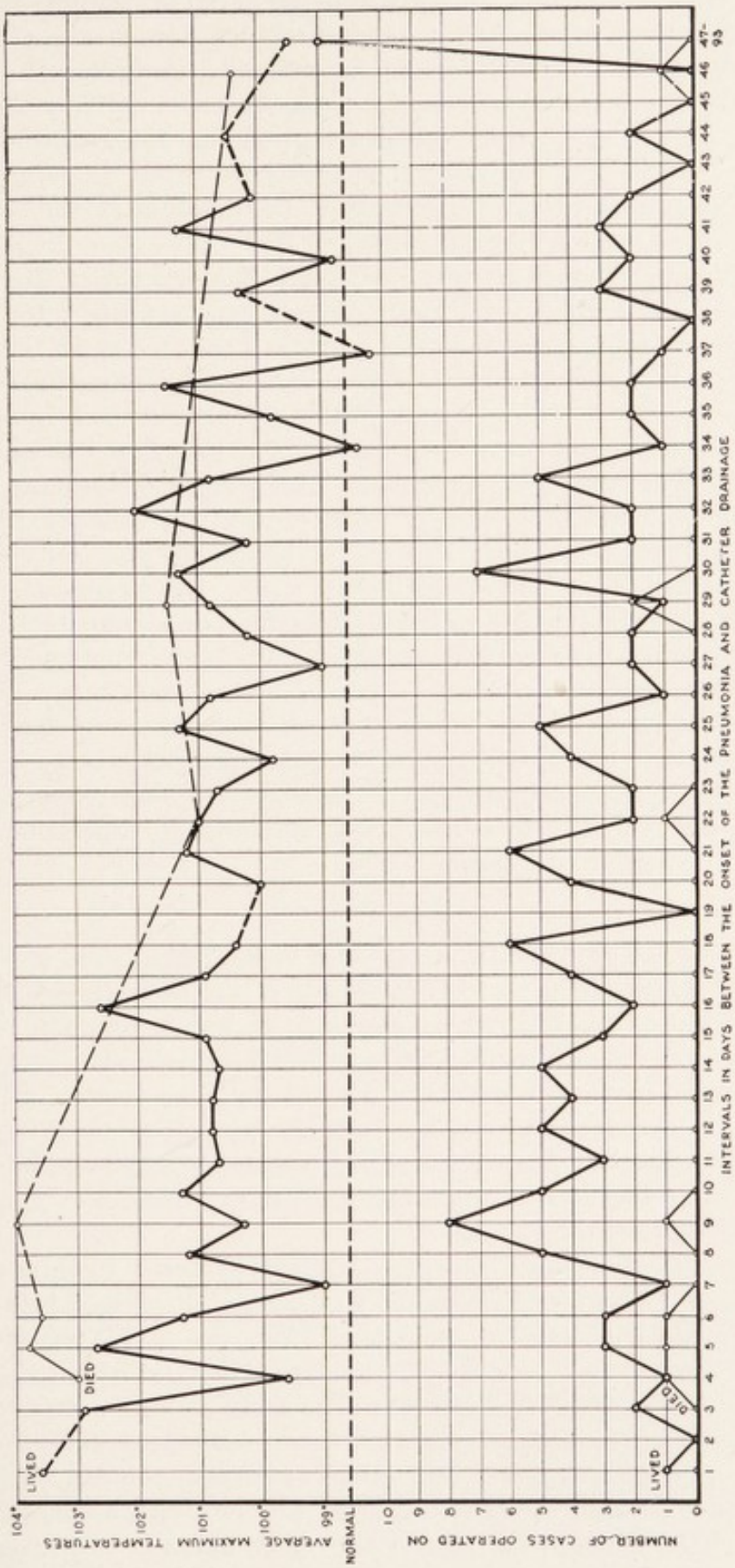


CHART LXVII.—Mortality following catheter drainage begun at varying intervals after onset of pneumonia.

that the pulmonary infection was subsiding. This was also the most favorable time for operation. The high temperatures observed on the day of operation after the second week of the disease were probably due to the pleural infection and not to the pneumonia. It is difficult, however, to refute the argument that the majority of the fatalities occurred early in the course of the infection, regardless of operation, and that the grouping of the fatal postoperative cases in the first week might be accounted for in this way.

There is no way in which the records of the patients in the Army camps can be used to establish beyond question the value of a delayed operation in lowering the mortality rate. Although the reports of the Camp Lee commission and the reports from Camp Pike, where aspiration by trocar and canula was resorted to, show that the mortality was lower in the groups of cases treated in this way than among those treated by immediate operation, the cases treated by preliminary aspiration occurred during the last few weeks of the epidemic, when the severity of the infection was subsiding, or were mild infections scattered throughout the spring and summer months of 1918. In Chart LXVII is a series of cases treated by catheter drainage and with antiseptics. This series shows that, although the mortality was low in the 144 cases which have been collected for study, the average temperatures on the day of aspiration would indicate that the cases were relatively mild. No extensive studies were carried out during the same epidemiologic period comparing the effects of immediate and delayed operation.

Delayed operation was not considered necessary in empyema complicating lobar pneumonia, for the condition of these patients was such that they were usually good surgical risks when the diagnosis was made. When the exudate was discovered before the crisis, preliminary aspiration was considered to be the logical treatment.

## NUTRITION.

Among the most profitable undertakings of the commission at Camp Lee [9] was a study of the nitrogen output of patients in the early stages of empyema associated with the hemolytic streptococcus. It was a common observation that these patients became emaciated and lost strength with great rapidity, and that generous feeding should be a part of their treatment. The amount of nitrogen lost, however, had not been clearly defined.

In spite of some difficulty in obtaining proper chemical equipment, fairly satisfactory determinations of total nitrogen in the urine and exudate were made in three representative cases.[9]

The nutrition of several cases was studied in detail by means of their nitrogen balance. The food consumed was accurately weighed and the fuel value and the nitrogen content calculated from the tables of Atwater and Bryant. The urine was collected in 24-hour periods, and its nitrogen content determined by the method of Kjeldahl. The daily excretion of nitrogen into the pleural cavity was obtained by measuring and analyzing the exudate each time the patient was aspirated. After operation, the exudate could not be collected and the daily pleural nitrogen excretion was assumed to be the same as just before operation. Since the daily amount of nitrogen in the exudate was not over 2.5 gm. per day, this assumption involves no serious error.

The nitrogen of the feces is disregarded, and for this reason the nitrogen balances given are slightly too favorable.

In Tables 52, 53, and 54 the nitrogen intake and output of three patients are given. Complete 24-hour specimens of urine could not always be obtained and figures are omitted on such days.

TABLE 52.—*Food intake and nitrogen balance, Case I.*

| Period ending 9 a. m. | Food. | | Urine. | | Exudate. | | | | Nitrogen balance. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Nitrogen. | | | |
| | Calories. | Grams, nitrogen. | Volume, c. c. | Grams, nitrogen. | Volume, c. c. | Per cent. | Grams. | Grams, day. | |
| Apr. 28 | 1,408 | 9.7 | 1,000 | 16.4 | ..... | 0.747 | ..... | ..... | − 8.7 |
| Apr. 29 | 1,758 | 11.9 | 2,050 | 31.7 | ..... | ..... | ..... | ..... | −21.8 |
| Apr. 30 | 1,160 | 9.0 | 1,925 | 19.9 | 540 | .741 | 4.0 | 2.0 | −12.9 |
| May 1 | 2,210 | 14.6 | 2,250 | 21.0 | ..... | ..... | ..... | ..... | − 7.2 |
| May 2 | 3,732 | 24.0 | 2,915 | 16.9 | 215 | .711 | 1.5 | .8 | + 6.4 |
| May 3 | 3,322 | 23.2 | 3,030 | 13.0 | ..... | ..... | ..... | ..... | + 8.5 |
| May 4 | 2,955 | 20.2 | 3,060 | 16.2 | 480 | .691 | 3.3 | 1.7 | + 2.3 |
| May 5 | 3,573 | 25.3 | 2,740 | 19.6 | ..... | ..... | ..... | ..... | + 4.1 |
| May 6 | 3,837 | 22.2 | 1,500 | 14.2 | 360 | .869 | 3.1 | 1.6 | + 6.4 |
| May 7 | 3,108 | 23.3 | 1,770 | 18.1 | ..... | ..... | ..... | ..... | + 3.9 |
| May 8 | 3,288 | 22.2 | 2,050 | 18.8 | ..... | ..... | ..... | ..... | + 2.1 |
| May 9 | 3,780 | 26.5 | ..... | ..... | 345 | 1.158 | 4.0 | 1.3 | ..... |
| May 10 | 3,347 | 21.7 | 1,750 | 19.1 | ..... | ..... | ..... | ..... | + 1.3 |
| May 11 | 3,662 | 25.6 | 1,640 | 19.3 | 220 | 1.201 | 2.6 | 1.3 | + 5.0 |
| May 12 | 2,793 | 16.9 | 1,490 | 17.0 | ..... | ..... | ..... | ..... | + 1.4 |
| May 13 | 3,510 | 25.1 | 1,600 | 14.8 | ..... | ..... | ..... | ..... | + 9.1 |
| May 14 | 1,679 | 11.0 | 1,590 | 17.2 | ..... | ..... | ..... | ..... | − 7.5 |
| May 15 | 464 | 3.4 | 250 | 3.2 | Operated 3 p. m., May 14. These two days not properly separated. | | | | − 7.7 |
| May 16 | 2,444 | 16.3 | 1,560 | 29.3 | | | | | + 7.0 |
| May 17 | 3,125 | 21.5 | 1,310 | 13.2 | ..... | ..... | ..... | ..... | + 7.0 |
| May 18 | 2,794 | 18.0 | 1,310 | 10.4 | ..... | ..... | ..... | ..... | + 6.3 |
| May 19 | 2,850 | 19.7 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| May 20 | 2,807 | 18.3 | 1,700 | 14.6 | ..... | ..... | ..... | ..... | + 2.4 |
| May 21 | 1,839 | 11.8 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| May 22 | 2,194 | 13.2 | 1,710 | 19.3 | ..... | ..... | ..... | ..... | − 7.4 |
| May 23 | 2,503 | 14.5 | 1,520 | 15.8 | ..... | ..... | ..... | ..... | − 2.6 |
| May 24 | 2,577 | 17.3 | 2,200 | 18.4 | ..... | ..... | ..... | ..... | − 2.4 |
| May 25 | 2,518 | 17.4 | 1,210 | 9.7 | ..... | ..... | ..... | ..... | + 6.4 |
| May 26 | 3,754 | 25.1 | 1,240 | 12.1 | ..... | ..... | ..... | ..... | +11.7 |
| May 27 | 3,156 | 20.4 | 1,700 | 15.5 | ..... | ..... | ..... | ..... | + 3.6 |
| May 28 | 3,880 | 25.4 | 1,790 | 16.4 | ..... | ..... | ..... | ..... | + 7.7 |
| May 29 | 3,969 | 23.4 | 1,800 | 14.6 | ..... | ..... | ..... | ..... | + 7.5 |
| May 30 | 3,972 | 25.3 | 1,530 | 16.0 | ..... | ..... | ..... | ..... | + 8.3 |

TABLE 53.—*Food intake and nitrogen balance, Case II.*

| Period ending 9 a. m. | Food. | | Urine. | | Nitrogen balance. | Period ending 9 a. m. | Food. | | Urine. | | Nitrogen balance. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Calories. | Grams, nitrogen. | Volume, c. c. | Grams, nitrogen. | | | Calories. | Grams, nitrogen. | Volume, c. c. | Grams, nitrogen. | |
| May 17 | 2,136 | 12.8 | 2,980 | 21.3 | −8.5 | June 2 | 2,042 | 13.6 | 1,570 | 14.0 | − 0.4 |
| May 18 | 3,106 | 18.4 | 3,390 | 19.7 | −1.3 | June 3 | 2,666 | 16.2 | 1,350 | 14.3 | + 1.9 |
| May 19 | 3,638 | 21.1 | 3,070 | 15.8 | +5.3 | June 4 | 3,490 | 25.4 | 2,050 | 14.6 | +10.8 |
| May 20 | 3,751 | 22.4 | 4,680 | 17.5 | +4.9 | June 5 | 3,017 | 17.9 | 2,200 | 14.0 | + 3.9 |
| May 21 | 3,416 | 19.6 | 3,700 | 17.1 | +2.5 | June 6 | 2,095 | 12.7 | 2,650 | 16.1 | − 3.4 |
| May 22 | 3,205 | 15.8 | 2,880 | 18.2 | −2.4 | June 7 | 1,079 | 6.2 | 2,270 | 12.2 | − 6.0 |
| May 23 | 3,660 | 21.1 | 2,700 | 16.1 | +5.1 | June 8 | 1,600 | 10.5 | 990 | 8.7 | + 1.8 |
| May 24 | 3,737 | 18.8 | 3,540 | 17.6 | +1.2 | June 9 | 2,295 | 11.0 | 1,180 | 9.5 | + 1.5 |
| May 25 | 2,697 | 14.6 | 2,120 | 15.0 | − .4 | June 10 | 3,159 | 15.8 | 1,370 | 10.7 | + 5.1 |
| May 26 | 3,220 | 16.3 | 2,940 | 15.5 | + .8 | June 11 | 3,968 | 17.1 | 1,180 | 8.5 | + 8.6 |
| May 27 | 2,512 | 13.1 | 1,700 | 13.6 | − .5 | June 12 | 2,956 | 17.2 | 1,390 | 11.0 | + 6.2 |
| May 28 | 3,121 | 17.7 | 3,330 | 15.1 | +2.6 | June 13 | 3,208 | 14.8 | 1,570 | 11.6 | + 3.2 |
| May 29 | 2,520 | 12.8 | 1,820 | 11.3 | +1.5 | June 14 | 3,356 | 15.8 | 1,300 | 9.4 | + 6.4 |
| May 30 | 2,675 | 15.5 | 2,220 | 15.9 | −0.5 | June 15 | 3,495 | 18.8 | 1,040 | 9.8 | + 9.0 |
| May 31 | 3,037 | 19.7 | 2,900 | 15.3 | +4.4 | June 16 | 3,562 | 19.3 | 1,160 | 10.7 | + 8.6 |
| June 1 | 2,643 | 15.2 | 2,340 | 16.9 | −1.7 | June 17 | 3,630 | 19.1 | 980 | 9.5 | + 9.5 |

TABLE 54.—*Food intake and nitrogen balance, Case III.*

| Period ending 9 a. m. | Food. | | Urine. | | Exudate. | | | | Nitrogen balance. |
|---|---|---|---|---|---|---|---|---|---|
| | Calories. | Grams, nitrogen. | Volume, c. c. | Grams, nitrogen. | Volume, c. c. | Nitrogen. | | | |
| | | | | | | Per cent. | Grams. | Grams, day. | |
| Apr. 28 | 1,408 | 9.7 | 3,030 | 20.3 | | 0.827 | | | −12.9 |
| Apr. 29 | 2,397 | 16.4 | 4,300 | 22.1 | | | | | − 8.0 |
| Apr. 30 | 1,745 | 10.6 | 4,900 | 22.2 | 595 | .790 | 4.7 | 2.3 | −13.9 |
| May 1 | 2,061 | 18.2 | 3,710 | 22.7 | | | | | − 6.8 |
| May 2 | 3,403 | 21.7 | 2,990 | 21.0 | 415 | 1.123 | 4.7 | 2.3 | − 1.6 |
| May 3 | 3,097 | 21.8 | 3,240 | 17.7 | | | | | − 1.8 |
| May 4 | 1,261 | 8.9 | | | (a) | (a) | | | |
| May 5 | 1,842 | 13.2 | | | | | | | |
| May 6 | 2,263 | 16.1 | 870 | 14.0 | | | | | + .1 |
| May 7 | 2,040 | 13.1 | | | | | | | |
| May 8 | 2,007 | 10.5 | 760 | 10.1 | | | | | − 1.6 |
| May 9 | 1,891 | 10.9 | 850 | 11.6 | | | | | − 2.7 |
| May 10 | 3,057 | 21.1 | 1,000 | 10.9 | | | | | + 8.2 |
| May 11 | 2,700 | 18.6 | | | | | | | |
| May 12 | 2,610 | 16.1 | 1,180 | 11.3 | | | | | + 2.8 |
| May 13 | 3,297 | 22.5 | 1,500 | 7.4 | | | | | +12.6 |
| May 14 | 3,522 | 25.4 | 930 | 7.6 | | | | | +16.8 |
| May 15 | 3,479 | 26.1 | 1,120 | 11.4 | | | | | +12.7 |
| May 16 | 3,466 | 20.5 | 1,390 | 6.2 | | | | | +12.3 |
| May 17 | 2,932 | 19.21 | 870 | | | | | | |
| May 18 | 2,580 | 16.03 | 900 | 4.4 | | | | | + 9.6 |
| May 19 | 3,129 | 21.6 | | | | | | | |
| May 20 | 3,103 | 21.2 | 2,210 | 16.8 | | | | | + 2.4 |
| May 21 | 3,170 | 22.4 | 2,250 | 10.9 | | | | | + 9.5 |
| May 22 | 3,219 | 19.1 | 1,470 | 11.4 | | | | | + 5.7 |
| May 23 | 3,331 | 19.4 | 2,480 | 13.8 | | | | | + 3.6 |
| May 24 | 2,761 | 17.2 | 1,500 | 10.3 | | | | | + 4.9 |
| May 25 | 3,760 | 24.7 | 1,460 | 9.2 | | | | | +13.6 |
| May 26 | 4,228 | 26.7 | 2,770 | 11.0 | | | | | +13.7 |
| May 27 | 3,284 | 22.3 | 2,060 | 12.2 | | | | | + 8.1 |
| May 28 | 3,640 | 24.6 | 1,880 | 12.1 | | | | | +10.5 |
| May 29 | 3,715 | 23.0 | 1,310 | 12.9 | | | | | + 8.1 |
| May 30 | 3,470 | 23.5 | 1,590 | 14.4 | | | | | + 7.1 |

a Resection.

The patients had been kept on a soft diet containing from 1,000 to 1,700 calories, previous to the nitrogen determinations, and were losing from 12 to 20 gm. of nitrogen per day. They were placed on the regular hospital diet, supplemented by extra feedings of eggs and milk. No attempt was made to keep them at a constant level of feeding since the increased accuracy of the figures would not have justified the loss of food to the patient.

Charts LXVIII, LXIX, and LXX represent the relation of the nitrogen balance to the food intake. The broken line represents nitrogen gain or loss in grams, and the unbroken line represents the food intake in calories. Nitrogen equilibrium is placed at 3,000 calories. With the scale used (5 gm. of nitrogen and 500 calories each represented by the same unit), the curves run quite parallel. Wherever the unbroken line is above the broken line, more than 3,000 calories would have been required to keep the patient in equilibrium, and wherever the broken line is above the unbroken line, less than 3,000 calories would have maintained equilibrium. The distance between the lines is a rough measure of the amount above or below 3,000 calories required to maintain equilibrium.

It will be noticed that in the acute stage of the disease with a high temperature, from 3,000 to 3,300 calories were needed to maintain equilibrium. It will also be noted that some patients lost weight although they had a constantly positive nitrogen balance. This was undoubtedly due to the fact that the nitrogen of the feces was disregarded. Probably from 3,300 to 3,500 calories would have been needed to maintain body weight.

Since these patients might lose in one day of low feeding as much as could be regained in several days of high feeding, it was important that a close watch be kept on their food intake. It was recommended that they be placed as early

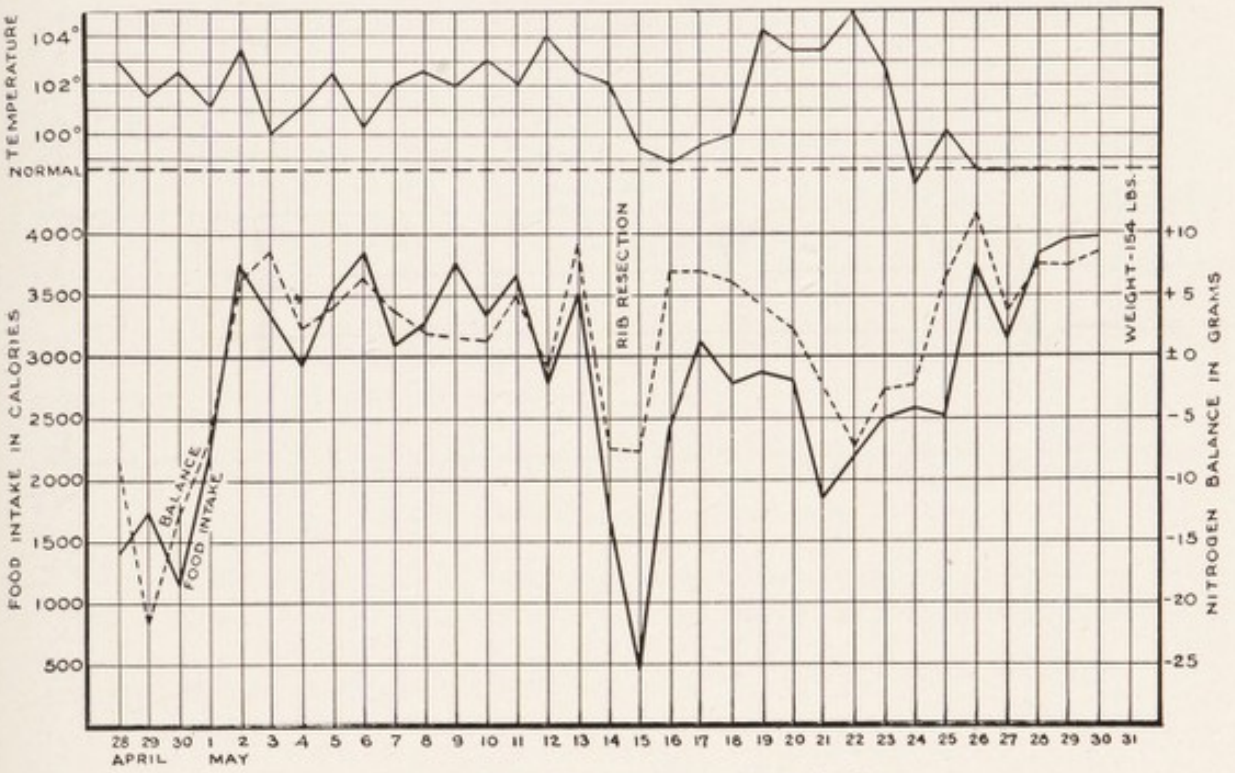


CHART LXVIII.—Nitrogen conservation. Case I.

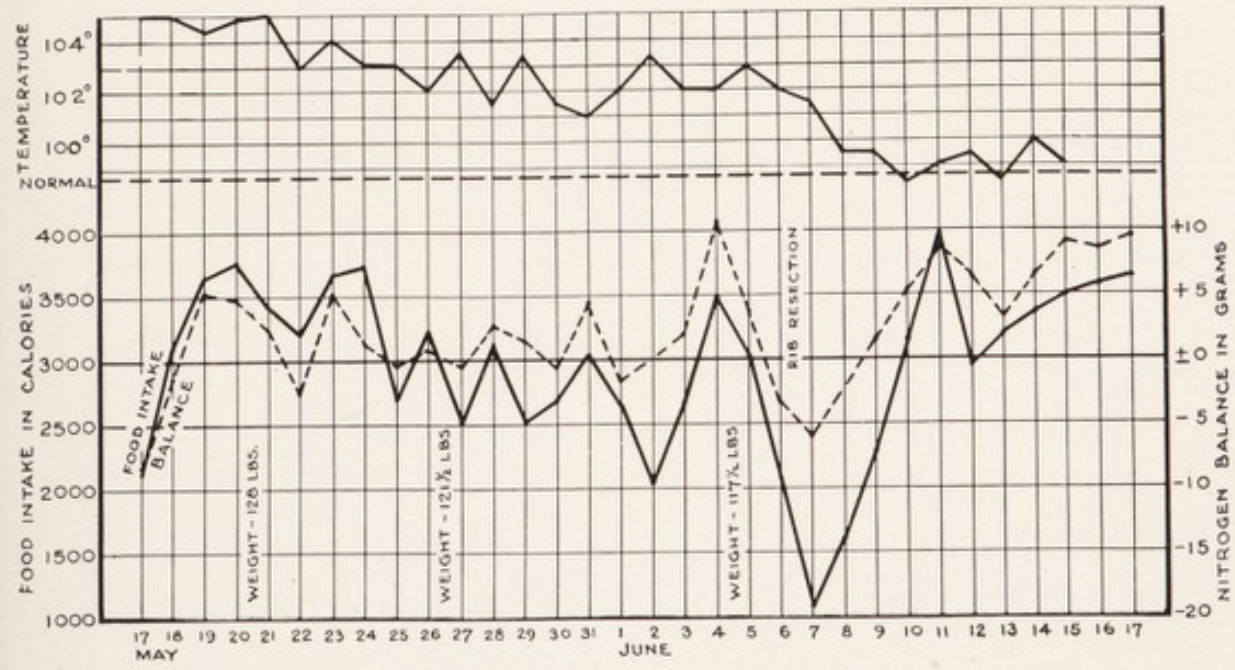


CHART LXIX.—Nitrogen conservation. Case II.

as possible on a standardized diet containing from 3,300 to 3,500 calories, and kept on this until they reached their normal weight. The fuel value of any food remaining uneaten was estimated, and extra feedings of eggs, milk, etc., were given to make up the total. While the patient was very ill, lactose drinks were used and, when necessary, glucose was given by rectum or intravenously. The patient was weighed on admission and at least once a week thereafter.

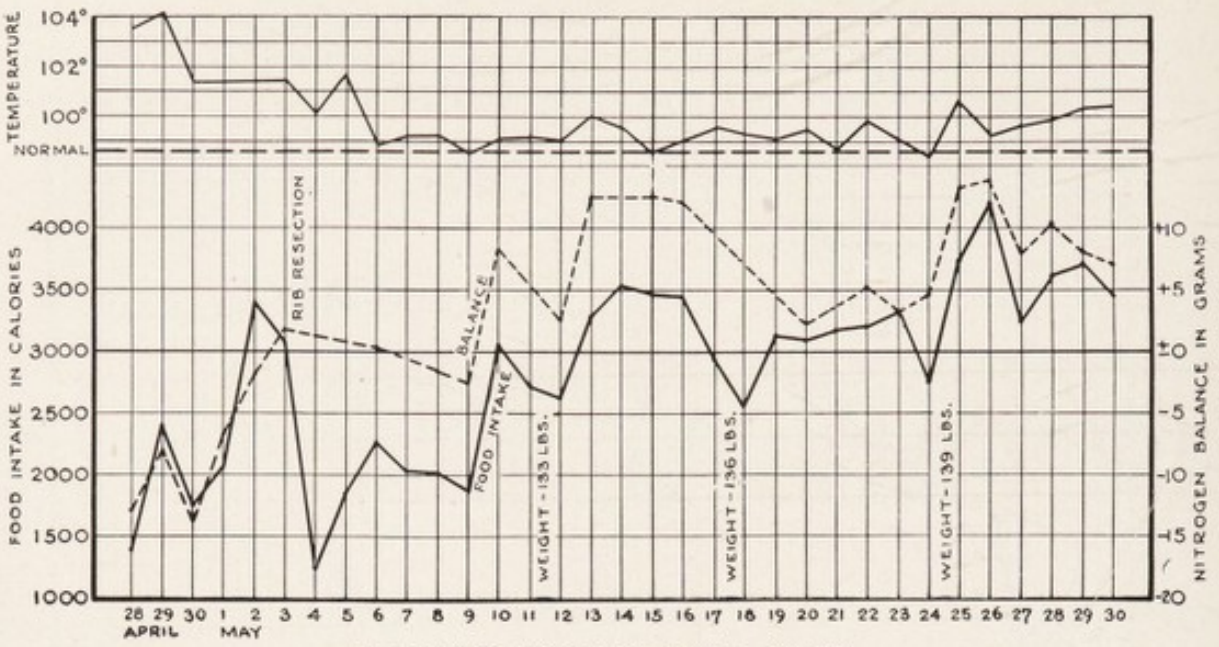


CHART LXX.—Nitrogen conservation. Case III.

Tables 55 to 61 show a few sample diets used at Camp Lee. The cost of this diet was estimated by the mess officer of the hospital to be 87 cents a day.

TABLE 55.—*High calorie diet during the acute febrile stage in Case I, May 1–2, 1918.*

| | Quantity in grams or cubic centimeters. | Proteins. | Fats. | Carbohydrates. | | Quantity in grams or cubic centimeters. | Proteins. | Fats. | Carbohydrates. |
|---|---|---|---|---|---|---|---|---|---|
| Milk | 1,680 | 55.0 | 67.0 | 84.0 | Cream tomato soup | 150 | 3.0 | 1.6 | 6.0 |
| Sugar | 36 | ..... | ..... | 36.0 | Custard (2 cups) | ..... | 10.2 | 15.4 | 64.0 |
| Eggs (4) | ..... | 26.4 | 24.0 | ..... | Rice | 60 | 2.4 | .8 | 21.2 |
| Toast | 135 | 15.5 | 2.2 | 82.6 | Cocoa | 180 | 7.0 | 8.3 | 11.3 |
| Butter | 32 | ..... | 27.2 | ..... | Orange (one-half) | ..... | .3 | .1 | 4.6 |
| Meat, scraped | 80 | 16.7 | 8.5 | ..... | Oatmeal | 150 | 4.2 | .7 | 17.2 |
| Puree peas (2 tablespoons) | ..... | 2.5 | .1 | 3.1 | Apple sauce | 60 | .1 | .5 | 24.8 |
| Potato | 50 | 1.2 | ..... | 10.4 | Calories, 3,732; nitrogen, 23.95 | ..... | 149.7 | 166.5 | 382.9 |
| Ice cream | 100 | 5.2 | 10.1 | 17.7 | | | | | |

TABLE 56.—*High calorie diet during the acute febrile stage in Case I, May 2–3, 1918.*

| | Quantity in grams or cubic centimeters. | Proteins. | Fats. | Carbohydrates. | | Quantity in grams or cubic centimeters. | Proteins. | Fats. | Carbohydrates. |
|---|---|---|---|---|---|---|---|---|---|
| Milk | 510 | 16.8 | 20.4 | 25.5 | Vegetable soup with noodles | 240 | 7.3 | 0.1 | 2.8 |
| Eggs (5) | ..... | 33.0 | 30.0 | ..... | Macaroni with cheese | 100 | 5.0 | 4.5 | 15.8 |
| Sugar | 18 | ..... | ..... | 18.0 | Farina pudding | 100 | 3.3 | 3.4 | 17.9 |
| Chicken | 80 | 16.0 | 8.8 | ..... | Apricots, stewed | 75 | .6 | ..... | 12.6 |
| Baked potato | 86 | 1.7 | .1 | 15.8 | Junket | 100 | 3.3 | .4 | 7.0 |
| Butter | 28 | ..... | 23.8 | ..... | Cocoa | 300 | 12.1 | 14.9 | 18.8 |
| Toast | 225 | 25.9 | 3.6 | 137.7 | Grapefruit | 150 | 1.2 | .3 | 12.2 |
| Asparagus, creamed | 100 | 2.5 | 5.7 | 4.6 | Oatmeal | 210 | 5.9 | 1.0 | 24.1 |
| Spinach, puree | 100 | 3.6 | 7.1 | 4.5 | | | | | |
| Chocolate pudding | 120 | 5.1 | 7.7 | 21.0 | | | | | |
| Cream | 30 | .7 | 5.5 | 1.3 | Calories, 3,322; nitrogen, 23.2 | ..... | 145.0 | 137.5 | 353.5 |

TABLE 57.—*High calorie diet during the acute febrile stage in Case I, May 9–10, 1918.*

| | Quantity in grams or cubic centimeters. | Proteins. | Fats. | Carbohydrates. | | Quantity in grams or cubic centimeters. | Proteins. | Fats. | Carbohydrates. |
|---|---|---|---|---|---|---|---|---|---|
| Milk | 810 | 26.7 | 32.4 | 40.5 | Apple sauce | 134 | .3 | 1.1 | 49.8 |
| Eggs (3) | ..... | 19.8 | 18.0 | ..... | Pudding, bread custard | 102 | 6.5 | 5.0 | 25.8 |
| Sugar | 25 | ..... | ..... | 25.0 | Lemon (1) | 1 | 1.0 | .7 | 8.5 |
| Chopped beef | 80 | 22.1 | 6.2 | ..... | Cocoa | 570 | 20.9 | 25.8 | 32.5 |
| Potato | 70 | 1.7 | .1 | 14.6 | Hominy | 200 | 4.4 | .4 | 35.4 |
| Puree peas | 70 | 9.8 | 4.0 | 26.8 | Prunes | 110 | .6 | .1 | 24.5 |
| Toast | 143 | 16.4 | 2.3 | 87.5 | | | | | |
| Butter | 20 | ..... | 17.0 | ..... | Calories, 3,347; nitrogen, 21.71 | ..... | 135.7 | 121.4 | 405.4 |
| Custard | 132 | 5.5 | 8.3 | 34.3 | | | | | |

TABLE 58.—*High calorie diet during the acute febrile stage in Case I, May 10–11, 1918.*

| | Quantity in grams or cubic centimeters. | Proteins. | Fats. | Carbohydrates. | | Quantity in grams or cubic centimeters. | Proteins. | Fats. | Carbohydrates. |
|---|---|---|---|---|---|---|---|---|---|
| Milk | 1,050 | 34.6 | 42.0 | 52.5 | Fish | 70 | 14.0 | 1.7 | ..... |
| Eggs (6) | ..... | 39.6 | 36.0 | ..... | Chocolate pudding | 110 | 5.0 | 7.9 | 27.8 |
| Lemon (1) | ..... | 1.0 | .7 | 8.5 | Ice cream | 130 | 6.8 | 13.1 | 23.0 |
| Sugar | 28 | ..... | ..... | 28.0 | Vegetable soup | 420 | 10.5 | ..... | 18.0 |
| Orange juice | 60 | .5 | .1 | 7.0 | Cocoa | 120 | 5.0 | 6.3 | 8.0 |
| Oatmeal | 200 | 5.6 | 1.0 | 23.0 | Custard | 90 | 3.8 | 5.7 | 23.4 |
| Toast | 255 | 29.3 | 4.1 | 158.1 | Peach | 40 | .3 | ..... | 4.3 |
| Butter | 30 | ..... | 25.5 | ..... | | | | | |
| Potato | 82 | 2.0 | .1 | 17.1 | Calories, 3,662; nitrogen, 25.55 | ..... | 139.7 | 147.5 | 398.8 |
| Spinach | 80 | 1.7 | 3.3 | 2.1 | | | | | |

TABLE 59.—*Diet on day of rib resection in Case I, May 13–14, 1918.*

| | Quantity in grams or cubic centimeters. | Proteins. | Fats. | Carbohydrates. | | Quantity in grams or cubic centimeters. | Proteins. | Fats. | Carbohydrates. |
|---|---|---|---|---|---|---|---|---|---|
| Lemon albumen | ..... | 3.9 | 0.6 | 12.5 | Cornflakes | 30 | 4.0 | .4 | 22.3 |
| Milk | 1,140 | 37.6 | 45.6 | 57.0 | Sugar | 28 | ..... | ..... | 28.0 |
| Orange | 175 | 1.4 | .3 | 20.3 | | | | | |
| Cocoa | 300 | 12.0 | 15.0 | 19.0 | Calories, 1,679; nitrogen, 11.2 | ..... | 68.9 | 71.3 | 177.5 |
| Cream of tomato soup | 120 | 3.0 | 9.4 | 6.4 | | | | | |
| Vegetable soup | 240 | 7.0 | ..... | 12.0 | | | | | |

TABLE 60.—*Diet following operation in Case I, May 14–15, 1918.*

| | Quantity in grams or cubic centimeters. | Proteins. | Fats. | Carbohydrates. | | Quantity in grams or cubic centimeters. | Proteins. | Fats. | Carbohydrates. |
|---|---|---|---|---|---|---|---|---|---|
| Eggnog | 150 | 8.4 | 8.8 | 6.0 | Whiskey (calories 105) | 30 | ..... | ..... | ..... |
| Oatmeal | 200 | 5.6 | 1.0 | 23.0 | | | | | |
| Milk | 190 | 6.3 | 7.6 | 9.5 | Calories, 464; nitrogen, 3.41 | ..... | 20.3 | 17.4 | 53.5 |
| Sugar | 15 | ..... | ..... | 15.0 | | | | | |

TABLE 61.—*Convalescent high calorie diet in Case I, May 25–26, 1918.*

| | Quantity in grams or cubic centimeters. | Proteins. | Fats. | Carbohydrates. | | Quantity in grams or cubic centimeters. | Proteins. | Fats. | Carbohydrates. |
|---|---|---|---|---|---|---|---|---|---|
| Milk | 2,060 | 68.0 | 82.4 | 103.0 | Creamed peas | 72 | 4.3 | 5.4 | 9.6 |
| Eggnog | 700 | 33.0 | 36.0 | 30.0 | Stewed peaches | 83 | 1.6 | 1.1 | 41.3 |
| Meat | 30 | 6.7 | 8.6 | ..... | Junket | 62 | 2.1 | 2.5 | 11.1 |
| Potato | 65 | 1.6 | ..... | 13.6 | Cornflakes | 15 | .1 | ..... | 6.0 |
| String beans | 60 | .7 | ..... | 2.3 | Sugar | 15 | ..... | ..... | 15.0 |
| Bread | 100 | 9.2 | 1.3 | 53.1 | Bacon | 29 | 5.6 | 14.5 | ..... |
| Toast | 57 | 6.5 | .9 | 34.9 | Grapefruit | 180 | 1.1 | .2 | 11.6 |
| Butter | 20 | ..... | 17.0 | ..... | | | | | |
| Rice pudding | 95 | 6.2 | 4.7 | 23.0 | Calories, 3,734; nitrogen, 25.06 | ..... | 156.6 | 206.8 | 285.2 |
| Thin cream | 60 | 1.5 | 6.0 | 2.7 | | | | | |
| Cream tomato soup | 350 | 8.4 | 26.2 | 17.8 | | | | | |

The feeding of the patients during the acute stage of the illness required the persistent efforts of the nursing staff. Feeding was accomplished after operation with less difficulty and the average increase in weight was more evident. This was due of course both to the increasing appetites of the patients

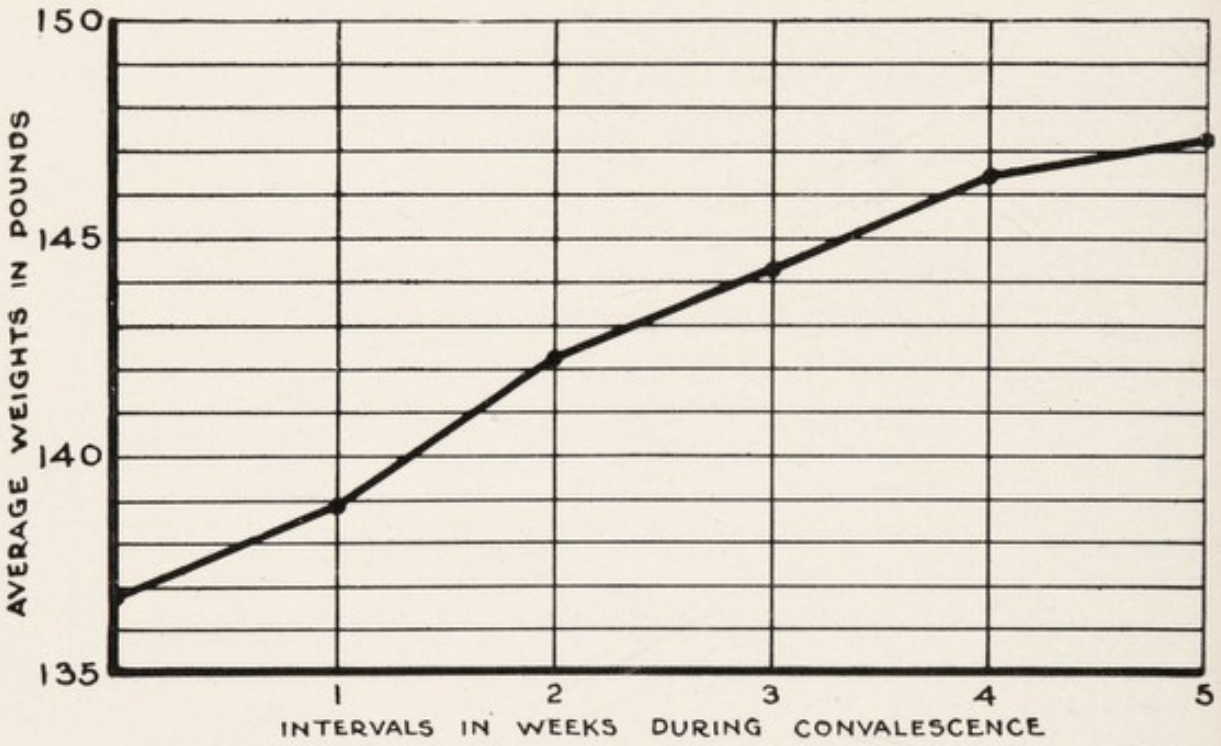


CHART LXXI.—Average postoperative increase in weight of 71 patients on a high calorie diet.

and to the lowered metabolic rates during defervescence. When, following operation, the patients did not gain on a high calorie diet, careful examination usually revealed undrained pleural pus pockets. The average weights of 71 patients on a diet of 3,000 to 3,500 calories have been charted for a period of five weeks after operation.

## ROUTINE MEDICAL CARE.

During the acute febrile period of these streptococcus infections medicinal remedies were only of symptomatic value. Digitalis was used in some military hospitals with but little benefit. When it was employed, 4 or 5 c. c. of standardized tincture were given on the second or third day of the pneumonia. Occasionally, smaller doses were given for several days. It must be remem-

bered, however, that the majority of the patients were young, robust men and that there were few who had chronic cardiac disease. Death was usually due to extensive infection of the lungs or the serous cavities and not primarily to cardiac failure. Atropine was valuable at times in the treatment of edema of the lungs. The administration of the drug was continued until the pupils were slightly dilated. When the edema was fully developed, and the patient was cyanotic, atropine was valueless. The tolerance for atropine was apparently increased during the pneumonia, as larger doses were needed than are ordinarily required to obtain the physiological effect in the average patient. Codeine and morphine were invaluable for the pain and delirium.

During the winter months the majority of the cases of bronchopneumonia were not improved by outdoor treatment. Fresh air at ordinary room temperature was most beneficial. As they lessened the delirium, temporarily lowered the temperature, and stimulated the circulation, tepid sponge baths were employed during the height of the fever. In anemic patients transfusions of large quantities of blood (1,000 c. c.) were valuable during the third and fourth weeks of the disease. No benefit was observed from the use of streptococcus serum and vaccines employed as curative measures.

### CONVALESCENT CARE AND TREATMENT.

Medical care during convalescence after operation was confined to dietary measures and to the treatment of the sequelæ of the infection. When possible, high calorie diets were continued for several weeks after the empyema wounds were healed. The patients who were kept on diets of 3,000 to 3,500 calories were not only in better physical condition but the diets served as a therapeutic test regarding the permanency of the wound closure. When the patients did not gain weight on this diet, pus was found in the closed sinus or other pleural foci of infection were discovered. A few were found to be tuberculous.

The most important part of the medical observation during convalescence was the repeated examination of the chest. In the majority of instances all pleural pus pockets were discovered and drained soon after the pneumonia had subsided. However, in 4 to 5 per cent of the patients, purulent pleural pockets were found from the third to the sixth month of convalescence. The symptoms of these were persistent temperature and tachycardia and the patients were always under weight. Few of these patients gained on forced feeding. The examination consisted in careful physical inspection, repeated Roentgen-ray observations, and aspiration of the thorax when there was any question of the pathological condition.

There were few other sequelæ. Albuminuria persisted during convalescence in about 1 per cent of the patients, but it was rarely observed after an interval of two years. It was most common among patients in whom the empyema had not been completely drained. Tachycardia was observed in about 6 per cent of the patients convalescent from streptococcus infections. About 5 per cent of these patients had undiscovered septic foci in the pleura or lung, but no cause was found for the remaining 1 per cent. The tachycardia was often associated with cyanosis, dyspnea, and cardiac pain on exertion. Frequently these symptoms cleared up after graduated exercises. In other cases where the tachycardia was permanent, it was evidently due to a chronic myocarditis and cardiac insufficiency.

Graduated exercises were begun soon after operation for the empyema. Ordinarily, the patients were ambulatory within one or two weeks after the operation. At first the exercises consisted of light work around the wards, then outside duties and exercises were added as soon as the physical condition of the patients permitted. After the wounds were healed marches and the routine exercises described by the Army manuals were prescribed under careful medical supervision.

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## CHAPTER VII.

## THE SURGICAL TREATMENT OF EMPYEMA IN THE ACUTE AND CHRONIC STAGES.

In any case of empyema the treatment should be aimed at the saving of life, the prevention of chronicity, and the restoration to conditions that are as nearly normal as possible. In order to accomplish these purposes certain principles have been worked out which are based on fundamental considerations of the physiology and pathology involved. These principles are, essentially, the avoidance of an open pneumothorax during the period in which a severe pneumonia is likely to be present, the maintenance of the nutrition of the patient, and attempts at the early sterilization and obliteration of the cavity. After an empyema has become definitely chronic, with a discharging sinus of a duration of several months, problems arise in its treatment which are different from those affecting an acute case. This question, as well as the treatment of the surgical complications of empyema, will be considered later on.

In most of the camps in the United States during the early part of the influenza epidemic of 1917–18, practically all cases of empyema were treated by the then conventional method of operation and open drainage as soon as diagnosis was made of the presence of infected fluid in either one or both of the pleural cavities. The associated high mortality strongly suggested that the current ideas of treatment needed modification. Answers to a questionnaire[1] which was sent out to the various camps by the Surgeon General were compiled in March, 1918, and an average mortality of 30.2 per cent was reported in the cases diagnosed as empyema. In some of the camps, however, the mortality was so high that it approached 90 per cent in the operated cases. Observations of the Empyema Commission at Camp Lee[2] led to a conviction that many patients who were operated on died as a result of the additional burden of asphyxia incidental to the creation of an open pneumothorax during the period of acute pneumonia. Therefore, instead of creating an immediate open drainage as soon as a diagnosis was made of the presence of an infected pleural fluid, such cases were treated first by preliminary aspiration and later were subjected to open drainage. An immediate drop from 40 per cent to 4.3 per cent occurred in the mortality following the institution of this method. At some of the other camps, also, a similar procedure had been instituted, with results that were more favorable than those obtained by the conventional methods of treatment. At the same time, and in view of the fact that reports from the hospitals in France indicated that the chest could be opened as widely as desired for the purpose of removing foreign bodies, widespread consideration was given the importance of the factor of open pneumothorax in the early stages of an empyema. Because of the uncertainty and confusion incident to the important bearing of the open pneumothorax, two members of the Empyema Commission were detailed to take up the whole question experimentally. The result of this experimental work, published at that time, was in part as follows:[3]

### THE MECHANICS OF THE THORAX IN RELATION TO EARLY DRAINAGE.

The process of inspiration consists essentially of a sudden enlargement of the thorax which results in a rush of air down the trachea into the lungs. The

antithesis of this process is the act of expiration, a sudden diminution of the volume of the thorax which forces air out of the lungs again. It is evident that the essential condition which must be created by enlargement of the thorax in order to accomplish the rush of air down the trachea to the lungs is a diminution of pressure within the lungs. Under ordinary conditions the pressure within the pleural space is less than atmospheric pressure. Donders,[4] who was the first to measure these pressures in the human, found values of −9 mm. of mercury at the end of inspiration and of −7.5 mm. of mercury at the end of expiration. If this pressure should be positive (equal to or more than atmospheric pressure) during the act of inspiration, obviously there would be no rush of air down the trachea into the lung.

For these reasons it is of the greatest importance to consider not only how the intrapleural tension may be altered but the effects of such changes as well. The most striking way in which to demonstrate the effects of suddenly altering intrapleural pressure is to create an open pneumothorax—an effect which always follows the creation of an early, open drainage of a case of empyema. The ordinary conceptions of the effects of an open pneumothorax have been based upon the faulty reasoning that any opening in the chest wall, no matter of what size, would result immediately in the establishment of atmospheric pressure within the pleural cavity on the side of the opening. These conceptions carry with them the idea that the mediastinum acts as a more or less rigid partition between the two pleural cavities and that when an opening is made into one pleural cavity the lung on that side becomes collapsed and respiration is maintained by the other lung. These ideas have become so deeply ingrained that all through the literature one finds references to the "collapsed" lung on one hand and the "sound" or "healthy" lung on the other. For example, Garré[5] in a series of diagrams to illustrate the conditions in open pneumothorax, shows the mediastinum as a straight line, in cases in which the opening is small, with one lung collapsed and retracted and the other lung (on the unopened side) of normal size and apparently unaffected. In cases with a large opening essentially the same condition is shown except that there is a slight bulging of the mediastinum away from and toward the opening in inspiration and expiration respectively. Likewise, the lung on the side of the opening is shown as collapsed and contracted into a small mass about the hilus, whereas the opposite lung appears to be relatively unaffected. L. Mayer[6] summarizes from the literature the prevalent views on the changes produced by an open pneumothorax:

> On the healthy side the modifications due to the pneumothorax with a small opening should adjust themselves by a deviation of the mediastinal pleura, the two surfaces of which are no longer submitted to conditions of identical equilibrium; on inspiration the lowering of the intrapulmonary pressure of −7 mm. mercury not manifesting itself on the fistula side, the mediastinal pleura should become curved toward the healthy side and narrow the expansion of the other lung; the inverse should be produced at expiration. In reality these theoretical differences are minimal and are scarcely established by experimentation. If, on the contrary, the pleural opening is widely gaping the atmospheric air enters and goes out freely at each respiratory movement and the lung of this side will not be called upon at all to become distended. At each inspiration the pressure of the two sides of the mediastinal pleura will be different; on the healthy side negative pressure of 7 mm. Hg., on the other side atmospheric pressure, with aspiration of the mediastinum toward the healthy side, toward which it ought to be markedly convex. In moderate and light expiration the pressure on the two sides remains equal; but if a forced or sudden expiration supervenes the pressure is raised in the normal lung while it remains constant on the incised side, giving a convexity of the mediastinum on the side of the pneumothorax.

Direct experimental observations, which were made by Graham and Bell[3] while members of the Empyema Commission of the United States Army,[2] show that these conceptions are erroneous, in that, in the normal thorax the mediastinal structures offer so little resistance to changes of pressure that any change in one pleural cavity affects the other to practically the same extent.

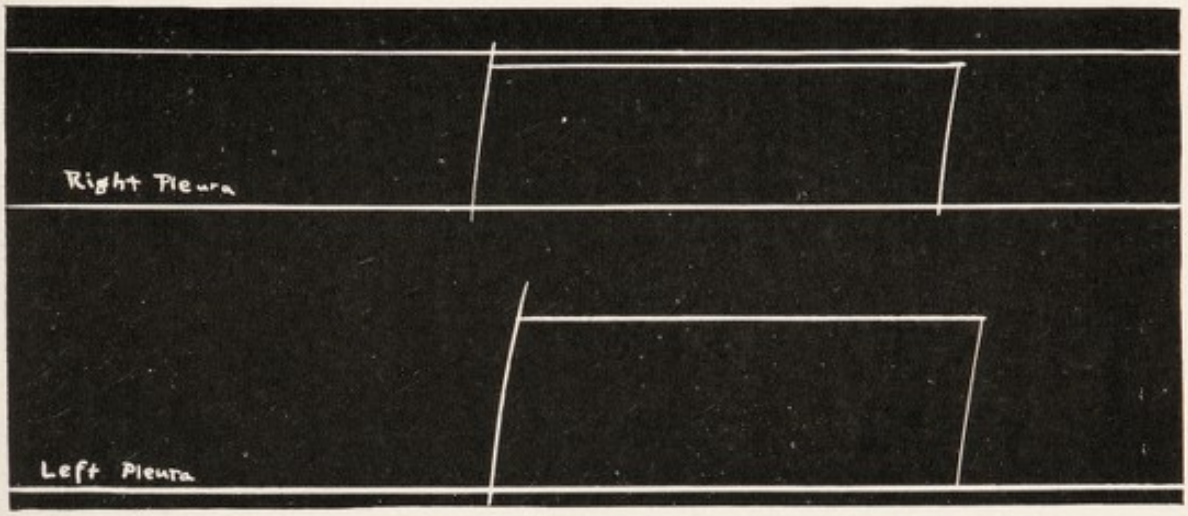


FIG. 56.—Tracing showing that when the left pleural cavity of a fresh adult human cadaver is inflated with air at a pressure of 10 cm. of water the right pleural cavity registers a pressure of 9 cm. The top line is a record of a pressure of 10 cm. made with the tambour attached to the right pleural cavity. Calibration showed that the actual pressure was 9 cm. of water.

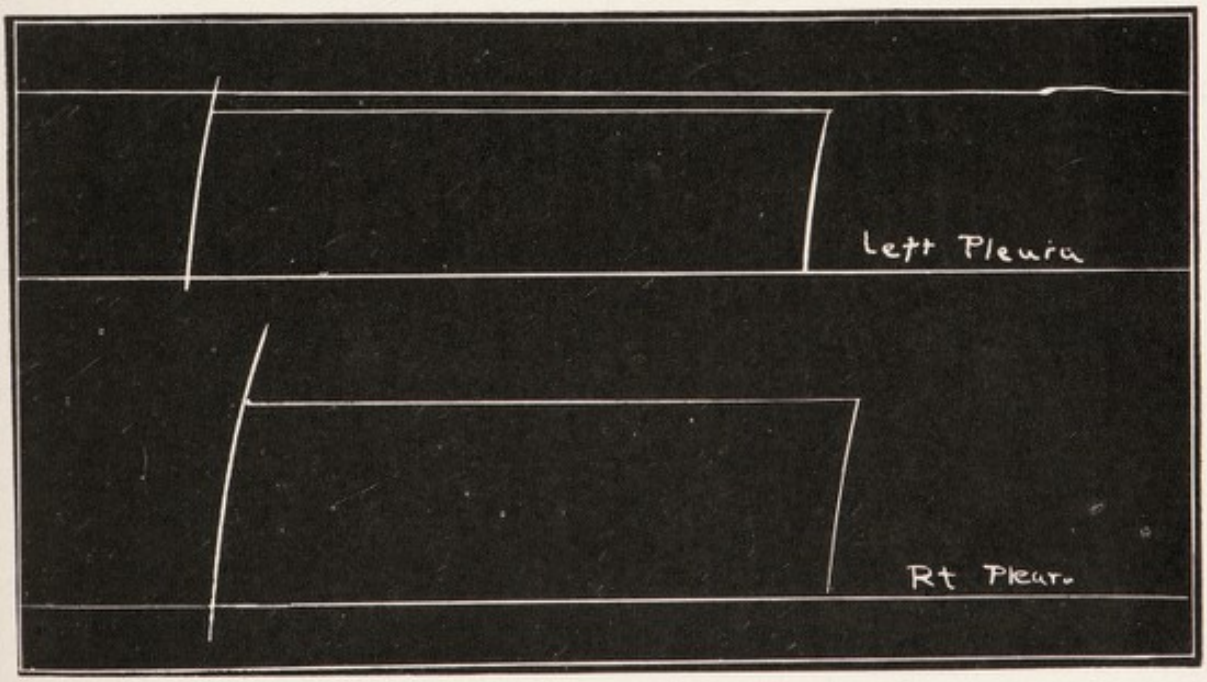


FIG. 57.—A tracing similar to that shown in Fig. 56 with the right pleural cavity inflated. Calibration showed that in this case also there was difference in pressure of only 1 cm. of water (about 0.8 cm. of mercury).

There is, therefore, practically an equilibrium of pressure throughout the normal chest and from the standpoint of pressure relationships the normal thorax can be considered as one cavity instead of two. When one pleural cavity is inflated with air at a known pressure of 10 cm. of water the pressure in the other pleural cavity is found to vary from 9 to 9.5 cm. of water. In other words, even with so slight a pressure as 10 cm. of water, the resistance of the

mediastinum is equivalent to the pressure exerted by only 0.5 to 1 cm. of water. Reduced to terms of mercury this value is equivalent to only about 0.4 mm. or 0.8 mm., respectively, and is, therefore, negligible. One lung, then, does not collapse to an appreciable extent more than the other, and the commonly supposed condition of collapse of one lung with maintenance of respiration by the other does not occur. Moreover, the pressure even in the opened pleural cavity does not come into equilibrium with that of the atmosphere until after death, owing to the constantly changing size of the thorax as a result of the respiratory movements. In this respect it is difficult for some to recognize the difference between a structure with fixed walls and one, like the thorax, which has moving walls. During expiration, the intrapleural pressure in open pneumothorax actually exceeds that of the atmosphere, but both by theory and by actual determination the intrapleural pressure becomes less than atmospheric pressure on inspiration. The results were the same in the human and in the dog.

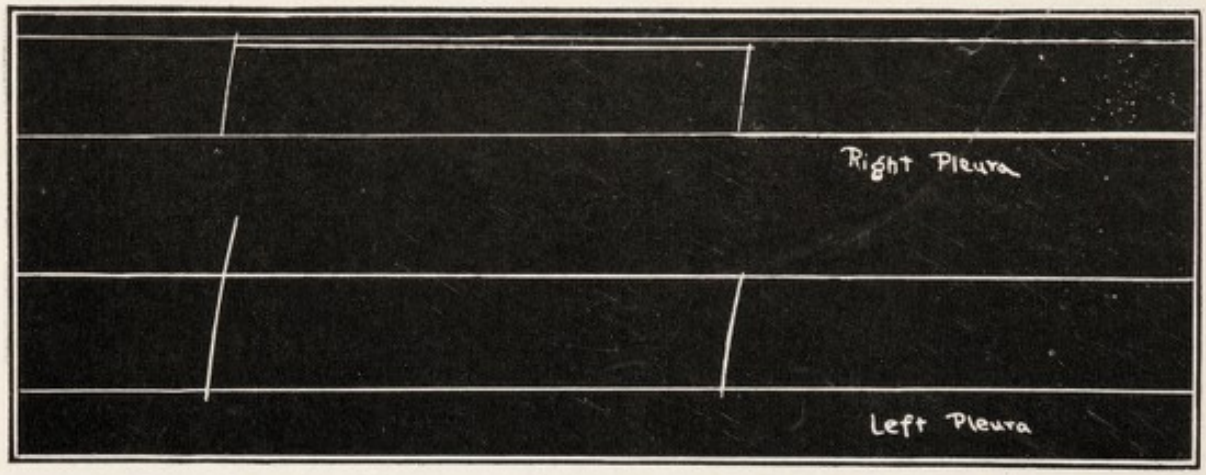


FIG. 58.—Tracing made in the same way as is Fig. 56 with a recently killed dog, which shows that the dog is strictly comparable with the human, since here, also, the difference in pressure between the two pleural cavities amounted to only 1 cm. of water.

A more direct method of determining whether the lungs are equally compressed consists of measuring their relative densities when one pleural cavity is inflated with air at a known pressure. If the pressure relationships in both pleural cavities are affected about equally by altering the pressure in one, then both lungs should be about equally compressed and should show almost equal relative densities. The results obtained on five dogs bear out this idea.

| | Density of lungs. | |
|---|---|---|
| | Left. | Right. |
| No. 1. Right pleural cavity inflated with air to a pressure equal to that of 10 cm. of water | 0.74 | 0.74 |
| No. 2. Left pleural cavity inflated | .73 | .69 |
| No. 3. Left pleural cavity inflated | .70 | .72 |
| No. 4. Control, not inflated | .52 | .48 |
| No. 5. Control, not inflated | .43 | .51 |

By showing an equal amount of compression of both lungs when only one pleural cavity is inflated these results lend striking support to the conclusion drawn from the other experiments: in the normal thorax, alterations of pressure in one pleural cavity are accompanied by practically the same changes in the other pleural cavity.

If, in the living dog, an open pneumothorax is created on one side, a characteristic response occurs which is manifested not only by a change of intrapleural pressure on the opened side but also by a change of the same kind and of practically the same degree on the unopened side. Briefly, the phenomena which occur are as follows: Immediately after making the opening there is a simultaneous change of pressure in the two pleural cavities from an entirely minus or negative (less than atmospheric) phase to one which oscillates between a positive or plus (more than atmospheric) and a minus phase. The size of the opening, as will be shown later, materially influences the extent of the change of pressure. The respirations are sometimes slowed and increased in amplitude, but at other times they are accelerated. As the intrapleural pressure diminishes, the intratracheal pressure tends to become constant, as would be expected, since the intratracheal pressure is a rough index of the amount of air passing down the trachea. Immediately upon closure of the opening, there is a simultaneous response in both pleural cavities with a more complete restoration of negative pressure, a diminution of the amplitude of the respiratory movements and oscillations again of negative and positive intratracheal pressure on inspiration and expiration. These changes can be better understood by reference to the accompanying reproduction of a tracing.

The extreme mobility of the human mediastinum in the absence of adhesions has been shown in X-ray studies on pneumothorax by Stivelman and Rosenblatt,[7] and more recently by Stivelman, Hennell, and Golembe.[8] The work of these observers tends to confirm the truth of the general idea, developed in the experimental work under discussion, of the practical equilibrium of pressure throughout the normal thorax. Murphy,[9] recognizing the dangerous tendency of the mediastinum to "flutter" in an open pneumothorax, recommended traction on the lung in an attempt to immobilize the mediastinum.

West[10] reached a conclusion which seems to agree rather closely with the idea developed by Graham and Bell. He apparently made no actual measurements of the pressures, but had he done so it would seem that the results would probably have been in exact agreement with these two members of the Empyema Commission. He states:

> When one pleural cavity is laid freely open to the air there will then be atmospheric pressure on both sides of the visceral pleura; the elasticity of the lungs will come into play, and the exposed lung will collapse. But this is not all, for the alterations in pressure do not affect the one lung only; the mediastinum being not a fixed partition, but a movable one, the elasticity of the opposite lung also comes into play; with the result that the mediastinum and the organs therein are drawn over to the sound side. Thus it follows that the opening of one pleura not only satisfies the elasticity of the one lung, but goes a long way to satisfy the elasticity of the other. If, for example, the pressures be reduced to figures, and we assume for the sake of illustration that in a healthy man the total elastic contractility of the two lungs together amounts to 50, the opening of one pleura may satisfy this elasticity to the extent of 40, leaving only 10 for the unsatisfied elasticity of the opposite lung. Thus, in pneumothorax, which is the corresponding pathological condition, if the lungs are healthy and their elasticity at the maximum, the total respiratory capacity will be suddenly reduced by four-fifths.

Lenhart[11] obtained results in experiments on rabbits which he said tended to confirm the results of the experiments of the members of the Empyema Commission.

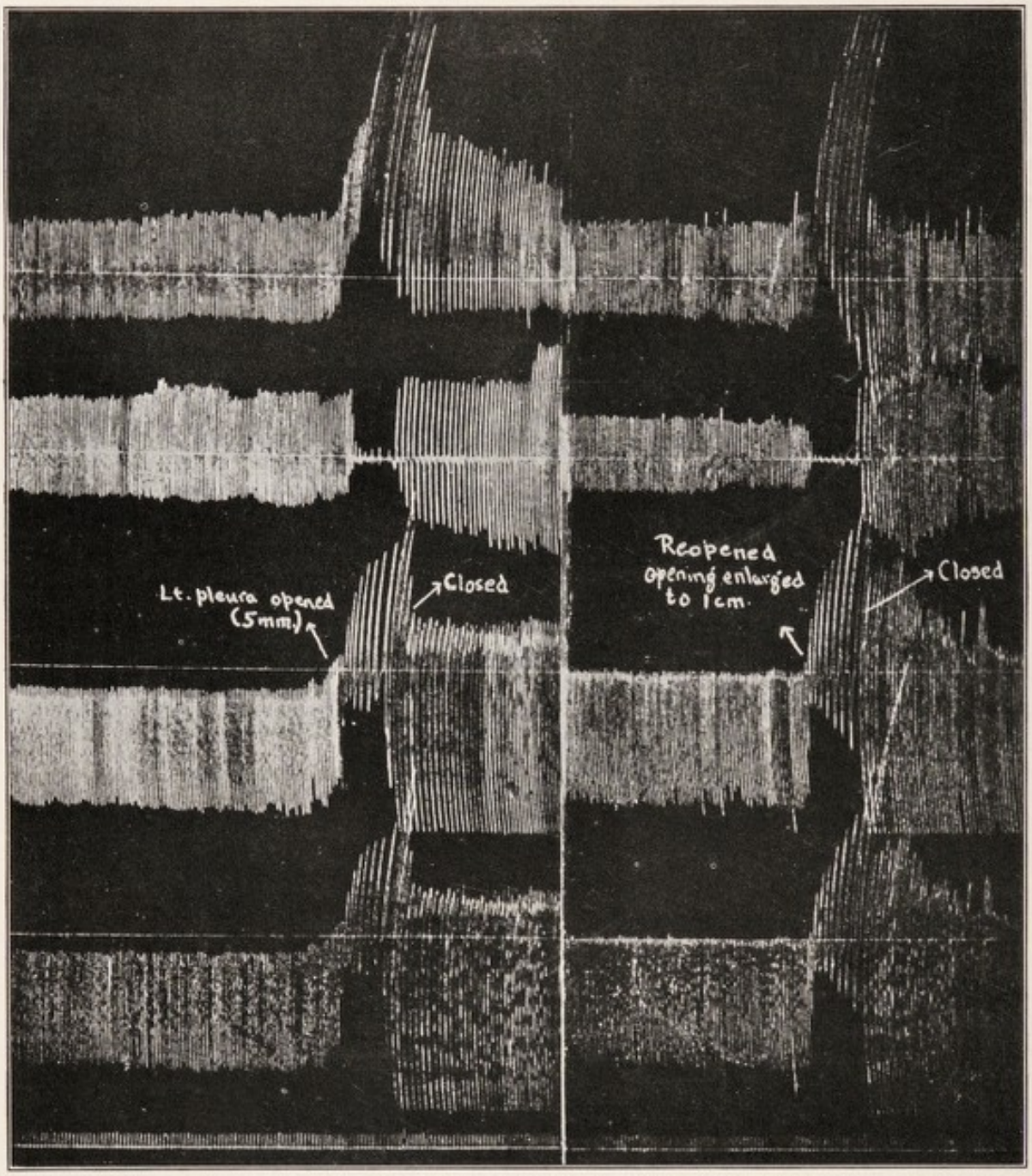


FIG. 59.—A tracing made on the living dog under ether anesthesia to show the nature of the reaction to an open pneumothorax with a moderate opening, as indicated in the changes in the respiratory movements, in the tracheal pressure and in the pressures in both pleural cavities. The uppermost tracing represents the respiratory movements, the next the tracheal pressure, the third the left pleural pressure, and the fourth one the right pleural pressure. The lowest line indicates the time in seconds. The base lines were drawn at atmospheric pressure. The interval represents a duration of six minutes. Immediately after making the opening there is a simultaneous change of pressure in the pleural cavities from an entirely negative phase to one which is mostly positive. The respirations are slowed, but are increased in amplitude. Because the intrapleural pressure is largely positive, practically no air enters the trachea and the intratracheal pressure tends to be at equilibrium with atmospheric pressure. Immediately upon closure of the opening there is a simultaneous response in both pleural cavities, with restoration of negative pressure to a large extent, diminution of the amplitude of the respiratory movements and oscillations again of positive and negative intratracheal pressure, with inspiration and expiration. After an interval of six minutes, during which time the air in the pleural cavities has probably been absorbed, the intrapleural pressure has again become entirely negative.

It should be stated here that often, in small punctured wounds of the chest, even where the lung has been injured, the air does not enter the pleural cavity to create a pneumothorax, but instead it finds its way into the soft tissues of the chest wall. This phenomenon is frequently seen in association with fractured ribs. As an explanation of it West[12] suggested that the cohesion between the two layers of pleura is so great that a considerable force is necessary to separate them. MacEwen[13] has also adopted this explanation.

The older conceptions of the immediate establishment of atmospheric pressure within a pleural space, as soon as an open pneumothorax is created, fail to take into consideration the fact that the thorax, instead of being a rigid box, has movable walls, which, by changing the size of the contained space, likewise change the pressure within it. If the older conceptions were correct, then a small opening into the chest would have the same consequences as a large one, because in each case "collapse" of the corresponding lung would occur. It would follow from this that, in a normal chest, a unilateral, open pneumothorax ought never to be fatal, regardless of how large the opening might be, since the worst possible consequence would be the "collapse" of one lung. Similarly, also, with the same line of reasoning, a bilateral, open pneumothorax should always be promptly fatal. Experiences, however, both experimental and in the World War, which controvert these two conclusions, have been many. A dog, for example, will live indefinitely with a bilateral open pneumothorax if the openings are not too large. It is also easy to demonstrate experimentally that a definitely quantitative relationship exists, in any individual with a normal thorax, between the size of the opening in an open pneumothorax and the danger of death, because the really important factor is the amount of air which enters the chest from the outside with each inspiration.

A mathematical expression has been devised by which it is possible to approximate, in a given case, the maximum opening in the chest wall which is compatible with life. This expression is as follows:

$$X = \frac{V - \frac{R_1}{R_2}T}{\frac{R_1}{R_2}T} aC$$

In this expression $V$ is the "vital capacity", $R_1$ is the rate of respiration before the opening is made, $R_2$ is the rate of respiration after the opening is made, $T$ is the tidal air (approximately 500 c. c.), $a$ is a factor less than 1 (assumed to be about 0.8), and $C$ is the area of the glottis (about 2.25 sq. cm.). By substituting numerical values the determination of $X$ becomes a problem of simple arithmetic. The average vital capacity $V$ and the "tidal air" $T$ are given by Howell[14] as 3,700 c. c. and 500 c. c., respectively. The normal rate of respiration $R_1$ during complete rest is about 15 per minute, and the maximum rate $R_2$ for the greatest possible depth of respiration is about 60 per minute.

$\frac{R_1}{R_2}T$ then equals 125 and

$$X = \frac{3700 - 125}{125} aC = 28.6\ aC$$

$$X = 28.6\ (0.8 \times 2.25) = 51.5 \text{ sq. cm.}$$

In other words, in an individual with an average vital capacity (3,700 c. c.), an opening of about 51.5 sq. cm. (8.1 sq. in.) is the largest for which compensation can be made if the mediastinum has a normal mobility. It is obvious, however, that when the factor $V$ ("vital capacity") is increased the value of $X$ will also increase. Consequently those individuals whose vital capacity is greater than 3,700 c. c. will be able to withstand openings of greater areas than 51.5 sq. cm. In this connection it is noteworthy that Peabody and Wentworth [15] have shown that the average vital capacity for men is considerably higher than that of the general average of both men and women. The average value based on their observations on men is 4,633 c. c. If this value is substituted for $V$ in the given equation, the value for $X$ is found to be 64.8 sq. cm. (10 sq. in.). The maximum opening, therefore, for which the average man can compensate is about 64.8 sq. cm. In the exceptionally large man of athletic build, as for example in the case of the man mentioned by Peabody and Wentworth who had a vital capacity of 7,180 c. c., a relatively enormous opening in the chest wall can be compensated for.

In such a case, for instance, the value of $X$ in the equation would be 101.3 sq. cm., or 15.6 sq. in. Practically, the opening must be somewhat smaller, as the extra work performed by the muscles of respiration to establish compensation increases the amount of air required. The presence of toxemia, infection, or any other cause which increases the level of metabolism will decrease the safety limits of the maximum size of the opening, as will also any condition reducing the available breathing space of the lung. The use of general anesthesia will probably also act in the same way. It should be borne in mind that the value of $X$ represents the approximate maximum opening compatible with life only so long as the respiratory muscles can maintain a maximum respiratory movement, and, in addition, that it is only an approximation because of variability in different individuals of some of the other factors, as for example, $C$. It is striking, however, that, owing to the negligible resistance offered by the mediastinum, it makes very little difference whether there is a unilateral or a bilateral open pneumothorax, provided that the combined areas of the openings in the bilateral case do not exceed the area of the unilateral opening. This fact clearly controverts the former conception of the necessary "collapse" of a lung after the creation of a pneumothorax. If in a living dog an opening into the chest be made in a suitable place for inspection, as, for example, in about the 5th interspace in the mid-axillary line, the expansion and contraction of the lung can be observed to occur with each act of respiration.

The reasons for this quantitative relationship are to be found in the following facts: (1) It is possible to maintain life as long as the lungs can inspire the tidal air, which normally is from 300 c. c. to 500 c. c.; (2) a considerable encroachment on the volume of the two lungs can be made before a stage is reached at which it is no longer possible for the lungs to obtain the tidal air; and (3) in the compensatory reaction, by an increase in the amplitude of the respiratory movements, the thorax is so enlarged that actually more air may enter through the pneumothorax opening without encroaching to the same extent on the tidal air than would be the case if the thorax were not enlarged.

It must be particularly emphasized, however, that this consideration of the practically negligible resistance of the mediastinum, with the associated equality of pressure throughout the thorax, refers only to the normal thorax. Obviously, a thickening of the mediastinum by old inflammation and the

presence of strong adhesions will change the conditions and will permit the development of a considerably greater pressure on one side than on the other.

An open pneumothorax induces other harmful effects than those on respiration. These have been summarized by Sauerbruch [16] as loss of heat, danger of infection, and disturbances of the circulation. Sauerbruch has made the important observation that the loss of heat from an open pneumothorax may exceed that which follows an extensive laparotomy incision with eventration of the intestine; and owing to the changed pressure relationships, a stasis in the venous system occurs which is shown by an actual increase of pressure in the femoral vein.

In the case of a closed pneumothorax conditions very different from those in an open pneumothorax are present. In the description of the characteristic changes produced by making a free opening into the pleural cavity it was stated that the closure of the opening resulted in a sudden restoration of negative pleural pressure and a prompt relief from dyspnea. Obviously, after making the closure, air is retained in the pleural cavity, so that the very striking difference in the phenomena observed must be due merely to the fact that an open pneumothorax has been converted into a closed one. Although air is absorbed from the pleural cavity, it disappears only slowly; and the sudden benefit noted by the closure of the opening can not be attributed to the immediate disappearance of the air. Apparently the explanation of the relative harmlessness of a closed in comparison with an open pneumothorax lies in the fact that the ability to compensate for interference with aeration of the lungs is limited. In a closed pneumothorax, no matter how much air is contained in a pleural cavity no additional air can enter.

In such a case, in animal experimentation, it is necessary for the animal to increase his respiratory effort only sufficiently to create that negative pressure which would allow him to breathe the requisite amount of air to maintain oxygenation of his blood. Under conditions of rest this amount is equivalent to the tidal air, which in the human is a relatively small fraction of the vital capacity (from about one-seventh to one-twelfth). A fatal asphyxia, therefore, should not occur until so large a proportion of the lung capacity has been replaced by air in the pleural cavity that the animal's vital capacity equals his tidal air, provided that the animal is at rest, and his ability to compensate by increasing his respiratory effort is good and that there is no extraordinary demand for air, such as might arise from toxemias. When an open pneumothorax is converted into a closed one, particularly if the closure is made at the end of expiration, the amount of air enclosed in the pleural cavity is very much less than the normal difference between the tidal air and the vital capacity, and naturally, therefore, there is comparatively little dyspnea. However, in the case of an open pneumothorax, there is an active competition for air going on between the trachea and the pleural opening. At each inspiration air not only enters the trachea but also enters the pleural cavity, and if the diameter of the pleural opening is the same as that of the glottis, practically the same amount of air will enter the pleural cavity as will enter the lungs and the animal will be compelled to increase his respiratory effort to get the tidal air into his lungs. If the opening is considerably larger than the glottis, it will be still more difficult to get the required amount of air into the lungs. When it is so large that more air than the difference between the tidal air and the original vital capacity enters the pleural cavity with each inspiration, the animal will no longer be able to obtain the requisite tidal air and death from asphyxia will occur. This theoretical discussion is,

of course, only an approximation and is not strictly accurate, since it is necessary to consider the actual amount of air entering by each opening rather than merely the differences in area, a consideration which also involves the relative lengths of the pleural opening and the trachea with the resultant friction to the passage of air. Observations, however, both clinical and experimental, tend to confirm the truth of this explanation. Clinically, it is well known that an individual of average size may have no alarming dyspnea from a pleural exudate amounting to 2,000 c. c. or 2,500 c. c. Exudates in greater amounts, however, frequently produce very severe dyspnea, particularly if the respiratory muscles are weak. Graham and Bell experimentally injected into the pleural cavity of a dog of 8 kilos, through a small needle, as much as 1,800 c. c. of air over an interval of 20 minutes without producing any marked asphyxia. Beyond that point, however, additional injections of only 50 c. c. at a time each had a very noticeable effect in increasing the dyspnea, and the animal died after about 2,100 c. c. of air had been injected.

The considerations of the effects of pneumothorax discussed above receive clinical confirmation from the experience in the World War with wounds of the chest. Reference has already been made to the fact that Army surgeons found not only that surprisingly large gaping wounds of the thoracic wall did not necessarily result in a fatal asphyxia, but also that bilateral "sucking" wounds were not inevitably fatal. These findings are easily explained, however, by the quantitative relationship between the size of the opening, the "vital capacity," and the other factors mentioned above in this connection. For it has been shown, on the basis of calculations described, that an average normal man, even without adhesions, can compensate for an opening of about 64.8 sq. cm. (10 sq. in.) until his respiratory muscles become fatigued or unless his need of oxygen becomes abnormally great. Practically, in operative procedures on the chest, measures are always adopted by the operator to reduce the size of the opening. An opening, which is apparently very large, is often actually much smaller, because of the presence in the incision of a lung which has been delivered out, gauze sponges, instruments and fingers of the operator or of his assistants, all of which by their plugging tend to reduce the area of the opening. The delivery of the lung outside of the chest wall also accomplishes, to some extent, the immobilization of the mediastinum. There is, therefore, apparently a perfect harmony between the conceptions of pneumothorax based on the above experimental results and the clinical observations on wounds of the thorax.

The theory of the action of pneumothorax which has been presented here is based very largely on the idea that the mediastinum offers only a negligible amount of resistance to changes of pressure in the thorax. From this it follows also that both lungs would be almost equally compressed by any sudden increase of pressure within the thorax, an idea which has been further substantiated by experiment. One can not, however, draw the conclusion that in chronically increased pressures the results are necessarily the same as in the suddenly induced increases. There are many reasons, indeed, for thinking that a difference exists and that, when a considerable amount of fluid has been in one pleural cavity for a prolonged period (several days or longer) the effect on the lung on the fluid side differs from that on the other side. It is a matter of common experience at autopsy on cases with pleural effusions, either simple or purulent, to find the lung much smaller on the side of the effusion. This fact has been one of the chief reasons in the past for

assuming that the mediastinum is a relatively rigid partition which would allow a marked compression of one lung without there being a noticeable effect on the other. Frequently, it has been used also as an argument against the theory of the effects of pneumothorax which have been stated here. In this connection it is necessary, however, to note the following facts: Adhesions are almost always present in cases in which there is a pleural effusion. These adhesions tend to stabilize the mediastinum and permit a marked difference of pressure in the two pleural cavities, a difference which can not occur in the normal individual without adhesions. The mere fact that one lung is smaller than the other does not necessarily imply that the smaller lung has been compressed. Even the absence of air from a part or the whole of the lung does not imply compression.

The results of the experimental work of Graham and Bell, as well as their conclusions, have been confirmed by others. Stivelman, Hennell, and Golembe [8] have reached identical conclusions both in experiments on rabbits and in therapeutic artificial pneumothorax work in the humans. They state:

> Graham and Bell touched the heart of the subject when they came to the conclusion that: "From the standpoint of pressure relations, the thorax may be considered as one cavity instead of two. Any change in pressure in one pleural cavity will affect also the other one almost equally." The results of our own experiments * * * also support this view. * * * In the presence of a flexible mediastinum the intrathoracic equilibrium in pneumothorax is very delicately adjusted, and any disturbance in the intrathoracic pressure on the treated side will have a proportionate effect on the intrathoracic pressure on the untreated side.

Experiments on animals by both Simon [17] and Betchov [18] have likewise corroborated the truth of the fundamental conclusions reached by Graham and Bell. Lenhart,[11] in a number of experiments on rabbits, came to the same conclusion. He states that his experimental results tend to confirm the truth of the conclusions drawn by Graham and Bell.[a]

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[a] Since the preparation of this manuscript in the summer of 1922, some of the theoretical aspects of open pneumothorax discussed here have been questioned. For example, Matas (The Value of Artificial Aids to Respiration in Acute Operative Collapse of the Lungs, *Archives of Surgery*, 1922, v. 110), Duval (Les données actuelles de la chirurgie intrathoracique unilatérale en plèvre libre, *La Presse médicale*, 1922, xxx, 409), Yates (Effects of Acute and Chronic Pneumothorax: A Preliminary Report, *American Journal of the Medical Sciences*, 1923, clxv, 1), and, more recently, Snyder (paper, as yet unpublished, delivered before the American Association for Thoracic Surgery at Chicago, May 30, 1923), have stated that in the dog a communication exists between the two pleural cavities. They infer from this that conclusions drawn from experiments on the dog are not applicable to the human. The conclusions of Graham and Bell are considered by some as being seriously compromised. The author of this chapter has answered these criticisms in part in an article in the *Journal of the American Medical Association* (June 23, 1923, 1825), and also in *La Presse médicale* (February 14, 1923, 141). The controversy has not yet been settled. The most important conclusion, however, has not been challenged, namely, that the "vital capacity" of an individual determines very largely the size of the pleural opening which is compatible with life, when there are no adhesions and no induration of the mediastinal pleura. The plan of treatment of acute empyema based on this conclusion has now been generally accepted in this country, and the results obtained have been good evidence of its general truth. As regards the less important details, the author has never been able to find the alleged opening in the mediastinal pleura in the normal dog, although there is no question about the diffusion through the mediastinum of various salts and dyes. In this connection important considerations are: (1) Can a unilateral pneumothorax be created in the dog? (2) Is there much difference between the dog and the human in the amount of deflection of the mediastinal structures which can be produced? The first question is answered in the affirmative and the evidence is submitted in the author's publications referred to above. In answer to the second question it may be stated that recent experiments performed by the author indicate that there is a close agreement of the dog with the human even when relatively high pressures are created in one side of the thorax. In either case the actual thinness of the mediastinal pleura is not of great importance, because when air is introduced on one side, the lung of the other side acts as a buttress against the mediastinal pleura, hugging it closely in every part of its area. The degree of deflection of the mediastinum, therefore, becomes related to the degree of compressibility of the opposite lung. However, one conclusion from the work of Graham and Bell is in error and should be corrected. It was stated that when an alteration of pressure is made in one pleural cavity of a normal thorax there is an alteration of practically the same degree in the other pleural cavity. This is true for pressures up to about 10 cm. of water, but they have found recently that for greater pressures it does not hold. For example, in the fresh human cadaver, if air is injected into one pleural cavity until a pressure of 21 cm. of water is obtained, the reading in the other cavity has been found to be 15 cm. of water; in the freshly killed normal dog the corresponding readings have been found to be 20 cm. and 13 cm. of water respectively. In Graham's earlier work with Bell the effects of pressures above 10 cm. of water were not determined. It was proposed to do this; but the experimental work was suddenly interrupted by the fact that Graham was sent to an overseas organization before the completion of the work. This later finding will also permit a slightly larger theoretical maximum non-fatal opening in the chest wall than was allowed in previous calculations.

During the World War, while the work of the Empyema Commission was in progress, the vital capacities of the patients were not investigated, but subsequently there was opportunity to make some studies of this character in civil cases. It is interesting that such studies have tended to confirm the validity of the mathematical expression concerning the maximum nonfatal opening. A case which shows this relationship is briefly described:

A young man who gave a history of having had pneumonia in the early part of February, 1922, and in whom pus had been found by aspiration, March 4, was admitted to the hospital March 7. An aspiration which was then performed resulted in the withdrawal of about 300 c. c. of moderately thick pus containing hemolytic streptococci. A question as to the existence of an active pneumonia induced the postponement of the operation for a few days. On March 12, immediately before the operation, the vital capacity reading was 1,600 c. c. and the tidal air 400 c. c. It was felt that, by this time, sufficiently firm adhesions would be present to circumscribe the abscess and prevent a general pneumothorax on that side. A resection of the eighth rib in the right posterior axillary line was made under nitrous oxid and oxygen anesthesia, and 400 c. c. of pus escaped. Immediately after the escape of the pus an alarming dyspnea occurred which was promptly relieved by plugging the opening. On releasing the plug of gauze the dyspnea recurred; and it was again relieved by applying a firm pad of dressings over the opening after a large drainage tube and a Carrel tube had been hurriedly inserted into the wound. Although the dyspnea was lessened after the opening had been covered, it persisted to an uncomfortable degree for several hours. On the second day a tracing of the wound was taken and its area was computed by means of an Amsler planimeter, which revealed an area of about 2.1 sq. in. If stabilizing adhesions were not present, therefore, the operative opening of 2.1 sq. in. allowed him a margin of safety of only 1.2 sq. in., and it is not surprising that severe dyspnea resulted. As further evidence that firm adhesions were not present at the time of operation, is the fact that one week later the cavity measured 1,300 c. c., although at operation only 400 c. c. of pus escaped, an indication that probably the alarming dyspnea was the result of a more or less general pneumothorax.

After establishing drainage of the empyema the vital capacity increases. The diminution of the size of the cavity usually goes hand in hand with an increase in the vital capacity. This relationship is shown in the following table compiled from observations made in another case:

*Course of diminution of cavity and increase of vital capacity.*

| Date. | Capacity of cavity. | Vital capacity. | Tidal air. |
|---|---|---|---|
| | c.c. | c.c. | c.c. |
| Feb. 24, 1922 | 260 | 1,250 | 300 |
| Mar. 3, 1922 | 90 | 1,750 | 300 |
| Mar. 28, 1922 | 60 | 1,950 | ..... |
| Apr. 17, 1922 | 25 | 2,300 | 300 |

## AVOIDANCE OF OPEN DRAINAGE DURING PNEUMONIC STAGE.

In the light of what has already been said concerning the pathology of pneumonia and empyema, especially that due to the hemolytic streptococcus, and the physiological basis of treatment, it seems rational to conclude, that if an open pneumothorax is created by establishing drainage in a patient who is

already partly asphyxiated, such a serious burden may be added to him that he will succumb. He will certainly die if enough interference with his breathing exists to make his vital capacity equal his tidal air; for under such circumstances he will not be able to tolerate even a tiny opening in his chest. When the Empyema Commission substituted a method of repeated aspirations during the pneumonic stage with a deferred drainage operation, in place of an early open operation, at Camp Lee the mortality dropped from a little more than 40 per cent to 4.3 per cent. Similar striking reductions in the mortality occurred in other camps when early open drainage was abandoned. In a statistical article Stone [19] has shown the marked reduction in mortality which occurred at Fort Riley, Kansas, after the early open operation was abandoned. His cases are divided into three series and the following quotation from his article reveals the striking difference in mortality:

1. First series: Early operation (October 20, 1917, to January 21, 1918), 85 cases; mortality, 61.2 per cent.
2. Second series: Early aspirations and late operation (January 12, 1918, to August 10, 1918), 96 cases; mortality, 15.6 per cent.
3. Third series: Early aspirations and late operation (October 18, 1918, to February 14, 1919), 94 cases; mortality, 9.5 per cent.

Souligoux,[20] who advises early open drainage in all cases of acute empyema, states that the mortality of the streptococcus cases is never less than 25 per cent, a conclusion which seems to be significant in the light of the much lower mortality obtained in the United States Army when an early open drainage was not performed. In addition to the danger of an open pneumothorax there are certain other dangers inherent in even so minor an operation as the establishment of drainage. One of these is the possible creation of a septicemia. This danger exists particularly in the streptococcal cases. In fact, in several instances at Camp Lee, a positive culture of streptococci was found shortly after operation in patients whose blood immediately before the operation was sterile. The operations referred to were both simple intercostal incisions and rib resections performed early during the pneumonic stage of the empyema. The fact that positive blood cultures were very uncommon in other cases made it seem that doubtless some definite relationship existed between the early operation and the creation of a septicemia. This appears to be all the more likely when one recalls that a very close analogy exists between these streptococcal infections of the lungs and pleura and the ordinary streptococcal cellulitis cases which occur in other parts of the body. Experience has clearly shown in the case of ordinary streptococcal cellulitis, that free incisions during the acute stage aggravate the condition.

There are two ways by which some drainage at least can be accomplished without creating an open pneumothorax. One of these consists of repeated aspirations to be followed later by open drainage, and the other of the establishment of continuous closed drainage by means of a tightly fitting tube so arranged as to exclude air. Both aspiration and continuous closed drainage are old methods. Although each has had its enthusiastic advocates from time to time, neither method exclusively has given satisfactory results.

In 1844, before the Royal Medical and Chirurgical Society of London, Hamilton Roe [21] advocated aspiration as a therapeutic measure in empyema. He reported 9 cases of purulent effusion, of which 8 were said to have recovered and 1 died. Of 39 cases of pleural effusion of all kinds which had been reported

in British medical journals between 1812 and 1842 as having been treated with aspiration, only 11 had died. Roe emphasized the importance of early paracentesis, not later than three weeks from the outset. At the same meeting, Theophilus Thompson reported the recovery of a case of empyema in a child upon whom he had performed repeated paracentesis in the preceding summer, carefully excluding the entrance of air by tying "thin skin" over the end of the cannula during the procedure. In this country Henry I. Bowditch [22] was one of the first to employ paracentesis in pleural effusions of all kinds, and it was largely owing to his enthusiastic advocacy of the method that it became popular in America. He gave credit to Dr. Morrill Wyman of Cambridge, Mass., for the invention of the aspirating device which he used successfully on several cases.

A small percentage of cases of empyema will recover after aspiration alone, a few after a single aspiration, more after repeated ones. The method is not to be relied upon, however, and when used it should be only a temporary procedure for the purpose of tiding a patient over the acute pneumonic stage of the illness, with the expectation of establishing adequate drainage later. Of the acute cases studied by the Empyema Commission, 13 per cent recovered after aspiration alone. This agrees closely with Stone's [19] finding that at Fort Riley 11.3 per cent recovered. Holt [23] says that of 139 cases of children treated by aspiration, 25 recovered (18 per cent), 8 of these by a single aspiration, 13 died (9.3 per cent), and the remaining 101 were afterwards subjected to other treatment. Objections to the method of aspiration alone are, the difficulty of providing in this way adequate drainage because of the presence in the exudate of masses of fibrin and necrotic tissue which are too large to pass out through a needle or trocar; possible harm resulting from the puncture of the lung or a blood vessel with the needle, or from pleural reflexes; and the incontrovertible fact that most cases which have been treated by aspiration alone require a drainage operation later.

To perform paracentesis, a method should be used which does not permit the entrance of air into the pleural cavity. For this purpose the Potain aspirator is well adapted. The needle should be inserted into an intercostal space at the lower portion of the fluid. In most cases the site of election is in the eighth interspace in the posterior axillary line. The procedure can easily be made painless, or practically so, by an intelligent use of local anesthesia. To accomplish this, it is important that not only should the skin and subcutaneous tissues be anesthetized but the parietal pleura also should be anesthetized. One-half per cent novocaine is advantageous for this purpose. For the aspiration the patient should be in a comfortable position; it is not necessary that he should be in any particular position. The fluid should be withdrawn slowly, and the aspiration may be continued until either no more fluid is obtained or untoward symptoms supervene. Capps and Lewis [24] have shown experimentally in dogs that irritation of an inflamed pleura frequently leads to a collapse with a sudden drop of blood pressure similar to the syncope sometimes observed in the human during aspiration or irrigation of the pleural cavity. They found that artificial respiration was the most effective means of restoring the blood pressure.

If a method of repeated aspirations is to be carried out, the process can be repeated as soon as any considerable reaccumulation of exudate occurs. In

the Army epidemic it was found that it was desirable usually to repeat the aspiration in from four to six days. If repeated aspirations are made, the appearance of the fluid will change. In a streptococcal case, for example, where the fluid is at first serofibrinous, slightly blood tinged and thin enough to pass through the aspirating needle without much difficulty, it will gradually become thicker and more frankly purulent, assuming at the same time a slightly greenish tinge. If the aspirations have been made at intervals of three or four days, usually by the third or fourth aspiration it will be definitely frank pus. As a rule, also, coincident with the change in the character of the fluid, a general improvement in the patient's condition will have been noted, as shown by a diminution in the fever, the disappearance of cyanosis and extreme dyspnea, a better quality of the pulse, and an increase in the appetite. Frequently the path of the needle becomes infected, and occasionally an abscess forms in the soft parts.

Continuous drainage by a "closed" method, that is, one which does not permit the entrance of air to the pleura, is also an old practice, although, as Binnie [25] says, "in recent years it has been frequently rediscovered and modified in unessential details." One of the first enthusiastic advocates of it was Cresswell Hewett,[26] in 1876, who described his plan of "continuous aspiration" as follows:

> Paracentesis being performed with an ordinary trocar and canula, a caoutchouc (rubber) tube is placed through the canula into the empyema cavity; the canula is then extracted, and the outer end of the caoutchouc tube is attached to a glass tube, piercing the cork and reaching to the bottom of the vessel containing a weak solution of Condy's fluid or antiseptic. By gently lowering and raising the bottle the cavity is washed out, and by changing the first bottle for another and similar one the cavity is evacuated of pus, and filled with antiseptic solution; thus the pressure on the vessels in the wall of the sac is not much, if at all, altered, and hemorrhage and transudation are prevented. The amount of fluid to remain in the cavity is lessened day by day, by increasing the siphon action of the apparatus by keeping the bottle at a lower level, each day than the day previous.

Bülau [27] in 1891 proposed a method almost identical to that of Hewett except that he recommended irrigations with lime water through the tube. Since that time the principle of suction drainage has been rather generally, and particularly in this country, credited to Bülau, although Hewett had antedated him by 15 years. During the World War the principle was extensively revived again in the United States Army camps and subjected to modifications to such an extent that almost every camp had its own pet scheme for continuous suction drainage, for each of which the enthusiastic advocates made claims of vast superiority over all other methods.

Mozingo,[28] one of the most enthusiastic of the recent advocates of the principle of closed drainage, combines a system of closed drainage with irrigation by Dakin's solution and Murphy's fluid (2 per cent solution of formaldehyde in glycerin). Diederich [29] had employed a method very similar to Mozingo's at Camp Pike before Mozingo's arrival there. Mozingo reports a series of 138 cases, 45 acute and 93 chronic, treated by himself, with a mortality of less than 2 per cent. He regards an open drainage operation as practically never necessary and states that he has not found it necessary in his series of cases. It does not seem likely that an exclusively closed method could have such uniformly good results unless particularly favorable conditions were present, such as diminished virulence.

Theoretically, the early establishment of continuous drainage, with negative pressure, should have the advantages of keeping the pleural cavity relatively free from liquid exudate and organisms, of aiding the expansion of the lungs, as well as of avoiding an open pneumothorax with its attendant dangers. Practically, however, it seems doubtful if the results are appreciably better than with the method of repeated aspirations. There is, also, the additional risk, slight though it may be, that a delirious and unmanageable patient, by interference with the apparatus or the drainage tube, may allow air to enter his pleural cavity and may suffer from the effects of an open pneumothorax before it can be corrected. This danger was one of the considerations which deterred the Empyema Commission from adopting as a routine the establishment of continuous drainage, with negative pressure, although in some cases it was used.

Regardless, however, of whether repeated aspirations or a method of continuous closed drainage is used to tide the patient over the acute pneumonic stage, it would seem that every case should be regarded as one in which an operation for the creation of free drainage will be necessary at the proper time. It should be regarded as exceptional for a case of empyema not to require free drainage. If the exudate clears up under the conservative treatment and does not return, operation may be withheld, but the patient should be under close observation for at least a month.

Aside from the danger of creating an open pneumothorax during the pneumonic stage, there are certain advantages in a deferred operation. By the time the pneumonia has subsided and the exudate has become frankly purulent, a more or less diffuse cellulitis of the pleura has become converted into an abscess shut off by adhesions from the rest of the pleural cavity. An operation at this stage not only minimizes, therefore, the risk of creating an open pneumothorax because it is not necessary to open into the free pleural cavity, but it presents the safer aspect, well known to surgeons, which the drainage of a streptococcus abscess always has over premature incisions into cases of cellulitis before an abscess has formed. Even if an open pneumothorax should, by chance, be created, the patient is in a much better condition to withstand its harmful effects, because the subsidence of the active pneumonia has the effect of making the area of the air inlet to the lungs larger than when many of the bronchioles and much of the lung parenchyma are blocked by the pneumonic process, so that the pleural opening is incapable of producing the same amount of harm; the pressure of adhesions and the inflammatory thickening and induration of the mediastinum tend to make the mediastinum less mobile; the patient's need of oxygen is less because of an approximately normal metabolism; and the respiratory compensation is more efficient since, owing to a diminished toxemia, the respiratory muscles will not become so easily fatigued.

The danger of early open operation has been recognized by Legendre,[30] who divides patients with empyema into two classes. The first class comprises those with "white dyspnea" in whom the dyspnea is moderate, the respiration rate being about 25 to 30 per minute. The pallor is due to toxemia. The pulmonary lesions are either extinct or nearly well. In such cases a considerable time has elapsed since the beginning of the infection. After operation the fever subsides promptly, the dyspnea improves progressively, and recovery is the rule. The second class comprises those with "blue dyspnea," in whom the rate of respiration is from 45 to 50. There is marked cyanosis of the face

and extremities. These symptoms are in proportion to the pulmonary and not the pleural lesions. Operation increases the dyspnea, has no effect on the fever, and is generally promptly followed by death.

The only aspect of an acute empyema which may require an immediate interference for relief is the presence of alarming or distressing dyspnea. The only type of dyspnea which may arise and which is amenable to relief by intervention is that induced by an excessive pressure within the thorax. This pressure may be the result either of an excessive amount of fluid exudate alone, or of a combination of a spontaneous, rapid accumulation of air within the pleura, in addition to the fluid. In either case prompt relief can almost invariably be given by aspiration. Pneumococcal empyema differs considerably from streptococcal empyema in the fact that ordinarily it is not recognized until after the subsidence of the pneumonia. In this sense it is "metapneumonic," as suggested by Gerhardt.[31] When it is recognized, therefore, many of the conditions are usually found to be present which one strives to accomplish in the streptococcal cases by the preliminary aspirations. Doubtless it is mainly for this reason that, formerly, when early open drainage was extensively practiced in empyema, the mortality in the pneumococcal cases was generally much lower than in those due to the streptococcus.

These considerations lead to this pertinent question: In a case which has had a preliminary treatment by aspirations or by continuous closed drainage, when should an operation for drainage be performed? There can be no hard and fast rule for deciding, but when the exudate has lost its serofibrinous nature and has become frankly purulent, thus indicating that the pneumonia has subsided and that adhesions have formed to wall off the abscess, operation may safely be performed. Ordinarily, 3 or 4 aspirations are performed during the course of from 10 days to 2 weeks.

As to the type of operation employed for drainage, either an intercostal incision may be used, with the idea of later removing a portion of a rib if necessary, or a rib resection may be done at once. Moschcowitz preferred usually to begin with a simple intercostal incision. Certain cases will recover merely by use of an intercostal incision but the majority will probably heal more quickly if a portion of a rib is removed to provide more adequate drainage. One of the disadvantages of rib resection over simple intercostal incision is the greater danger of a chronic sinus from an osteomyelitis of the rib. Either operation can usually be performed satisfactorily with novocaine anesthesia, although there is probably no objection to the use of nitrous oxide and oxygen. The following method of inducing local anesthesia was employed by the Empyema Commission: Infiltration of the whole field of operation beginning with the production of a small skin wheal by use of a hypodermic needle and syringe, and supplementing the local infiltration by blocking the appropriate intercostal nerves in the subcostal grooves close to the spine. Because of communicating branches from the adjacent intercostal nerves it is advantageous to block not only the particular nerve to the rib to be resected but also the one above and below, respectively. For example, if the eighth rib is to be resected, not only is the eighth intercostal nerve blocked but also the seventh and ninth. It will usually be found more satisfactory to combine the two procedures of nerve blocking and the local infiltration. The operation should then be painless.

The particular rib selected for resection depends considerably upon the location of the empyemic abscess. A rib at the lowest border of the abscess will

ordinarily be chosen, but never one lower than the ninth because of the danger of injury to the diaphragm. Most commonly the eighth or ninth rib in the posterior axillary line is the one selected. Anterior drainage is never done except in the unusual cases in which the abscess is immediately behind the anterior wall. Chevrier [32] found on the cadaver that resection of the sixth rib in the posterior axillary line permitted the retention of 650 c. c. of fluid in the recumbent posture and from 1,250 to 1,300 c. c. in the erect posture; while the resection of the eighth rib in the scapular line caused the retention of 300 c. c. in the recumbent posture and from 150 to 200 c. c. in the erect posture. Observations on the cadaver, however, are not entirely applicable to the living, because after death the cessation of respiratory movements eliminates to a great extent the power of the thorax to empty itself. The movement of the diaphragm must be important in this respect. Binnie [25] states that an opening made at the angle of the seventh, eighth, or ninth rib will drain the cavity absolutely when the body is recumbent.

After making the rib resection it is advisable to have the patient cough or strain a little. This procedure will frequently force into the surgical opening large masses of fibrin. These masses of fibrin are sometimes as large as the palm of the hand, and if they are retained they delay healing. By this procedure they may usually be easily recognized and removed at the time of the operation. By digital exploration or by the use of an endoscope, large masses, which fail to appear by having the patient cough or strain, may sometimes be recognized. Some surgeons attempt also to break up adhesions with the finger. Logically, this would seem to be a practice to be strongly condemned; no one would think of similarly breaking up the adhesions around an abdominal abscess. One of the objects in deferring the operation is to localize the infection into an abscess. Why then disseminate the infection again? Likewise, the practice of attempting decortication in an operation for acute empyema is most unwise and will certainly do more harm than good in most cases.

In the practice of the Empyema Commission usually two rubber tubes, as suggested by Mitchell, which were beveled at the end and fenestrated, were passed into the cavity and anchored on the outside with safety pins. Preferably these should be of fairly stiff rubber (not soft enough to collapse of themselves) and with an inside lumen of about a half inch in diameter. The tubes ordinarily should pass just far enough into the cavity to permit retention. If there is difficulty in holding a tube in place a strip of adhesive plaster through the pin and attached to the skin will usually suffice to hold it in place. Through one of the tubes one or two Carrel tubes are placed in such a way as to insure thorough irrigation of the cavity. The fenestrations in the tube, even if they do not project into the cavity, permit some degree of irrigation of the sinus tract, a feature which is very desirable. If, instead of using free open drainage as outlined here, it is desired to practice some one of the closed methods of suction drainage, it may be done. Here again, however, in spite of theoretical advantages, after an extensive trial of both methods, one can not be convinced that practically any better results are obtained with methods of closed drainage. A device which was used in a large number of cases by the Empyema Commission is shown in Figure 60. Other measures which are sometimes resorted to for the purpose of excluding air are the use of valvular tubes of which many different kinds have been suggested. The simplest type consists of a tube the

external end of which is covered with a loose piece of thin rubber or of some similar material which will allow fluid to escape from the cavity but which on inspiration will be sucked up against the opening in the tube and exclude air. One of these, suggested by Moschcowitz and used by the Empyema Commission, is illustrated in its preliminary report.[2]

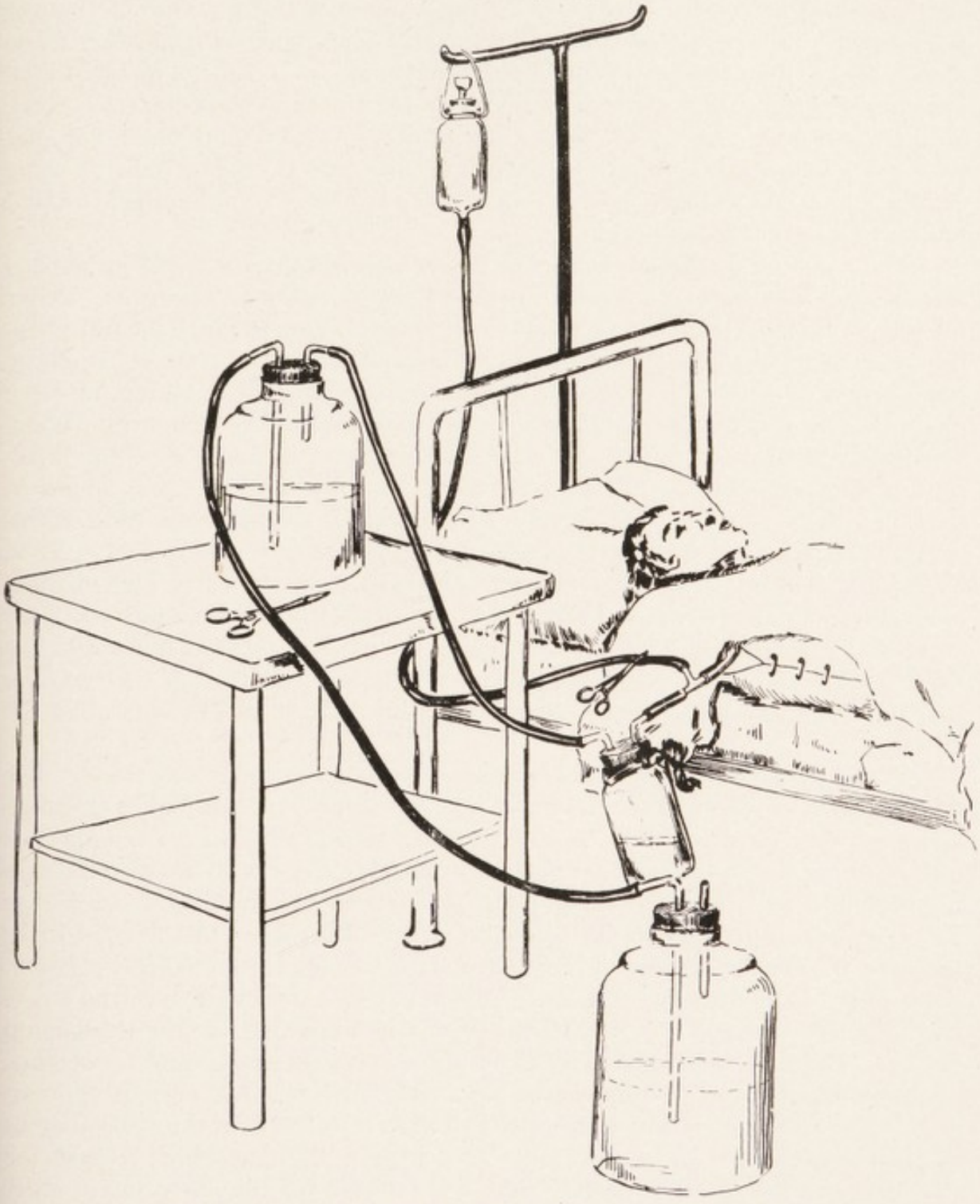

FIG. 60.—Apparatus for alternate aspiration and flushing of an empyema cavity.

Not only is there no apparent advantage in the use of closed, sucking devices for continuous drainage, but there are even certain disadvantages. One of the principal objections is that, with most forms of apparatus, it is necessary for the patient to remain in bed. This is a distinct disadvantage because it is very desirable for all such patients to be up and out of bed as soon

as the heart and general condition will permit. If, however, a valvular tube of some kind is used, such as shown in Figure 60, or such a device as that advocated by Von Eberts;[33] or, if a Politzer bag is put on the tube, as recommended by Bryant,[34] then it will be possible for the patient to be out of bed. Mozingo[28] has claimed as one of the advantages of his method that the patient can get out of bed early. But there are some objections, also. One of these is the difficulty in keeping the tube and connections air-tight for more than a few days. In accordance with a general rule, applicable to all foreign bodies, in the presence of suppuration there is a tendency for the tube to become loosened. Müller[35] and others have had the same difficulty. As soon as the tube becomes loosened a little pus begins to collect around it; and if rubber dam or some similar material has been used to seal over the wound, the pus spreads around under it and excoriates the skin.

The question of the advantage of early open drainage was put to experimental test in a series of 20 dogs in which empyema was produced. After several preliminary failures to produce an empyema by the intrapleural injection of from 10 to 15 c. c. of pure broth cultures of a virulent strain of hemolytic streptococci, a successful result was finally accomplished by injecting, into the pleural cavity of a 6-kilo dog 30 c. c. of a broth culture of the same strain which was highly virulent for mice. The dog died in about 12 hours after the injection, and at autopsy the left pleural cavity (the injected side) was found to contain about 200 c. c. of slightly blood-stained, serofibrinous fluid which contained myriads of streptococci and a few necrotic leucocytes. This exudate resembled in every respect the exudate obtained from the early human cases of streptococcus empyema at Camp Lee. Subsequently, this exudate was used successfully in doses of from 1 to 5 c. c. for the production of empyema in the series of 20 dogs. In 10 of the 20 dogs intercostal pleural drainage with cocaine (0.5 per cent) anesthesia was established within from 4 to 24 hours after the injection.

To the other 10 dogs which served as controls nothing was done. The operations were all carried out under strictly aseptic precautions and sterile dressings were later applied. A stiff rubber drainage tube with a one-quarter inch (6 mm.) lumen was used for each dog and the tube was stitched to the skin in order to hold it in place. The point selected for the drainage in each case was the sixth interspace in the anterior axillary line, since this seemed to be the most dependent portion of the thorax with the dog in the natural position. Each of 16 of the dogs received 2 c. c. of the exudate, two each received 3 c. c. and two each received 1 c. c. All the injections were made in the left pleural cavity. The dogs were paired as carefully as posssible according to weights, so that each dog operated upon had a control which was not only of approximately the same weight but which also had been injected with the same amount of pleural exudate. In general, out of each pair, the dog which seemed the stronger, and the better operative risk, was selected for the operation in order to give the operation every possible chance, since many of the dogs were poorly nourished and were victims of mange. In spite of all this, however, of the 10 operated dogs all but 1 died (a mortality of 90 per cent), and of the unoperated dogs only 7 died (a mortality of 70 per cent). Of the series of unoperated dogs one fatality was also in a dog which on the fourth day, while apparently well,

was badly injured in a fight with another dog, and received extensive lacerations in the neck, the back, and the hind legs. Death occurred two days later, and at autopsy the pleural cavity contained no exudate and appeared normal. It seems probable that it would not have died if it had not been for the wounds received in the fight.

It was a striking fact that, of every pair of dogs which died, the one which had been drained died from one to two days before its control, with two exceptions in which both the operated and the control dogs died at about the same time. It never happened that, of a pair, the unoperated dog died before the operated one. The only dog of the operated series which survived pulled its dressings off and pulled out the tube on the next day after the operation. When seen shortly afterwards (within three hours after the dressings had been pulled off) the pleurel opening had already closed so that the dog no longer had an open pneumothorax. This was the only dog which disturbed his dressings. As a rule, death occurred in the operated dogs from 48 to 72 hours after the operation and in the control series from the fourth to the fifth day. Of one pair, each of which had been injected with 2 c. c. of the pleural exudate, both the control and the operated dog died after about 24 hours following the injection. The operated dog in this case had been drained four hours after receiving the injection. The operated dogs, as a rule, not only died more quickly than their controls, but from the time that the pleural opening was made they all seemed more seriously sick than the unoperated dogs. They would lie quietly curled up, refusing food and resenting disturbance. The unoperated dogs were much more active. Immediately after operation each dog was placed in a cage by himself, was furnished with an abundance of water and food, and the cage was kept clean. In almost every instance the dressings were changed daily, dry sterile dressings being substituted for the soiled ones, with rigid aseptic precautions, even to the extent of wearing sterile gowns and sterile rubber gloves during the procedure. Each of the operated dogs had a profuse drainage of thin serofibrinuous discharge, sometimes slightly bloodstained, which microscopically showed innumerable streptococci and only a few leucocytes which were usually necrotic.

Each dog that died was examined at autopsy within a few hours after death. All of the operated dogs had been drained well, as shown by the absence of appreciable amounts of exudate in the pleural cavity. In practically every instance there was an extensive deposit of fibrin on the pleura, and there were many recent adhesions. In general, there were more adhesions in the dogs that had been drained than in the controls. Two dogs showed, in additon to a left pleuritis, involvement of the pericardium and the other pleura also. It was interesting to note that the pericardial fluid contained a noticeably smaller amount of organisms than the left pleural cavity and that the right pleural exudate contained even fewer. In other words, it appeared as if the infection had passed right through the pericardium and mediastinum from the inoculated left side. Of these two dogs, one had been and the other had not been drained. Three of the dogs that had been operated upon showed at autopsy pockets of pus behind the upper part of the sternum, which resembled very much those which had been described frequently in the human

cases. This condition was never observed in any of the dogs which were not drained.

The fact that in this series there was a slightly higher mortality in the dogs that had had early drainage than in a control series of the same number which received no treatment of any kind seems to indicate very strongly that, under the conditions of the experiment, early drainage at least is of no benefit to the animal, and, if anything, it is rather a source of harm. Presumably the harm is produced by the open pneumothorax, with the train of resulting effects which have been discussed earlier in this chapter. Any comparison, furthermore, with the condition of streptococcus empyema in man must carry with it the important consideration that, theoretically, this experimental empyema in dogs does not begin to contraindicate the early establishment of an open pneumothorax to the same extent as the human condition for the reason that the dogs do not have the associated pneumonia which seems to have been universally present in the human cases and which necessarily lowers the threshold of safety for the establishment of an open pneumothorax.

### EARLY STERILIZATION AND OBLITERATION OF THE CAVITY.

The avoidance of an open pneumothorax during the pneumonic stage of an empyema will unquestionably result in a lower mortality. But a reduction in the mortality is not the only consideration in the treatment. Another principle of cardinal importance is the prevention of a chronic empyema. To accomplish this, it is necessary both to sterilize and to obliterate the cavity. Unless both of these conditions are fulfilled, permanent healing does not take place. There has been too much of a tendency among recent writers to consider as healed those cases in which the sinuses are closed and in which for the time being there is an absence of fever. It is impossible to be certain that an empyema has really healed until several months have elapsed without a recurrence.

Sterilization, when it really occurs, is actually accomplished by natural forces from within the body. Antiseptics will not sterilize living tissues, especially those antiseptics which are applied to the surfaces of infected tissues. Adequate drainage is by far the most effective artificial aid to natural sterilization which can be supplied. But in spite of apparently adequate drainage and in spite of irrigations with or without the use of antiseptics some cases of acute empyema become chronic.

The failure of these cavities to obliterate themselves has been due, in all probability, chiefly to an inability on the part of the lung of the affected side to expand sufficiently to fill its side of the thorax. This inability to expand is dependent chiefly on the following factors: Fibrosis of the lung as a result of inflammation and the thick, inelastic coat of exudate which covers the exposed surface of the lung and limits its inflation. This thick coat of exudate may be likened to a tightly fitting corset around the lung which obviously will interfere with its expansion, although, actually, it does not surround the lung.

Evidence of the failure of the lung to expand properly is presented at autopsies on cases of unhealed empyema. It is revealed by finding that the lung on the affected side is smaller than the opposite one, and that the exposed

surface of lung is coated with a dense layer of exudate which is sometimes fibrinous and sometimes organized connective tissue, in association frequently with a lake of pus contained within the thorax. The inequality in the size of the two lungs has frequently been ascribed to the collapse of the lung on the opened side from open pneumothorax, and it has been even used as an argument against the validity of the conclusion of the equilibrium of pressure throughout the thorax as developed in the experimental part of this chapter. It seems more probable, however, that there are other explanations. In the first place, widespread necrosis occurs with final destruction of areas of lung substance. As this necrotic lung tissue is removed by expectoration and by gradual absorption a considerable amount of fibrosis must occur during the healing process, which must necessarily result in the lung being smaller than normal. At the same time the opposite lung may undergo hypertrophy, since the presence of long-standing adhesions and inflammatory induration have immobilized the mediastinum to such an extent that the healthy lung is no longer subjected to compression by slight changes of pressure in the affected pleural cavity. The remaining air-containing portions of the affected lung, however, are not able to undergo hypertrophy to the same extent as they might otherwise do because of the thick coat of organized inelastic exudate which inhibits an adequate inflation of this lung.

It is obvious, therefore, that the early removal of this membrane is highly desirable. Because, at least in the streptococcal cases, organization of this exudate is known to occur early, it is clear that, other things being equal, the longer it is allowed to remain on the lung the longer it will take to obliterate the cavity. For the cavity is obliterated only when the lung is in contact everywhere with the parietal pleura. In the past, recourse has been had chiefly to mechanical means for the accomplishment of this purpose, as, for example, decorticating operations of the general type devised by Delorme.[3] Although in some cases these mechanical means have yielded brilliant results, on the whole they have been unsatisfactory. They have been associated with a high mortality and frequently they have not cured the patient. The fundamental defect in the rationale of such procedures is that attention is directed to only one of the two main objects of the treatment of empyema, namely, only to the obliteration of the cavity. It is fully realized that nature's efforts at sterilization are greatly aided by the obliteration of the cavity, but the frequency with which empyema recurs after the lung has apparently expanded to fill up the pleural cavity is evidence of the desirability of more active efforts directed toward the sterilization of the cavity.

In neutral 0.5 per cent solution of sodium hypochlorite (Dakin's solution) we have an agent which, on theoretical grounds, should be nearly ideal as an aid to drainage. For not only will it help materially to sterilize the cavity but, also, by its solvent action on the exudate, it will effect decortication and thereby help to obliterate the cavity. Clinical experience, based on thousands of cases in Army hospitals, has seemed to indicate very strongly that in the overwhelming majority of cases, if properly used, Dakin's solution will accomplish these purposes. Wilensky,[37] however, has questioned the superiority of Dakin's solution over simple irrigation.

For the details of its preparation and use the reader is referred to the book by Carrel and Dehelly,[38] and to Chapter IV of this section. The use of

Dakin's fluid should be begun immediately after the operation. The Carrel tubes which project outside of the dressings are attached to a bottle containing the solution, and the proper amount is allowed to run in. The custom of the commission was to give at first just a little less than the amount of exudate removed at operation; for example, if 250 c. c. of pus were removed, about 200 c. c. of Dakin's fluid would be run into the cavity at intervals of about every two hours during the day and of three or four hours during the night. The outside dressings can be changed as often as they become saturated. Once a day all the dressings are removed and the cavity is thoroughly flushed with the solution. Measurements of the capacity of the cavity are also made at the daily dressings, and as the cavity diminishes in size the amount of Dakin's solution is likewise decreased. It is believed that it is essential to use fresh solution which is not more than two days old and to protect the skin with vaselined gauze. If these precautions are carried out there will be few complaints of an irritation of the skin. Cultures should be made from time to time, preferably at intervals of three or four days, to note the progress in sterility. In a favorable case, after about three days there will be no more pus and in a week or 10 days no more bacteria will be found on culture. Usually, however, the pus has not disappeared in so short a time, and in the average case a much longer time is necessary for the elimination of the streptococci.

The cavity may not be obliterated, however, by that time. Two procedures are then possible. The drainage tract may be closed either by a simple plastic operation or by allowing it to close spontaneously after removal of the tube; or the irrigation and drainage may be continued until the cavity has obliterated itself, diminishing gradually the amount of solution used. The first method ignores the pneumothorax cavity in the belief that it will take care of itself without further trouble. This method gives quick, brilliant results in the successful cases but there is no doubt that it will also give more recurrences than the second method. Stewart,[39] Mozingo,[28] Moschcowitz,[40] and Heuer [41] have all advocated this procedure. It seems that the question is really one for the patient to decide. If he would prefer to take the risk of a recurrence in order to save perhaps a couple of weeks of time the method would be justifiable. At present it is not accurately known what the risk is, since there are no suitable statistics available showing the percentage of recovery. Certainly, the cavity should not be considered as sterile until at least two or, preferably three, successive cultures show no growth. No reliance should be placed merely on smears.

In a large proportion of cases (about 15 per cent of the streptococcal cases) difficulty in irrigation is encountered because of the presence of a communication with the lung, a pleuropulmonary fistula, which permits the irrigating fluid to run into the lung. In such instances violent coughing will immediately follow the attempt to irrigate and the patient will usually complain of the taste of chlorine, if Dakin's solution has been used. The great majority of these cases heal spontaneously in a few days. The usual procedure of the commission in handling them was to stop all irrigation for three or four days and then to try again. Usually on the second attempt no complaint of discomfort will be made. Sometimes by changing the position of the patient slightly it will be possible to irrigate even before the communication with the lung has healed.

The main value of Dakin's solution seems to be the fact that it sterilizes and obliterates the cavity chiefly through its power of dissolving necrotic tissue. Its direct antiseptic value is of minor importance, but yet it tends to prevent secondary infection. It is impossible to avoid the sucking of organisms into the wound, no matter with what care the dressings are done; and in the past patients with empyema have usually been infected with secondary organisms of all kinds so that the odor of a group of them in a single ward was often overpowering. The Dakin-Carrel technique certainly minimizes secon-

FIG. 61.—Free tissue plugging empyema drainage opening.

dary infection, and Army experience showed that it was possible to have 50 or more of these patients in a single ward without any disagreeable odor at all.

As a rule, the decorticating effect produced by Dakin's fluid is a gradual process which is accomplished by the slow solution of the false membrane of fibrin and necrotic tissue. In some cases, however, this membrane is removed suddenly in one large mass or in several smaller pieces. As evidence of the decorticating ability of Dakin's solution an epitome of a striking case is here presented.

Pvt. G., 22 years old, was wounded in the arm and leg in October, 1918, in the Argonne.[42] He developed a pneumonia on the left side, followed by

Fig. 62.—Microscopic section of tissue illustrated in Fig. 61.

empyema in November. He was drained through a thoracotomy incision. When first seen by Graham on June 2, 1919, at United States Army General Hospital No. 28, Fort Sheridan, Ill., he had a small opening in the seventh interspace in the left posterior axillary line which was draining a considerable amount of pus containing large numbers of hemolytic streptococci. According to the patient's own account, Dakin's solution had been used on him occasionally at some of the various hospitals in which he had been, but never systematically. He was markedly underweight, had a septic appearance, and had an afternoon temperature which ranged from 101° to 102° F. He had entirely recovered from the wounds of the extremities. A measurement of the empyemic cavity showed a capacity of 350 c. c. and the patient stated that a measurement which had been made two months previously had showed the same capacity. Under local anesthesia a portion of the seventh rib was resected, and immediately after the operation instillations of 200 c. c. of Dakin's solution at two-hour intervals were begun with provisions for adequate free drainage. On the sixth day a large piece of tissue was found plugging the drainage opening. Two days after the expulsion of this tissue the empyemic cavity would hold only 35 c. c. of fluid instead of 350 c. c. and no growth of bacteria was obtained from the secretion. Ten days later the patient was entirely healed and examination both by ordinary physical means and with the X-ray revealed no cavity remaining. On August 28 he returned from a month's furlough, apparently entirely well and having gained 35 pounds in weight. Two months later he was still entirely well. The rapid decortication with later sudden expansion of the lung to fill the cavity such as happened in this case is unusual, but yet it has been observed several times.

The piece of tissue was irregular in outline and flat. Its longest diameter measured

nearly 6 cm. and its widest diameter about 5 cm. It was nearly 0.5 cm. in thickness. It was yellowish-white in color, smooth except for folds on its surface, and in gross appearance it closely resembled fibrin; in fact, it was considered to be fibrin until microscopic sections were made. The microscopic examination, however, showed that the main portion consisted of necrotic, organized tissue. Except for a narrow strip of inflammatory tissue, which evidently indicated the side attached to the lung, the whole section was occupied by bands of wavy fibrils, arranged parallel to one another, with here and there the faint remaining outlines of what apparently had been blood vessels. The entire absence of nuclei except in the inflammatory zone was striking. The fibrils were readily stained by Van Gieson's stain for connective tissue, but they were not stained by Weigert's method for fibrin. Undoubtedly, therefore, the tissue was chiefly fibrous connective tissue which had become necrotic and was not unorganized fibrin. Throughout the inflammatory zone, and occasionally in the area just beyond, were seen irregular clumps of organisms. Many of these could be clearly distinguished as streptococci and they were Gram-positive.

Despite the advantages of irrigation which have been discussed above certain dangers are associated with it other than those due merely to a communication with the lung. Bleeding occurs sometimes, although it is usually only slight in amount. It is indeed rare that an alarming hemorrhage results from irrigation, although cases have been reported in which large amounts of blood have been lost. Usually, in cases of bleeding, if the irrigation is stopped for a day or two it may be resumed without further trouble. Attacks of syncope, which in a few instances have been fatal, have been reported. These have sometimes accompanied paracentesis or thoracotomy; and sometimes merely an irrigation has seemed to produce them. Wilson Fox,[43] in 1891, collected 17 cases of sudden death which he felt were due to some one of these procedures. Hippocrates is said to have observed the danger of fatal syncope in aspiration if the fluid were too suddenly removed. Some of these serious complications are doubtless due to cerebral embolism (Gee and Horder),[44] others are probably concerned with the pleural reflexes studied by Capps and Lewis.[24] In Graham's experience with about 400 cases of empyema treated by irrigations there were no attacks of syncope in association with irrigations of the pleural cavity.[3] On one occasion, while undergoing a rib resection under local anesthesia for empyema, a patient had two severe general convulsions on the operating table, became comatose, and died about 36 hours afterwards. At autopsy a diffuse streptococcal meningitis was found. On another occasion a patient under the care of a colleague died suddenly with an acute dilatation of the heart about five minutes after being at stool. It is well to bear these dangers in mind, but they are of such rare occurrence that they should not deter one from obtaining the advantages which irrigations offer. In this connection a study made by Stevens [45] on recurrence in empyema is important. Of 56 cases healed under simple drainage without irrigations, there were 14 recurrences, or 25 per cent; of 67 cases healed under the Dakin-Carrel treatment with drainage, there were 8 recurrences, or only 12 per cent.

## CHRONIC EMPYEMA.

Chronic empyema may be found either as a previously unrecognized accumulation of pus in the chest, or in a case presenting a discharging sinus. It is remarkable that often a patient will go for a year or more with a very large

accumulation of pus within the chest, frequently containing large numbers of hemolytic streptococci, without sufficient local or general disturbance to make medical consultation seem necessary. The only symptoms complained of may be a cough, pain in the side, or loss of strength. On examination, however, in addition to the local evidence of fluid in the chest, there will also be found more or less emaciation, which may be extreme, fever of about 101° F. in the afternoons, leucocytosis, and often some degree of scoliosis. A Roentgen-ray examination and an exploratory aspiration will furnish the additional evidence, if this be necessary, for the diagnosis.

Discharging sinuses are of several different types. There are those which merely lead into relatively large cavities, those which communicate with the lung or with a bronchus but do not lead into a large cavity, combinations of the two, and sinuses which lead only down to the pleura or to a rib.

The most important causes of persistent sinuses are inadequate drainage, presence of foreign bodies, communications with the lung, cavities that can not be obliterated spontaneously, and tuberculosis or similar infections. In an experience with 138 cases of chronic empyema at Fort Sheridan in the spring and summer of 1919, by far the most common cause was found to be insufficient drainage of the empyemic cavity. It was apparent that one of the surest ways by which to turn an acute empyema into a chronic one is the failure to provide proper drainage. The various methods of closed drainage through small tubes and catheters have unquestionably saved lives during the acute pneumonic stage, but in many instances they have also been responsible for the transition of an acute empyema, which should have healed, into a chronic, unhealed one. It was appalling to find case after case which had been treated for 10 or 12 months supposedly by drainage, but in which the only provision for drainage was a tiny tube (often a Carrel tube) projecting from an opening no larger than itself, which led into a cavity containing 300 or 400 c. c. of pus, and even this tube often was tied into a knot to prevent the admission of air. Moreover, so much faith had been placed in suction that in very many cases apparently no attempt had been made even to make the drainage opening at a dependent part of the cavity. These are the great dangers from the unintelligent use of the various closed methods. The treatment of empyema is still surgical, and its proper handling requires the judgment of an experienced surgeon. It can not be turned over safely to an inexperienced person. Mozingo states as one of the advantages of this method of treatment: "The postoperative treatment in greater part may be done by a nurse or a properly instructed member of the family".[28] Doubtless, what he means is that most of the irrigations can be done by some one with ordinary intelligence, but there exists among general practitioners too much of a feeling that a method like that of Mozingo's has made the treatment of the condition practically automatic.

Foreign bodies constitute another important cause of persistent sinuses. Of these, the principal are sequestra of ribs, pieces of various kinds of drainage material, notably tubes and gauze, and, in gunshot cases, such things as shell fragments. Communications with the lung which may exist in association with persistent sinuses are of various kinds. One of these is the pleuropulmonary fistula. This is the most common type. It is due probably to the rupture of a small subpleural pulmonary abscess into the pleural space. The

communication with the lung may persist for a long time. Usually, however, it heals spontaneously. Another communication is the bronchial fistula. Here, the communication exists with a large bronchus. This type is less likely to heal spontaneously, and the fistula frequently becomes lined with epithelium. It may be so large that the patient may be able to breathe comfortably through it. Both of these types may communicate only with the main cavity, or, as often happens in the case of a bronchial fistula, the fistula may communicate directly with the outside, and no other cavity may exist. Fistulæ which communicate with the lung frequently lead into abscesses or into areas of bronchiectasis. Some sinuses merely lead down to a rib or cartilage which is the site of a chronic infection without the presence of definitely demonstrable sequestra.

Cavities that can not be obliterated spontaneously are in most instances due to improper management earlier in the course of the disease. They are usually found either in cases in which a free open drainage was instituted at too early a period or in cases in which adequate drainage has never been provided. In the work of the Empyema Commission it was found that most of the largest cavities and those which gave the most difficulty in obliterating were in the cases in which evidently an open drainage operation had been performed in the pneumonic stage. At Fort Sheridan, in 1919, it was found that the cavities which were the most difficult to obliterate without a plastic operation were in empyema cases which had existed for a year or more with very inadequate drainage. The principal causes are that, due to the persistence of the infection, the exudate on the lung becomes organized into fibrous tissue which thereby limits its expansion, and the fact that the lung itself undergoes fibrosis and contraction. At the same time the increased rigidity of the mediastinum tends to prevent the crowding over of the other lung and mediastinal structures into the diseased side, so that the cavity persists.

It is well known that pleurisy due to tuberculosis and other similar types of infection, such as actinomycosis, does not heal readily. Sinuses in such cases tend to persist. Of the 138 cases of chronic empyema at Fort Sheridan, 13 (10 per cent) were proven to be tuberculous.[46]

Every patient with a chronic empyema should be examined carefully with reference to the nature of the infection, the size and contour of the cavity and the presence of foreign bodies.

Cultures should be made from the secretion obtained from well within the cavity and not merely from the sinus. Other methods, of course, should be used for determining the presence of a tuberculous or similar infection, such as the microscopic examination of a piece of the wall of the sinus, and the examination of the sputum for the organisms.

Many variations exist in the nature of the cavities found. Some are large, occupying practically the entire half of the thorax; others may have a capacity of only a few cubic centimeters. Some cavities are unilocular but perhaps in the majority of cases of chronic empyema they are multilocular. The presence of adhesions causes constrictions in various places, in what may have originally been a single large cavity, with the result that all sorts of irregularities in shapes may occur. It is this irregularity in the shape of the cavity that is very often responsible for the chronicity of the case, because proper drainage has been

impossible under existing conditions. Especially is this the case in hour-glass constrictions.

It is very important, therefore, that as nearly as possible an exact diagonsis should be made of the size and contour of the cavity with which one has to deal. There are several methods available which are of great help. Instrumental exploration with a long flexible probe, such as a uterine sound, or with a pair of long curved dressing forceps will provide much information. The most valuable method of studying these cavities, however, is by means of the Roentgen ray. Tuffier [47] has used to his satisfaction a modified cystoscope which he inserts into the chest cavity and in that way gets a direct vision of the conditions present. Such a procedure is very helpful. It will often happen, however, that in order to obtain the necessary knowledge of what the conditions actually are, an operation will be required. Even sequestra from a rib will often fail to show in the Roentgen-ray plate because of the obscurity caused by a greatly thickened pleura.

### TREATMENT OF CHRONIC EMPYEMA.

The kind of treatment recommended will vary greatly according to the particular case. The main indications are to provide adequate drainage, remove foreign bodies, accomplish sterilization, and then to supplement these, if necessary, with operative procedures to hasten the obliteration of the cavity. General hygienic measures are also very valuable.

It is well to begin the treatment of the ordinary case of chronic empyema rather conservatively; for it is often amazing to see how much can be accomplished merely by establishing adequate drainage and promoting sterilization of the cavity. The old sinus, therefore, should be enlarged to whatever degree may be necessary in order to secure a proper inspection and examination of the old tract and the cavity. This will almost always require the resection of a portion of one or more ribs. The ribs over the old sinus may be found fused together or in regenerating they may have assumed various bizarre shapes. It is not uncommon for the sinus tract to be surrounded by a ring of newly formed bone. Having explored the old tract and the cavity for foreign bodies, the object then should be to secure satisfactory drainage. To accomplish this it may be necessary to convert a multilocular cavity into one which is unilocular. This may require the separation of adhesions at various points and perhaps a considerable amount of greatly thickened pleura can be removed safely at this time. If the opening already made is not in a position which will drain the dependent portion of the cavity, either it should be extended downward or a new opening should be made. It can not be too strongly emphasized that free drainage is the most important indication of all in the treatment of these cases. In the ordinary case drainage should be provided at first. No sutures should be put into the wound but several Carrel tubes should be placed in advantageous locations, leaving one or two drainage tubes of large caliber in the wound to prevent too rapid closure. There is no fear of serious danger from pneumothorax in this type of case because the presence of adhesions and inflammatory thickening have stabilized the mediastinum. Irrigations with Dakin's solution are begun at once.

It was a frequent observation of the members of the Empyema Commission that often very large cavities which had remained practically stationary for months would become rapidly obliterated as soon as sterilization was accomplished by combining satisfactory drainage and irrigations with Dakin's solution. Hedblom[48] has presented an interesting table which shows the reduction in size of the cavities in 51 cases of chronic empyema (all existing over three months) accomplished by a combination of free drainage and irrigations with Dakin's solution.

| Cases. | Capacity of cavity. | Average number of days of treatment. | Capacity of cavity at end of treatment. | Average percentage decrease in capacity of cavity. |
|---|---|---|---|---|
| | | | c. c. | |
| 11 | Less than 100 c. c | 35.9 | 10 | 90.0 |
| 16 | 100 to 250 c. c | 34.1 | 11- 27.5 | 89.0 |
| 15 | 250 to 500 c. c | 56.4 | 11- 22 | 95.6 |
| 5 | 500 to 1,000 c. c | 45.2 | 11- 22 | 97.8 |
| 4 | 1,000 to 2,000 c. c | 32.0 | 80-160 | 92.0 |

| | Cases. |
|---|---|
| Complete recovery | 34 |
| Sinus at last report | 6 |
| No late report | 6 |
| Convalescence not completed | 4 |
| No benefit (tuberculosis) | 1 |
| | 51 |

The advantages of a plan of procedure such as outlined above are not only that many cases may be healed in this way with a minimum of risk and of deformity, but also, if a more severe plastic operation becomes necessary later, it can be done in a relatively clean field.

As already indicated, however, there are some cases which can not be healed by this comparatively simple procedure. For such cases a more elaborate operation will be required. Operations for this purpose, of which many have been devised, have been developed from two different basic ideas. One of these was that in order to obliterate the cavity the rigid chest wall should be made nonrigid in order to fall down upon the nonexpanding lung, and the other was to free the lung from its inelastic coat of fibrin and fibrous tissue in order to permit it to expand to meet the chest wall. The former was illustrated particularly in the operations devised by Estlander[49] and by Schede.[50] Estlander's operation consisted in the multiple resection of ribs; and Schede added to this the resection of the thickened parietal pleura. For details, reference may be made to the original articles or to any textbook on operative surgery. The other type of operation was originally suggested by Fowler[51] and almost simultaneously by Delorme.[52] It carried out the procedure now generally known as decortication, by which was meant the stripping off from the lung of the fibrous tissue which prevents its expansion.

There are many objections to operations of this type. In the first place they all carry with them a high mortality and a low percentage of complete cures, so that a patient has very little assurance of a complete relief from his

trouble even if he undergoes the serious risk entailed by the operation. This is well borne out in the following statistics of Tuffier:[53]

| Operation. | Mortality, per cent. | Cure, per cent. | Percentage of cases requiring another operation. | Percentage of cases not followed. |
|---|---|---|---|---|
| Estlander | 18 | 50 | 32 | ..... |
| Schede | 28 | 50 | ..... | 22 |
| Delorme | 15 | 48 | ..... | 37 |

Extensive decortication is usually accompanied by a large amount of hemorrhage. In many cases it is impossible to accomplish an extensive decortication because the fibrous tissue on the surface of the lung is only part of a more general fibrosis of the whole lung and projections of scar tissue extend from the surface deep into the substance of the lung.

The operations of the type of Estlander and Schede leave a very bad deformity which is not only anatomical but physiological as well.

Various modifications of these thoracoplastic operations have been suggested, some of which will be mentioned briefly. Souligoux,[54] recognizing the difficulties of decortication, advocates the separation of the adhesions at the periphery of the cavity. This mobilization of the lung allows those parts of it which are still capable of inflation to expand sufficiently to fill a cavity which otherwise it could not do. He combines with this procedure a modified Schede operation. Ransohoff advocates gridiron incisions in the pleura over the lung with the idea of allowing it to expand.[55] Robinson has practiced the transplantation of flaps of muscle, particularly the latissimus dorsi, in order to fill up a cavity with living tissue which will provide granulations.[56] Tuffier and Depage advocate closure of the pneumothorax cavity after cultures have shown streptococci to be absent and after the pleura has been shown not to secrete when dressed only with sterile gauze without the further use of Dakin's solution.[47] In other cases they perform various combinations of decortication and mobilization of the lung. Heuer also has closed some chronic empyemic cavities after sterilization, disregarding the pneumothorax.[41] Beck has transplanted flaps of skin into the cavity.[57] Lambotte, in 1911, had enthusiastically advocated the same procedure in intractable empyemic cavities.[58]

The treatment of fistulæ which communicate with the lung deserves mention. It has been stated elsewhere that the small pleuropulmonary fistulæ which occur commonly in acute empyema usually heal spontaneously. Sometimes, however, fistulæ of this sort persist. They then probably connect with a small bronchus. It is common to find small areas of bronchiectasis in the portion of lung into which some of these fistulæ lead. In such cases the fistulæ really act as safety valves discharging purulent material from the diseased portion of lung. They commonly attain the size of 2, 3 or more millimeters in diameter and they are often very long and tortuous. The external opening may be at a distance of 6 inches or more from the connection with the lung. These fistulæ pursue an almost typical clinical course. Spontaneous closure frequently occurs and continues for a few days, or perhaps a couple of weeks at a time, during which time the patient will have a sense of fulness in the side, will show some fever, and will often cough up pus. The

fistula then opens again spontaneously, pus drains out, and the patient is relieved of symptoms. There may be no empyemic cavity left in the ordinary sense, and the fistulous tract may be the only evidence that the original empyema has not healed. After experience with a considerable number of such cases, it appears that they should either be treated radically or be left alone. If radical treatment is undertaken the fistulous tract should be dissected up and a partial resection of the lung should be made, including the diseased area. It is not necessary to make an extensive resection, and the edges of the lung can be sutured together again with catgut, as in any other pulmonary resection which includes only a portion of a lobe. Less radical measures consist in excising the sinus down to the lung, cauterizing the pulmonary opening and suturing it across. In one case the stump of the sinus was buried in the lung and covered over with healthy lung tissue in much the same way as an appendix stump is buried in the cecum. The true bronchial fistula usually communicates with one of the main bronchi or with one of its principal branches. It may sometimes be almost large enough to insert a finger into it; and not infrequently it is possible for a patient to breathe through it comfortably with his nose and mouth occluded. Recent bronchial fistulae, even of large size, may close spontaneously. In one patient upon whom a lobectomy was performed a bronchial fistula, which was large enough to permit respiration through it, was present for six weeks. Three weeks later it was entirely closed, and it stayed healed. Those which persist for several months, however, are usually permanent and require operative correction. The most satisfactory results are obtained when the fistula is dissected up to its communication, cut off, and the opening closed, after cauterization of the epithelium. Eggers[59] has written an article dealing exclusively with this subject which gives some good points in the treatment of the condition.

Another method of limited value in the treatment of chronic empyema and of chronic sinuses in the chest is the use of Beck's bismuth paste. On the average the results in the Army were very unsatisfactory. When fistulae are present the paste is very likely to be disseminated through the affected lung and even into the other lung. If sequestra or other foreign bodies are present the paste will serve only to prevent drainage by plugging the opening. There is always also the danger of bismuth poisoning.

As in the treatment of acute empyema, it is important to give a generous mixed diet. The rapid gain in weight which occurs in these cases after establishing satisfactory drainage is often astounding; it is common to have a gain of as much as 30 or 40 pounds in the first month. It is advisable also to keep these patients out in the open air continuously if possible. Blowing exercises are helpful as in acute empyema.

Another procedure which was found to be of value in these cases is blood transfusion. Conditions in the Army hospitals afforded a very unusual opportunity of obtaining blood from those who had just recovered from the same infection. This blood probably contained enough immune antibodies to have very superior advantages over normal blood. One patient, transfused by Moschcowitz and Stevens, made an almost miraculous recovery. At the time of the transfusion he had, in addition to a very large cavity, a severe nephritis and a heart murmur. It seemed hardly possible that he could live, but he made a complete recovery with obliteration of the cavity.

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## CHAPTER VIII.

## THE SURGICAL TREATMENT OF THE REFRACTORY EMPYEMA CAVITIES.

When the crest had been reached in the treatment of strictly postwar surgical cases and the number of these cases had begun to wane, the Army found itself confronted with a large number of chronic empyema patients, the residue of the influenza epidemic of 1918 and 1919. The well-recognized measures of treatment, though applied with consummate skill and untiring patience by the ablest surgeons in the country, went unrequited so far as this particular group was concerned. It was necessary to discover in these apparently contradictory operative procedures and end results the reason or reasons for failure. This accomplished, it would then be possible to modify the methods previously in vogue so as to effect a cure and, at the same time, if necessary, to controvert opposing opinions. All the patients in question were poor surgical risks, depleted both in mind and body, and any attempt at surgical repair had to be done step by step, but never until the full confidence of the patient had been gained.

An experience before the World War first led the author of this chapter to believe in the wisdom of the "open" type of operation as the logical method to pursue. At that time, he was attempting to do a decortication on a patient who had had five previous operations for chronic empyema, when the hemorrhage encountered became so profuse that it was necessary to clamp the bleeding points, leave the clamps in position and pack the remaining cavity. This, of course, was before the introduction of Dakin's solution, and the present method of its use, but subsequently, he was astonished to see the ease with which the antiseptic solution could be applied directly to every recess of the cavity, the rapidity with which the cavity became clean, and the promptness with which it was afterwards obliterated. That the obliteration was permanently successful was evidenced by the fact that this patient, an officer, remained constantly on active duty from the time in question, and that he served in France throughout the strenuous days of the World War. It seemed but logical that these conditions should be simulated in the treatment of the postinfluenzal cases of chronic empyema if the hemolytic streptococcus, a very resistant type of organism, with which they were infected, was to be rendered inert.

When the majority of the Army camp base and general hospitals throughout the United States were closed many cases of chronic empyema were still under treatment. These cases had been subjected to many operations in the attempt to obliterate the cavities permanently and to secure final healing of the wounds. The patients of this type were gathered into a few permanent hospitals, the greater number being transferred to Walter Reed General Hospital, Washington, D. C., where it was possible to study and to treat them with every possible facility, and where the "open type" of operation was put into practice in the fall of 1920.[1]

In this connection, it is well to enumerate briefly the principal etiological factors observed during the treatment of these cases. Patients who presented pleurobronchial fistulæ numbered 60.8 per cent, 90 per cent had osteomyelitis of the ribs, with or without sequestration, 75 per cent showed accessory pockets or diverticula, and 15 per cent had foreign bodies in the nature of rubber tissue, drainage tubes, or bismuth paste.[2] One hundred per cent were infected

with hemolytic streptococci, and 15 per cent had underlying constitutional conditions, such as tuberculosis and syphilis. The problem of the surgeon was to obliterate the cavities in these cases by a method which would not only result in minimal mutilation, but which would increase the vital capacity and yet result in a low mortality. The "open" operation, carried out in repeated stages, seemed to approach this ideal more closely than any other known method.

Inasmuch as the previous operative methods carried out at a time when these patients were better able to withstand operative trauma and overcome infection, had failed in the hands of competent surgeons, it seemed that an operation should be attempted which would not only obviate the causes of previous failure, but which would, by minimizing shock, be well within the limits of safety. It was obvious that these patients could not withstand an extensive operation. The cavities were badly infected, and since resected ribs projecting into such cavities often resulted in osteomyelitis with sequestration, it seemed that the logical procedure was to lay the cavities completely open for direct irrigation and inspection.

The reason for this open type of operation was more apparent when it was found that a large percentage of cases of chronicity and recurrence was due to diverticula, which had not been observed at the time of the earlier operations. These diverticula drained by minute sinuses into the main cavity, or in some cases into an unobliterated and infected pocket, anterior or posterior to the residual sinus tract, which had failed to heal when obliteration of the greater part of the cavity occurred. However, pleurobronchial fistulæ were the major factors resulting in chronicity, and any attempt to close these fistulæ in a septic field was useless and dangerous. With these complications playing such a prominent part in the chronicity of this condition, an operative procedure was necessary which would eliminate these factors and at the same time would permit a patient with low vital capacity and little resistance to undergo the necessary surgical treatment with minimal shock.

Since the complete procedure could not safely be done at one time, a fractional or step-like operation was adopted in which no previous step would be nullified by the lapse of time intervening between the subsequent phases.

At this point it is necessary to emphasize the fact that these patients had not been improving. The majority of the cavities had been draining and discharging pus for three or four years. In spite of the markedly thickened parietal pleura, an appreciable cavity still remained with a collapsed, nonfunctioning lung and with a pleurobronchial fistula in 60.8 per cent of the cases.

All these patients required some form of operation that would give them a complete cure; consequently postponement was out of the question, for as time elapsed, they would continue to grow progressively worse and become poorer surgical risks. It was therefore necessary to take the case in hand before some secondary condition intervened to snuff out what little vitality remained. Furthermore, from the economic standpoint alone, an operation of this character was justified, for if hospitalization could be terminated, and the patient healed and restored to at least a fraction of his former earning capacity, he became an asset rather than a liability to the community.

During the preoperative treatment the patient was placed on a high caloric diet. Cultures from the cavity were then sent to the laboratory to determine the type of infection present. Other routine laboratory examina-

tions, including red, white, and differential blood counts, estimation of the hemoglobin, Wassermann reaction, and urinalysis, were carried out. Examination of the sputum for tubercle bacilli was most important. The vital capacity was determined in the majority of the patients. Preliminary irrigation with Dakin's solution was instituted for a few days prior to operation to render the patient less septic. In the interim, careful blood-pressure readings were made. The blood group was determined and the blood checked against that of a prospective donor for transfusion. One-quarter grain of morphine sulphate and one one-hundred-and-fiftieth grain of atropine sulphate were administered one and one-half hours before operation. In addition one-sixth grain of morphine sulphate was given 30 minutes before the operation was actually begun. Paravertebral anesthesia, combined with superficial and deep infiltration in the region of the operation, was carried out with one-half per cent novocaine solution. Nitrous oxide and oxygen were subsequently given only to the point of analgesia. This procedure, in addition to relieving pain, served to allay fright and to render the patient less susceptible to his surroundings. A preoperative transfusion was necessary in markedly septic and emaciated cases.

In the first cases which came to operation, the upper portions of the cavity were first attacked, provided there was simple and dependent drainage, otherwise the lower parts of the cavities were exposed to establish effective drainage at the earliest possible moment. In the later cases it proved most satisfactory to expose the lower part of the cavity in all instances. An incision was made over that portion of the cavity which was to be exposed. The outlines of this cavity had previously been localized with accuracy with bismuth injections and Roentgen-ray plates. The superficial muscle layers were exposed, clamped with large forceps to eliminate hemorrhage, and severed. After the surrounding tissues had been infiltrated with one-half per cent novocaine solution each rib was detached from the immediate musculature for a distance of 2 or 3 cm. beyond the limit of the cavity. The main portions of the ribs were separated subperiosteally. It was imperative that the subperiosteal separation did not extend to a point where the rib was to be divided, but was stopped at a half inch from the point of rib resection.

Since 100 per cent of these cases were infected, it was advisable to avoid subperiosteal resection at the point of rib division for the following reasons: Osteomyelitis, with or without sequestration, was present in 90 per cent of these cases. In almost every instance it proved to be the cut end of a rib which had sequestered for one-half to three-fourths of an inch beyond the point of the previous resection by the well-recognized subperiosteal method. These infected rib ends subsequently became detached and were displaced into the pleural cavity by muscle movements or by pressure of the skin or scar tissue contracting over the site of the former operation. They, in turn, became secondary foci of infection. It was repeatedly demonstrated during the war that the Bunge[3] amputation, which calls for the removal of the periosteum one-fourth inch above the point of division of the bone, is invariably followed by sequestration when the bone is denuded to this extent. Even simple periosteal separation is also frequently followed by similar results, especially in cases for reamputation where there had been prolonged suppuration at some previous time. For these reasons the periosteum was cut flush with the rib on section. Sequestration has not been seen in any of the cases where this method has been followed. Because of the added difficulty which this procedure involves, since hemorrhage

is much greater here than where subperiosteal resection is practiced, every effort should be made to control the vessels in the vicinity of the ribs to be sectioned before they are cut through.

The onset of shock is usually simultaneous with the resection of the bony structures overlying the chest wall. Therefore, at this stage of the operation, the anesthetist was instructed to make careful readings of the systolic and diastolic blood pressures and to closely observe the pulse rate and general condition of the patient. It was an infallible rule to use these criteria as a guide to the extent of operative procedure to be undertaken at any one step. When the systolic pressure fell to 90 mm. of mercury, the operation was discontinued, even if the general condition of the patient was good and the pulse rate within the limits of safety, since experience had shown that in some cases a subsequent drop of 10 to 20 mm. would occur during the first hour or two after operation. The inclination is but natural for the surgeon to do as much as possible at one time provided the patient's life is not being endangered, but on two occasions during the first operations in this series when the surgeon was apparently within the limits of safety the patients rapidly passed into profound shock and died, although they had been on the table less than 40 minutes. The value of brief and repeated operations was thereby forcibly demonstrated.

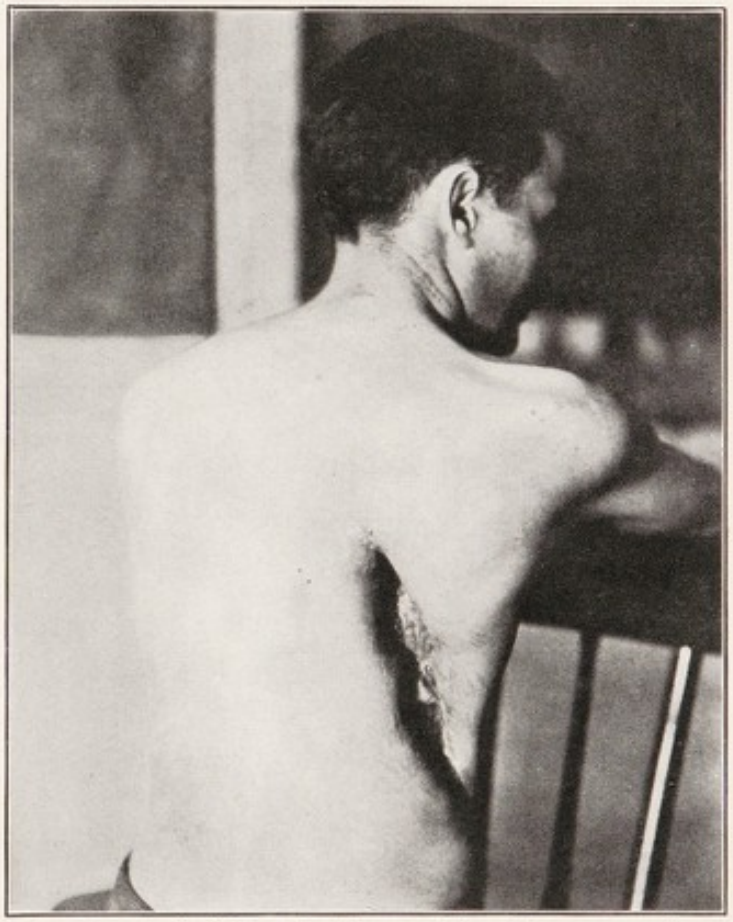

FIG. 63.—Cavity illustrating the use of the skin as a protective covering.

Having resected the bony structures overlying the part of the cavity to be exposed, the parietal pleura was next excised and that portion of the cavity was exposed. After the cavity had been exposed to the desired extent, the skin was inverted over the severed muscle and anchored, together with the muscle over the resected rib stumps, by means of silkworm gut sutures. The object of this was to prevent the muscle and skin, which were necessary for the final closure, from retracting and becoming atrophied, and also to render the dressings less painful, since the sensitive areas were covered with skin as a protective covering (Fig. 63).

Multiple scarification was practiced on that portion of the skin sutured under tension to cause relaxation and to prevent sloughing. The dressing was then applied after 8 to 10 Carrel tubes, interspaced in layers with gauze, were placed in the cavity. The whole area was gently packed in this fashion. One Carrel tube, to be retained in place for 48 hours, was placed under each infold

of the skin and muscle. The outer dressings were then applied and the patient was removed to the recovery room if his condition warranted.

When necessary, restorative measures were promptly instituted to combat shock. These restorative measures comprised, principally, the local application of heat, the administration of a shock enema, composed of spiritus frumenti 60 c. c. and coffee 120 c. c., and the elevation of the foot of the table. Normal salt solution was administered intravenously, and blood was obtained for transfusion. The citrate method of transfusion was employed. The blood was given to the patient through the apparatus used to administer the normal saline If a second fall in blood pressure occurred and the symptoms of shock persisted a second transfusion was given. However, postoperative shock occurred rarely if the surgeon adhered to the fixed principles of the steplike operation. Only two cases in this entire series required a second transfusion.

FIG. 64.—Five subcavities. Three posterior cavities obliterated, and two anterior cavities still partly open.

All danger of shock being over, the patient was returned from the recovery room to his respective ward on the day following the operation. It was found to be imperative that the ward surgeon who dressed these cases daily be present at the operation so that he might be fully informed of the particular complications that existed and that he understand the objective to be reached as well as the complications that might ensue. The routine treatment adopted in the postoperative care of these cases was the classical Carrel-Dakin technique as employed in the sterilization of septic wounds. The number of tubes depended upon the size of the cavity. The cavity was packed throughout its entire extent to prevent any overhanging of wound margins. It was important that no portion of the exposed cavity be roofed over at any time by the encroachment of the contracting soft tissues or by unhealthy granulations. The dressings were changed daily and at the same time the wound was thoroughly flushed out with Dakin's solution and the packing reapplied. As soon as the patient's general condition had improved to the point where further operative procedure was warranted, he was again prepared in the manner previously described and more of the contiguous structures overlying the cavity was attacked. This procedure was continued until the cavity was eventually laid wide open in its entirety. In some instances as many as five subcavities were detected. The majority of these subcavities had not been

detected by the Roentgen ray and had not been discovered in former operations because of the very minute openings which would admit only the smallest probe. These openings, however, led to cavities, the capacities of which were from 15 to 50 c. c. The cavities were not evident before irrigation had been instituted for from 10 days to 2 weeks.

The collapsed lung was freed from its fibrous pleural covering in one of two ways, depending usually upon the character of the fibrous deposit. In the thin-walled, hemolytic streptococcus pleura, which was too adherent to permit a line of cleavage, the lung was freed by a 2 per cent alcoholic solution of gentian violet applied in the form of a pack.[a] This pack was applied for two consecutive days, after which the cavity was constantly irrigated with Dakin's solution until the entire blue coating of devitalized tissue had exfoliated. A second application of gentian violet was made if necessary. This solution was also used in very thick pleuræ but the action was slower, except when it was employed in conjunction with discission. On the first case this agent was used for three consecutive days, but it was soon discovered that the destructive action led to the breaking down of the superficial air cells, and herniation of the lung was at times alarming. In a second case the pleura ruptured, and there was hemorrhage in a third. Consequently, this dye was used with great care and never in the strength given except in the open type of operation. The other method of pulmonary mobilization practiced was a discission after the method of Ransohoff. The method of Ransohoff was used in preference to surgical decortication, which was usually employed shortly before closure and occasionally in the wards without anesthesia or pain to the patient.

Surgical decortication was practiced in some cases but it was found that the expansile power of the lung was lost much earlier than if chemical decortication was employed. By these methods, cavities of 500 c. c. capacity have been reduced to 50 c. c., but these or any other methods of decortication did not result in the expansion of a lung which had undergone fibrosis.

After a cavity of large capacity had been reduced to a minimum by expansion of the lung, seven consecutive sterile cultures of the wound were obtained when possible. The cavity was then ready for closure. It was necessary, however, to close some cases in which it was impossible to get as many as seven consecutive sterile cultures, but the results were satisfactory. The treatment of these wounds was exactly the same except that the temporary drainage was allowed to remain for an extra 24 hours.

Several other factors, aside from the corrective surgical measures, apparently entered into the obliteration of these cavities. Regardless of what has been written relative to the assumption that the diaphragm on the affected side does not ascend in the presence of dense adhesions, it did occur. The healthy lung also tended to push over into the inadequately filled pleural cavity of the affected side and in this way helped toward obliteration even when the mediastinum was fairly rigid. Granulation was a factor in reducing the size of small cavities.

The subsequent closure of these empyema wounds was accomplished in progressive phases, when it was deemed necessary, in the same manner that a graded method was used to expose them. Before taking up in detail the technique of plastic closure, however, the closure of bronchial fistulæ deserves

[a] The gentian violet obtained since the war has been useless as a decorticating agent even when the strength was increased to 6 per cent. The preparation used on the cases described in this chapter was a pre-war preparation that was on hand at Walter Reed General Hospital. What the active agent in this particular brand of gentian violet was is not known—whether it was an impurity or whether it was specially pure.

special mention, as this complication proved one of the most intractable. The fallacy of attempting to close these fistulae in the presence of sepsis requires further emphasis. Even in the presence of repeated sterile cultures the advisability of completely closing any fistula in cases of this type is questionable, for the surgeon could never be certain as to the complications which might arise. Even in the hands of capable surgeons closure has been followed by such complications as lung and brain abscesses. In this connection, it might be well to mention, and it is probably fortunate, too, that no absolutely reliable method of closing every bronchial fistula was found. While the recognized method of purse-string suture with inversion closed some, it was found far more satisfactory to reduce the size of the fistula by a partial suture and to allow it to close by granulation after local stimulating applications of a 2 per cent alcoholic solution of gentian violet. Some of the early cases were closed by suture and the implantation of muscle over the closed fistula. A Carrel tube was left in the wound near the closed fistula for 48 or 72 hours. Although this method was not considered ideal, it was far less dangerous than the implantation of a skin flap which would form a much more resistant barrier if complications should arise. The greatest success in the closure of fistulæ was obtained after a combination of procedures which included the mobilization of the lobe with the fistula and the area in which the fistula emerged on the surface of the lung, or the partial reduction of the size of the fistula by suture. Each procedure was followed by the application of gentian violet. The actual cautery was used in a few instances, but was successful only in those cases with very minute fistulæ which did not require much treatment. It was absolutely imperative that no attempt at final closure of the cavity be made while a patent pleuropulmonary communication existed. Through such an opening the pathogenic bacteria present in the upper air passages naturally found ready access to the more susceptible overlying soft tissues, and caused continuous reinfection. This was apparently the explanation for the failures which occurred following other operative methods.

Having progressed thus far in the treatment of the case, and having eliminated all the factors which might account for the chronicity of the empyema, the surgeon was ready to close the wound permanently. Local anesthesia and gas analgesia were employed. The skin was freed from the underlying muscle bodies and was undermined to the required extent. The muscles, which had been saved at the previous operation, were freed sufficiently from their attachment to allow complete resuturing over the residuum of the cavity. All the muscle tissue which might be required was utilized to obliterate the space and the parts of the severed muscles were brought in apposition by sutures so as to restore the normal contour of the chest wall as far as possible and to allow flexibility with a movable skin surface. This could be accomplished in all cases except in those in which the muscles had been destroyed by previous operations and by infection. During the dissection for the liberation of the skin and muscles preliminary to final closure all raw surfaces were kept covered with packs moist with Dakin's solution to check oozing and to maintain sterility. After all the redundant scar tissue had been excised, the edges of the skin and the underlying muscles were approximated by a figure-of-eight silkworm gut suture. Rubber dam and Carrel tubes were inserted along the suture line to permit drainage. Multiple scarification of the skin was resorted to wherever it

appeared that tension interferred with the proper circulation of the part. The dressings were firmly applied to prevent the occurrence of any spaces between the contiguous layers of tissue. The pressure also aided in obliterating the cavity.

Whenever a cavity was so large that complete closure was impossible in one operation, an attempt was made to close only the upper parts of the cavity in this manner, and the remainder was closed at subsequent operations. The Carrel tubes were removed in 24 hours, the rubber dam drainage in 48 hours, and the sutures in 7 days.

The following classification, based on the condition of the patients when they were admitted to the empyema service at Walter Reed Hospital, is presented for convenience of description:

Group I: Patients belonging to this group presented great postoperative deformities, cavities with a capacity of 300 to 500 c. c., osteomyelitis of the ribs, rigid chest walls, and diminished vital capacity due to the compression or fibrosis of the lung or both (Fig. 65).

Group II: No postoperative deformity was found in these cases, and they had only moderately sized cavities of 300 to 500 c. c. capacity. The chest walls were flexible and the lung tissue was capable of ready expansion when liberated from the resistant thick pleura (Fig. 66).

Group III: This group was characterized by no postoperative deformities, but it presented enormous cavities, varying in size from 1,000 c. c. to the entire capacity of the side involved. Collapsed lung with fibrosis was always present, as well as a rigid chest wall, which had resulted from osseous regeneration between the ribs (Fig. 67).

Group IV: In this group there were no postoperative deformities. The cavities were small, chest walls were flexible, and the lung tissue was expansile (Fig. 68).

Irregular group: Those in the upper row of the cases in this class have very little postoperative deformity. Those in the middle and lower rows had moderate postoperative deformities, due to rib resection and osteomyelitis before admission (Fig. 69).

Owing to the fact that such a large percentage of these cases had complications, such as osteomyelitis, bronchial fistulæ, secondary cavities, and multiple draining sinuses, they are not mentioned in the above groups, nor have they been used as a basis for a more intricate classification of this condition.

Naturally some modification of the technique described was necessary, usually to meet the exigencies of the type of case undergoing treatment.

In the treatment of cases belonging to Group I, where the deformity and destruction were so great that there was little or no available muscle tissue, and, in addition, the lung had undergone fibrosis, the existing deformity could not be corrected though the cavity itself was laid open. The bronchial fistulæ were closed preferably by mobilization of the involved lung or by local applications, except in the case of very large fistulæ, which were reduced in size by partial suture and afterwards completely closed by local applications of gentian violet. This technique eliminated all dangers incident to sudden surgical closure of these fistulæ. The extreme cases in this group showed no marked improvement in the vital capacity following operation.

In cases belonging to Group II the entire cavity was laid wide open by the many-stage operation. After all the bronchial fistulæ had been closed and the

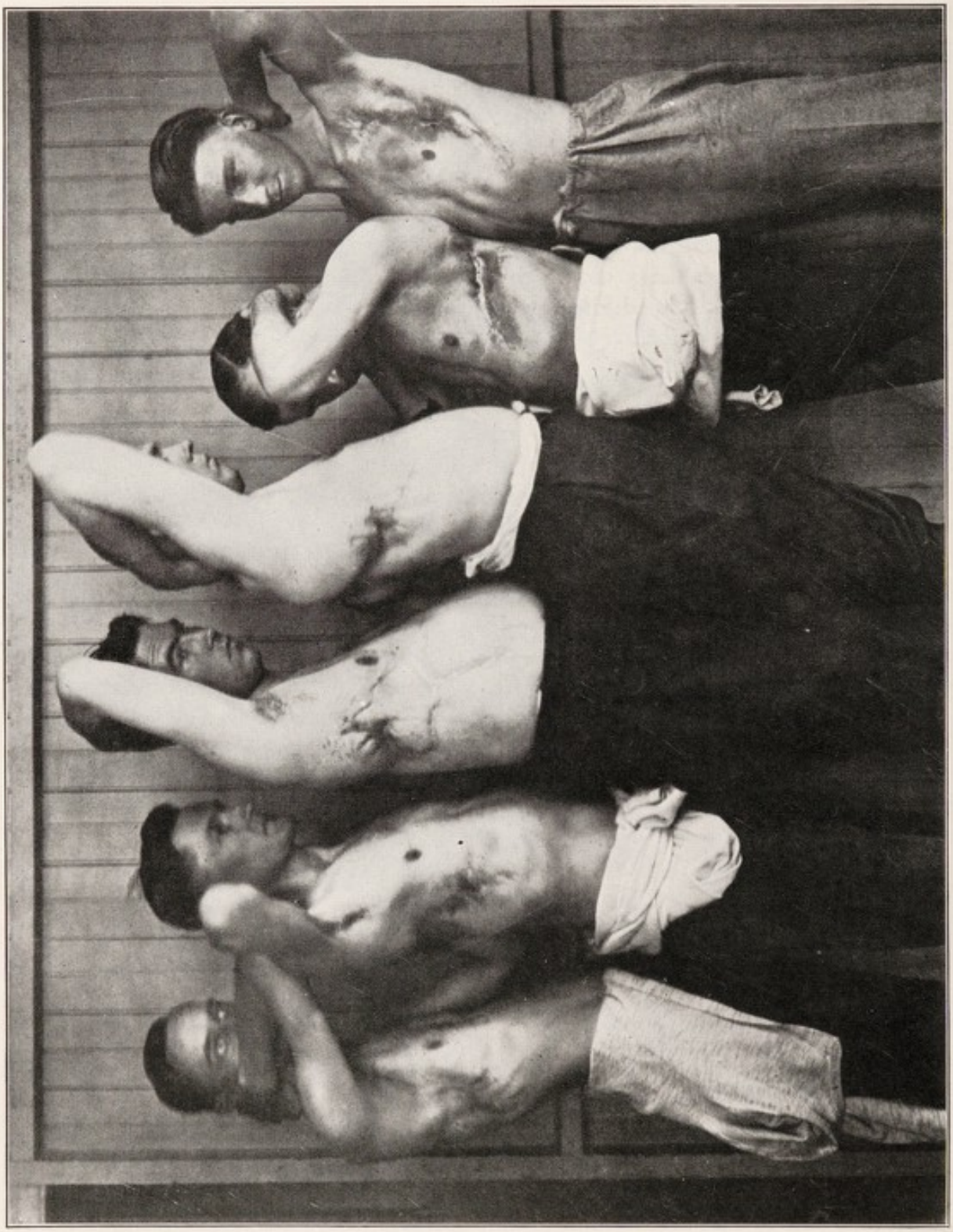

FIG. 65.—A representative group illustrating Group I of the text.

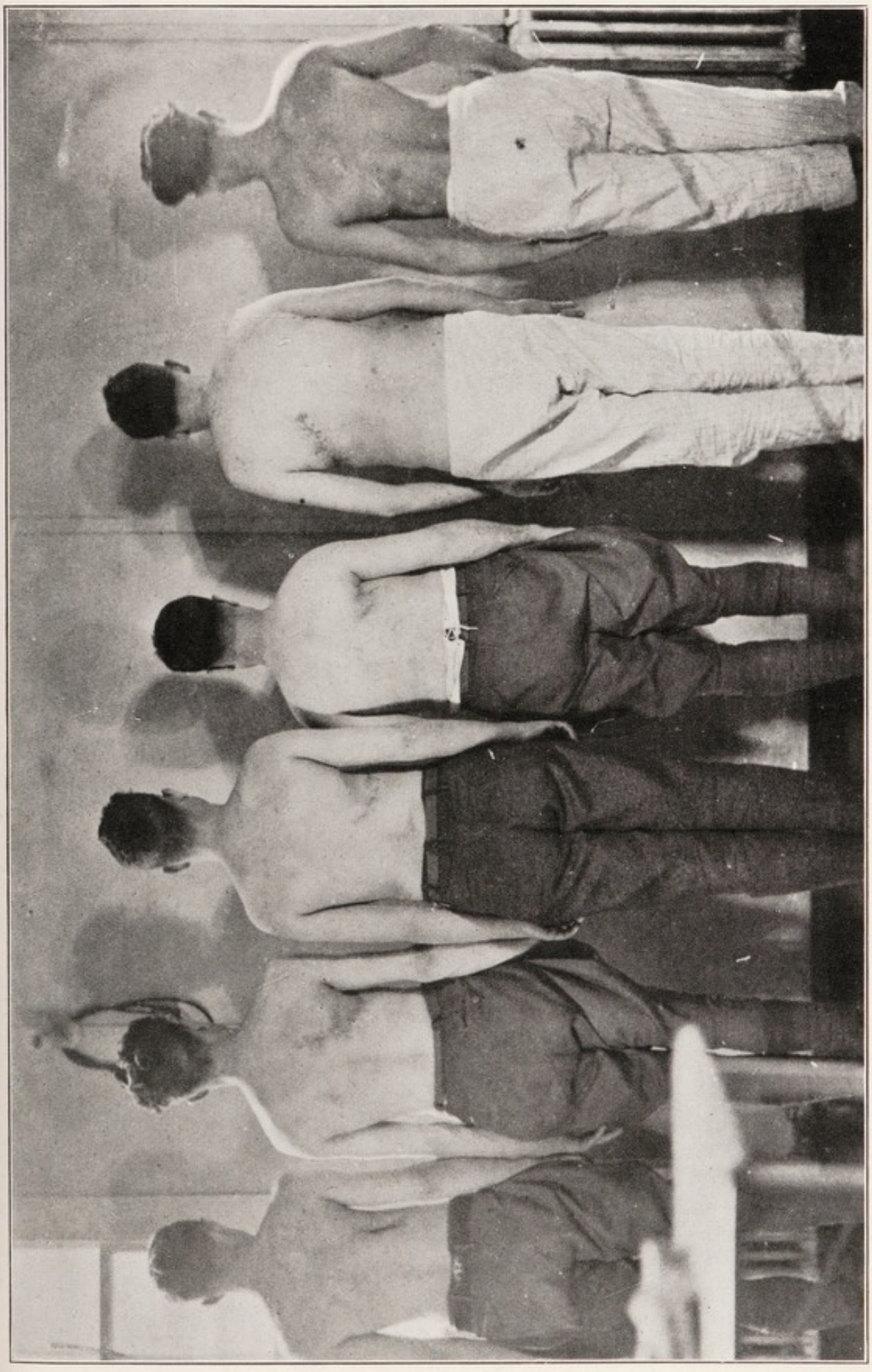

FIG. 66.—A representative group illustrating Group II of the text.

lung had been decorticated, the cavity was obliterated by the expansion of the lung. The final closure was affected according to the technique already described. The greatest number of chronic empyema cases fell in this group. They should have a flexible chest wall and practically no deformity following operation.

In the cases of Group III, in which the entire lung was collapsed and bound down, the wounds were enlarged to remove the infected rib-ends and to permit direct irrigation of the cavity. The operation, furthermore, provided more dependent and better drainage. After all sinuses were laid open and sterilized every effort was made to expand the lung by chemical decortication and discission. After the maximum of expansion was obtained by these means, provided all infected and necrosed ribs had been removed, the remaining cavity was obliterated by some modification of the Wilms or Sauerbruch operations.

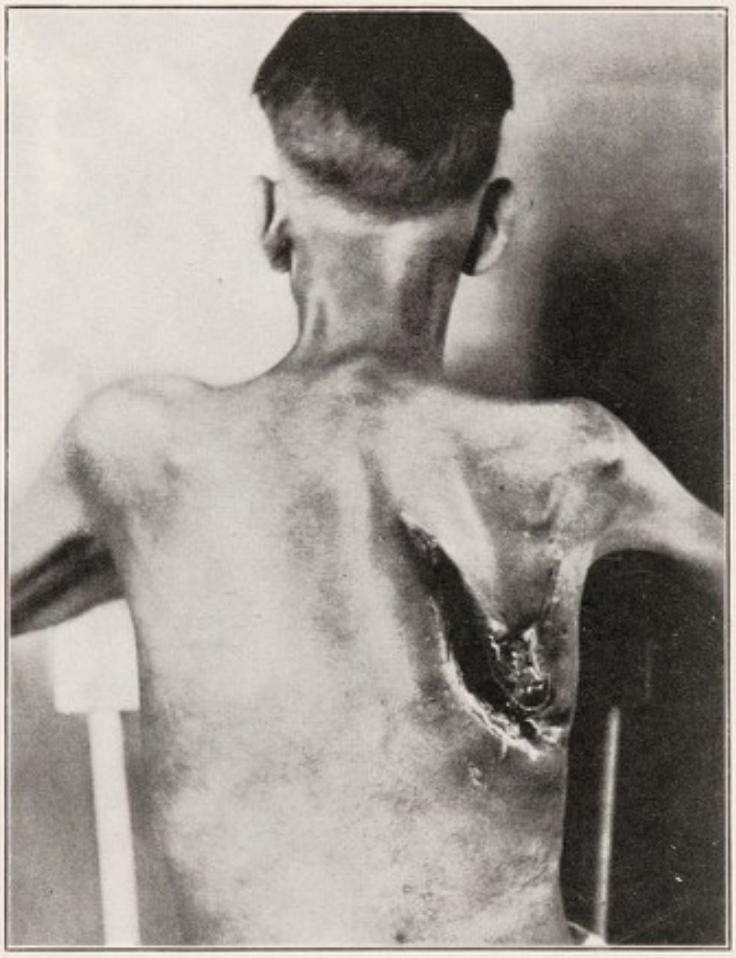

FIG. 67.—The type of case included in Group III of the text.

In cases belonging to Group IV little if any treatment was necessary other than irrigation with Dakin's solution after the cavity was laid open and the fistulæ closed, except plastic muscle closure following the sterilization of the cavity.

Further postoperative treatment was as follows: The patients were kept on a high caloric diet, their weights were recorded at weekly intervals, and daily calisthenics (deep-breathing exercises) were instituted as soon as healing had occurred.

The vital capacities were determined after the wounds were closed and were compared with the readings made on admission. There was an increase of from 500 to 1,500 c. c. in the lung capacity. This increase is of decided importance to the patient as an evidence of heightened resistance to respiratory infections. Improvement is further substantiated by the excellent physical condition of these patients and increases in weight of from 10 to 40 pounds.

In a series of 40 cases studied at the Walter Reed General Hospital, 21 were of from 3 to 4 years' duration; 5 were of 2 years' duration, and the remaining number varied from 6 to 18 months.

Twelve of this number had had radical operations of the most extreme form and 24 had had multiple thoracotomies with removal of one or more ribs when admitted.

The results in this series were as follows: Thirty-five closed; three died; one left hospital before ready for closure; one undergoing syphilitic treatment

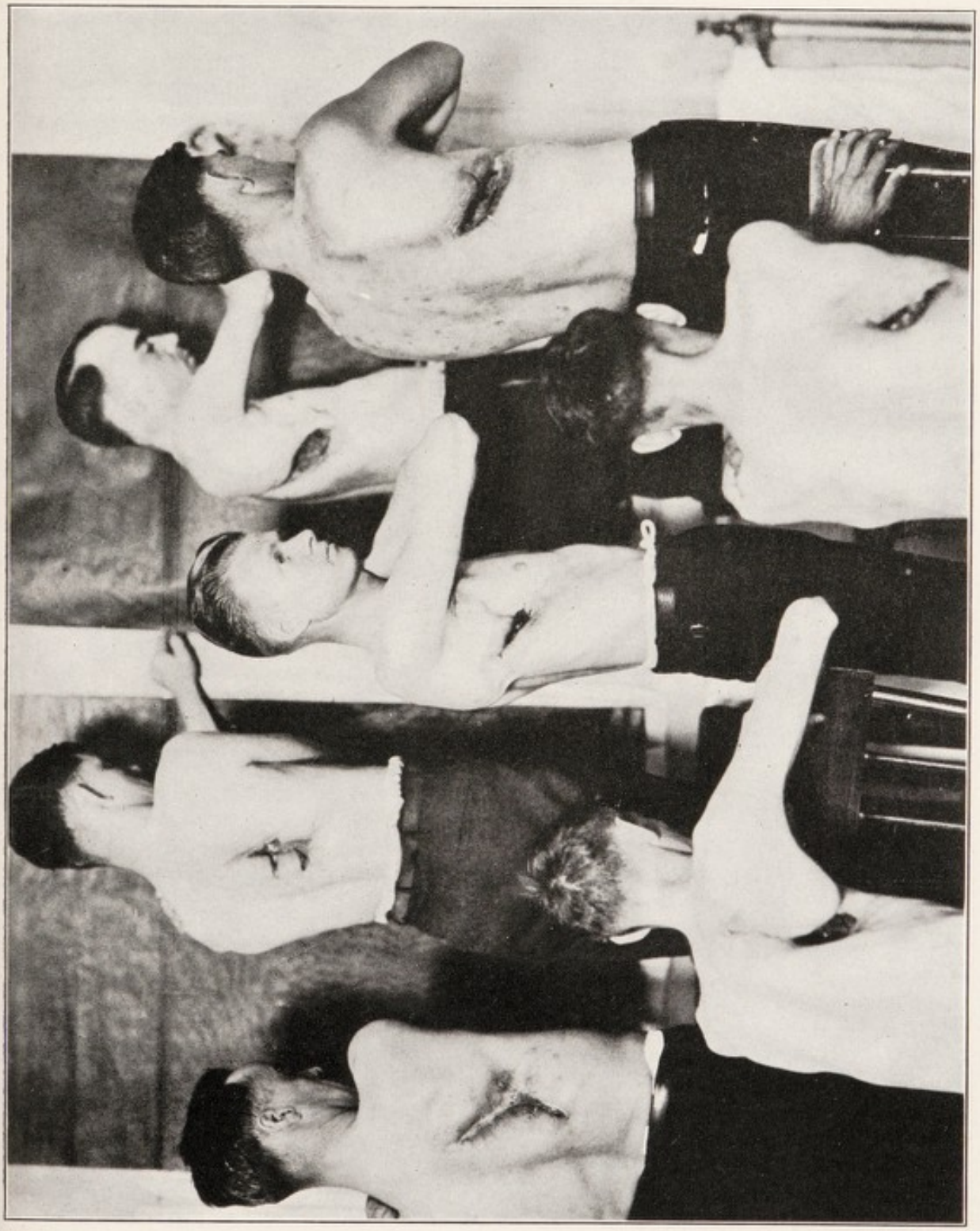

FIG. 68.—A representative group illustrating Group IV of the text.

FIG. 69.—A representative group illustrating the "irregular" group of the text.

and ready for closure. One hundred and seventy-three operations were necessary to complete the work on these cases by the many-staged method.

CONCLUSIONS.

1. The chronic type of empyema, especially those with large cavities, should occur but seldom if early aspiration followed by negative pressure treatment is promptly instituted.

2. Empyema cavities can be obliterated by discission and chemical decortication plus implantation of certain muscle bodies.

3. The patient's vital capacity and resistance to intercurrent disease can be increased by complete eradication of infection and the methods of decortication already mentioned.

4. Chemical decortication, if used injudiciously, may result in rupture of the visceral pleura, dangerous herniation of the lung, and hemorrhage, but the expanded lung retains its expansile power longer than when surgical decortication is practiced. (It should never be used in such a concentrated form except in the open type of operation.)

5. The pleurobronchial fistula is one of the commonest causes of persistent cavities.

6. Subperiosteal resection of ribs at the point of division should be discarded and rib section flush with periosteum adopted.

7. Obliteration by expansion of lung which means increased vital capacity should be practiced rather than cavity diminution by collapse of the chest wall.

8. Sterilization of the cavity can often be accomplished even in long-standing cases, but re-infection will invariably occur if the parietal pleura is not removed in a case of over one year's duration, especially if it is of the hemolytic streptococcus variety.

9. Daily cultures of the wound are necessary to check the progress and to determine the amount of Dakin's solution to be used.

10. The many-step, open or fractional operation, has the following advantages:

(*a*) It permits direct inspection and Dakinization of the entire cavity.

(*b*) It permits the detection and eradication of diverticula which are often missed on X-ray examination.

(*c*) It aids in the detection of osteomyelitis and foreign bodies.

(*d*) It insures such immediate improvement in profoundly septic cases that they will permit further operative procedure being carried out with low mortality.

(*e*) It affords easy removal of the parietal pleura and discission or chemical decortication of the visceral pleura.

(*f*) It allows the detection and direct closure of bronchial fistula.

(*g*) The operation can be discontinued at any stage, only to be finished later when the patient's condition permits, with a mortality far below that of the standard radical operation.

As regards the treatment of this type of case, the entire procedure is based upon the recognition of the soundness of the contention learned in the school of experience, that there is no short cut or abbreviated method whereby a cure can be obtained. Like every new departure in surgery, the operative technique is naturally the paramount prerequisite of that particular method, yet, in this instance, constant and careful Dakinization, together with massive and irksome daily dressings necessary to ensure sterilization, are indispensable desiderata in obtaining an ample reward for all the hardship the patient has endured.

## CASE REPORTS.

Case 1.—R. G. H., age 33 years. September 8, 1918, developed influenza and pneumonia. September 18, 1918, complication, empyema, left, hemolytic streptococcus type. Aspirated twice. October 22, 1918, thoracotomy; resection of 10 cm. of seventh rib, midaxillary line; drainage; irrigation with Dakin's solution. September 10, 1919, decortication; resection of seventh eighth, ninth, and tenth ribs; dependent drainage; patient received a number of minor operations to institute drainage. September 24, 1920, Walter Reed General Hospital, admitted to empyema service.

Condition on admission: Stretcher case; poorly nourished; anemic; present weight 117 lbs. (normal weight 155 lbs.); fingers clubbed; extremities edematous. Examination of chest revealed sinus discharging pus 9th interspace, midaxillary line, left chest, with a large irregularly shaped cavity extending from second to eighth rib, midaxillary line. Radiographs showed marked collapse, left lung; extensive scar formation and marked thickening of parietal pleura; much proliferation of new bone formation from resected ribs; and some osteomyelitis of rib stumps. Small secondary cavity or diverticulum extending into the hilus of lung. Capacity of cavity 300 c. c. Clinical laboratory examination: Wassermann negative; sputum negative for tubercle bacilli; white blood count, 13,950; red blood count, 3,810,000; urine negative; culture from cavity showed heavy growth of hemolytic streptococcus. Blood pressure: Systolic, 110; diastolic, 80; pulse pressure, 30. Vital capacity reading, 1,500 c. c.

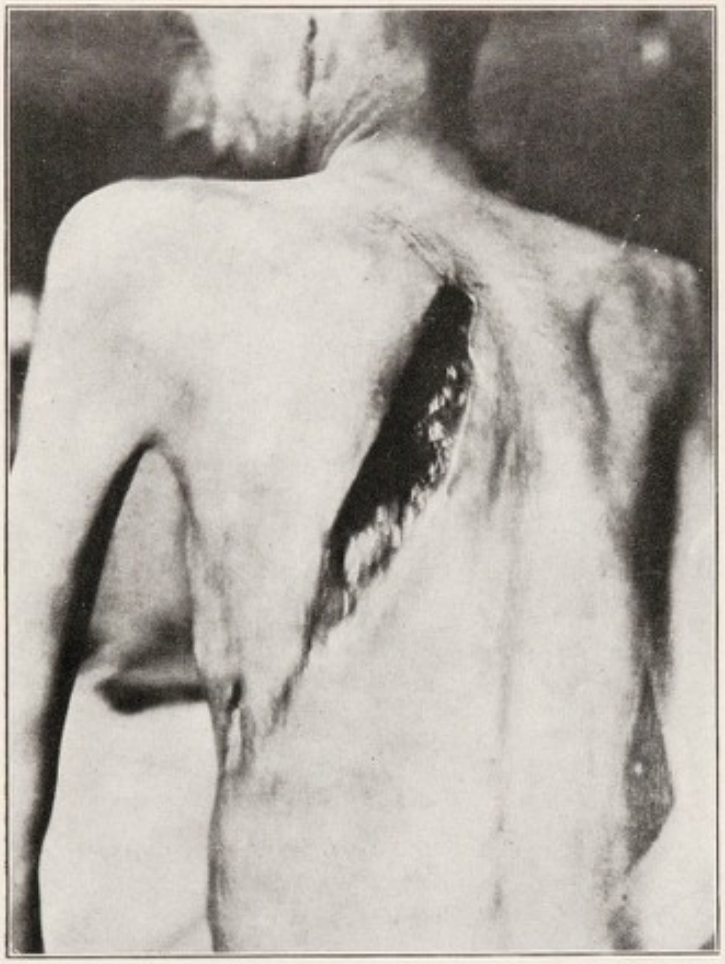

Fig. 70.—Case 1: A high incision to evacuate a large extrapleural abscess incident to osteomyelitis of the ribs. The illustration shows the great emaciation of the patient on admission.

December 9, 1920, operation; resection of 15 cm. of third, fourth, fifth, and sixth ribs, posterior scapular line, left chest; cavity laid wide open and preparation for active dakinization. February 4, 1921, operation; resection of 10 cm. of seventh, eighth, ninth, and tenth ribs, posterior axillary line; excision of thickened parietal pleura forming roof of cavity; skin inverted over muscle and saved for final closure; entire cavity exposed over posterior aspect and active dakinization continued. (Fig. 70.) April 7, 1921, operation; resection of 10 cm. sixth, seventh, and eighth ribs, anterior axillary line, left chest; anterior aspect of cavity laid wide open for the continued dakinization; discission of visceral pleura to allow lung expansion and the thickened parietal pleura excised. May 6, 1921, operation; partial plastic closure, upper aspect of posterior cavity; implantation of a portion of subscapularis and infraspinatus muscles into apex of cavity; superficial muscles, which had been saved at previous operation, brought in apposition and sutured; skin closed by silkworm gut; multiple scarification of skin to cause relaxation; active dakinization continued. June 21, 1921, operation; partial closure, anterior aspect of cavity; superficial muscles brought in apposition and sutured; skin closed with silkworm gut; posterior aspect of cavity left open for active dakinization. July 18, 1921, operation; removal of segments of seventh, eighth, and ninth ribs, which had previously been resected in anterior axillary line and detached posteriorly when cavity was laid wide open; active dakinization continued. September 3, 1921; operation; resection of 5 cm. of regenerated tenth rib stump which had become osteomyelitic;

dakinization continued. November 9, 1921, secondary closure with implantation of superficial muscle body in remaining cavity formation: additional superficial muscles brought over the implantation and fixed, leaving the resected rib stumps extrapleural when skin was brought in apposition. This was done because this case was considered tuberculous, due to the extensive rib necrosis, and should there be any additional necrosis of the rib stumps, the condition would be extrapleural and localized. February 24, 1922, incision of scar in posterior scapular area; removal of necrosed rib stump which had been left extrapleural at last operation. This rib resection had no relation to empyema. Wound left wide open for active dakinization and observation. March 1, 1922, empyema cavity completely obliterated since November 20, 1921; lung well expanded. April 15, 1922, patient improving; exposed to sun daily; on calisthenics and lung exercises; appetite good; weight and strength returning. June 26, 1922, patient entirely healed; X ray showed all cavity formation obliterated; lung well expanded; general condition excellent; weight 140 lbs; vital capacity reading 2,300 c.c.

Factors that were combated in this case were hemolytic streptococcus infection, osteomyelitis of ribs and rib stumps with bridging and overlapping, secondary cavity and diverticula, and the necessity for the removal of an almost solid plate of bone due to marked regeneration with bridging and overlapping of previously resected rib.

FIG. 71.—Case 1: A posterior view of the final result.

CASE 2.—C. G., age 33 years. October 21, 1918, developed influenza and pneumonia. November 16, 1918, complication, empyema, left, hemolytic streptococcus type; aspirated four times. November 22, 1918, thoracotomy; resection of portion of seventh rib. March 3, 1919; additional rib resection and drainage instituted. May 3, 1919, operation; resection of 20 cm. of eighth rib posterior axillary line, left chest; Carrel tube inserted and good drainage instituted. The patient was treated by this method until June 24, 1919, when he was transferred to General Hospital No. 19, Oteen, N. C., because of a diagnosis of suspected tuberculosis. August 7, 1919, operation; resection of portions of sixth, seventh, and eighth ribs; dakinization continued. October 31, 1919, Estlander type of operation with resection of portions of third, fourth, fifth, sixth ribs and a portion of the regenerated seventh rib, with partial collapse of left chest wall; drainage instituted. February 19, 1920, resection of portions of second, third, and fourth ribs midclavicular line, thus causing additional collapse of left chest wall. June 2, 1920, incision made over seventh, eighth, and ninth ribs and necrotic posterior stump resected. January 17, 1921, admitted to empyema service, Walter Reed General Hospital.

Condition on admission: Ambulatory case; anemic; highly septic; poorly nourished; present weight 110 pounds (normal weight 175 pounds); fingers clubbed; extremities edematous. Examination of chest revealed multiple sinuses, in scars of previous operations, leading down to resected rib stumps, which had become osteomyelitic; marked deformity in contour of left chest due to previous collapsing operations; large cavity formation extending from first rib to tenth rib

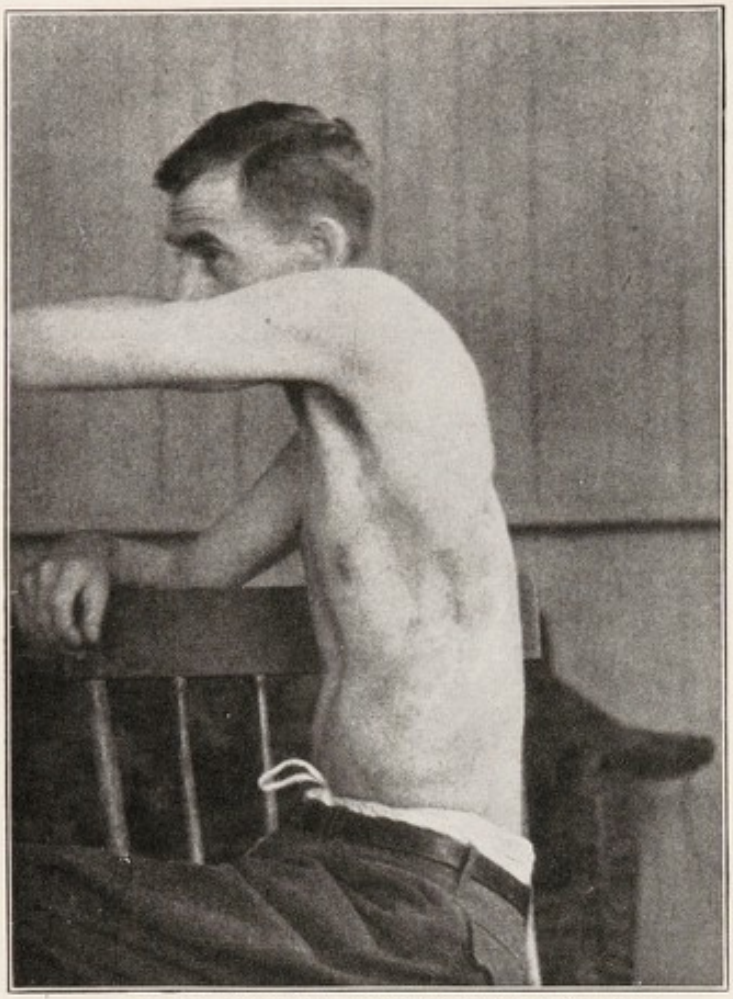

FIG. 72.—Case 1: A lateral view of the final result.

FIG. 73.—Case 2, as admitted to Walter Reed General Hospital. Necrosis of all ribs, from the third to eleventh, with multiple sinuses.

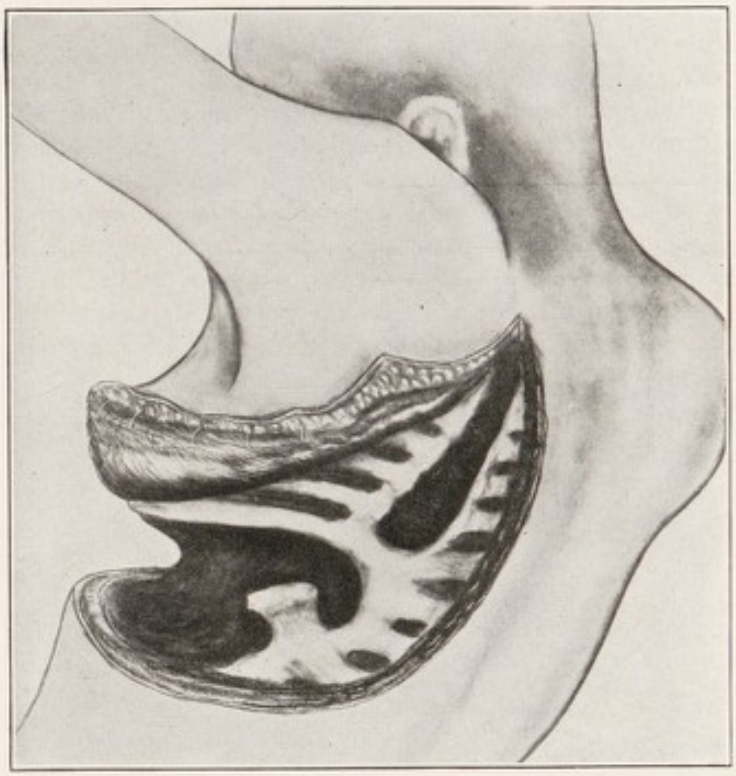

FIG. 74.—Case 2: Regenerated necrosed ribs exposed for removal.

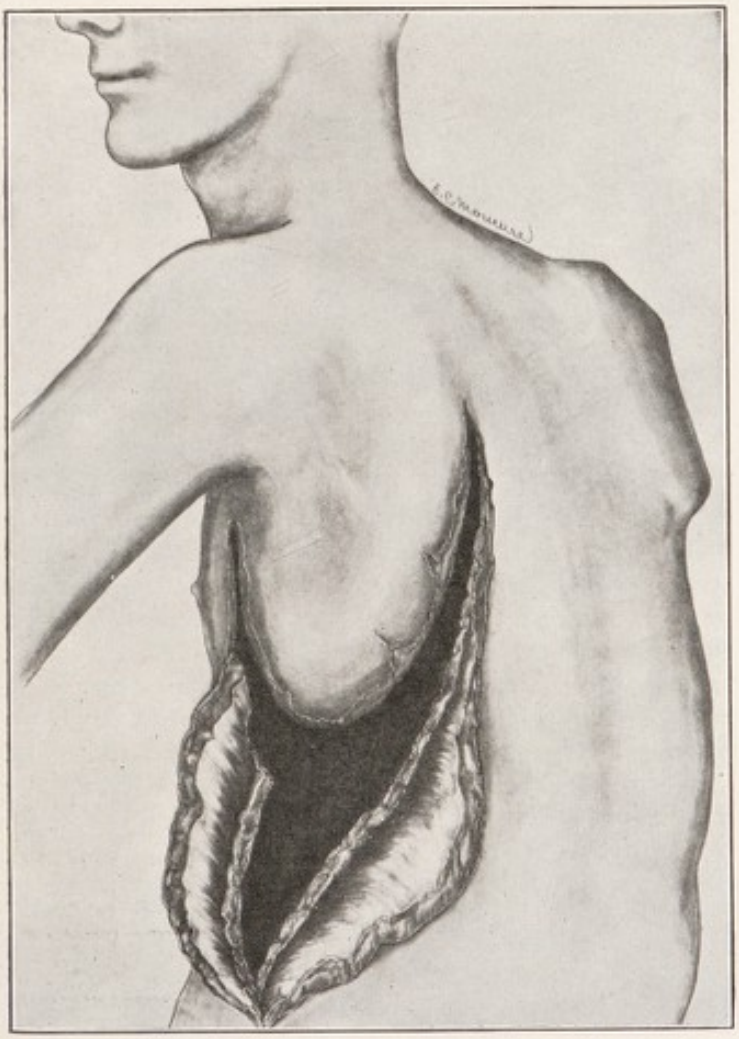

FIG. 75.—Case 2: The wound after the removal of the necrosed ribs.

lateral chest. Radiograph showed marked collapse of left lung with extensive thickening of the pleura from apex to base and a bismuth-filled cavity (capacity of 400 c.c.) with osteomyelitis and sequestration of rib stumps. Clinical laboratory examination: Wassermann negative; sputum negative for tubercle bacilli; white blood count, 10,300; red blood count, 3,640,000; urine negative; culture from cavity showed heavy growth of hemolytic streptococcus. Blood pressure.—Systolic, 108; diastolic, 80; pulse pressure, 28. Vital capacity reading, 1,500 c. c.

January 21, 1921, incision along posterior scapular line with resection of necrotic rib stumps; excision of thickened parietal pleura and scar tissue; skin inverted over muscle as a measure of preservation for final closure; cavity left open for active dakinization. March 16, 1921, resection of anterior portion of eighth, ninth, and tenth rib stumps with excision of roof of cavity; removal of all thickened pleura; discission of visceral pleura to allow lung expansion; active dakinization continued. April 8, 1921, resection of fourth, fifth, sixth ribs, midaxillary line; excision of thickened pleura; exposure of entire cavity; dakinization continued. May 7, 1921, resection of necrotic rib stumps; discission of visceral pleura to allow lung expansion: dakinization continued. June 3, 1921, partial plastic closure of lower part of cavity converging with diaphragm; implantation of portion of superficial muscle body at that point and a plastic skin flap sutured over defect; dakinization continued in upper part of cavity. July 11, 1921, partial plastic closure of upper posterior part of cavity by means of implantation of a portion of the subscapularis and infraspinatus muscle to obliterate the remaining portion which had not been obliterated by lung expansion; skin and superficial muscles brought in apposition and sutured; remaining portion of cavity left open for active dakinization. November 28, 1921, resection of necrotic rib stumps of third, fourth, and fifth ribs, anterior aspect; excision of overlying thickened pleura; removal of detached sequestrated rib stump from apex of remaining cavity formation; active dakinization continued. February 3, 1922, plastic closure of remaining cavity formation by means of implantation of superficial muscle bodies which had been saved at previous operation; remaining superficial muscle structure brought in apposition and sutured; excision of scar formation along skin margin and skin closed by silkworm gut; multiple scarification of skin to cause relaxation; rubber dam drainage for 48 hours. March 11, 1922, cavity completely obliterated; lung well expanded; X ray showed no evidence of osteomyelitis of remaining rib stumps; general condition good; patient gaining weight. June 21, 1922, excision of old adherent scar; plastic skin-closure of area with silkworm gut; multiple scarification of skin to cause relaxation; rubber dam drainage for 48 hours. June 28, 1922, skin area entirely healed; lung expanded and in apposition with chest wall; general condition excellent; present weight 125 pounds; vital capacity reading, 1,900 c. c.

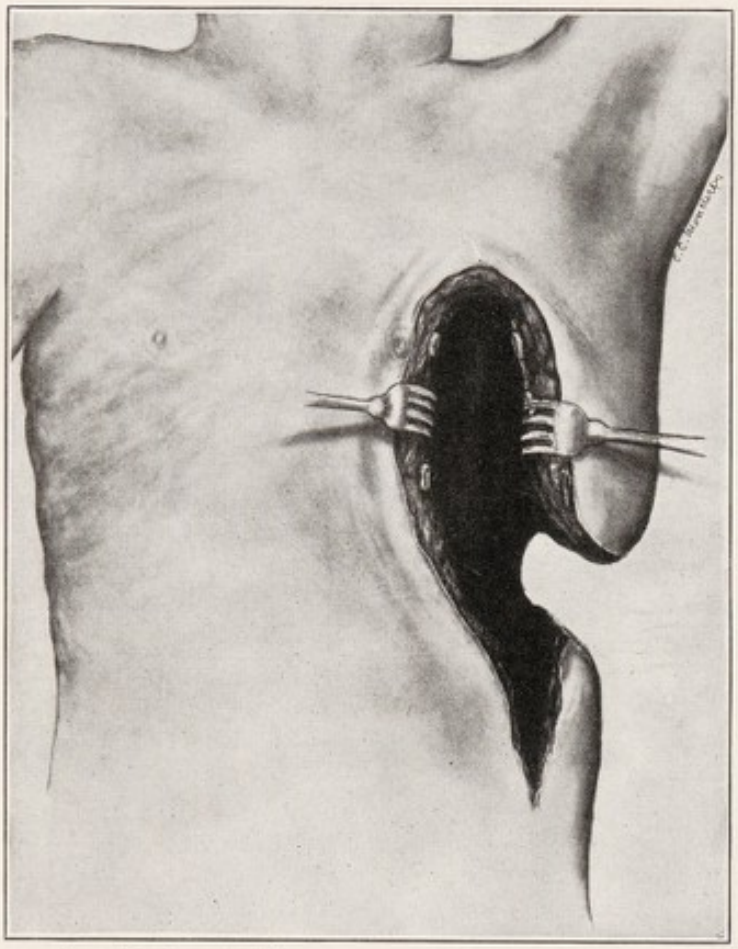

FIG. 76.—Case 2: The open wound before the final closure.

Factors that were combated in this case were hemolytic streptococcus infection, osteomyelitis of rib stumps, numerous collapsing operations, left chest wall, with bridging and overlapping by regenerated rib formation, marked disturbance of respiration due to deviation of mediastinum. Patient could not withstand any fractional operation without all of the measures to combat shock.

CASE 3.—R. C. N., age 25 years. October 6, 1918, developed influenza and pneumonia. November 1, 1918, complication, empyema, right pleural cavity, hemolytic streptococcus type; aspirated three times. November 11, 1918, thoracotomy; resection of 10 cm. of seventh rib, posterior axillary line; drainage instituted. May 19, 1919, resection of sixth and seventh ribs, 15 cm. at site of original thoracotomy; Carrel tubes inserted into cavity and active dakinization instituted. July 21, 1919, resection of 10 cm. of eighth rib, anterior axillary line; dependent drainage instituted in eighth interspace. September 3, 1919, modified Schede operation, resection of a portion of the fifth, sixth, seventh, eighth, ninth, and tenth ribs; roof of cavity removed; lung partially decorticated and mobilized; muscle and skin sutured; dependent drainage instituted by means of one Carrel tube. January 5, 1920, incision along scar of last operation; resection of the anterior and posterior stumps of fifth, sixth, and seventh ribs and a resection of 10 cm. of the fourth rib; decortication of visceral pleura at apex of cavity; dependent drainage, upper aspect of wound closed. April 23, 1920, excision of scar and sinus tract; cavity laid open; resection of anterior ends of previously resected ribs and a partial decortication of visceral pleura; upper aspect of cavity closed by muscle and skin; dependent drainage and irrigated with Dakin's solution. November 10, 1920, admitted to empyema service, Walter Reed General Hospital.

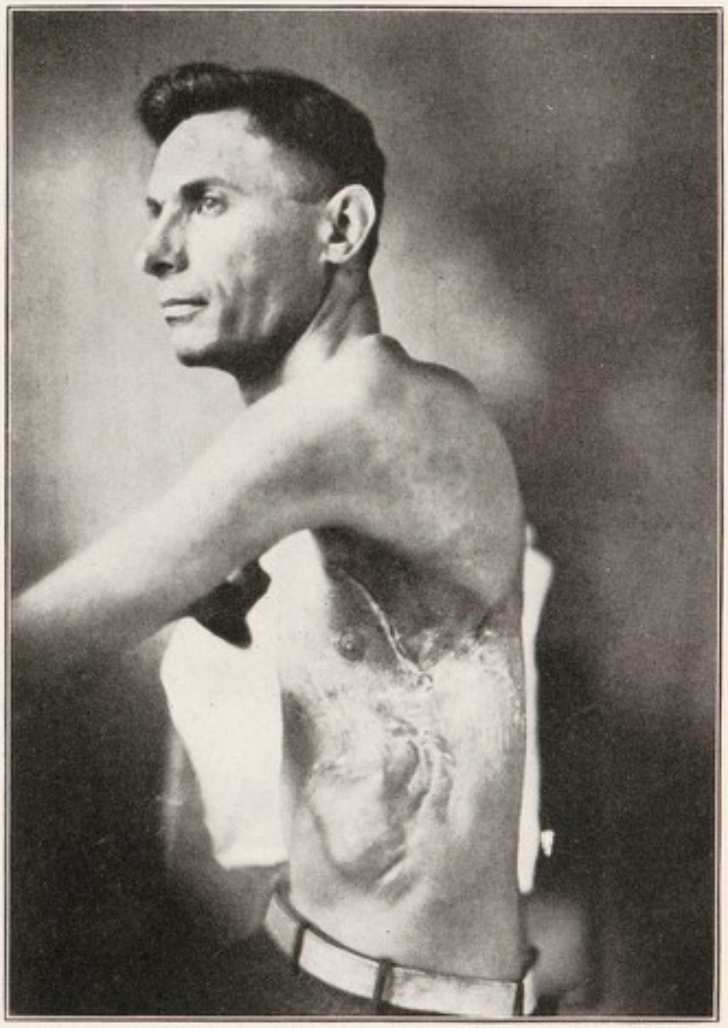

FIG. 77.—Case 2: The final result after closure of the wound.

Condition on admission: Poorly nourished; anemic; present weight, 140 pounds (normal weight, 185 pounds).

Examination of chest: Sinus discharging pus at the ninth interspace, midaxillary line, right chest, with a large cavity formation present. Radiograph showed marked collapse of the right lung with extensive thickening of visceral pleura, right lateral chest, from apex to base; ribs, fourth to tenth, inclusive, overlying cavity formation having been previously resected. Cavity formation extended from third to ninth rib with a capacity of 300 c. c. Clinical laboratory examination: Wassermann negative; sputum negative for tubercle bacillus; white blood count, 14,200; red blood count, 3,620,000. Urine negative; culture from cavity showed hemolytic streptococcus. Blood pressure: Systolic, 110; diastolic, 76; pulse pressure, 34. Vital capacity reading not taken. November 18, 1920, incision over cavity, muscle and skin retracted; discission of visceral pleura; cavity left wide open and preparation made for active dakinization. December

27, 1920, resection of necrosed rib stumps; cavity left wide open and dakinization continued. February 9, 1921, lung well expanded and the greater part of the cavity formation obliterated; cavity sterile after seven consecutive daily cultures; patient ready for final closure. February 10, 1921, secondary closure of cavity; muscle and skin brought in apposition and sutured; silkworm gut with rubber dam drainage; multiple scarification of skin to cause relaxation. Following operation patient developed profound shock, and in spite of all the active combative measures taken, he died three hours later.

The factors to be combated in this case were hemolytic streptococcus organism; osteomyelitis of rib stumps; the amount of operative procedure that had been instituted, with resultant scar formation, made it almost impossible to find enough healthy tissue for closure.

CASE 4.—R. C. K., age 22 years. March 17, 1921, developed measles. March 29, 1921, complication, pneumonia. April 8, 1921, complicated empyema, right pleural cavity, hemolytic streptococcus type. Aspirated five times. May 20, 1921, intercostal thoracotomy, right seventh interspace, posterior axillary line; drainage instituted by means of two rubber tubes. July 13, 1921, admitted to empyema service, Walter Reed General Hospital.

Condition on admission: Ambulatory case; poorly nourished; anemic; present weight 105 pounds (normal weight, 155 pounds). Examination of chest: Sinus, discharging pus, seventh interspace, posterior axillary line; pleurobronchial fistula present and drainage not dependent. Radiographs showed a marked collapse of the right lung with some thickening of the parietal pleura and a cavity formation extending from the second rib to the base with an hour glass contraction of this cavity about the sixth rib, posterior axillary line. Clinical laboratory examination: Wassermann negative; sputum negative for tubercle bacilli; white blood count, 35,300; red blood count, 4,000,000; urine negative; culture from cavity showed hemolytic streptococci and gram-negative bacilli. Blood pressure: Systolic, 118; diastolic, 78; pulse pressure, 40. Vital capacity reading, 1,600 c. c.

July 25, 1921, operation; resection of 15 cm. of sixth, seventh, and eighth ribs, posterior scapular line; roof of cavity excised, and two sinuses leading into the upper and lower aspect of the cavity exposed; skin and muscle preserved for future closure; preparation of cavity for active dakinization. September 8, 1921, operation; resection of 15 cm. of fourth, fifth, sixth, seventh, and eighth ribs, posterior scapular line; roof of upper cavity removed and fistula exposed; contiguous lung tissue mobilized; skin inverted over severed muscles and cavity left open for active dakinization. October 12, 1921, operation; excision of adherent scar tissue and removal of small skin flap, institution of drainage of lower cavity which extended into mediastinum between the lower lobe of the right lung and the diaphragm. December 5, 1921, operation; secondary closure of upper aspect of the cavity, muscle and skin brought in apposition and sutured by means of silkworm gut; rubber dam drainage instituted; lower aspect of cavity left open for dakinization. January 10, 1922, operation; resection of 10 cm. of eighth, ninth, and tenth ribs, posterior axillary line; lower cavity, leading into the mediastinum, exposed after the thickened parietal pleura forming the roof of cavity had been excised; another pleurobronchial fistula exposed; cavity left wide open for active dakinization. March 1, 1922, fistula closed. Lower cavity one-fifth its original size. Cavity sterile. May 10, 1922, small cavity obliterated by lung expansion and ascension of the diaphragm. Entire area healed by granulation. The result being satisfactory, it was not deemed necessary to resect scar and make secondary closure. June 15, 1922, patient healed; fistula closed; all cavity formation obliterated; lung well expanded; general condition excellent; has taken on weight; weight on admission 105 pounds; present weight 142 pounds. Vital capacity reading, 3,100 c. c. Patient completely cured and discharged from hospital June 15, 1922.

Factors to be combated in this case were hemolytic streptococcus organism present; osteomyelitis with rib sequestration; pleurobronchial fistula; secondary cavity and diverticula.

CASE 5.—L. J. McC., age 24 years. February 18, 1919, developed pneumonia. February 22, 1919, complication, empyema, right, hemolytic streptococcus type. Received 11 operations, including thoracotomies, Schede and Estlander types of operation, with resection of third to

eleventh right ribs, inclusive, and attempted resection of second right rib. November 15, 1920, admitted to empyema service, Walter Reed General Hospital.

Condition on admission: Patient acutely sick from accumulation of pus in old healed cavity, and about 25 pounds under weight. Radiograph showed a dense shadow over the right base suggestive of fluid. Pleura thickened from base to apex. Lung collapsed. Prior resection of the third to eleventh right ribs, inclusive, with bone proliferation and bridging. The external right chest resembled the contour lines of a map from the many previous lines of incision. Clinical laboratory examination: Wassermann, negative; sputum, negative for tubercle bacilli; blood showed slight anemia with high leucocyte count due to acute condition; streptococcus hemolyticus the prevailing and dominant organism in this case from the beginning.

January 10, 1921, patient showed evidence of reaccumulation of pus in chest. Needling with trocar canula and threading of small drainage tube into cavity permitted escape of pus. On attempting to use Dakin's solution, it was found that patient had a pleurobronchial fistula and the solution had to be discontinued. January 31, 1921, incision in line of previous incision in anterior axillary line; portion of fifth rib resected; cavity left open in preparation for active dakinization. April 11, 1921, exposure of cavity posteriorly and further exposure anteriorly with resection of necrotic rib stumps of sixth, seventh, and eighth ribs posteriorly and fourth, fifth, and sixth ribs anteriorly. The two incisions were separate and not connected externally but a narrow sinus led from one to the other within the cavity proper. Both wounds left widely open for dakinization. April 21, 1921, incision connecting the anterior and posterior wounds; dissection of connecting sinus tract internally with excision of intervening rib stumps. The chest now presented one large, deep wound of about 500 c. c. capacity. Cavity left widely open for active dakinization. May 18, 1921, small sinus tract found in upper angle of wound and excised. June 8, 1921, plastic closure. The bronchial fistula was still patent and had resisted closure by cauterization.

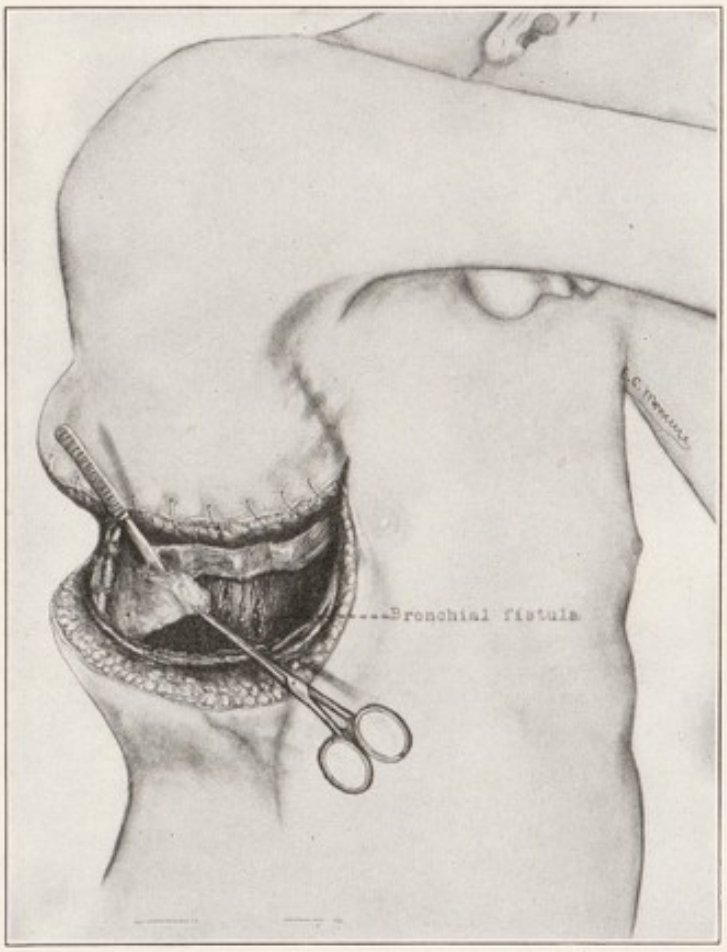


FIG. 78.—Case 5: Steps in the closure of the bronchial fistula.

At this operation the cavity, which had obliterated about 75 per cent, could be entirely obliterated by the implantation of muscle bodies lying along the upper and lower margins of the cavity. The bronchial fistula was closed by mobilizing it, inserting a purse-string suture and slightly inverting it; then the area was carefully covered in by a small muscle implantation sutured in situ. The skin and subcutaneous tissues were freely undermined on both sides and the tissue united by sutures under some tension. Rubber tissue drainage. Only superficial muscle slough followed. July 26, 1921, there was a little undermining of the skin in the middle third of the wound with slight slough due to tension. Superficial incision was made and the skin divided. Wound allowed to granulate. Following this the wound gradually healed. August 12, 1921, almost healed; Dakin's solution discontinued and gentian violet was used instead, as there was only a small place in the skin to close. September 2, 1921, patient healed; looked fine; felt strong; appetite was good; gaining in weight. October 1, 1921, patient granted two months' leave of absence. May 11, 1922, patient, after having been healed eight months, discharged cured.

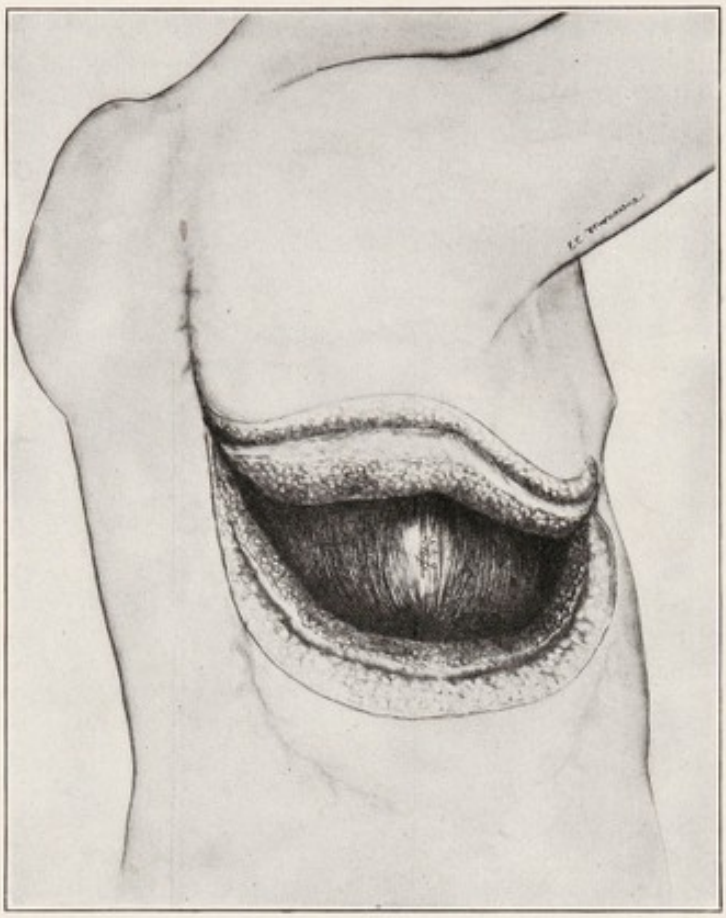

FIG. 79.—Case 5: Further operative procedure in the closure of the wound.

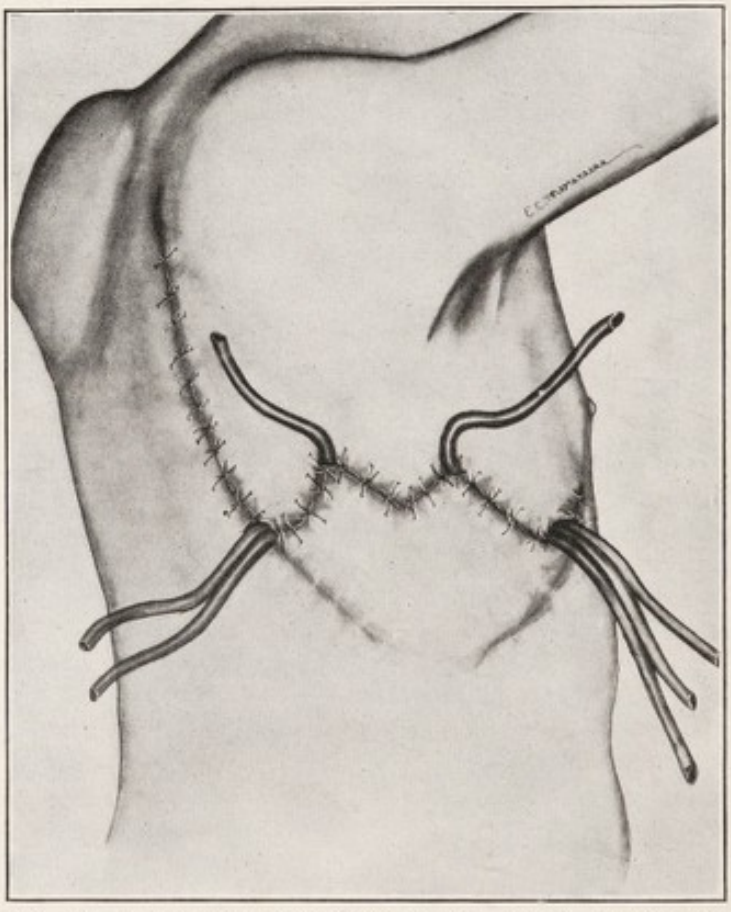

FIG. 80.—Case 5: The final closure of the wound, showing the method of inserting the Carrel tubes.

Factors to be combated were streptococcus hemolyticus, extensive collapse of lung with an almost total pneumothorax; numerous diverticula and recesses were infected and, having no drainage, were the foci of frequent recurrence; sequestra following extensive involvement of many of the rib stumps; at the time of the first fractional operation the chest wall was so scarred from 11 previous operations and there was such extensive cross-bone formation and bridging that operation for the removal of these structures overlying the cavity was made extremely difficult; pleurobronchial fistula present.

Case 6.—M. C. B., age 27 years. April 26, 1918, developed pneumonia, right lower lobe. May 1, 1918, complication, empyema, right. Aspirated May 2, 1918, and 500 c. c. of fluid removed. Aspirated every other day and fluid removed on 10 occasions. May 28, 1918, intercostal thoracotomy. Wound drained for five months following this. Patient had intermittent dakinization. August 15, 1918, bismuth paste injected into cavity and wound allowed to close. Capacity of cavity at this time was about 500 c. c. Wound remained closed until November, 1918, when the sinus reopened and drained for a period of three weeks. Sinus again allowed to close and remained closed until March, 1919, when it was again opened to drain pus until the latter part of May, 1919. Cavity remained healed until June, 1920. June 11, 1920, operation at a civilian hospital and part of the sixth rib resected. From this time until he was admitted to the empyema service, Walter Reed General Hospital, he continued to drain pus quite freely. January 10, 1921, admitted to empyema service, Walter Reed General Hospital.

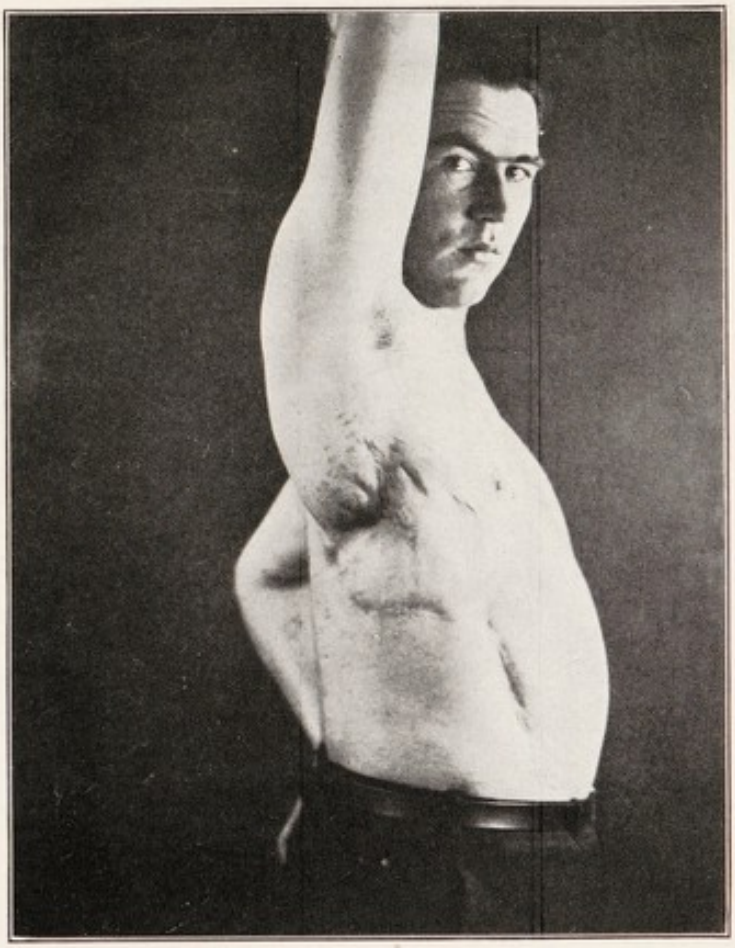

Fig. 81.—Case 5: Final result.

Condition on admission: Patient anemic and undernourished; highly septic; weight, 132 pounds (normal weight, 150 pounds). Examination of chest revealed sinus at the level of the ninth interspace in the posterior axillary line, discharging pus freely. Sinus extended upward and backward and was apparently 20 cm. in length. Radiograph of chest showed resection of the sixth, seventh, and eighth ribs and a partial collapse of the right lung; thickening of the pleura from the base to the apex; definite osteomyelitis with probably sequestration of the sixth rib; the sinus passing upward and backward from the level of the eighth rib and terminating in an elongated cavity which reached the fifth interspace posteriorly. Measurements of the capacity of the cavity show that it held about 400 c. c. Clinical laboratory examination: Wassermann, negative; red blood count, 4,400,000; white blood count, 12,850; hemoglobin, 75 per cent; urine, negative; blood culture, negative; sputum, negative for tubercle bacilli; culture from exudate of cavity showed staphylococcus aureus and streptococcus hemolyticus.

Patient was placed on active dakinization for three days previous to operation. January 13, 1921, partial resection of the eighth and ninth ribs for drainage purposes only, with removal of the outer and lower wall of the cavity. Following this operation, patient was treated intensively with Dakin's solution until February 15, 1921, when the second step of the operative procedure was done. At this time there was resection of the fifth, sixth and seventh ribs, posterior, with an

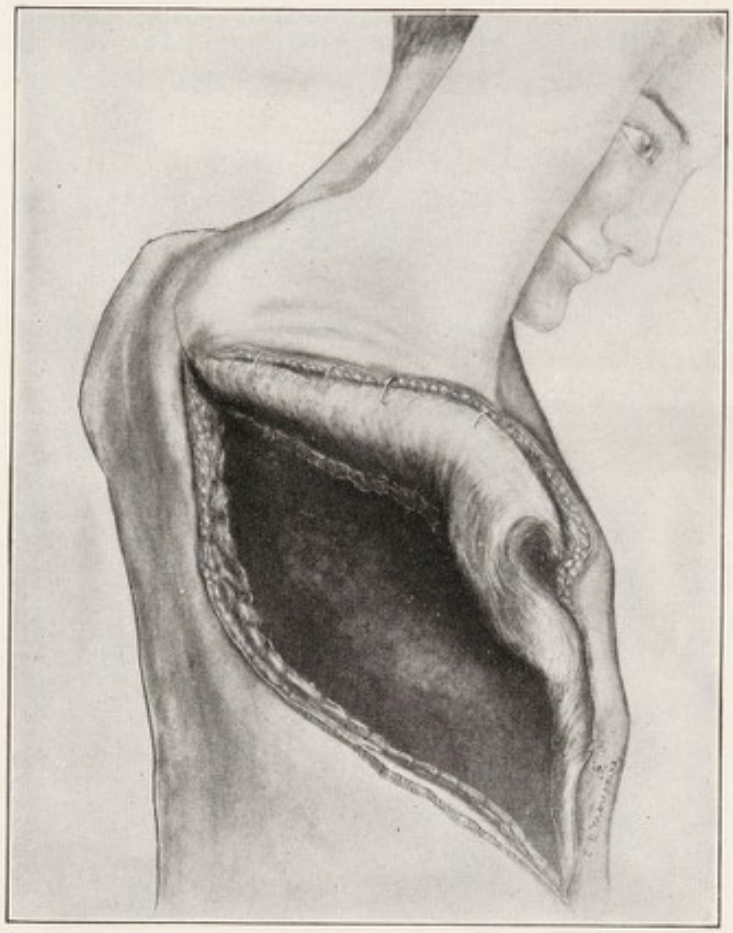

FIG. 82.—Case 6: The wound preliminary to muscle implantation.

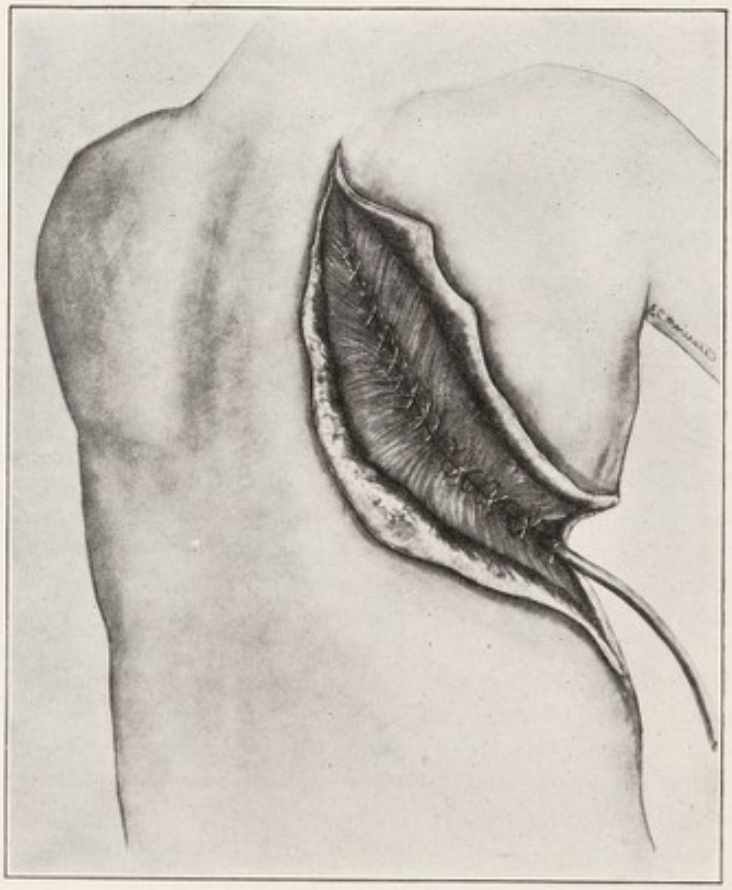

FIG. 83.—Case 6: Muscle suture.

excision of all tissues forming the roof of the cavity. Cavity was left widely open and actively dakinized. April 8, 1921, the third operative step was undertaken. Sections of third, fourth, fifth, and sixth ribs were removed. Sterile cultures of the wound having been obtained prior to operation, it was thought advisable to attempt to obliterate the upper angle of the cavity by muscle implantation; so a part of the erector spinæ muscle was split and implanted into the apex of the wound and sutured in place. Practically all of the muscle thus implanted was retained and there was but little sloughing. The lower part of the wound seemed to be obliterating rapidly and the patient's general condition had improved considerably. May 2, 1921, X ray showed an osteomyelitis with sequestration of the terminal end of the previously resected third rib. The muscle body which had been implanted filling in this area was split and the sequestration removed. July 7, 1921, operation. A small fistulous tract found leading down to the ninth rib stump. This portion of the rib was resected and a plastic closure of the lower half of the wound, by implantation of the contiguous muscle bodies, was done. The skin was undermined on either side and brought forward, covering in all of the lower half of the wound. July 27, 1921, operation; plastic closure of the upper half of the wound by implantation of subscapularis muscle; sliding skin flap from either side brought forward and sutured. Rubber tissue drainage was placed in the line of closure and a firm dressing applied to the wound. October, 1921, patient entirely healed and feeling fine.

At the time of the first plastic operation the capacity of the cavity had diminished to about one-fourth of its original size. On discharge the X ray showed moderate collapse of the right chest wall; a rather marked thickening of the pleura but no cavity; the lung was well expanded. January 5, 1922, patient discharged cured, after having been healed three months.

FIG. 84.—Case 6: Final result.

## Factors to be combated were hemolytic streptococcus organism present; osteomyelitis with rib sequestration; Beck's bismuth paste which had remained in cavity 13 months; three diverticula draining into main cavity.

CASE 7.—C. C., age 19 years. January 22, 1921, developed measles. February 12, 1921, complication, mastoiditis. February 14, 1921, mastoidectomy. February 15, 1921, complication, pneumonia. April 29, 1921, empyema, right pleural cavity, hemolytic streptococcus type. Aspirated once. May 3, 1921, thoracotomy; resection of 10 cm. of seventh rib, right anterior axillary line, with the institution of drainage and irrigation of cavity with Dakin's solution. June 9, 1921, admitted to empyema service, Walter Reed General Hospital.

Condition on admission: Ambulatory case, poorly nourished; present weight, 120 pounds (normal weight, 140 pounds). Examination of chest: Sinus discharging pus, right seventh interspace, anterior axillary line; drainage not dependent in this case. Radiographs showed partial collapse of the right lung with some thickening of pleura right lateral chest, and a cavity formation extending from the fifth to tenth rib lateral chest, right. Clinical laboratory examination: Wassermann, negative; sputum, negative for tubercle bacilli; red blood count, 4,540,000; white blood count, 10,350; urine, negative; culture from cavity showed heavy growth of hemolytic streptococci. Blood pressure: Systolic, 124; diastolic, 78; pulse pressure, 46. Vital capacity reading, 2,400 c. c.

June 28, 1921, operation; resection of ninth and tenth ribs, midscapular line, right chest, and the institution of proper drainage; cavity left open for Carrel-Dakin technique for its sterilization. November 8, 1921, operation; resection of 15 cm. of sixth, seventh, eighth, and ninth ribs, posterior axillary line, right chest, with the removal of thickened pleura over a cone-shaped secondary cavity; discission of visceral pleura to allow lung expansion; skin inverted over muscles to save them for final closure and to render dressings less painful; preparation of cavity for dakinization. December 13, 1921, operation; secondary closure of muscle and skin with a portion of the infraspinatus and subscapularis muscles implanted into the upper portion of the secondary cavity, which was not completely obliterated by lung expansion; the muscle and skin, saved at former operation, then brought in apposition and the entire area was closed with rubber dam drainage between sutures; skin scarified to cause relaxation and to prevent suture sloughing. December 28, 1921, patient entirely healed; feeling fine; appetite good and taking on weight rapidly. Radiograph showed total obliteration of the cavity and lung well expanded. January 20, 1922, general condition excellent; weight on admission to this hospital was 120 pounds; present weight, 170 pounds; vital capacity reading 3,300 c. c. March 3, 1922, empyema healed. Patient transferred to the ear, nose, and throat service for treatment for old salivary fistula at lower end of old mastoid wound. June 30, 1922, patient returned to empyema service for disposition. Fistula healed. Empyema healed. Patient ready for discharge.

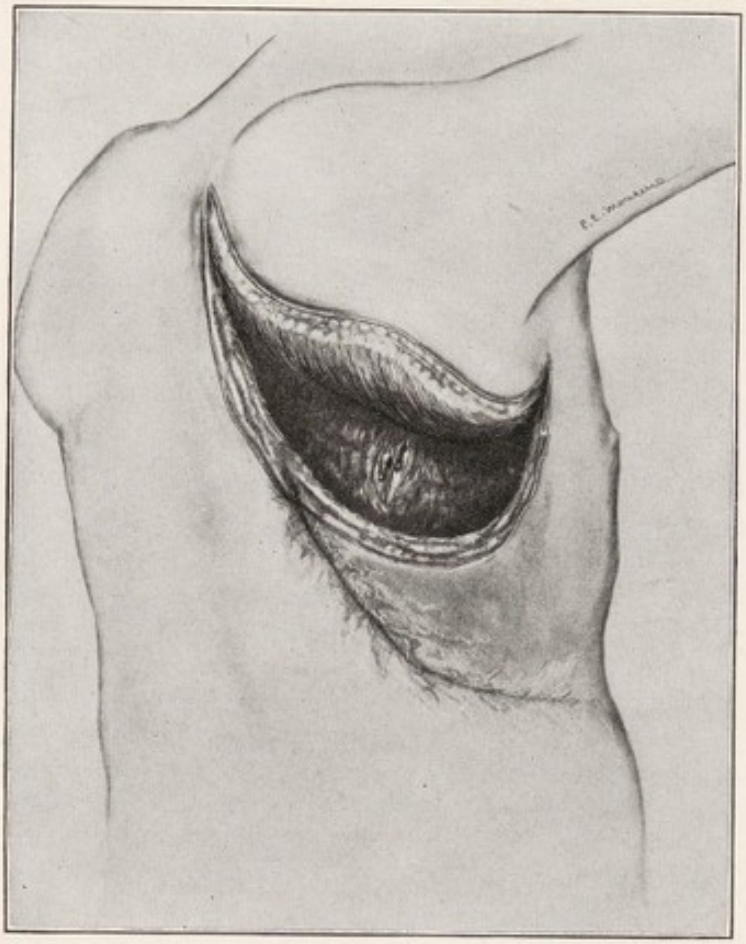

FIG. 85.—Case 8: The wound before final closure, showing a persistent bronchial fistula.

Factors to be combated were hemolytic streptococcus organism present; secondary cavity draining pus into main cavity; primary drainage was not dependent; additional aspirations should have been done by negative pressure before rib resection and lung collapse.

CASE 8.—S. R., age 28 years. March 30, 1918, developed pneumonia. April 3, 1918, complication, empyema, right pleural cavity, hemolytic streptococcus type. Aspirated once. April 3, 1918, intercostal thoracotomy, seventh interspace, midaxillary line; drainage instituted; daily irrigation with Dakin's solution and dichloramine. June 10, 1918, another cavity found draining into the one that was opened, making capacity 450 c. c.; Dakin tubes inserted and classical Carrel-Dakin technique for the sterilization of wounds instituted through primary incision.

Daily aspiration of other areas of chest caused the cavity wound to close and the cavity to again fill with pus; drainage reinstituted by opening the original wound. Formalin and glycerin (2 per cent) were used but no improvement was noted. Treated by this method of procedure for some time, and when wound would close negative pressure treatment was tried.

January 14, 1919, operation; resection of a portion of the ninth rib, right posterior axillary line; dependent drainage instituted and active dakinization started. August 19, 1919, decortication operation with fish-hook incision and resection of fourth, fifth, sixth, seventh, eighth, ninth, tenth, and eleventh ribs; outer wall of cavity removed en masse; visceral pleura decorticated; muscle and skin closure with one drainage tube in dependent portion of wound. September 23, 1919,

healed. January 10, 1920, wound reopened. Large cavity present; bronchial fistula noted; hemoptysis with persistent cough; almost impossible to irrigate the cavity with any solution, due to the fistula. August 19, 1919, diagnosed as chronic parenchymatous nephritis in conjunction with empyema; cavity kept open and irrigated in spite of patent fistula. Hemoptysis persisted; dressed and treated in the manner stated until November 1, 1920. November 20, 1920, admitted to empyema service, Walter Reed General Hospital.

Condition on admission: Ambulatory case, anemic, highly septic, poorly nourished; present weight, 117 pounds (normal weight, 147 pounds). Persistent cough, with frequent expectoration of purulent blood tinged sputum. Examination of chest revealed marked deformity in the contour of the right chest wall due to collapsing operation. A sinus was present discharging pus, posterior scapular line at a level corresponding to eighth rib. Radiographs showed marked collapse of right lung with extensive thickening of pleura, right chest, from apex to base, and a long cavity formation extending from the second to the ninth rib lateral chest, with a capacity of 300 c. c. A large pleurobronchial fistula present and some regeneration and overlapping of rib stumps with osteomyelitic changes. Clinical laboratory examination: Wassermann, negative; sputum, negative for tubercle bacilli; white blood count, 12,300; red blood count, 3,480,000; urine showed heavy trace of albumin; culture from cavity showed heavy growth of hemolytic streptococcus. Blood pressure: Systolic, 148; diastolic, 90; pulse pressure, 58. Vital capacity reading, 1,500 c. c.

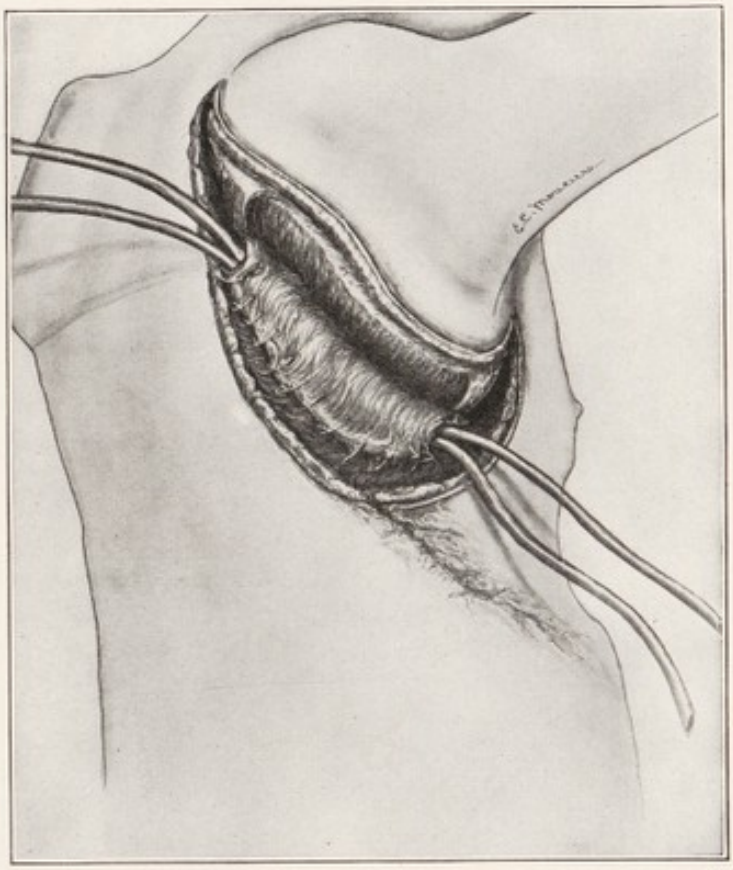

FIG. 86.—Case 8: The implantation of a muscle flap and the insertion of Carrel tubes, in the final closure of the wound.

November 29, 1920, operation; incision along old posterior scar line and extended by a U-like figure to anterior axillary line; entire cavity laid wide open; excision of all thickened pleura forming roof of cavity; skin and remaining muscle tissue saved for final closure. A fistula was noted, and the contiguous lung was mobilized. Preparation of cavity for active dakinization. January 20, 1921, operation; resection of 10 cm. of second, third, fourth, and fifth ribs in the posterior scapular line, right chest; implantation of a portion of the levator anguli scapulæ and erector spinæ muscles into the apex of cavity over pleurobronchial fistula; and closure of upper aspect of cavity with muscle and skin; cavity about sterile but active dakinization continued in lower aspect, which was left open. June 1, 1921, secondary closure of remaining wound; severed superficial muscles and skin brought in apposition and sutured; rubber tube and rubber dam drainage for 48 hours; multiple scarifications of skin to cause relaxation. July 12, 1921, operation; fistula still patent; small incision over posterior aspect in old scar line; lung mobilized about fistula; tract ligated by means of purse string, and another muscle flap implanted over area of closed fistula; wound packed and allowed to granulate. August 4, 1921, fistula still patent. Treated with 2 per cent alchoholic solution of gentian violet. The next day the communication was closed and remained closed. Wound granulated and was entirely healed on August 22, 1921. September 30, 1921, all cavity formation obliterated; lung well expanded and fistula remaining closed; patient gaining weight; general condition excellent. October 10, 1921, patient cured; present weight, 140 pounds; general condition excellent; vital capacity, 2,300 c. c. January 7, 1922, patient discharged as cured, after having been healed four months.

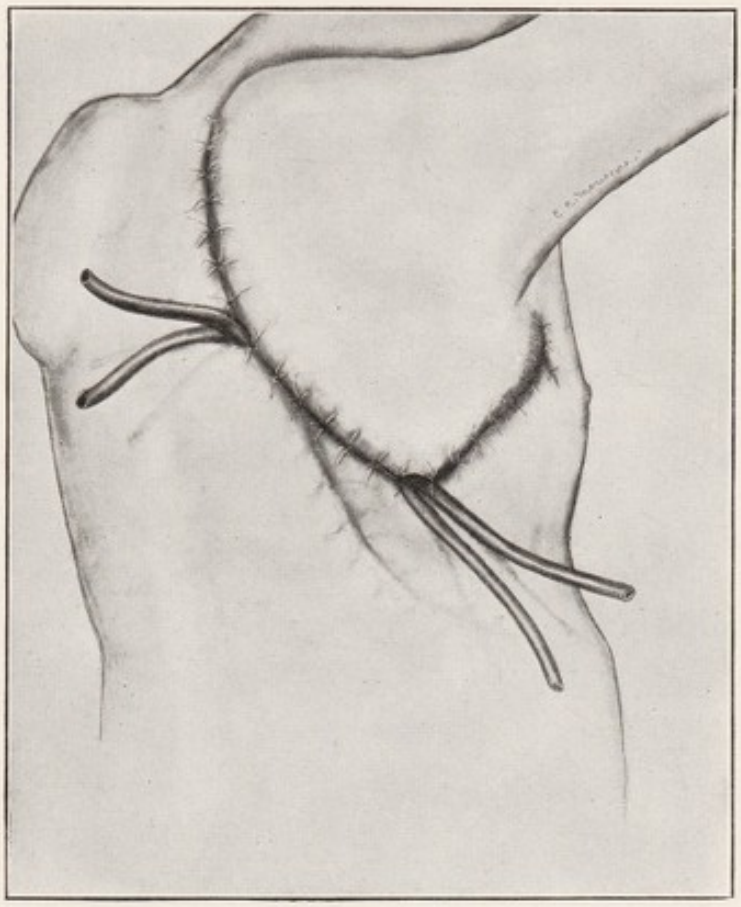

FIG. 87.—Case 8: The final skin suture.

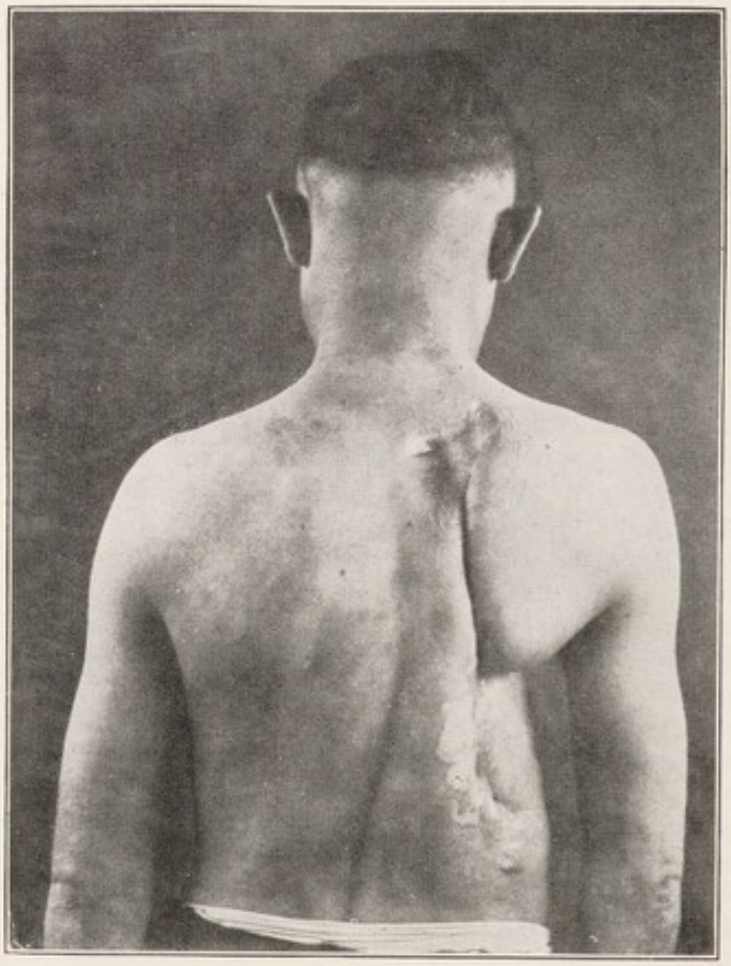

FIG. 88.—Case 8: Final result.

Factors to be combated in this case were hemolytic streptococcus present; osteomyelitis; nephritis; pleurobronchial fistula; marked destruction of soft tissues, and deformity of chest wall.

Case 9.—H. T., age 24 years. January 22, 1919, developed influenza, followed by lobar pneumonia. January 26, 1919, complication, empyema, right pleural cavity, hemolytic streptococcus type. Later, developed otitis media, acute, catarrhal, right.

Prior to his admission to the empyema service, Walter Reed General Hospital, the patient had four operations with resection of the fourth to tenth ribs, inclusive. November 26, 1920, admitted to empyema service, Walter Reed General Hospital.

Condition on admission: Ambulatory; general condition good; weight, 127 pounds (normal weight, 140 pounds). Examination of chest revealed a sinus, discharging pus, tenth interspace. Radiograph showed marked collapse of right chest wall with elongated, bismuth-filled cavity, approximately 16 cm. in length and 2.5 cm. at its widest portion, in the lateral portion of the chest just under the soft tissue covering, and extending from the tenth interspace to the fifth interspace, axillary line. There had been a resection of the fourth to tenth ribs, right side. Cavity showed smooth outlines with no evidence of diverticula or bronchial fistulæ. Clinical laboratory examination: Wassermann, negative; sputum, negative for tubercle bacilli; urine, negative; red blood count, 4,880,000; white blood count, 8,800; hemoglobin, 85 per cent. Blood pressure: Systolic, 120; diastolic, 80; pulse pressure, 40. Vital capacity reading not taken. Culture from cavity showed hemolytic streptococcus and staphylococcus aureus.

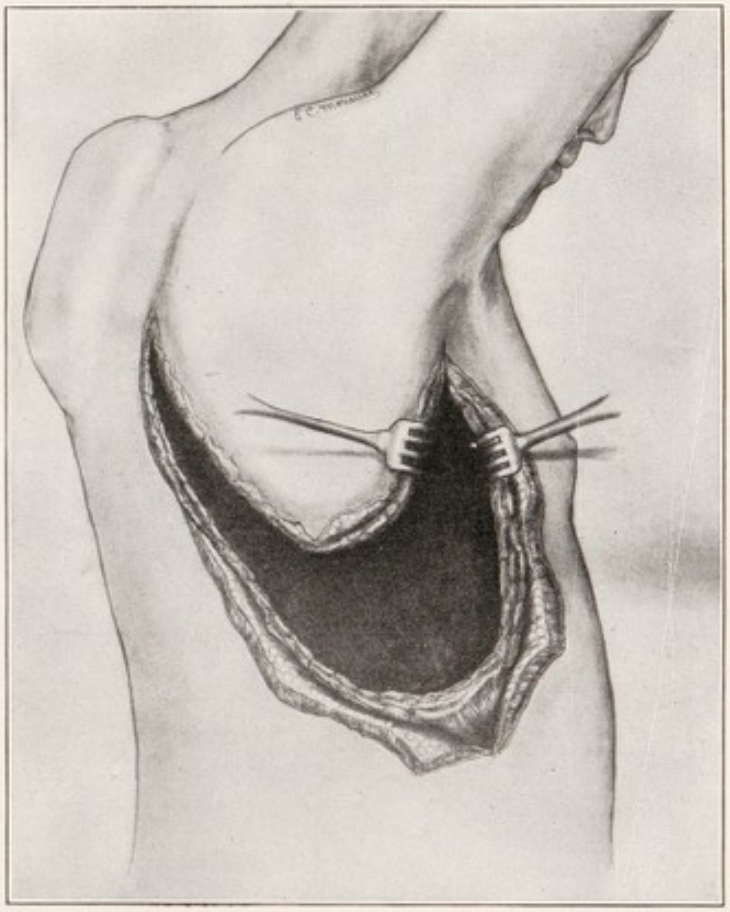

Fig. 89.—Case 9: The wound before muscle implantation and skin suture.

December 2, 1920, the first step of the fractional type operation was accomplished. The upper angle of the wound was attacked; ribs were resected and the old cavity was laid widely open at this point. Portions of the serratus magnus, the rhomboideus major and subcapularis muscles were implanted immediately into the cavity and sutured into place. The muscle bodies held and there was practically no sloughing following this operation. January 17, 1921, an incision at the lower angle of the old wound was made, the scar tissue was excised, and multiple sinuses were found leading in all directions. Sinuses were curetted and the wound left open. Patient placed on active dakinization. His condition seemed to be improving somewhat and it was decided to refrain from further operative procedure until there was a more definite improvement in the general condition. Capacity of cavity at this time was 200 c. c. April 5, 1921, resection of third to eighth ribs over anterior and lateral chest wall; cavity laid wide open. The apex of cavity was found to be obliterated following the muscle implantation at previous operation. July 6, 1921, cavity obliterated, but there was found evidence of osteomyelitis of the seventh, eighth, and ninth rib stumps; necrotic rib stumps resected. July 27, 1921, a sliding skin flap, with its subcutaneous fat, was twisted on its pedicle and transplanted into the lower angle of the wound, entirely closing this part of the cavity. A small part of the cavity remaining above this point could be obliterated by lung expansion on forced inspiration of the patient. September 19, 1921, sinus tract allowed to close, as patient had had seven consecutive daily sterile cultures. November 1, 1921, patient

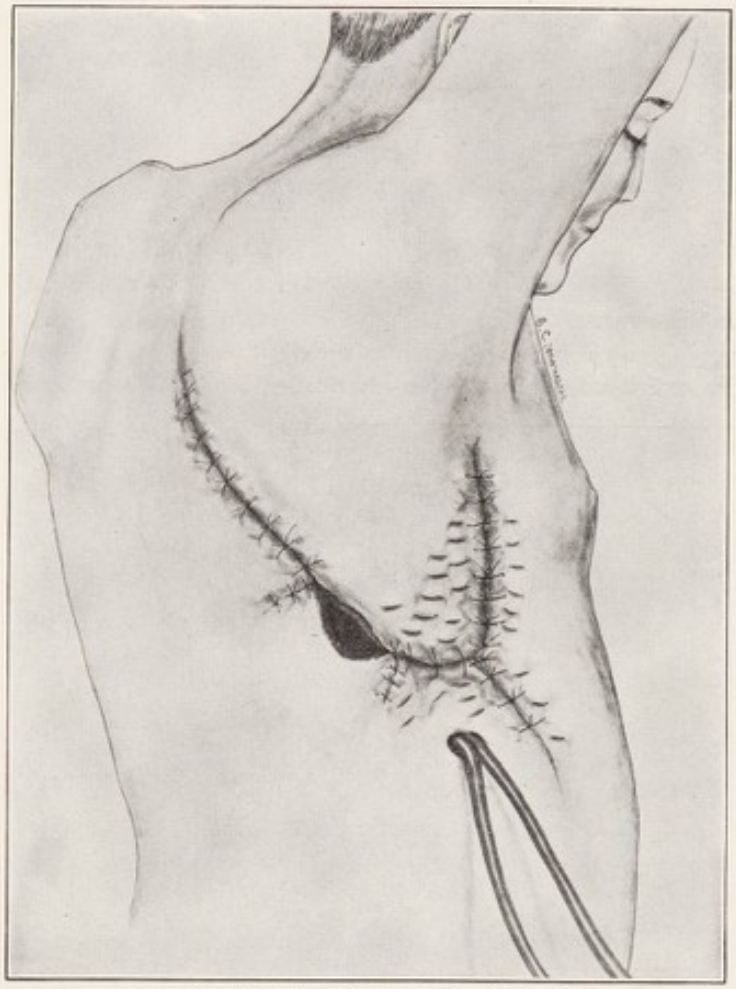

FIG. 90.—Case 9: Stages in the final closure.

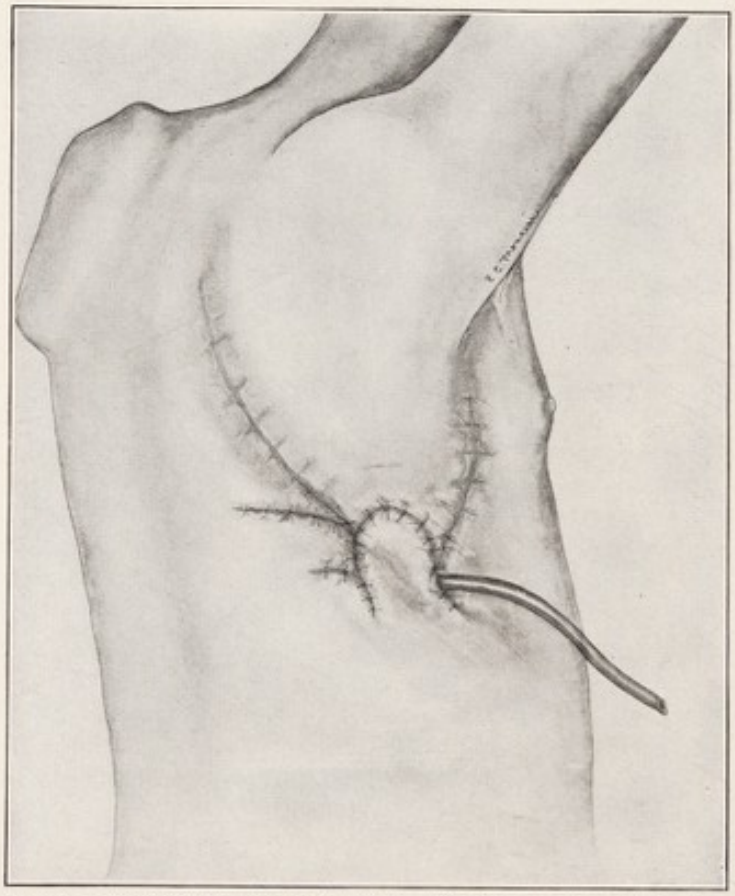

FIG. 91.—Case 9: The final skin suture, with the one Carrel tube for irrigation.

entirely healed. December 6, 1922, patient given a 30-day leave. January 6, 1922, returned from leave feeling fine, entirely healed; ready for discharge from hospital. January 31, 1922, patient discharged from hospital cured this date. X-ray picture taken prior to discharge showed rather marked collapse of chest wall, especially at the base, but no evidence of cavity.

### Factors to be combated were hemolytic streptococcus and staphylococcus aureus present; osteomyelitis of terminal rib stumps.

CASE 10.—J. S., age 19 years. February 2, 1921, developed pneumonia. February 15, 1921, complication, empyema, right pleural cavity, hemolytic streptococcus type. Aspirated six times. May 10, 1921, thoracotomy; trocar canula, with the introduction of a small catheter into cavity to institute drainage. At a subsequent date the opening was enlarged and by this method of procedure the patient was treated and irrigated once daily through two drainage tubes. July 3, 1921, admitted to the empyema service, Walter Reed General Hospital.

Condition on admission: Ambulatory case; poorly nourished; present weight, 133 pounds, (normal weight, 170 pounds). Examination of chest revealed a sinus discharging pus, 8th interspace, posterior axillary line, right chest. Radiographs showed marked collapse of right lung with some thickening of pleura right lateral chest, and a cavity formation extending from fifth to tenth rib, right chest; osteomyelitis, eighth rib, with sequestration. Clinical laboratory examination: Wassermann negative; sputum negative for tubercle bacilli; white blood count, 14,000; red blood count, 4,500,000; urine negative; culture from cavity showed hemolytic streptococci. Blood pressure: Systolic, 122; diastolic, 80; pulse pressure, 42. Vital capacity reading, 2,200 c. c.

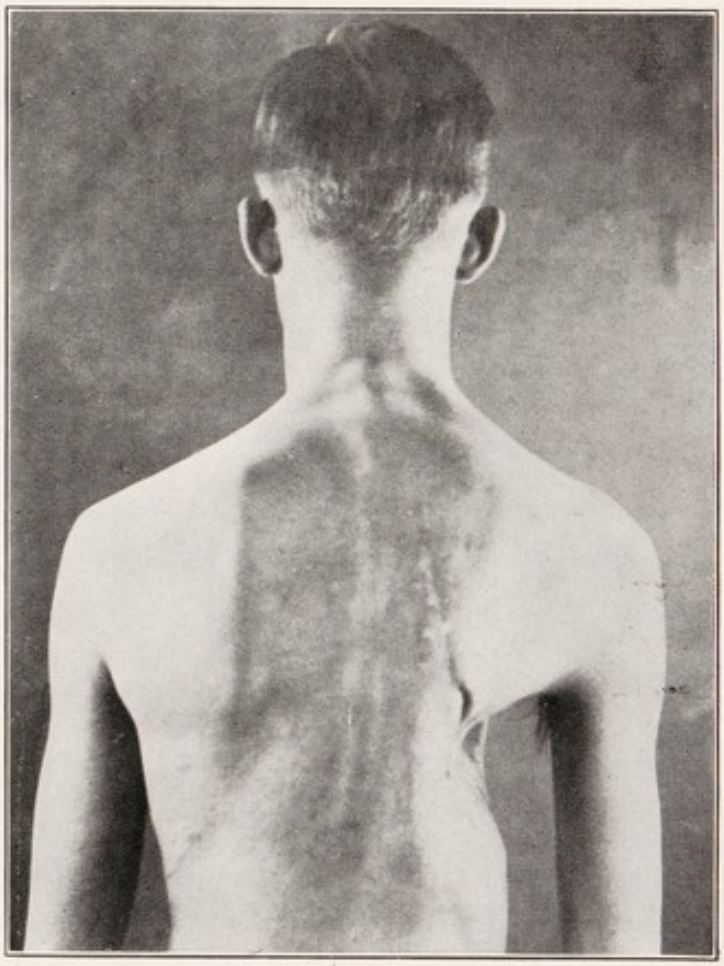

FIG. 92.—Case 9: The final result.

July 8, 1921, operation; resection of 10 cm. of seventh and eighth ribs, posterior scapular line, right chest; cavity opened and about 50 c. c. of pus evacuated; cavity left open and preparation made for dakinization. September 8, 1921, operation; resection of 15 cm. fifth and sixth ribs; excision of thickened parietal pleura forming roof of cavity; discission of visceral pleura to allow lung expansion; skin inverted over muscle to preserve it for final closure; and preparation of cavity for the Carrel-Dakin technique for its sterilization. October 14, 1921, patient developed a pericarditis with effusion, accompanied by some myocardial involvement. Treatment by rest in bed with an ice cap to heart and the administration of morphine sulphate to control pain. October 20, 1921, patient improving; heart compensating for the overwork put upon it; effusion being absorbed; pain now controlled by ice cap. October 30, 1921, has taken care of his complete effusion in pericardium; heart normal in size and function. December 7, 1921, operation; plastic closure with portion of the latissimus dorsi and infraspinatus muscles implanted into small remnant of cavity that was not completely obliterated by lung expansion. Cavity sterile after seven daily consecutive cultures. Muscle and skin closure. December 20, 1921, patient completely healed; feeling well; appetite improved; gradual gain in weight; present weight, 142 pounds; heart showed no ill effects from pericarditis with effusion and there was no recurrence. January 30, 1922, patient healed; general condition excellent; weight 150 pounds; vital capacity reading, 3,500 c. c. May 16, 1922, patient discharged cured, after having been healed four and a half months.

Factors to be combated in this case were hemolytic streptococcus organism present; osteomyelitis with rib sequestration; pericarditis with effusion; primary drainage not dependent; cavity with a capacity of 350 c. c.

CASE 11.—R. C. W., age 30 years. Received gunshot wound, multiple, right chest and right leg October 6, 1918, in action. October 17, 1918, developed bronchopneumonia, traumatic, complicated by empyema. Aspirated twice. November 1,1918, thoracotomy with resection of one and one half inches tenth right rib. Lower wound allowed to close, but pus continued to drain through upper gunshot wound of chest. December 8, 1918, operation; thoracotomy with resection of part of eighth right rib. Dakinization attempted but not continued because of pleurobronchial fistula. April 8, 1919, operation; resection of part of seventh right rib, midaxillary line; tube drainage. July 5, 1919, resection of fifth, sixth, and seventh right ribs, midaxillary line; dakinization of wound followed. Drainage of wound continued; various antiseptic solutions being used, including gentian violet and bismuth paste. The cavity remained unobliterated and patient continued to drain pus. January 20, 1921, admitted to empyema service, Walter Reed General Hospital.

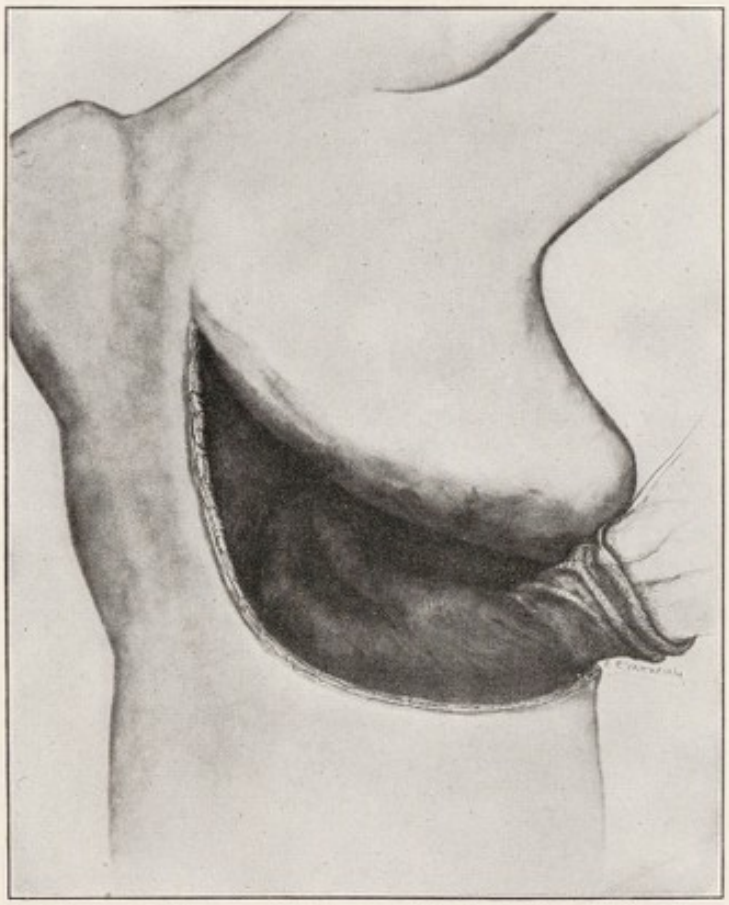

FIG. 93.—Case 11: The wound before muscle implantation and skin suture.

Condition on admission: General condition good. Examination of chest showed a sinus at level of the eighth rib, posterior axillary line, right chest. Sinus too small to admit tube drainage. Profuse discharge of thick pus on dressing. Radiograph showed a partial resection of parts of the fifth, sixth, seventh ribs anterior axillary line with resection of part of the ninth rib; a proliferation of the rib ends with union and cross union of previously resected ribs; cavity running posteriorly along the diaphragm, then upward to sixth rib posteriorly; cavity lying about the scapular line and about 6 cm. from the midline of spine; thickened pleura over entire right chest. Capacity of cavity about 500 c. c. Clinical laboratory examination: Wassermann negative; sputum negative for tubercle bacilli; urine negative; culture from cavity showed Gram-positive bacilli; no hemolytic streptococci; staphylococcus aureus present. Blood pressure: Systolic, 130; diastolic, 84. Vital capacity 2,400 c. c.

February 2, 1921, incision along old sinus tract; resection of sixth, seventh, eighth ribs over cavity; exposure of entire cavity with removal of parietal pleura and intercostal tissues; excision of sinus tract; discission of visceral pleura; cavity and wound packed with gauze; Carrel tubes placed and dakinization of cavity started.

The extent of the cavitation may be judged by the fact that at the daily dressing 42 Carrel tubes were laid in the cavity between the layers of gauze.

The cavity became clinically and bacteriologically clean within a short time, and its capacity diminshed with remarkable rapidity. At the time of the first plastic operation, April 1, the cavity had obliterated about 50 per cent. Frequent scarifications of the visceral pleura were made and this apparently hastened the obliterative process by permitting reexpansion of the underlying lung. April 1, 1921, removal of sequestrum of eighth rib. The cavity being sterile, a plastic closure of the upper angle of the cavity was done; contiguous muscle bodies at the lateral margin of the

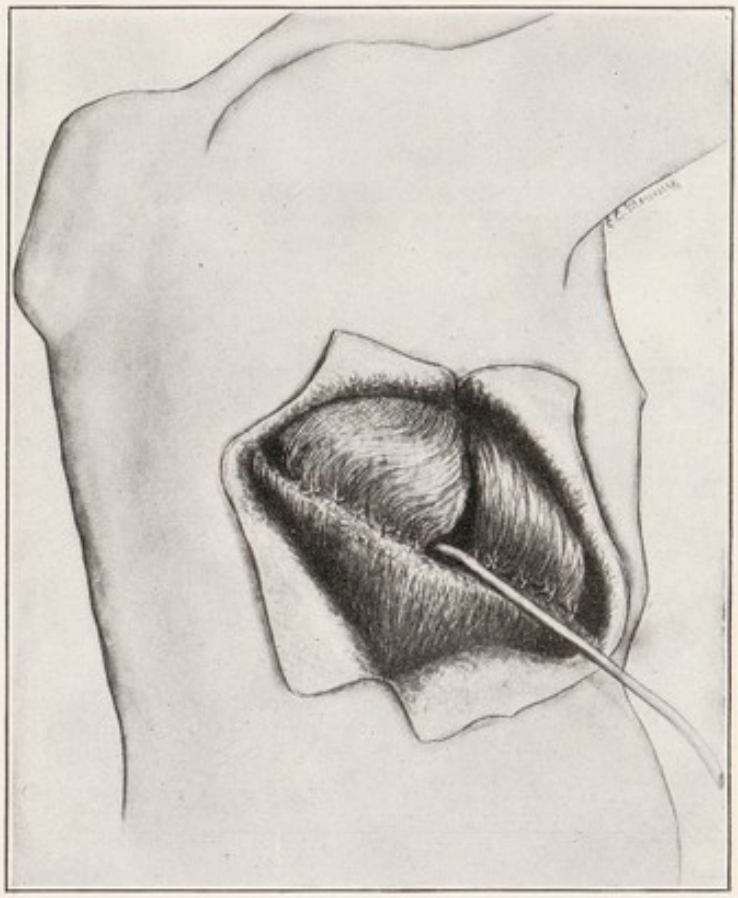

FIG. 94.—Case 11: The method used for muscle implantation.

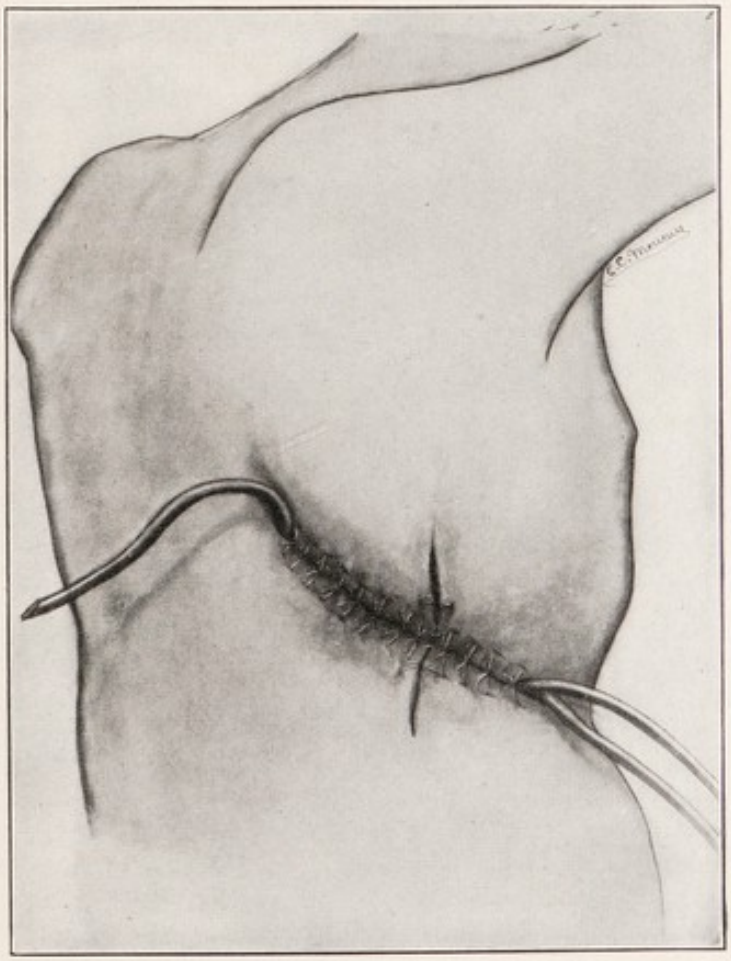

FIG. 95.—Case 11: The final suture of the skin.

wound were partially split and swung into the cavity and sutured in situ to the visceral pleura and sides of the wound. Following this implantation, there was slight superficial necrosis of the muscle implant, but the greater part of it became adherent and obliterated in the upper half of the wound and cavity. June 3, 1921, plastic closure of remaining cavity in its lower half. The upper half was now completely obliterated from the previous plastic operation. Plastic closure was done, as in the upper half, by the implantation of a large muscle plane. The skin and superficial tissues were brought into apposition and the wound was closed with rubber tissue drainage. The wound healed with the exception of a small sinus which persisted and continued to drain a slight amount of seropurulent exudate. July 12, 1921, incision along lower part of old scar, laying open a branched sinus tract. This tract was lined with infected granulations, but no rib involvement could be found. Tract was curetted and left open for Dakin treatment. The old cavity was found to be practically obliterated. September 16, 1921, operation; final plastic procedure to restore contour ofchest wall; small gutter depression along lower part of old cavity closed by suture of opposing muscle bodies and skin. Recovery uneventful; wound completely healed in two weeks following last plastic operation. Patient granted several sick leaves and kept under observation until May 11, 1922, when he was discharged as cured, having been healed seven months.

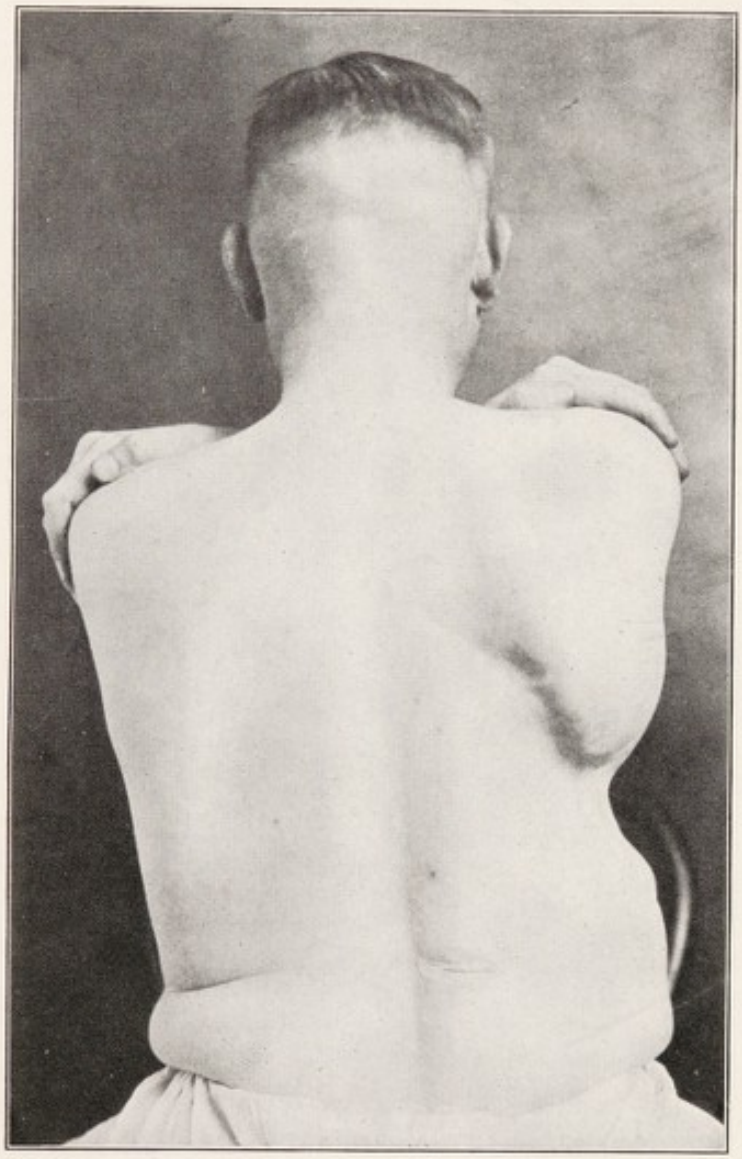

FIG. 96.—Case 11: The final result after complete healing.

Terminal examination showed no cavity formation, either clinically or by radiograph. Fair lung expansion on the involved side. There was but slight deformity of the chest wall. General condition of patient excellent.

Factors to be combated were hemolytic streptococcus, staphylococcus aureus and pyocyaneus organisms present prior to admission; extremely large cavity; osteomyelitis with sequestration of rib stumps; marked lung collapse, with dense adhesions and greatly thickened visceral pleura.

CASE 12.—A. M., age 22 years. March 22, 1919, developed pneumonia. March 27, 1919, complication, empyema, right pleural cavity, hemolytic streptococcus type. Aspirated five times April 14, 1919, operation; thoracotomy, resection of 10 cm. of eighth rib midaxillary line, right chest; 800 c. c. of pus evacuated and drainage instituted by double tube method; irrigations with Dakin's solution. November 10, 1919, admitted to empyema service, Walter Reed General Hospital.

Condition on admission: Ambulatory case, fairly well nourished but slightly anemic and under weight; weight on admission, 148 pounds (normal weight, 165 pounds); some edema and tenderness of joints of extremities; valvular heart disease, mitral insufficiency, in conjunction with myocarditis. Examination of chest: Sinus discharging pus eighth interspace, midaxillary line, right chest,

and a large cavity formation present. Radiographs showed marked collapse of right lung with extensive thickening of parietal pleura from apex to base; large cavity formation extending from fifth rib to base right posterior chest, the same being partially filled with pus, drainage not dependent, capacity of cavity about 400 c. c.; some displacement of heart to the right. Clinical laboratory examination: Wassermann negative; sputum negative for tubercle bacilli; white blood count, 9,250; red blood count, 4,350,000; urine negative; culture from cavity showed hemolytic streptococcus. Blood pressure: Systolic, 116; diastolic, 90; pulse pressure, 26. Vital capacity reading not taken.

Patient put on active dakinization, and a high caloric diet to improve general condition. Cultures were taken from the cavity daily to determine to what degree the Dakin's solution controlled the bacteria. Drainage not dependent, hence there was no improvement. Operative procedure was advised, but the patient refused operation and requested discharge from the service March 15, 1920, discharged from service, condition unchanged. December 6, 1920, readmitted to empyema service. Condition on readmission unchanged. Patient requested operation. December 15, 1920, operation: resection of 15 cm., sixth, seventh, eighth ribs, posterior axillary line, left chest; excision of thickened, parietal pleura forming roof of cavity; cavity laid wide open; discission of visceral pleura; skin inverted over muscle to preserve it for final closure; multiple scarification of skin to cause relaxation, and preparation of cavity for active dakinization. Patient developed profound shock following operation. All active measures to combat shock were instituted, but in spite of them the patient died two hours later.

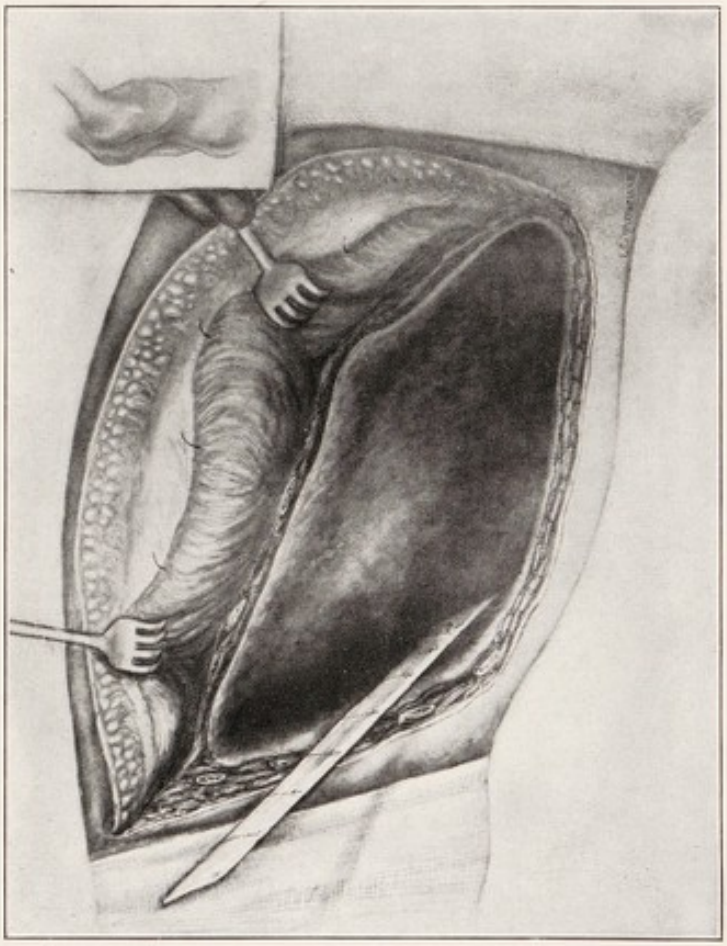

FIG. 97.—Case 13: A large cavity prepared for closure, showing the depth of the space to be obliterated.

Factors to be combated in this case were hemolytic streptococcus organism present; valvular heart disease, mitral insufficiency, in conjunction with myocarditis; osteomyelitis of seventh and eighth ribs; drainage not dependent.

CASE 13.—C. A. M., age 19 years. January 25, 1920, developed pneumonia. February 1, 1920, complication empyema, right pleural cavity, hemolytic streptococcus type. Aspirated five times. May 5, 1920, thoracotomy; resection of 5 cm. of eighth rib. Intermittent dakinization; drainage continued up to time of admission to Walter Reed General Hospital.

Condition on admission: General condition good; slight anemia; weight 200 pounds (normal). Examination of chest revealed sinus discharging pus at the level of the eighth rib, midaxillary line, right side. X-ray examination showed sinus at the level of the eighth rib leading into a cavity about 20 cm. in depth which extends backward and upward following the course of the seventh, eighth, and ninth ribs. Capacity of cavity 250 c. c. Clinical laboratory examination: Wassermann negative; urine negative; sputum negative for tubercle bacilli; red blood count, 4,500,000; white blood count, 5,200; hemoglobin 75 per cent; culture from cavity showed streptococcus hemolyticus. January 17, 1921, resections of 20 cm. of the eighth, ninth, and tenth ribs with excision of sinus tract leading to the spinal gutter. A second sinus tract was found leading to the posterior diaphragmatic sulcus. The original sinus and ribs surrounding it were not touched at this operation; cavity left wide open for active dakinization. March 14, 1921, second step of

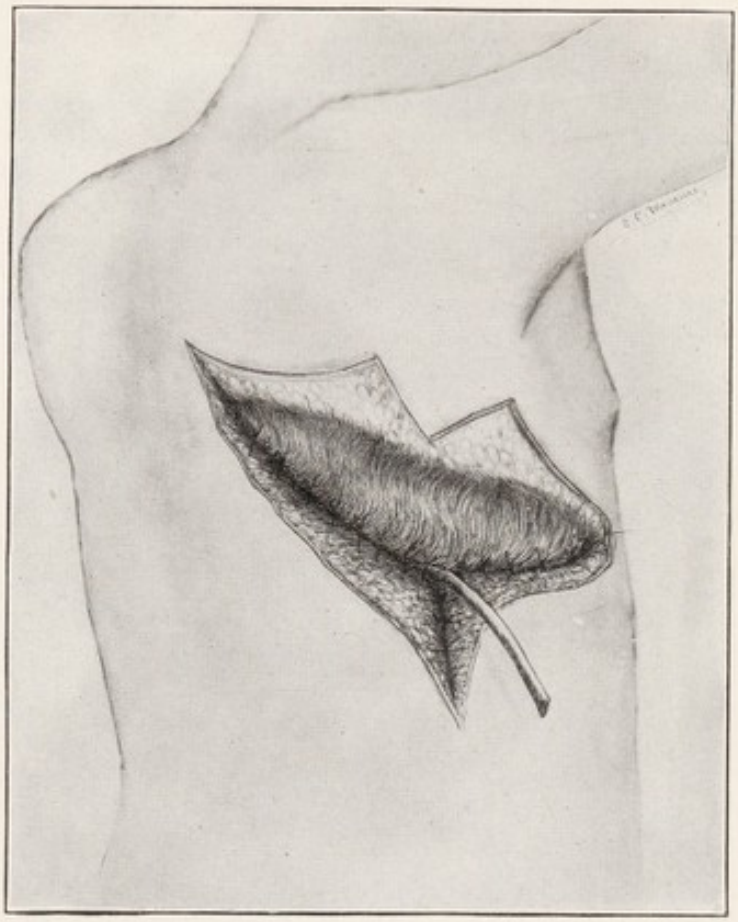

FIG. 98.—Case 13: Muscle implantation.

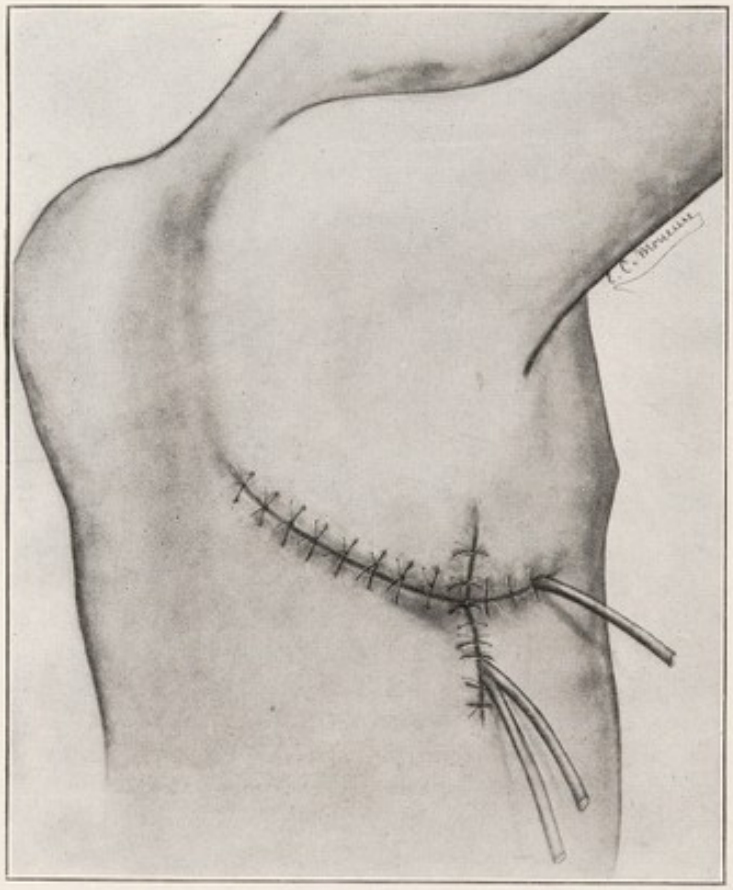

FIG. 99.—Case 13: Final suture of the skin flaps.

fractional operation done; excision of sinus tract with resection of about 10 cm. of ninth rib; cavity left open for dakinization. Following these operations, patient obliterated his cavity rapidly. May 12, 1921, the cavity at this time was less than one-fourth its original size; a plastic closure was done; implantation of part of the serratus magnus, to fill the remaining unobliterated portion, and sliding skin flaps were brought forward from each side and sutured. June 5, 1921, wound healed; general condition excellent. August 11, 1921, patient discharged, cured, after having been healed two months.

## Factors to be combated in this case were hemolytic streptococcus organism present; osteomyelitis of terminal rib stumps; diverticula or accessory pockets.

CASE 14.—P. B., age 23 years. January 30, 1921, developed pneumonia. February 25, 1921, complication, empyema, right pleural cavity, hemolytic streptococcus type. Aspirated twice. March 31, 1921, operation; thoracotomy; resection of 10 cm. of sixth rib, anterior axillary line, right chest; institution of drainage, and daily irrigations of cavity with Dakin's solution. Admitted June 9, 1921, to empyema service, Walter Reed General Hospital.

Condition on admission: Ambulatory case; poorly nourished; anemic; weight, 117 pounds. Examination of chest revealed sinus discharging pus sixth interspace, anterior axillary line, right chest; pleurobronchial fistula present, and large cavity formation with a capacity of 450 c. c. Radiographs showed marked collapse of the right lung with extensive thickening of the lateral aspect of the right parietal pleura from apex to base, and a cavity formation extending from the second to the tenth rib. Drainage inadequate and not dependent. Clinical laboratory examination: Wassermann negative; sputum negative for tubercle bacilli; white blood count, 13,750; red blood count, 4,210,000; urine negative; culture from cavity showed hemolytic streptococcus. Blood pressure: Systolic, 128; diastolic, 78; pulse pressure, 50. Vital capacity reading, 1,800 c. c.

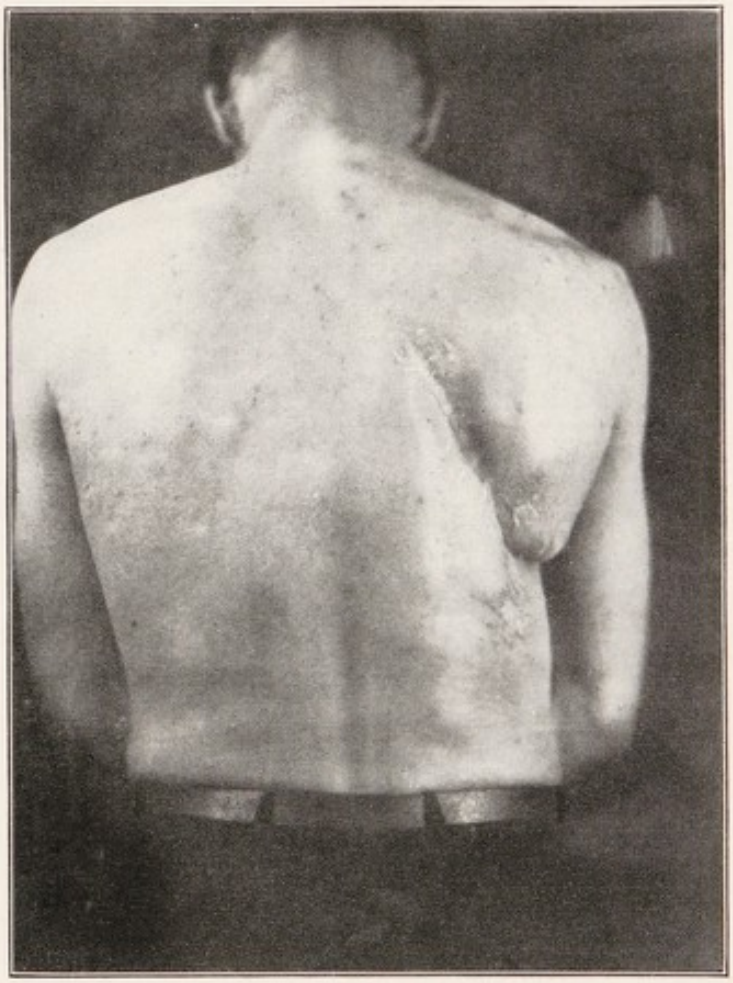

FIG. 100.—Case 13: Final result of closure.

June 28, 1921, operation; resection of 10 cm. of ninth and tenth ribs, midscapular line, right chest; cavity left open for active dakinization. October 13, 1921, resection of 10 cm. of sixth, seventh, and eighth ribs posterior axillary line, right chest; excision of thickened parietal pleura forming roof of cavity; skin inverted over muscles which were severed; cavity left open for active dakinization; fistula found closed since first operation, under treatment with gentian violet. December 2, 1921, operation; resection of 10 cm. of fifth, sixth, seventh, eighth, ninth and 5 cm. of the tenth and eleventh ribs, postscapular line, right chest, with the implantation of a portion of the latissimus dorsi into the apex of cavity, after discission of visceral pleura had been done. Partial closure of muscle and skin over upper aspect of cavity; lower portion left open for active dakinization. January 25, 1922, secondary closure of skin and muscle, lower portion of cavity; rubber dam drainage, with Carrel tube in most dependent portion. February 8, 1922, patient developed myocarditis, and appropriate treatment for this condition was instituted. Empyema closed; lung well expanded; all cavity formation obliterated. May 1, 1922, patient improving;

myocarditis clearing up; empyema entirely healed; and general condition good. June 5, 1922, patient discharged from hospital cured. Weight on admission, 117 pounds; weight on discharge, 137 pounds. Condition good; all cavity formation obliterated; lung well expanded; vital capacity reading, 2,900 c.c.; myocarditis greatly improved. Empyema completely cured; discharged cured June 5, 1922.

Factors to be combated were hemolytic streptococcus organism present; osteomyelitis with rib sequestration; secondary cavity formation; pleurobronchial fistula present; myocarditis, chronic.

CASE 15.—J. C., age 28 years. September 15, 1918, developed influenza and pneumonia. October 10, 1918, complication, empyema, left pleural cavity, hemolytic streptococcus type. Aspirated twice. October 16, 1918; operation; thoracotomy; resection of a portion of the sixth rib, midaxillary line; institution of drainage; and the irrigation of the cavity with Dakin's solution. November 17, 1918, a secondary drainage operation was done, with removal of a portion of the seventh rib. August 22, 1919, decortication operation with resection of portion of fifth, sixth, seventh, eighth, ninth, and tenth ribs; and drainage of the lower aspect of the cavity. September 17, 1920, resection of an additional portion of eighth rib stump and the resection of 5 cm. of the third and fourth ribs, posterior scapular line, left chest. Following this the patient would heal and break down, with a persistent expectoration of blood from pleuropulmonary communications. February 10, 1921, admitted to empyema service, Walter Reed General Hospital.

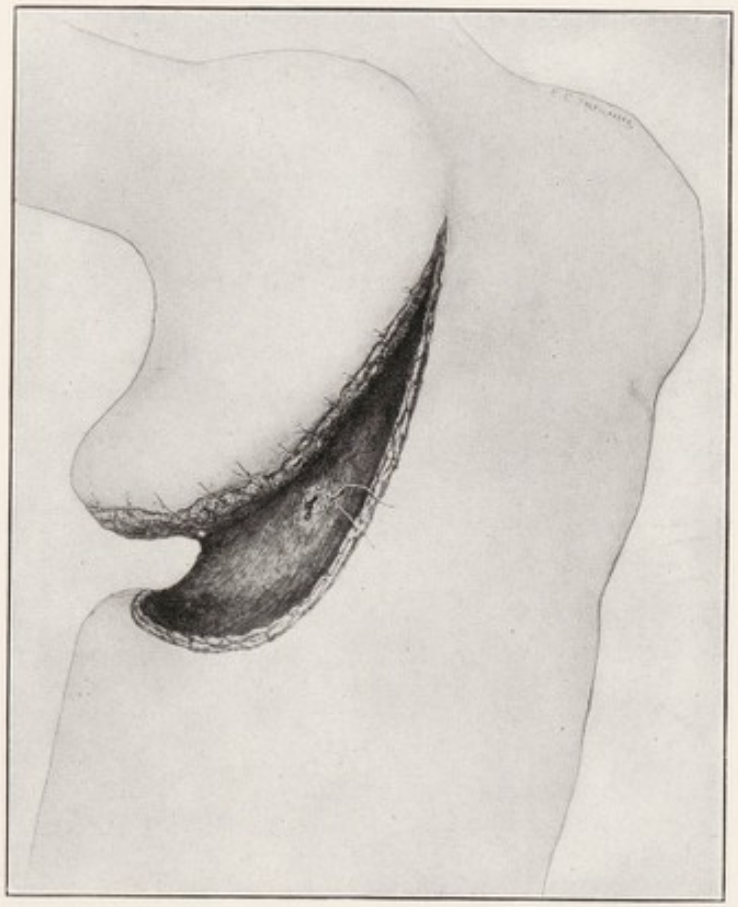

FIG. 101.—Case 15: Illustrating method of partial closure of bronchial fistula.

Condition on admission: Ambulatory case; anemic; poorly nourished; present weight 127 pounds (normal weight 145 pounds); extremely toxic with renal complications, chronic interstitial nephritis. Examination of chest revealed great deformity in the contour of the left lateral chest with an "ax chop" appearance and a sinus discharging pus, midaxillary line. Radiographs showed marked collapse of the left lung with extensive thickening of the pleura from apex to base, and a cavity formation extending from the third to the eighth rib, left lateral chest, having a capacity of 250 c.c. A pleurobronchial fistula was present and osteomyelitis of resected rib stumps noted. Clinical laboratory examination: Wassermann negative; sputum negative for tubercle bacilli; white blood count, 13,560; red blood count, 3,970,000; urine showed heavy trace of albumin and hyaline and granular casts; culture from cavity showed hemolytic streptococcus. Blood pressure: Systolic, 144; diastolic, 86; pulse pressure, 58. Vital capacity reading, 1,600 c.c.

February 18, 1921, operation; incision along line of old scar; cavity laid wide open; necrotic rib stumps removed; excision of thickened parietal pleura forming roof of cavity; discission of visceral pleura to allow lung expansion; all skin and muscles preserved for final closure and preparation of cavity for active dakinization. June 9, 1921, operation; partial closure of the cavity with the suturing of the fistula present, and the implantation of a portion of the latissimus dorsi muscle over it; upper aspect of cavity closed with muscle and skin; lower portion left open for active dakinization. September 13, 1921, incision of sinus tract leading posteriorly and upward; communicating with main cavity; the tract left wide open for active dakinization. October 1, 1921, cavity found to be sterile after seven consecutive daily cultures. October 5, 1921, resection

of 5 cm. of regenerated fifth and sixth ribs, posterior scapular line; discission of visceral pleura; fistula found closed. Plastic flap of the subscapularis muscle was implanted in upper aspect of remaining cavity; superficial muscles brought in apposition and sutured. Skin closed with figure-of-eight silkworm gut; multiple scarifications of skin to cause relaxation; lower aspect of wound left open to granulate. November 30, 1921, patient entirely healed and gaining weight; X-ray examination showed all cavity formation obliterated; general condition excellent; urine negative for albumin and casts. Weight on admission, 127 pounds; present weight, 148 pounds. Vital capacity reading, 2,400 c. c. March 1, 1922, patient's general condition excellent; appetite good. April 4, 1922, patient entirely healed and discharged from hospital, cured.

Factors to be combated were hemolytic streptococcus present; pleurobronchial fistula present; osteomyelitis of rib stumps; secondary cavity formation; chronic interstitial nephritis; marked collapse of left chest wall due to previous operative procedure.

Case 16.—R. R., age 24 years. February 1, 1921, developed pneumonia. March 25, 1921, complication, empyema, left cavity, hemolytic streptococcus type. Aspirated three times. April 25, 1921, operation; thoracotomy; resection of 10 cm. of seventh rib anterior axillary line, left chest; institution of drainage; cavity irrigated with Dakin's solution. June 9, 1921, admitted to empyema service, Walter Reed General Hospital.

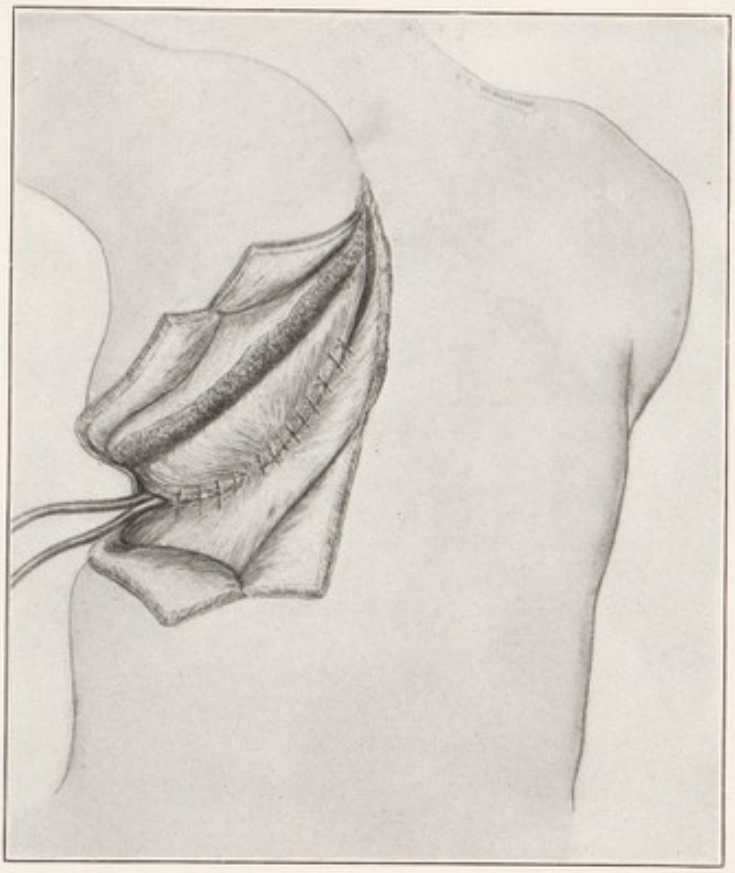

Fig. 102.—Case 15: Muscle implantation.

Condition on admission: Ambulatory case, fairly well nourished, but considerably underweight; weight on admission, 118 pounds (normal weight, 160 pounds). Examination of chest revealed sinus discharging pus, seventh interspace, anterior axillary line, left chest; and a cavity formation with a capacity of 700 c. c. Pleurobronchial fistula present and drainage not dependent. Radiographs showed a partial collapse of left lung with considerable thickening of the pleura, and a cavity formation extending from fourth rib to base, and posterior to the sinus leading to the cavity. Clinical laboratory examination: Wassermann negative; sputum negative for tubercle bacilli; white blood count, 9,450; red blood count, 5,010,000; urine negative; culture from cavity showed hemolytic streptococcus and staphylococcus aureus. Blood pressure: Systolic, 126; diastolic, 80; pulse pressure, 46. Vital capacity reading, 2,100 c.c.

June 28, 1921, operation; resection of 10 cm. of ninth rib, posterior axillary line; and the institution of dependent drainage; cavity left open for active dakinization. October 13, 1921, operation; resection of 20 cm. of sixth, seventh, and eighth ribs, posterior axillary line, left chest; excision of thickened parietal pleura forming roof of cavity; skin inverted over muscles that were severed and sutured over rib stumps; preparation of cavity for active dakinization. December 29, 1921, operation; resection of 10 cm. of seventh and eighth ribs, midaxillary line; removal of thickened parietal pleura; mobilization of lung about fistula and closure of posterior aspect of cavity, using muscle and skin. February 23, 1922, operation; resection of 10 cm. of posterior stump of seventh rib which showed osteomyelitis with sequestration; cavity left open for dakinization. March 8, 1922, operation; resection of 15 cm. of anterior stump seventh rib which showed osteomyelitis with sequestration. This portion of rib was regenerated bone which had become infected. Entire cavity

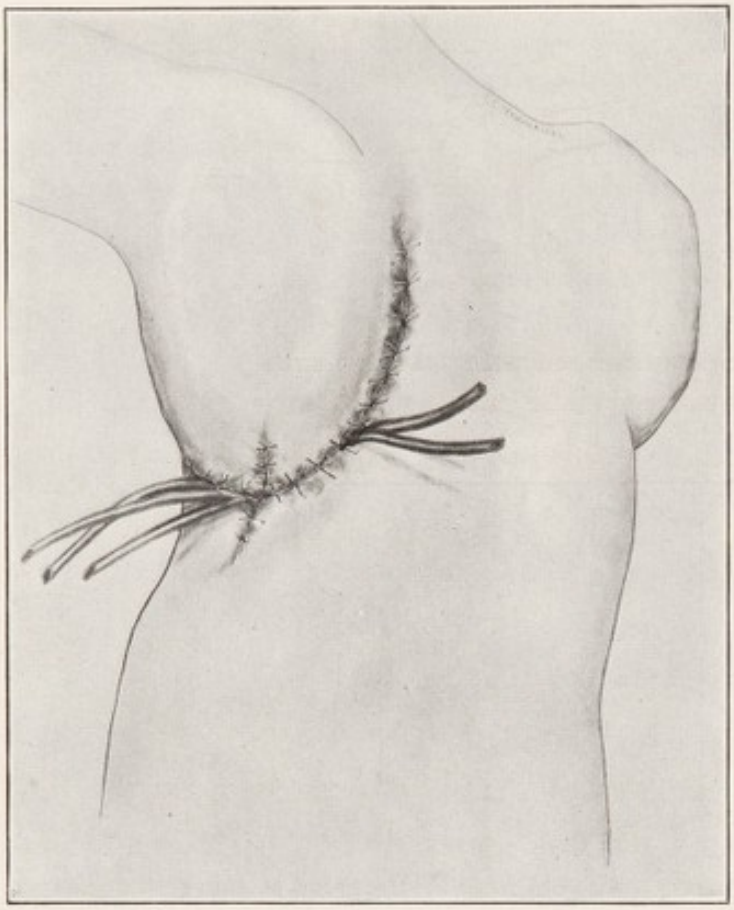

Fig. 103.—Case 15: Final skin suture.

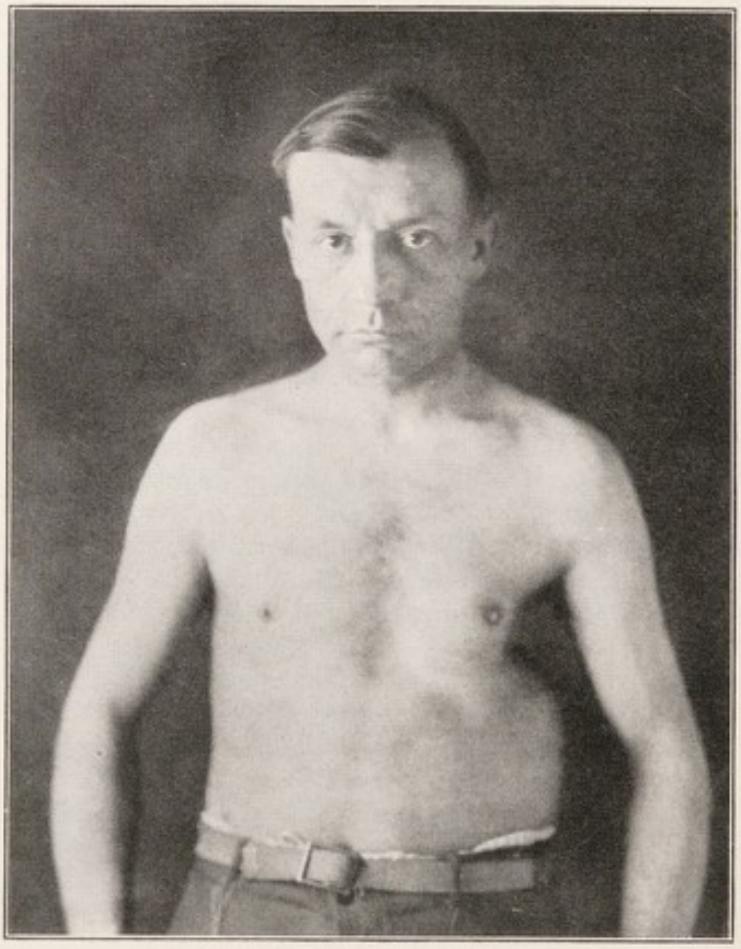

Fig. 104.—Case 15: End result.

left open for active dakinization. April 6, 1922, plastic closure of muscle and skin, with implantation of a portion of latissimus dorsi and subscapularis muscles into apex of cavity to obliterate multiple fistulæ; superficial muscles and skin brought into apposition and sutured by means of silkworm gut; rubber dam and one tube drainage for 48 hours; multiple scarification of skin to cause relaxation. May 15, 1922, patient entirely healed and doing well. June 25, 1922, patient entirely healed; all fistulæ closed; all cavity formation obliterated; lung well expanded; general condition excellent; vital capacity reading, 3,300 c. c.; weight, 152 pounds.

Factors to be combated in this case were hemolytic streptococcus and staphylococcus aureus present; osteomyelitis with rib sequestration; pleurobronchial fistulæ present; secondary cavity and diverticula; partial heart block.

Case 17.—W. G., age 30 years. October 1, 1918, developed influenza and pneumonia. October 13, 1918, complication, empyema, right pleural cavity, hemolytic streptococcus type; aspirated once. October 15, 1918, operation; thoracotomy, eighth interspace, posterior axillary line, with the institution of drainage. December 23, 1918, thoracotomy; resection of a portion of the eighth rib, posterior axillary line; better drainage instituted. September 24, 1919, decortication operation with resection of a portion of fifth, sixth, seventh, eighth, ninth, and tenth ribs; complete decortication of visceral pleura; wound closed with dependent drainage. Following this operation, there was a slough of the soft tissue along posterior incision and a protrusion of rib stumps into opening with exposure of nerve ending from posterior horn cells. Dressings were very difficult at this time; Dakin's solution was tried but was discontinued because of a bronchial fistula, which caused patient to strangle; iodoform emulsion used in dressings; mercuracrome also tried. Patient exposed to sun rays and to various forms of tub baths. Treated by these various methods until September 23, 1920. September 24, 1920, admitted to empyema service, Walter Reed General Hospital.

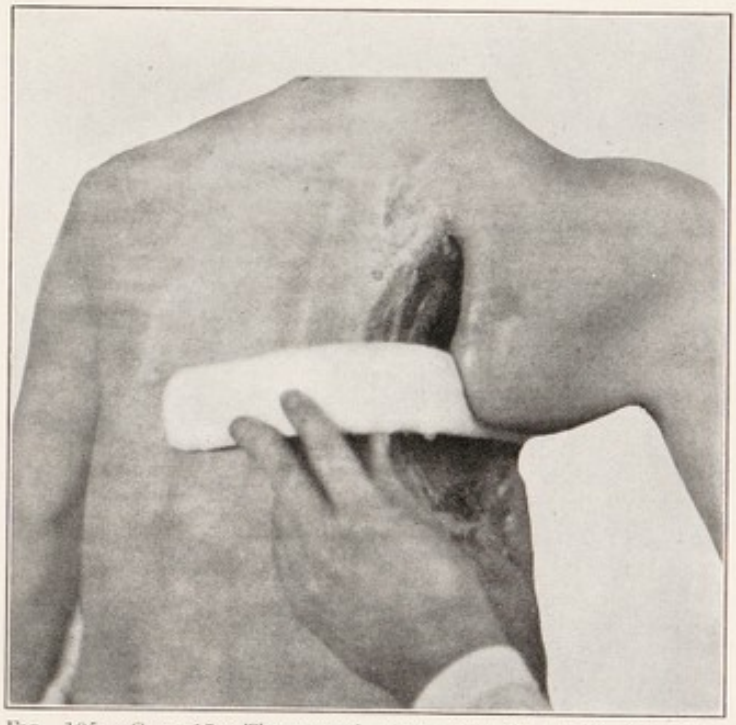

Fig. 105.—Case 17: The wound after removal of the fourth to eleventh ribs, exposed and necrosed on admission.

Condition of admission: Litter case; anemic; highly septic; poorly nourished; present weight 96 pounds (normal weight, 140 pounds). General condition extremely poor. Examination of chest revealed large open wound, posterior scapular line, with retraction of soft tissues in this area, and exposed necrotic posterior rib stumps fifth, sixth, and seventh, with much unhealthy granulation tissue about them; posterior horn cells exposed, and patient extremely sensitive over this area. This open wound communicated with cavity formation which had a capacity of 650 c. c. Radiographs showed almost total collapse of right lung with extensive thickening of the pleura, right chest, from apex to base and a large cavity formation extending from first to tenth rib, lateral chest. A large pleurobronchial fistula noted; marked osteomyelitis of resected rib stumps. A cold abscess was present over right sacroiliac region. Clinical laboratory examination: Wassermann negative; sputum negative for tubercle bacilli; white blood count, 9,750; red blood count, 3,750,000; urine negative; culture from cavity showed heavy growth of hemolytic streptococcus. Blood pressure: Systolic, 108; diastolic, 76; pulse pressure, 32. Vital capacity reading, 1,300 c. c.

This patient's general condition was so poor at time of admission that it was necessary to build him up before he could withstand even a fractional type of operation. This was accomplished by stomachics and a high-caloric diet; eggnogs at least three times daily. Cold abscess was injected with iodoform emulsion and strapped. Cavity given active dakinization

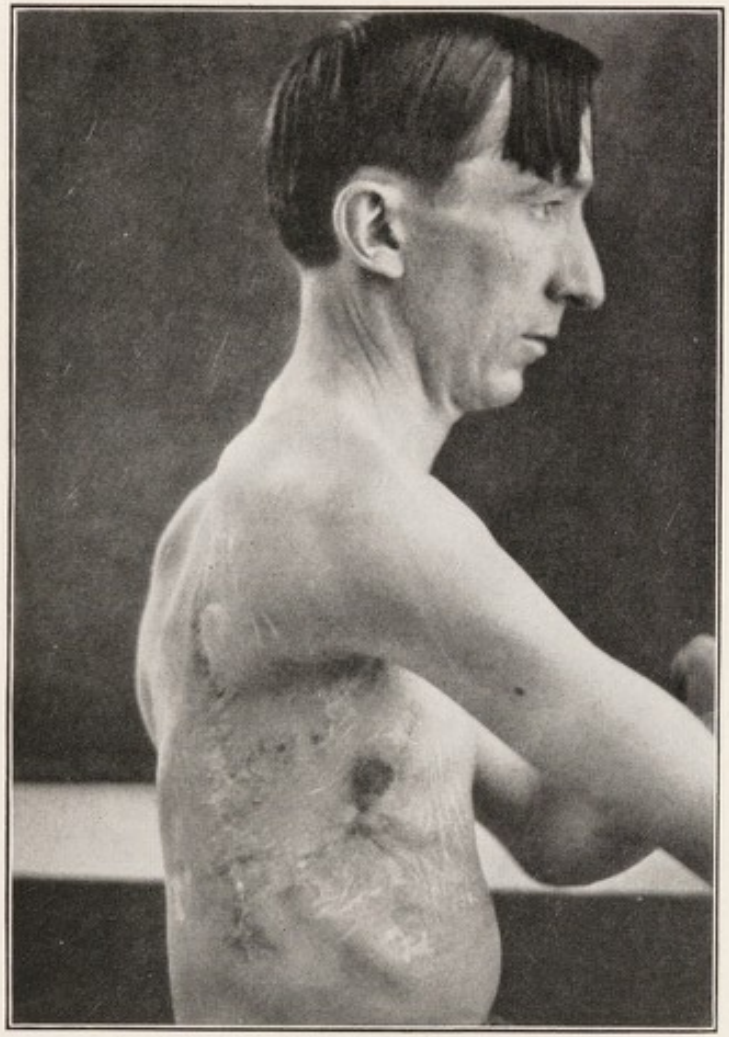

FIG. 106.—Case 17: Lateral view of final result.

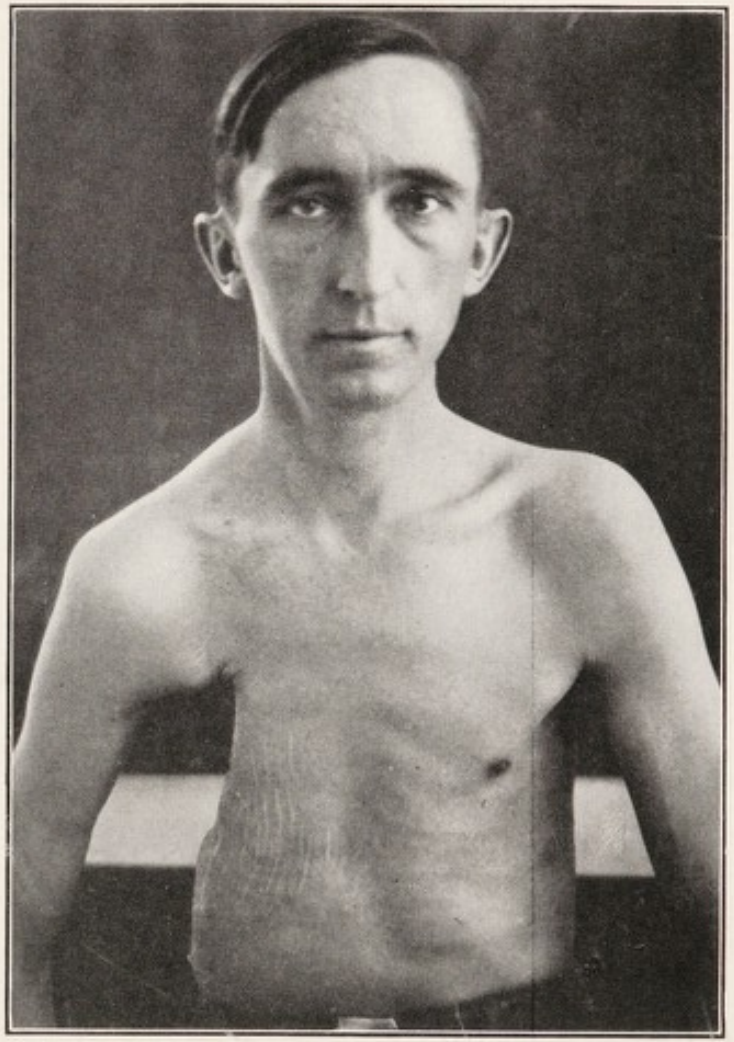

FIG. 107.—Case 17: Anterior view of final result, showing condition after shortening clavicle to bring scapula closer to lung so as to aid in obliteration of the cavity.

October 29, 1920, operation; resection of necrotic rib stumps, fourth, fifth, sixth, and removal of unhealthy granulations, with mobilization of lung about fistula; deep alcohol injection of nerves from posterior horn cells; cavity left open for active dakinization. February 4, 1921, resection of 15 cm. of third, fourth, fifth, sixth ribs, anterior chest, 1 inch from costochrondral junction; excision of thickened parietal pleura and discission of visceral pleura to allow lung expansion; skin inserted over severed superficial muscles and fixed; cavity left open for the continuation of active dakinization. April 13, 1921, operation; resection of a portion of ninth and tenth ribs, posterior axillary line; resection of regenerated portion of sixth and seventh ribs anterior axillary line; dakinization continued. June 21, 1921, operation; resection of 10 cm. of second, third, and fourth ribs posterior scapular line, right chest; excision of thickened parietal pleura and exposure of apex of cavity; mobilization of lung about fistula; dakinization continued; all muscle and skin saved and tucked beneath scapula. Following this operation, the angle of the scapula made pressure on underlying lung structure, hence patient was dressed with a thin steel rib 2 inches wide and so constructed as to fit the general contour of the chest. This band was well padded and passed beneath the angle of the scapula and was fixed in place by straps over shoulders and tape across terminal end of steel rib on unaffected side of chest. This held the angle of the scapula away from the underlying lung and did not interfere with active dakinization of the cavity. July 19, 1921, closure of bronchial fistula by means of mattress suture and mobilization of lung about the fistula; dakinization continued. September 13, 1921, decortication of visceral pleura about fistula that still remained patent; purse-string ligation of fistula; dakinization continued. October 1, 1921, fistula still patent, although considerably smaller; a 2 per cent alcoholic solution of gentian violet applied and the following day fistula was closed. This application was repeated to keep mechanical plug in fistula until granulations had obliterated tract. November 15, 1921, the remaining cavity formation in this case consisted of a pyramidal space, with its base in the upper aspect of the right chest between the clavicle anteriorly, first rib internally and superiorly and the scapula posteriorly, and with its apex downward and in the midaxillary line. It was necessary to devise some method to obliterate this space as a maximum amount of lung expansion had been obtained by discission of the visceral pleura. December 1, 1921, shortening of clavicle to obliterate aforesaid space; clavicle shortened 2 inches and fragments morticed and wired in apposition; muscle and skin closed over space. December 28, 1921, operation; resection of regenerated third and fourth ribs, anterior axillary line, to allow scapula free excursion of motion (since clavicle had been shortened) and to completely obliterate the space. Portions of the pectoralis major and subscapularis muscles were implanted into apex of space to act as a buffer between the scapula and the underlying lung structures. Following these operations, the angle of the scapula was reflected backward and outward, therefore the device to elevate scapula from underlying lung tissue was no longer required. Pleurobronchial fistula remained closed, and cavity practically sterile. February 2, 1922, plastic closure of anterior aspect of wound with muscle and skin; closure of the upper posterior aspect with muscle and skin using silkworm gut sutures; rubber dam drainage for 24 hours; multiple scarifications of skin to cause relaxation along the suture line and to prevent slough; lower aspect of cavity left open for active dakinization. February 27, 1922, further secondary closure and re-suture of small areas along posterior aspect left open for drainage; multiple scarifications of skin to cause relaxation of suture line; lowermost aspect of wound still left open for dakinization. March 23, 1922, additional closure of posterior aspect of wound, muscle and skin, leaving only a small area at lowermost aspect to heal by granulation, this area being so superficial that plastic flap did not seem necessary. March 30, 1922, all but healed; general condition good; has begun to take on weight; lung expanded; all cavity formation obliterated. June 12, 1922, sliding-flap graft of skin and subcutaneous tissue into unhealed area; plastic closure of remaining structures; multiple scarification of skin to cause relaxation; rubber dam drainage for 48 hours. June 26, 1922, patient all but healed.

Factors to be combated in this case were hemolytic streptococcus organism present; osteomyelitis; pleurobronchial fistula; cold abscess, and condition of tissues caused tuberculosis to be reckoned with; mechanics necessary to obliterate cavity; patient's general debilitated condition, with faulty metabolism; patient able to withstand only a few minutes on table.

CASE 18.—J. K., age 25 years. July 18, 1918, received penetrating gunshot wound right chest, machine gun bullet, in action. July 20, 1918, débridement operation. Was aspirated six times, a serosanguineous fluid being withdrawn. December 13, 1918, operation; exploratory thoracotomy seventh and eighth ribs, midaxillary line; bullet removed and wound closed. Numerous aspirations followed. January 1, 1919, developed empyema, hemolytic streptococcus type. January 15, 1919, area of previous thoracotomy reopened and drainage instituted with irrigation by Dakin's solution. Treated by this method and reopened a number of times. June 4, 1921, admitted to empyema service, Walter Reed General Hospital.

Condition on admission: Ambulatory case; fairly well nourished but showng some anemia; present weight, 140 pounds (normal weight 150 pounds); fingers clubbed; some edema of extremities. Examination of chest revealed sinus discharging pus, seventh interspace, midaxillary line, right chest, with a large cavity formation partially filled with pus. Radiographs showed marked collapse of right lung with extensive thickening of the parietal pleura, right lateral chest, from apex to base; a cavity formation extending from the second to tenth ribs with a capacity of 600 c. c.; and osteomyelitis of rib stumps which had been previously resected. Clinical laboratory examination: Wassermann negative; sputum negative for tubercle bacilli; white blood count, 12,600; red blood count, 4,560,000; urine negative; culture from cavity showed hemolytic streptococci. Blood pressure: Systolic, 115; diastolic, 70; pulse pressure, 45. Vital capacity reading, 1.600 c. c. June 9, 1921, resection of 10 cm. of sixth, seventh, and eighth ribs, midaxillary line, right chest; excision of thickened parietal pleura forming roof of cavity; skin inverted over muscles that were severed and the muscles fixed over rib stumps, to prevent retraction and preserve them for the final closure; cavity left wide open for active dakinization. June 30, 1921, resection of 10 cm. of sixth, seventh, eighth, and ninth ribs, posterior scapular line; excision of thickened parietal pleura en masse; skin fixed over severed muscles; cavity left wide open for active dakinization. July 25, 1921, resection of 10 cm. of fourth and fifth ribs, posterior scapular line; cavity left wide open and active dakinization continued. November 2, 1921, resection of 15 cm. of sixth, seventh, eighth and ninth ribs, anterior axillary line; removal of roof of cavity; active dakinization continued. October 3, 1921, resection of 20 cm. of eighth, ninth, and tenth ribs; removal of roof of cavity; discission of visceral pleura and dakinization continued. February 27, 1922, resection of 20 cm. of fourth and fifth ribs, anterior axillary line; removal of necrosed sixth and seventh rib-stumps, same line; and resection of 10 cm. of third rib, posterior scapular line; active dakinization continued. March 9, 1922, secondary closure of upper aspect of cavity, muscle and skin, with the implantation of a portion of the infraspinatus muscle into apex of cavity, severed superficial muscles, which had been saved, brought in apposition and sutured; excision of all scar formation; and skin closed by silkworm gut suture; rubber dam drainage along suture line; discission of entire visceral pleura before closure; and lower aspect of cavity left open for active dakinization. May 11,

FIG. 108.—Case 18: First stage in closure of the wound.

1922, partial plastic closure of empyema cavity, right chest, using muscle and skin, with implantation of superficial muscle body into remaining space after maximum lung expansion had been obtained; skin and muscle brought in apposition by means of silkworm gut; multiple scarification of skin to cause relaxation; and rubber dam drainage for 48 hours. June 28, 1922, plastic closure of posterior aspect of cavity with muscle and skin; muscle and skin brought in apposition and sutured by means of silkworm gut; rubber dam drainage for 48 hours; multiple scarification of skin to cause relaxation.

Factors to be combated were hemolytic streptococci present; osteomyelitis of ribs; diverticula or secondary cavities; constitutional psychopathic state; myocarditis, chronic.

CASE 19.—C. N., age 35 years. February 8, 1921, developed pneumonia. February 19, 1921, complication, empyema, right pleural cavity, hemolytic streptococcus type. Aspirated four times. March 6, 1921, operation; incision and drainage of empyema cavity. March 17, 1921, thoracotomy; resection of 10 cm. of seventh rib, midaxillary line, right chest; and better drainage instituted. May 30, 1921, incision over old scar and the resection of an additional 10 cm. of seventh rib, anterior aspect; and drainage reestablished. July 3, 1921, admitted to empyema service, Walter Reed General Hospital.

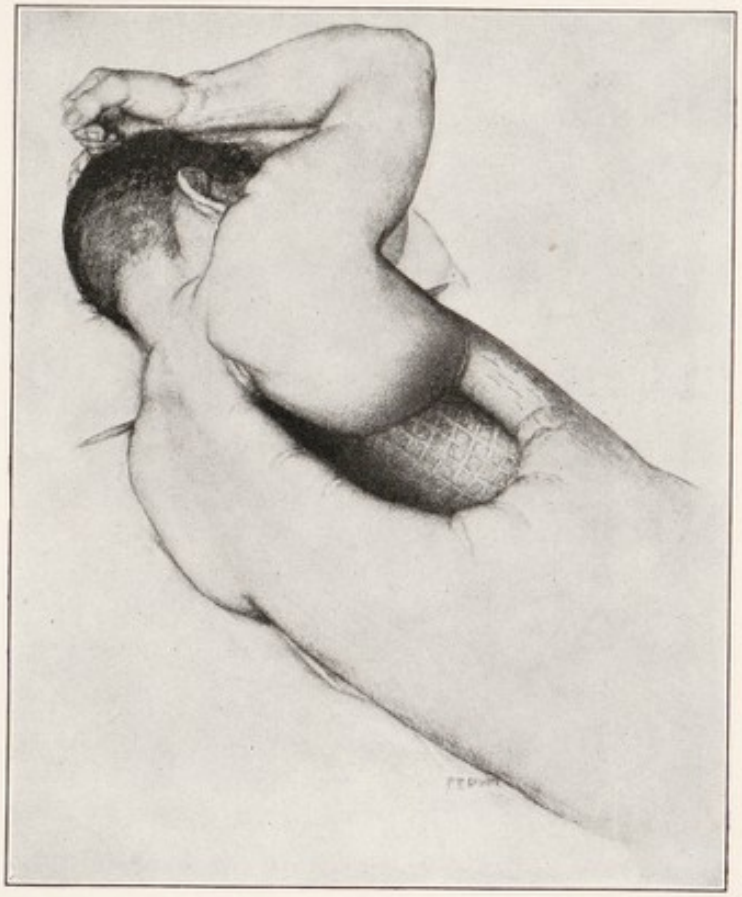

FIG. 109.—Case 18: Second stage in the closure of the wound.

Condition on admission: Ambulatory case; poorly nourished; present weight, 118 pounds (normal weight, 165 pounds). Examination of chest revealed sinus discharging pus seventh interspace, midaxillary line, right chest; pleurobronchial fistula present; and drainage not dependent. Radiographs showed a partial collapse of the right lung with some thickening of the pleura, right lateral chest, and a cavity formation extending from the fourth to the ninth rib and posterior to the sinus draining it. Clinical laboratory examination: Wassermann negative; sputum negative for tubercle bacilli; white blood count, 13,700; red blood count, 3,990,000; urine negative; culture from cavity showed heavy growth of hemolytic streptococcus. Blood pressure: Systolic, 128; diastolic, 88; pulse pressure, 40. Vital capacity reading 2,300 c. c. July 7, 1921, operation; resection of seventh and eighth ribs, posterior axillary line, right chest; roof of cavity removed; two pleurobronchial fistulæ exposed; skin inverted over muscle to preserve it for final closure and to render dressings less painful; cavity left open for active dakinization. July 25, 1921, resection of 15 cm. of the sixth rib, midaxillary line, rib stumps of the previously resected ribs removed; cavity widely exposed; discission of the visceral pleura; lung mobilized about fistula; cavity left open for active dakinization. September 29, 1921, excision of scar and mobilization of lung about fistula; cavity left open for dakinization. December 15, 1921, cavity apparently sterile after seven consecutive daily cultures; pleuropulmonary communications, closed. December 16, 1921, plastic closure; implantation of a part of the latissimus dorsi into that portion of the cavity which was not completely obliterated. The severed superficial muscles were brought in apposition, skin closed by figure-of-eight silkworm gut suture; and rubber dam drainage instituted. January 1, 1922,

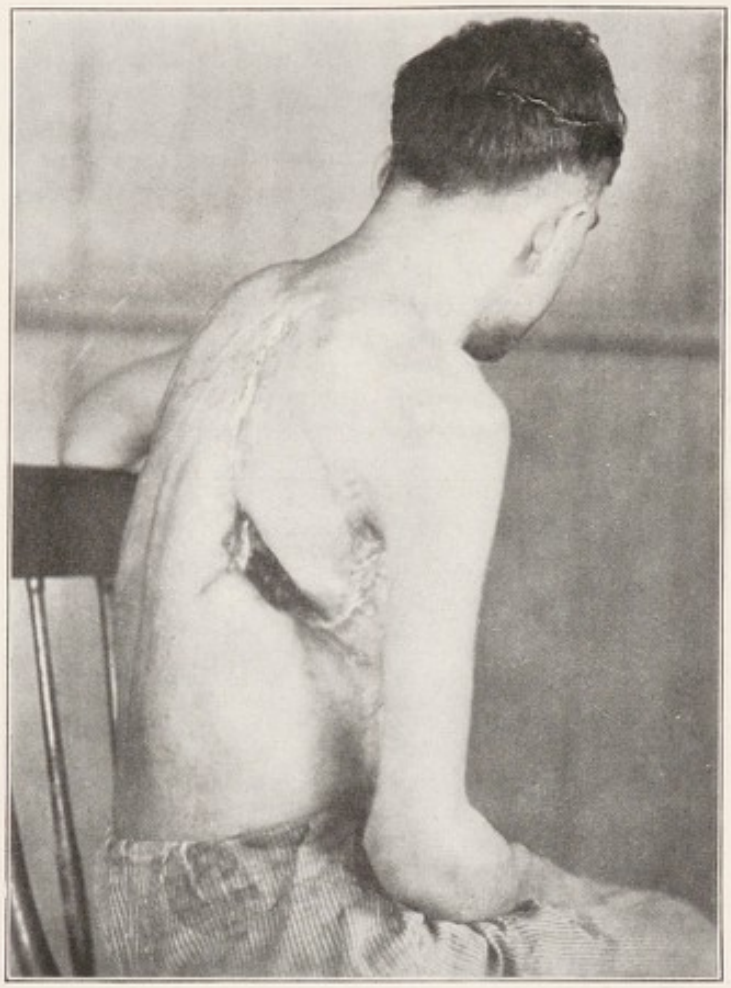

FIG. 110.—Case 18: Third stage in the closure of the wound.

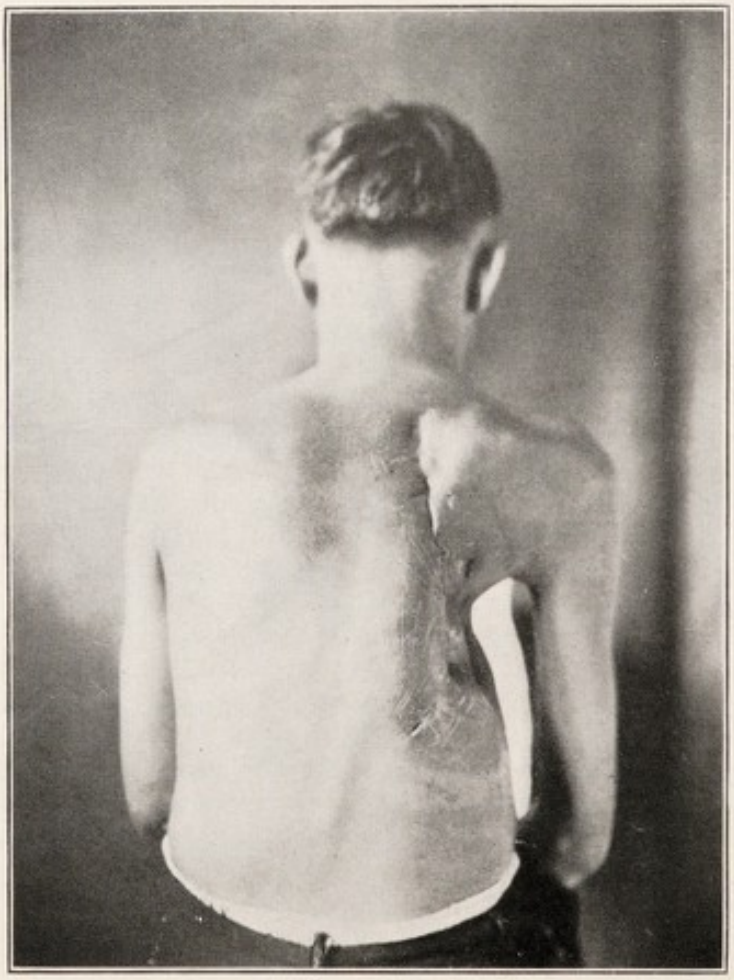

FIG. 111.—Case 18: Posterior view of the wound, with healing practically complete.

patient entirely healed; general condition excellent; increase in weight since first operation; X ray showed total obliteration of all cavity formation and the lung well expanded. February 1, 1922, general condition excellent; weight on admission to this hospital 118 pounds, present weight, 165 pounds; vital capacity reading, 3,400 c. c.

Factors to be combated in this case were hemolytic streptococcus organism present; osteomyelitis with rib sequestration; two pleurobronchial fistulæ; primary drainage not dependent.

Case 20.—H. S. J., aged 26 years. January 10, 1918, developed influenza and pneumonia. January 20, 1918, complication, empyema, right pleural cavity, hemolytic streptococcus type. Aspirated twice. January 24, 1918, thoracotomy; resection of portion of seventh rib, midaxillary line, with the institution of drainage for five months without irrigation, followed by irrigation with Dakin's solution for two weeks. June 19, 1918, additional rib resection; institution of better drainage. November 11, 1918, resection of portion of eighth and ninth ribs to allow better drainage; and daily irrigation with Dakin's solution. February 19, 1920, resection of sixth, seventh, eighth, and ninth ribs, right chest, midaxillary line; partial decortication of visceral pleura; removal of portion of thickened parietal pleura; cavity closed; rubber tube drainage. June 3, 1920, cavity reopened and further decortication was done in an attempt to obliterate cavity, lower aspect being left open for dakinization. November 10, 1920, admitted to empyema service, Walter Reed General Hospital.

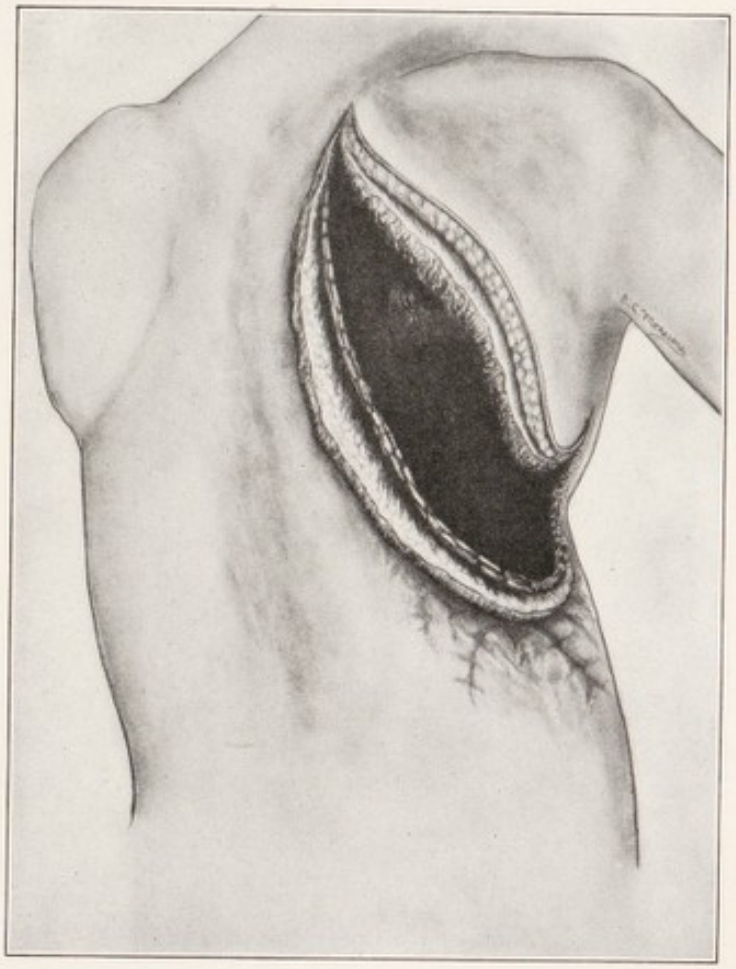

Fig. 112.—Case 20: Persistent bronchial fistula in a wound otherwise ready for closure.

Condition on admission: Ambulatory case; anemic; highly septic; poorly nourished; present weight, 111 pounds (normal weight, 145 pounds), fingers clubbed; extremities edematous. Examination of chest revealed sinus discharging pus, posterior axillary line; marked deformity of contour of right chest due to previous operations. Radiograph showed marked collapse of right lung with extensive thickening of pleura from apex to base, and a bismuth-filled cavity extending from second rib to midaxillary line, with multiple diverticula draining into main cavity. Capacity of cavity, 200 c. c. Pleurobronchial fistula present, the communication being almost direct to the hilus of the lung. Osteomyelitis of rib stumps present. Clinical laboratory examination: Wassermann negative; sputum negative for tubercle bacilli; white blood count, 12,600; red blood count, 3,750,000; urine showed trace of albumin; culture from cavity showed heavy growth of hemolytic streptococcus. Blood pressure: Systolic, 110; diastolic, 80; pulse pressure, 30. Vital capacity reading, 1,500 c. c.

November 17, 1920, resection of fifth, sixth, seventh, and eighth ribs, posterior scapular line, right chest; excision of thickened parietal pleura and scar tissue; cavity laid wide open; multiple diverticula noted, their roofs being excised; preparation of cavity for active dakinization. December 6, 1920, resection of 10 cm. of third, fourth, and fifth ribs; cavity laid wide open; dakinization continued. January 12, 1921, excision of another diverticulum, or sinus tract, draining into

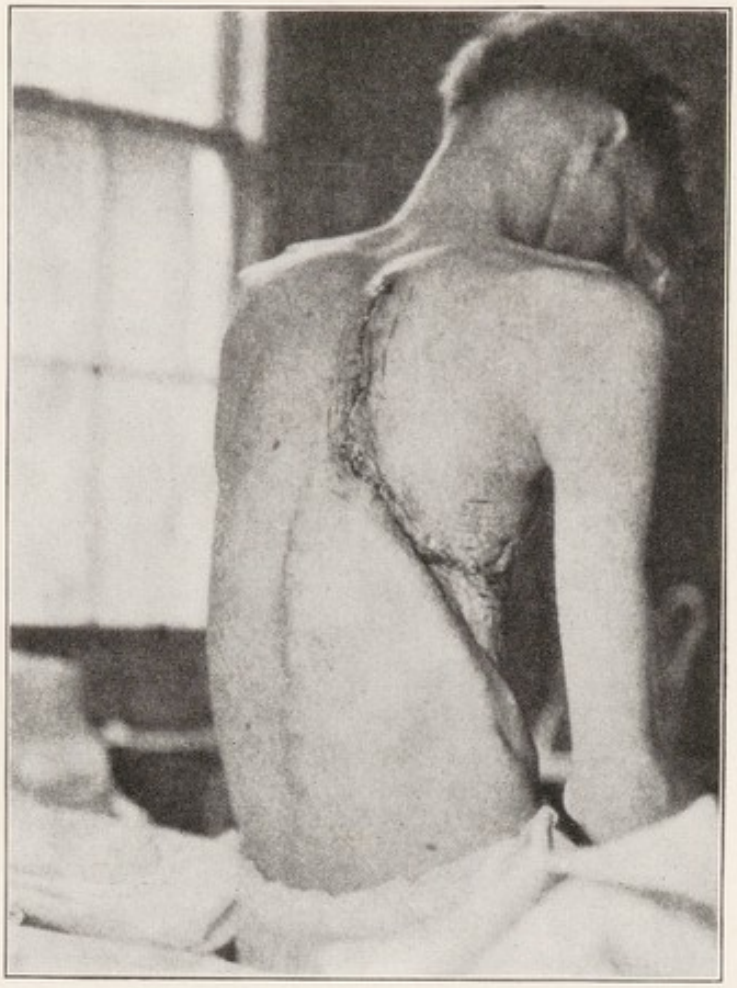

FIG. 113.—Case 20: The wound immediately after closure.

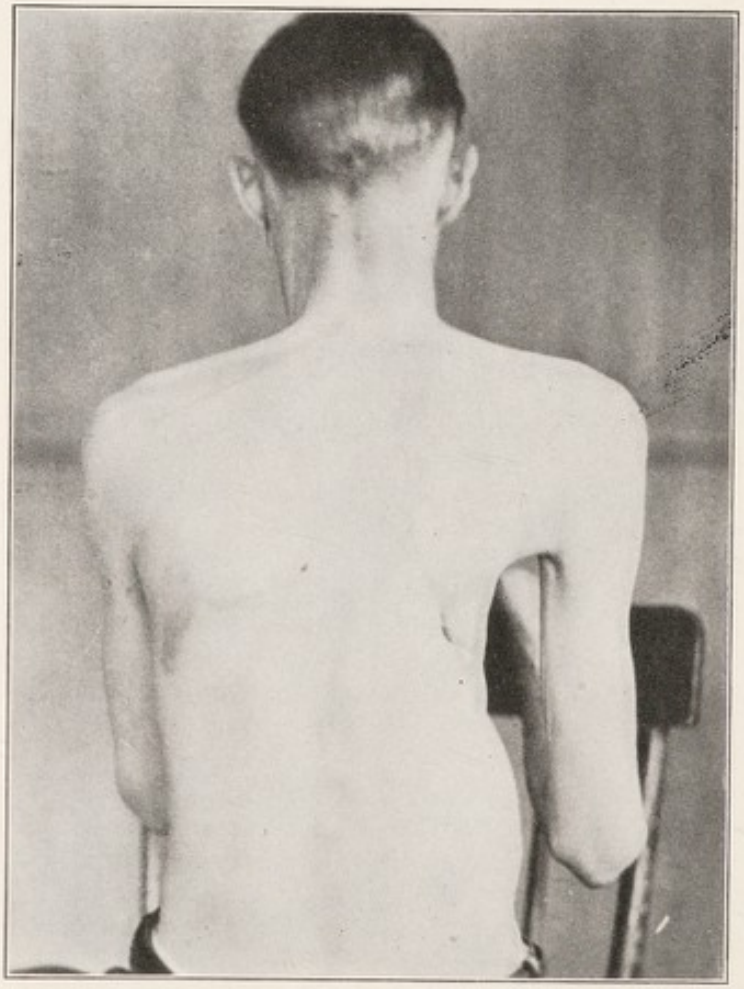

FIG. 114.—Case 20: Final result.

main cavity; dakinization continued. March 31, 1921, excision of old scar, lower aspect of cavity, and an additional portion of the eighth rib resected which had become osteomyelitic. May 17, 1921, incision, anterior axillary line; resection of parts of fifth, sixth, and seventh ribs; three additional sinus tracts found and excised; active dakinization continued. June 23, 1921, resection of third and fourth ribs, anterior axillary line; removal of roof cavity; dakinization continued; discission of visceral pleura and mobilization of lung about bronchial fistula. July 27, 1921, incision along old posterior scar; apex of cavity exposed posteriorly; dakinization continued. October 3, 1921, resection of 5 cm. of third rib, posterior scapular line; excision of thickened parietal pleura; discission of visceral pleura; mobilization of lung about bronchial fistula; dakinization continued. January 12, 1922, resection of regenerated stumps of third, fourth, and fifth ribs, anterior to posterior axillary line; portion of subscapularis muscle implanted over fistula after lung had been mobilized about fistula; anterior aspect of cavity closed; superficial muscle brought in apposition and sutured skin closed by means of silkworm gut; multiple scarification of skin to cause relaxation; posterior aspect of cavity left open for dakinization. March 3, 1922, secondary closure with implantation of portion of latissimus dorsi into remaining cavity which was not obliterated by lung expansion, fistula having remained closed following last operation and cavity sterile; superficial muscles brought in apposition and sutured; skin closed by means of silkworm gut; rubber dam drainage for 24 hours; multiple scarification of skin to cause relaxation. April 1, 1922, patient improving, but had small area of tenth rib showing osteomyelitis, requiring resection at a future date. May 5, 1922, operation; resection of 10 cm. of tenth rib, posterior axillary line, right chest, and excision of sinus tract leading down to it; entire area left wide open for active dakinization. June 26, 1922, patient entirely healed; fistula closed; all cavity formation obliterated; lung well expanded; general condition excellent; weight on admission, 111 pounds; present weight, 122 pounds; vital capacity reading, 2,200 c. c.

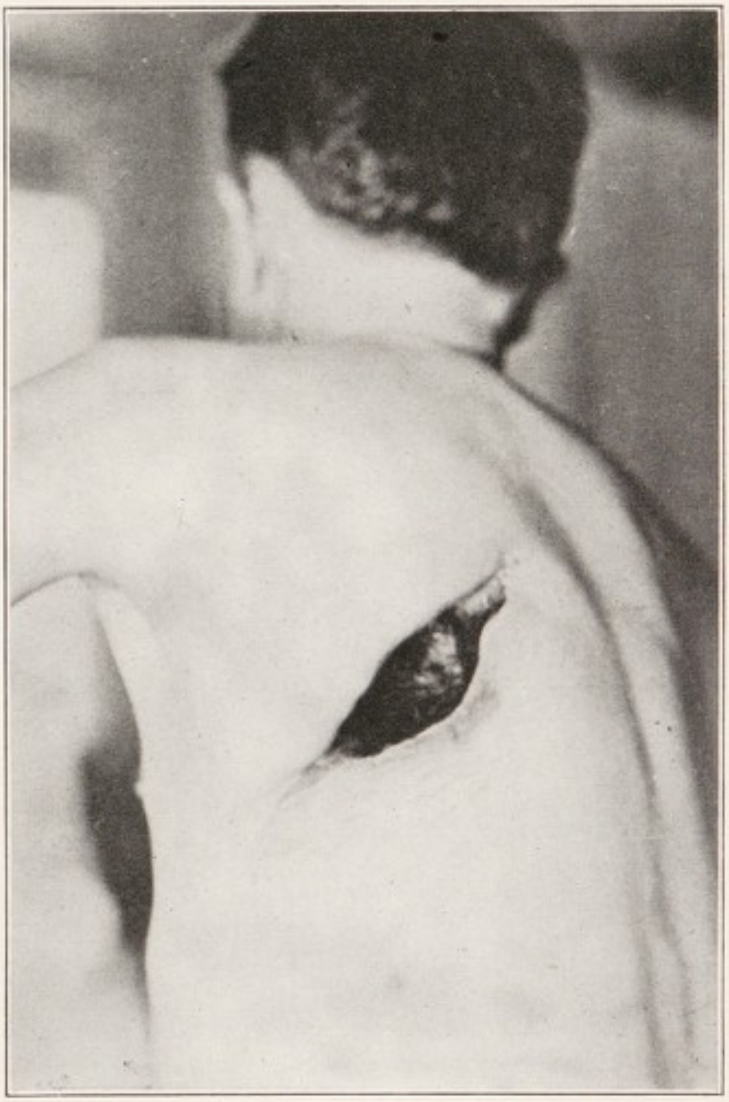

FIG. 115.—Case 21: A stage in the healing of the wound.

Factors to be combated in this case were hemolytic streptococcus infection; osteomyelitis of rib stumps; secondary cavities and diverticula; pleurobronchial fistula; marked bridging and overlapping of regenerated rib formation.

CASE 21.—R. H. S., age 30 years. November 1, 1918, in action, received a gunshot wound, left chest, penetrating sixth interspace, nipple line. November 4, 1918, developed influenza, which was complicated by pneumonia November 10, 1918, and by empyema, left pleural cavity, hemolytic streptococcus type, November 17, 1918. Aspirated four times. November 25, 1918, operation; thoracotomy; resection of a portion of the eighth rib midscapular line, with the institution of drainage. March 22, 1919, discharged from the service, still draining; had been reopened 12 times for the institution of drainage. January 26, 1922, admitted to the empyema service, Walter Reed General Hospital.

Condition on admission: Ambulatory case; fairly well nourished but considerably underweight, normal weight, 165 pounds; present weight, 145 pounds. Examination of chest: Sinus discharging pus, eighth interspace, midscapular line, left chest; drainage not dependent. Radiographs showed marked collapse of left lung; a cavity formation, with a capacity of 500 c. c. extending from the fourth to the ninth rib; heart considerably displaced to the right; and marked thickening of the parietal pleura, left lateral chest, from second rib to base. Clinical laboratory examination: Wassermann, negative; sputum, negative for tubercle bacilli; white blood count, 8,050; red blood count, 4,810,000; urine, negative; culture from cavity showed hemolytic streptococcus and staphylococcus aureus. Blood pressure: Systolic, 106; diastolic, 74; pulse pressure, 32. Vital capacity reading, 2,000 c. c.

January 31, 1922, operation; resection of 15 cm. seventh, eighth, and ninth ribs, midscapular line, left chest; excision of thickened parietal pleura forming roof of cavity; skin inverted over severed muscles and fixed over resected rib stumps to render dressings less painful and preserve structures for future closure; multiple scarifications of skin to cause relaxation; preparation of cavity for active dakinization. February 13, 1922, operation; resection of 15 cm. of fourth, fifth; and sixth ribs, posterior axillary line, left chest; removal of thickened parietal pleura forming roof of cavity; discission of visceral pleura to allow lung expansion; skin inverted over muscles that were cut and preserved for future closure; entire cavity left open for active dakinization. March 8,1922, cavity one-fourth its original size and the lung still expanding; bacterial examination showed only a few colonies of staphylococcus aureus. April 5, 1922, plastic closure muscle and skin, with the implantation of a portion of the latissimus dorsi into remaining space after maximum lung expansion had been obtained; skin and superficial muscles brought into apposition and sutured with silkworm gut; scarification of skin to cause relaxation; rubber dam and tube drainage for 24 hours. May 1, 1922, patient entirely healed; general condition excellent; increased weight since first operation; lung well expanded; all cavity formation obliterated. June 12, 1922, healed: physical condition excellent; weight 165 pounds; vital capacity, 3,400 c. c. Discharged, cured, June 12, 1922.

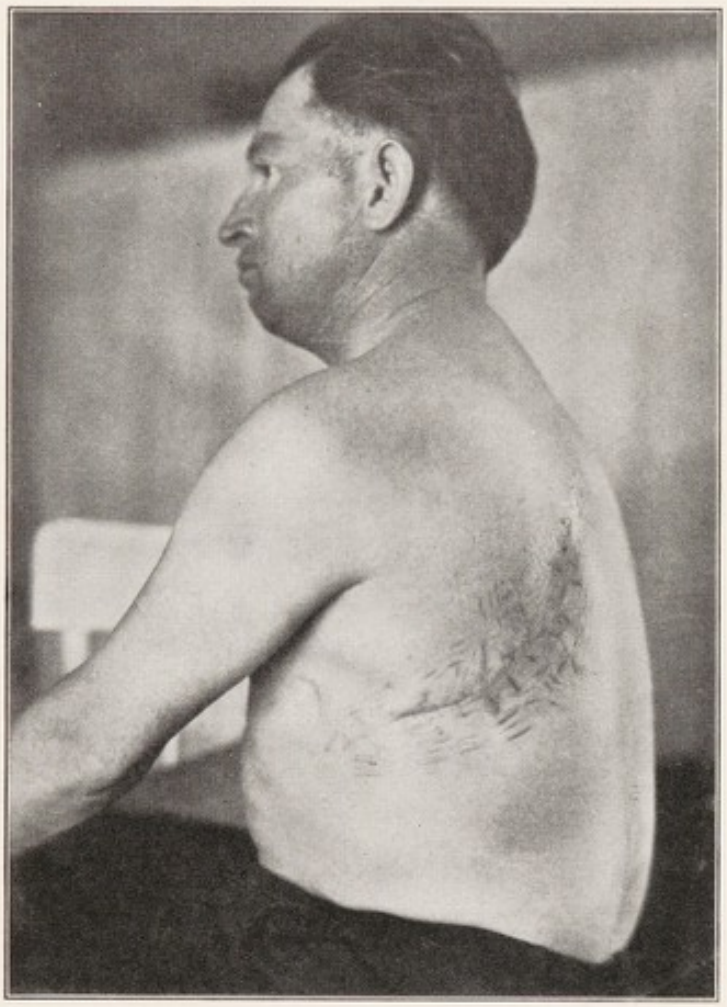

FIG. 116.—Case 21: A posterolateral view of the wound after complete healing.

## Factors to be combated in this case were hemolytic streptococcus organism present; osteomyelitis with rib sequestration; secondary cavity.

CASE 22.—W. L., aged 21 years. February 4, 1921, developed pneumonia. March 1, 1921, complication, empyema, left pleural cavity, hemolytic streptococcus type. Aspirated three times. March 20, 1920, thoracotomy; resection of 10 cm. of sixth rib anterior axillary line, left chest, with the institution of drainage, and cavity irrigated with Dakin's solution. June 9, 1921, admitted to empyema service, Walter Reed General Hospital.

Condition on admission: Ambulatory case; poorly nourished; weight at present, 108 pounds. Examination of chest revealed sinus discharging pus sixth interspace, anterior axillary line, left

chest, and a cavity formation with a capacity of 200 c. c.; drainage not dependent. Radiographs showed a partial collapse of the left lung, with marked thickening of the parietal pleura from the first rib to the base, lateral chest, and a cavity formation extending from the second to the eighth rib posterior to the sinus leading into cavity. Clinical laboratory examination: Wassermann negative; sputum, negative for tubercle bacilli; white blood count, 16,650; red blood count, 4,610,000; urine, negative; culture from cavity showed hemolytic streptococci. Blood pressure: Systolic, 112; diastolic, 74; pulse pressure, 38. Vital capacity reading, 2,100 c. c.

July 8, 1921, operation; resection of 15 cm. of fifth, sixth, and seventh ribs, mid-axillary line, left chest; excision of thickened parietal pleura forming roof of cavity; discission of visceral pleura to allow lung expansion; skin inverted over severed superficial muscles and fixed over ends of resected ribs to preserve it for final closure and to render dressing less painful; multiple scarifications of skin to lessen tension; cavity left wide open for active dakinization. August 10, 1921, discission of visceral pleura to allow lung expansion. Cavity now not one-fourth its original size, and cleaning up under dakinization. September 13, 1921, operation; plastic closure, with the implantation of a portion of the pectoralis major into the small remaining cavity

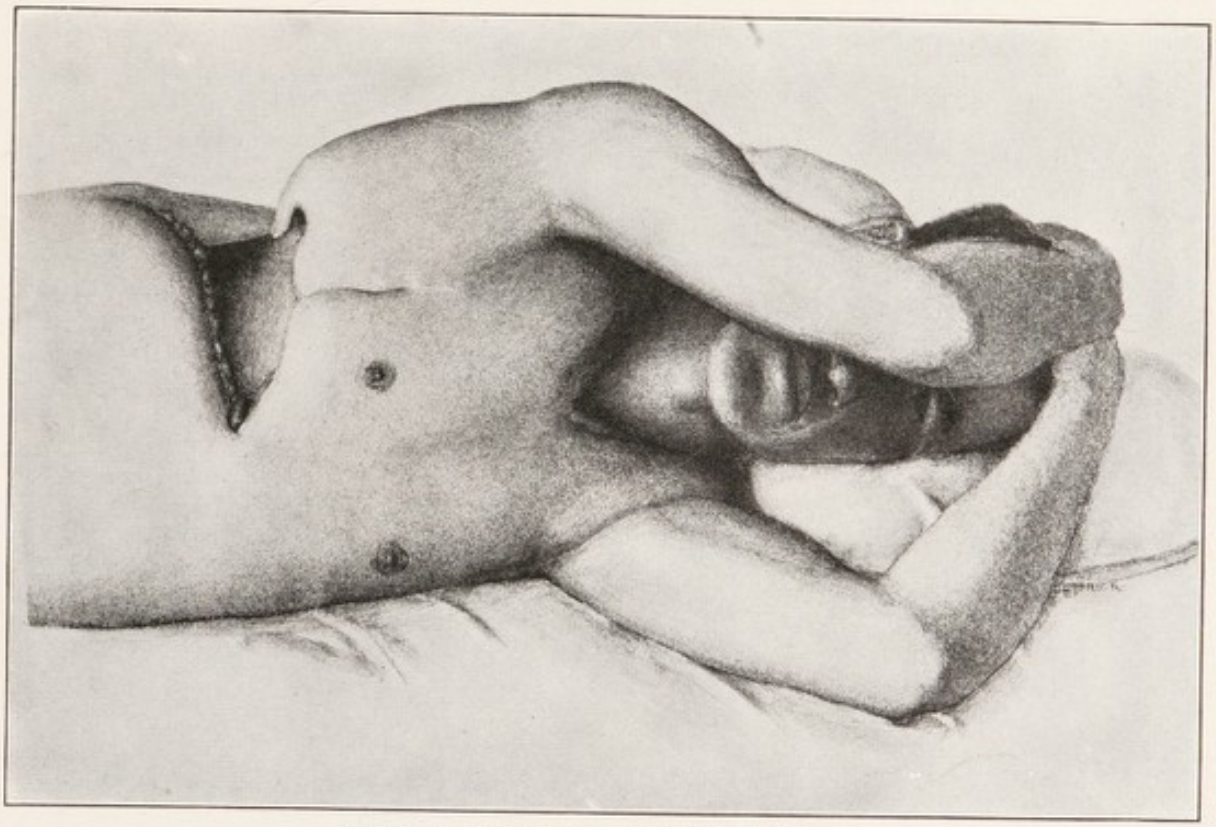

FIG. 117.—Case 23: The wound before closure.

which was not obliterated by lung expansion; the severed superficial muscles were brought into apposition and sutured with catgut; the skin freed and all scar tissue removed; edges brought in apposition and closed with figure-of-eight silkworm gut sutures; rubber dam drainage; multiple scarifications of the skin to lessen tension. November 5, 1921, patient healed and feeling splendidly; general condition excellent; weight at present, 127 pounds; vital capacity reading, 3,100 c. c.; discharged from hospital. cured, January 6, 1922.

Factors to be combated in this case were hemolytic streptococcus organism present; osteomyelitis of ribs; drainage not dependent.

CASE 23.—C. J. W., age 27 years. January 5, 1918, developed pneumonia. January 12, 1918, complication, empyema, right pleural cavity, hemolytic streptococcus type. Aspirated eight times. January 22, 1918, thoracotomy; resection of 10 cm. of eighth rib, posterior axillary line, right chest; rubber tube valve inserted for drainage, and Carrel tubes used to instill Dakin's solution. Remained under treatment by this method until May 15, 1919, when he was discharged from the service with an open sinus still discharging pus. Returned to his home and remained there under treatment by a private physician, chest being reopened nine times to institute drainage of a large accumulation of pus. August 11, 1921, admitted to empyema service, Walter Reed General Hospital.

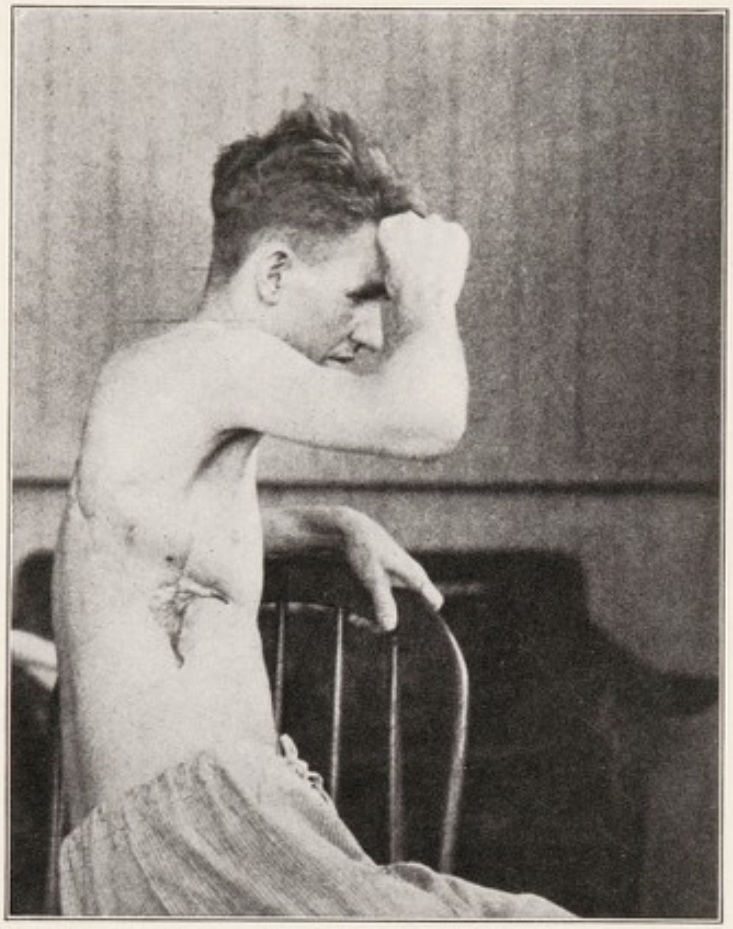

FIG. 118.—Case 23: A stage during healing of the wound.

FIG. 119.—Case 23: A lateral view of the final result.

Condition on admission: Ambulatory case; poorly nourished; present weight, 123 pounds (normal weight, 162 pounds). Examination of chest revealed sinus discharging pus, eighth interspace, posterior axillary line, right chest. Radiographs showed marked collapse of right lung with extensive thickening of pleura, lateral chest, from second rib to base; a cavity formation from fourth to tenth rib; a piece of rubber tubing, 2½ inches in length in the lower aspect of cavity. Pleurobronchial fistula present. Capacity of cavity, 400 c. c.; osteomyelitis with sequestration of the eighth and ninth ribs, which were fused and overlapping. Clinical laboratory examination: Wassermann negative; sputum negative for tubercle bacilli; white blood count, 9,200; red blood count, 4,500,000; urine showed trace of albumin; culture from cavity showed heavy growth of hemolytic streptococci. Blood pressure: Systolic, 142; diastolic, 84; pulse pressure, 58. Vital capacity reading, 1,800 c.c.

October 12, 1921, operation; resection of 15 cm. of the seventh, eighth and ninth ribs, posterior axillary line, right chest; cavity laid wide open and thickened parietal pleura excised; removal of Carrel valve or rubber tube which had been in cavity over two years; discission of visceral pleura to allow lung expansion; skin inverted over muscles to preserve it for final closure, and to render dressings less painful; preparation of cavity for Carrel-Dakin technique for its sterilization. October 31, 1921, operation; resection of anterior portion of seventh rib and part of costal cartilage, with a resection of 15 cm. of eighth rib, right chest, anterior axillary line, and the removal of overlying thickened pleura exposing secondary cavity; skin and muscle preserved for future closure; discission of visceral pleura to allow lung expansion. November 30, 1921, operation; resection of 20 cm. of fifth, sixth and seventh ribs, posterior scapular line, right chest, and resection of 5 cm. of eighth, ninth and tenth ribs same line, with removal of thickened pleura forming roof of secondary cavity which had been sterilized; discission of visceral pleura exposed, and implantation of a portion of the latissimus dorsi and subscapularis muscles into upper aspect of cavity; muscle and skin closure over this area. January 6, 1922, operation; resection of 10 cm. of the ninth, tenth and eleventh ribs, and excision of two sinus tracts, one following the course of the tenth rib and the other leading down to the twelfth rib, midaxillary line, right chest; skin inverted over muscle which was saved for future closure; area left open for active dakinization. February 6, 1922, operation; resection of 10 cm. of the fourth, fifth and sixth ribs, anterior axillary line, right chest, with the removal of the roof of another secondary cavity and the preparation of cavity for active dakinization. April 5, 1922, partial plastic closure of muscle and skin, with the implantation of portion of the superficial muscles into the upper aspect of the cavity, midaxillary line; injection of iodoform emulsion before area was closed; lower, anterior portion of secondary cavity likewise closed and skin and muscle brought in apposition and sutured with silkworm gut; emulsion injection; multiple scarification of skin to cause relaxation; rubber dam drainage for 48 hours. June 26, 1922, patient healed; fistula closed; all cavity formation obliterated; lung well expanded; general condition excellent; patient had taken on some weight; vital capacity reading, 2,500 c.c.

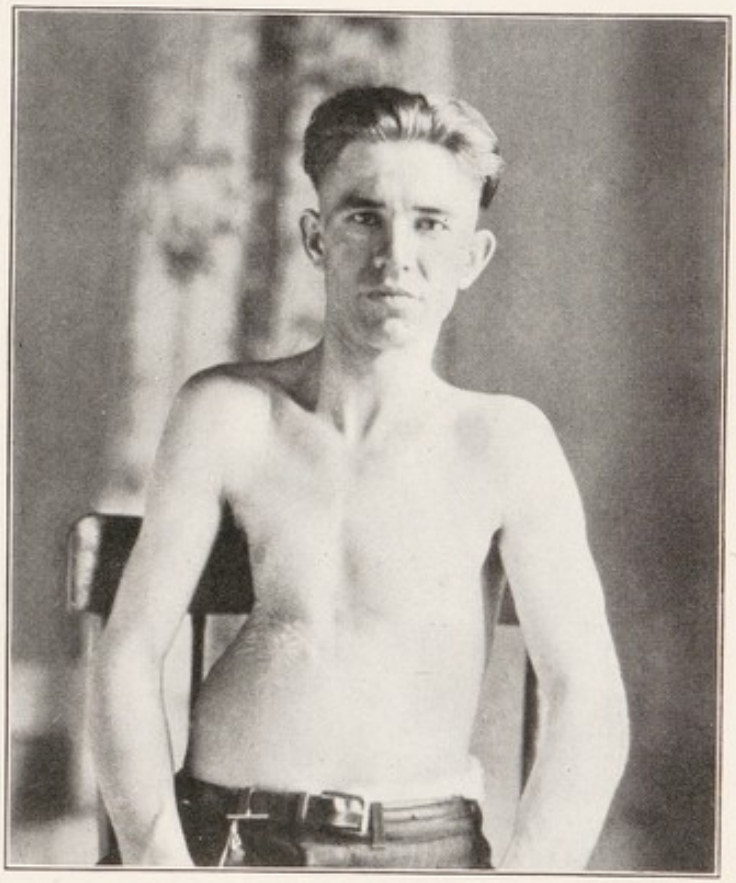

FIG. 120.—Case 23: Anterior view of the final result.

Factors to be combated in this case were hemolytic streptococcus organism present; Carrel valve rubber drainage tube left in cavity; osteomyelitis with rib sequestration; pleurobronchial fistula; secondary cavity and diverticula (five in number); nephritis, chronic, interstitial; tuberculosis, diagnosed by pathological specimen; chondritis of sixth, seventh and eighth costal cartilage.

CASE 24.—J. R. S., age 27 years. October 25, 1918, received a perforating, high explosive gunshot wound, left chest, in action. Débridement operation 12 hours later, and chest closed following operation without drainage. Five days later he was aspirated, with the removal of 1,600 c.c. of purulent, bloody fluid; two additional aspirations followed with the removal of frank pus. November 16, 1918, thoracotomy; resection of a portion of the seventh and eighth ribs, left chest, and the institution of drainage. Allowed to close three months later, although patient was expectorating bloody pus. February 26, 1919, returned to the United States and hospitalized under the suspected diagnosis of tuberculosis, pulmonary, inactive, left lung. Patient at this time had a pneumothorax and a pleuropulmonary communication with a large cavity formation and abundant expectoration of bloody pus. Hemolytic streptococcus organism was present in expectoration. Treated for tuberculosis at two tuberculosis hospitals. Patient partially able to drain his cavity by lying on his right side and coughing. During his stay at these hospitals he received numerous aspirations with the removal of from 300 to 500 c.c. of pus. Sputum continued to be negative and patient was treated as a tubercuolsis suspect until his admission to Walter Reed Hospital. May 10, 1921, admitted to the empyema service, Walter Reed General Hospital.

Condition on admission: Ambulatory case; anemic; highly septic; poorly nourished; weight, 130 pounds (normal weight, 190 pounds); expectorating bloody pus. Examination of chest revealed marked lagging of the left side on deep inspiration; scar formation over the seventh and eighth ribs, posteriorly; impaired resonance to flat note over entire left chest, breath sounds distant. Radiographs showed marked collapse of left lung, extensive thickening of parietal pleura from apex to base and a large cavity formation extending from fifth to ninth ribs; posterior chest partially filled with fluid. A small metallic foreign body was noted in the region of the left hilus. Pleurobronchial fistula present. Patient able to partially drain his cavity. There was osteomyelitis of the previously resected rib stumps. Clinical laboratory examination: Wassermann negative; sputum negative for tubercle bacilli; white blood count, 10,700; red blood count, 4,190,000; urine negative; culture from expectorated pus revealed hemolytic streptococcus and this organism was also present in cultures from cavity, when the latter was opened. Blood pressure: Systolic, 115; diastolic, 70; pulse pressure, 45. Vital capacity not taken.

May 20, 1921, operation; resection of 15 cm. of seventh, eighth, and ninth ribs, posterior scapular line, left chest; roof of cavity over this area excised; cavity laid wide open; pleurobronchial fistula exposed; 100 c.c. pus evacuated; preparation of cavity for active dakinization. June 4, 1921, operation; extension of incision along posterior border of scapula; resection of 15 cm. of sixth and seventh ribs; excision of thickened parietal pleura; cavity laid wide open; closure of bronchial fistula by purse-string suture, the communication being one of the main limbs of the bronchial tree near hilus; lung mobilized in this area and the implantation of muscle flap, part of the infraspinatus, over the site of the fistula; cavity prepared for active dakinization; skin inverted over severed muscles and fixed; wound firmly packed. Two hours later patient had secondary hemorrhage from the vessels of the hilus; active measures to control bleeding were instituted but there was considerable bleeding before hemorrhage could be controlled. Patient passed into profound shock and in spite of all combative measures died one hour later.

Factors to be combated were hemolytic streptococcus present; pleurobronchial fistula of one of the main bronchi near the hilus; osteomyelitis of resected rib stumps; no drainage except through expectoration; long-continued sepsis.

CASE 25.—C. O. R., age 19 years. February 13, 1921, developed measles; followed by pneumonia, April 1, 1921; and complicated by empyema, left pleural cavity, hemolytic streptococcus type, May 24, 1921. Aspirated six times. May 29, 1921, thoracotomy; resection of 10 cm. of eighth rib, posterior axillary line, with the institution of drainage. Irrigated daily. October 18, 1921, admitted to empyema service, Walter Reed General Hospital.

Condition on admission: Ambulatory case; fairly well nourished; normal weight, 158 pounds; present weight, 145 pounds. Examination of chest revealed sinus discharging pus, eighth inter-

space, posterior axillary line, left chest, and a cavity formation with a capacity of 100 c. c. Radiographs showed a partial collapse of the left lung with some thickening of the pleura from the fourth to ninth rib, left lateral chest, and a cavity formation, extending from the seventh to the ninth rib, filled with pus and containing a rubber tube in its lower aspect; heart displaced to the right. Clinical laboratory examination: Wassermann negative; sputum negative for tubercle bacilli; white blood count, 17,460; red blood count, 4,700,000; urine negative; culture from cavity showed hemolytic streptococcus and staphylococcus aureus. Blood pressure: Systolic, 138; diastolic, 88; pulse pressure, 50. Vital capacity reading, 2,700 c. c.

November 2, 1921, resection of 15 cm. of eighth and ninth ribs, posterior axillary line, left chest; excision of thickened parietal pleura forming roof of cavity; the removal of a 3-inch rubber tube and the evacuation of 100 c. c. of pus; skin fixed over severed muscle to prevent retraction; and cavity left wide open for active dakinization. December 1, 1921, cavity sterile after seven consecutive daily cultures; the lung had reexpanded and completely obliterated all cavity; only a small granulating wound of the skin and superficial tissues remained unhealed. December 15, 1921, patient healed and feeling well; lung well expanded; general condition excellent; weight at present, 164 pounds; vital capacity reading, 3,800 c. c. Discharged from hospital, cured, January 6, 1922.

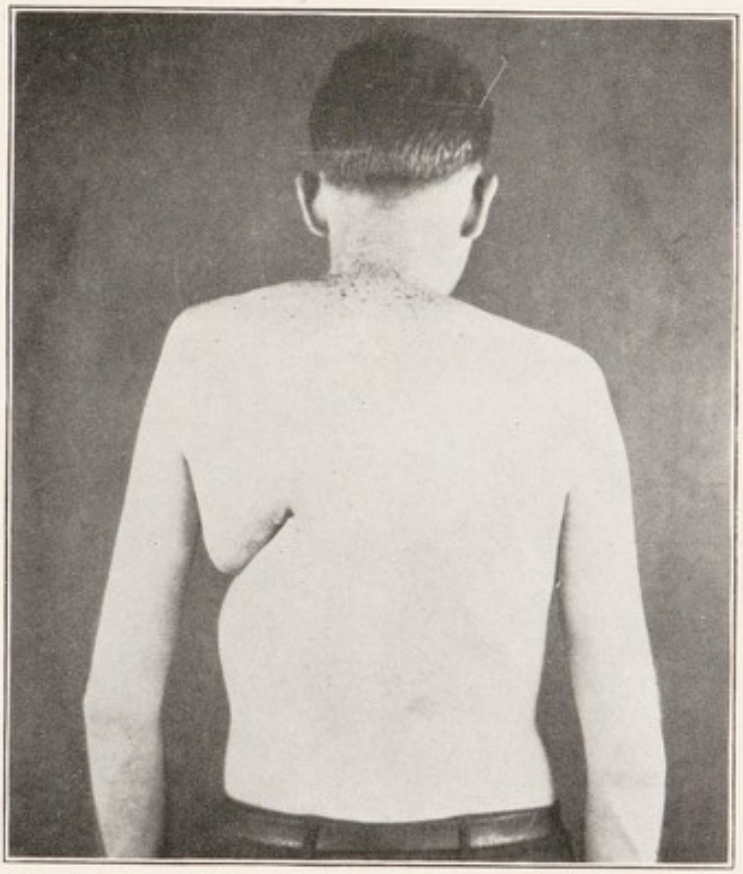

FIG. 121.—Case 26: Area beneath angle of scapula to be closed by skin and muscle suture.

Factors to be combated in this case were hemolytic streptococcus present; foreign body (rubber tube) which had remained in cavity for three months; osteomyelitis of eighth and ninth ribs.

CASE 26.—J. W. W., age 27 years. May 16, 1918, developed influenza, complicated by empyema, left pleural cavity, hemolytic streptococcus type, June 8, 1918. Aspirated once. June 10, 1918, operation: thoracotomy; resection of 10 cm. of seventh rib, anterior axillary line, left chest; pleural cavity opened and 500 c. c. of pus evacuated; rubber-tube valves inserted into cavity for drainage. October 5, 1918, operation; thoractomy; resection of a portion of the proximal end of the left seventh rib, and the institution of drainage. January 12, 1919, incision, with institution of drainage. September 17, 1919, resection of a portion of the seventh rib and regenerated bone, and drainage again instituted with a Dakin solution irrigation. Discharged from service February, 1920, and taken over as a Public Health patient, being treated in a number of hospitals, and was sent to Mont Alto, Pa., for treatment of suspected tuberculosis. December 5, 1921, admitted to empyema service, Walter Reed General Hospital.

Condition of admission: Ambulatory case; poorly nourished; normal weight, 165 pounds; present weight, 148 pounds; joints of extremities edematous and tender; persistent cough, with the expectoration of frank pus; highly septic; fingers clubbed. Examination of chest revealed marked lagging of the left side on deep inspiration; scar formation over the seventh rib from the anterior to the posterior axillary line; percussion revealed impaired resonance to flat note from second rib to base of left chest; auscultation breath sounds distant and indistinct. Radiographs showed marked collapse of left lung, with extensive thickening of pleura, left lateral chest, from second rib to base.

and a large cavity formation filled with fluid and extending from fourth rib, posterior chest, down to ninth rib; marked displacement of heart to the right. Pleurobronchial fistula present and patient was partially able to drain his cavity by lowering his head and coughing. Clinical laboratory examination: Wassermann negative; sputum negative for tubercle bacilli; white blood count, 12,700; red blood count, 4,200,000; urine negative; culture from cavity showed heavy growth of hemolytic streptococcus. Blood pressure: Systolic, 122; diastolic, 80; pulse pressure, 32. Vital capacity reading, 2,000 c. c.

December 14, 1921, operation; resection of 20 cm. of sixth, seventh, eighth, and ninth ribs, posterior axillary line, left chest; cavity laid wide open and 500 c. c. of pus evacuated; the thickened parietal pleura, forming roof of cavity, excised; discission of the visceral pleura to allow lung expansion and to mobilize the lung about fistula; skin inverted over muscle to preserve it for final closure; and cavity prepared for the Carrel-Dakin technique. January 5, 1922, discission of visceral pleura and the treatment of fistula with a 2 per cent alcoholic solution of gentian violet to mechanically plug it until granulations entirely obliterate communication. February 20, 1922, cavity entirely obliterated; pleurobronchial fistula closed; and wound sterile by seven consecutive daily cultures. February 24, 1922, operation; partial secondary closure; upper and posterior aspect of wound closed by muscle and skin with silkworm gut; and rubber dam drainage. March 8, 1922, operation; secondary closure, lower aspect of wound; all scar tissue removed and muscle and skin brought in apposition and sutured; rubber dam drainage; and multiple scarification of skin to cause relaxation and relieve tension. March 20, 1922, patient entirely healed; general condition excellent; weight on admission, 148 pounds; weight at present, 170 pounds; vital capacity reading, 3,200 c. c. June 15, 1922, patient discharged, entirely cured; healed two months; condition excellent.

FIG. 122.—Case 26: Lateral view of final result.

Factors to be combated in this case were hemolytic streptococcus present; pleurobronchial fistula present; osteomyelitis with sequestration of rib.

CASE 27.—C. F. N., age 20 years. February 4, 1921, developed pneumonia; complicated by empyema left pleura cavity, hemolytic streptococcus type, May 3, 1921. Aspirated once. May 5, 1921, thoracotomy; resection of 10 cm. of eighth rib, posterior scapular line, with the evacuation of 500 c. c. of pus and the institution of drainage; Dakin's solution used to irrigate cavity. December 3, 1921, admitted to empyema service, Walter Reed General Hospital.

Condition on admission: Ambulatory case; well nourished; about normal in weight (145 pounds). Examination of chest: Sinus discharging pus, eighth interspace posterior scapular line, left chest. Radiographs showed partial collapse of left lung, with some thickening of parietal pleura, left lateral chest, and a cavity formation extending from sixth to tenth rib, posterior scapular line, with a capacity of 100 c. c.; osteomyelitis of eighth and ninth ribs in the area of primary operation. Clinical laboratory examination: Wassermann negative; sputum negative for tubercle bacilli; white blood count, 9,800; red blood count, 4,890,000; urine negative; culture from cavity showed hemolytic streptococcus and staphylococcus aureus. Blood pressure: Systolic, 126; diastolic, 82; pulse pressure, 44. Vital capacity reading, 2,800 c. c.

December 8, 1921, operation; resection of 15 cm. of the seventh, eighth, and ninth ribs, posterior scapular line; excision of thickened parietal pleura forming roof of cavity; discission of visceral pleura to allow lung expansion; skin inverted over muscle to preserve it for final closure; and preparation of cavity for the Carrel-Dakin technique. January 20, 1922, lung had expanded and cavity was down to one-fourth its size and was sterile; patient's general condition was excellent. January 24, 1922, plastic closure; a portion of the latissimus dorsi implanted into the remaining space and the severed superficial muscles and skin brought in apposition and sutured; rubber dam drainage along suture line. February 15, 1922, patient completely healed and feeling well. Appetite improved; gain weight and strength. March 1, 1922, patient healed; general condition excellent; weight, 150 pounds. Vital capacity reading, 3,900 c. c. May 16, 1922, patient discharged, cured. Healed three months.

Factors to be combated in this case were hemolytic streptococcus present; primary drainage not dependent; osteomyelitis of eighth and ninth ribs.

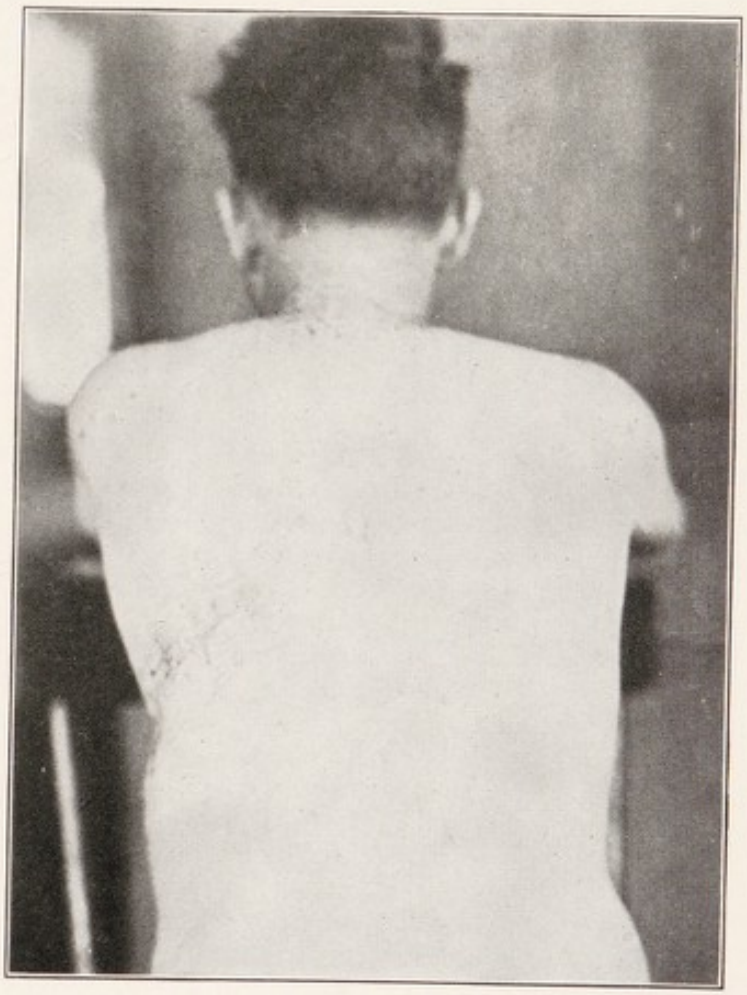

FIG. 123.—Case 26: Posterior view of final result.

CASE 28.—B. F. L., age 28 years October 13, 1918, was gassed in action in Argonne Forest (patient's statement), and was treated in hospital until December, 1918. Discharged from service February 27, 1919. Developed influenza and pneumonia March 1, 1919; complicated by empyema, left pleural cavity, hemolytic streptococcus type, March 20, 1919. Aspirated twice. March 28, 1919, operation; thoracotomy; resection of a portion of the eighth rib posterior axillary line, with the institution of drainage. June 8, 1920, thoracotomy; resection of a portion of the seventh rib, posterior axillary line, and the removal of regenerated eighth rib in the area of operation, with the institution of drainage. October 29, 1920, operation; resection of an additional portion of the anterior stumps of the seventh and eighth ribs, with the institution of drainage. Patient stated that he was reopened to institute drainage eleven times in addition to the above operations. January 20, 1922, admitted to empyema service, Walter Reed General Hospital.

Condition on admission: Ambulatory case; poorly nourished; normal weight, 140 pounds; present weight, 117 pounds; extremities edematous; patient showed the facies of sepsis; fingers clubbed; and marked anemia present. Examination of chest revealed sinus discharging pus seventh interspace, posterior axillary line, left chest; pleurobronchial fistula present. Radiographs showed marked collapse of left lung; extensive thickening of the parietal pleura from apex to base, left lateral chest, and a large cavity (capacity of 450 c. c.) partially filled with pus, extending from this rib to ninth rib, the upper aspect of cavity communicating with the main cavity only by means of a small sinus. Clinical laboratory examination: Wassermann plus minus (had been double plus and patient had received two courses of antisyphilitic treatment); sputum negative for tubercle bacilli; white blood count, 18,550; red blood count, 4,130,000; urine showed trace of albumin; culture from cavity showed hemolytic streptococci. Blood pressure: Systolic, 110; diastolic, 74; pulse pressure, 36. Vital capacity reading, 1,700 c. c.

January 23, 1922, operation; resection of 20 cm. of sixth, seventh, eignth, and ninth ribs, posterior axillary line, left chest; removal of thickened parietal pleura and the excision of thick bands of fibrous tissue dividing the main cavity into three subcavities; the fistula exposed and the skin inverted over the severed muscles; cavity left open for active dakinization. February 23, 1922, operation; resection of 20 cm. of fourth and fifth ribs and 5 cm. of the posterior stumps of the sixth and seventh ribs; excision of parietal pleura forming roof of secondary cavity; discission of visceral pleura to allow lung expansion; cavity left wide open for active dakinization; skin inverted over severed muscles and fixed over rib ends to prevent retraction and to render dressing less painful; multiple scarifications of skin to relieve tension. March 8, 1922, fistula closed by means of repeated applications of a 2 per cent alcoholic solution of gentian violet; cavity appeared to be cleaning up; patient's general condition greatly improved; all edema had disappeared from extremities. March 23, 1922, resection of 10 cm. of third and fourth ribs, posterior scapular line; removal of roof of secondary cavity and remaining sinus injected with iodoform emulsion; muscle implantation into apex of cavity to obliterate the remaining space; and continuation of active dakinization of entire cavity. June 9, 1922, resection of a portion of second, third, fourth, fifth and sixth ribs, posterior scapular line, left chest; excision of thickened parietal pleura forming roof of cavity; entire secondary cavity exposed and complete area left open for active dakinization. June 26, 1922, patient on active dakinization; entire cavity wide open. Bacterial count showed several sterile cultures. All edema of feet and ankles had cleared up. General condition greatly improved.

Because this patient was undergoing vigorous antisyphilitic treatment the cavity was left open.

Factors to be combated in this case were hemolytic streptococcus present; thickened pleura; faulty drainage; scoliosis; accessory cavity.

Case 29.—C. A. W., age 30 years. December 4, 1918, developed influenza and pneumonia; complicated by empyema, left pleural cavity, hemolytic streptococcus type, December 26, 1918. Aspirated once. December 27, 1918, thoracotomy; resection of a portion of the ninth rib, posterior axillary line, with the institution of better drainage, irrigated with Dakin's solution once daily to cleanse cavity. Discharged from the Service September 5, 1920, still draining. Patient stated that he had closed and had been reopened eight times to institute drainage. January 15, 1922, admitted to the empyema service, Walter Reed General Hospital.

Condition on admission: Ambulatory case; poorly nourished and considerably under weight; anemic and with a septic appearance; extremities edematous; fingers clubbed, weight on admission 135 pounds. Examination of chest revealed sinuses discharging pus over seventh and ninth ribs, posterior axillary line, left chest; pleurobronchial fistula present. Radiographs showed marked collapse of left lung with some fibrosis; extensive thickening of the parietal pleura from the second rib to the base, left lateral chest, and a cavity formation filled with pus extending from third rib to ninth rib. Capacity of cavity about 400 c. c. Clinical laboratory examination: Wassermann negative; sputum negative for tubercle bacilli; white blood count, 16,450; red blood count, 4,580,000; urine negative; culture from cavity showed hemolytic streptococcus and staphylococcus aureus. Blood pressure: Systolic, 128; diastolic, 80; pulse pressure, 48. Vital capacity reading, 1,600 c. c.

January 23, 1922, operation; resection of 30 cm. of seventh, eighth, ninth and tenth ribs posterior axillary line, left chest, excision of roof of cavity and thickened parietal pleura and the exposure of part of the cavity and the pleuropulmonary communication; skin inverted over muscle and saved for final closure; cavity left wide open for active dakinization. February 13, 1922, operation; resection of 20 cm. of fourth, fifth and sixth ribs, posterior scapular line, left chest; removal of thickened parietal pleura overlying cavity and secondary cavity exposed; discission of visceral pleura to allow lung expansion; entire cavity left wide open for active dakinization. March 8, 1922, patient's general condition greatly improved; cavity one-half its original size and apparently cleaning up; no edema of extremities present. May 29, 1922, plastic closure, muscle and skin, with the implantation of a portion of the subscapularis and latissimus dorsi muscles; tissues brought in apposition by means of silkworm gut sutures; rubber dam and two Carrel tubes used for drainage for 48 hours; multiple scarification of skin to cause relaxation. June 26, 1922, there were three small sinuses along suture line as result of infection following plastic closure, which were being gradually obliterated; lung well expanded; general condition excellent; patient was taking on some weight; vital capacity reading, 2,600 c. c. Patient entirely healed.

Factors to be combated in this case were hemolytic streptococcus present; pleurobronchial fistula present; fibrosis of lung; secondary cavities or diverticula; diminished vital capacity.

CASE 30.—A. T., age 30 years. November 27, 1921, received gunshot wound, perforating, left chest; complicated by empyema, left pleural cavity, hemolytic streptococcus type, December 5. 1921. Aspirated four times. Received two operations prior to admission to this hospital with resection of seventh and eighth ribs, midscapular line, left chest with the institution of drainage, February 14, 1922, admitted to empyema service, Walter Reed General Hospital.

Condition on admission: Ambulatory case; poorly nourished; under weight; highly septic and showing some anemia; weight on admission, 120 pounds (normal weight, 154 pounds). Examination of chest: Sinus discharging pus eighth interspace, midscapular line, left chest; pleurobronchial fistula present. Radiograph showed some collapse of left lung with considerable thickening of parietal pleura, left lateral chest, and a cavity formation extending transversely in region of fifth, sixth, and seventh ribs, which was partially filled with pus and having a capacity of about 300 c. c. Clinical laboratory examination: Wassermann negative; urine showed trace of albumin; sputum negative for tubercle bacilli; red blood count, 3,960,000; white blood count, 10,800; hemoglobin, 75 per cent; pus from cavity showed hemolytic streptococci. Blood pressure: Systolic, 118; diastolic, 80; pulse pressure, 38. Vital capacity reading, 1,900 c. c.

March 13, 1922, resection of 15 cm. of fifth, sixth, seventh, and eighth ribs, posterior axillary line; excision of thickened parietal pleura over cavity; discission of visceral pleura and lung freed about fistula; cavity left open for active dakinization; skin inverted over superficial muscle to preserve it for final closure. May 4, 1922, excision of diverticulum and entire cavity left open for continued dakinization; small detached sequestra removed from angle of scapula; and superficial muscle brought over angle of scapula and fixed. May 18, 1922, plastic closure of remaining empyema cavity with the implantation of both muscle and skin flap in situ; the entire area closed; muscle and skin brought in apposition and sutured by means of silkworm gut; multiple scarifications of skin to cause relaxation and to prevent slough; rubber dam drainage for 24 hours. June 5, 1922, there were two small areas along the suture line which were not healed as the result of infection following plastic closure. These were being gradually obliterated. June 26, 1922, all but healed; two small areas described above were nearly obliterated and had no connection with the empyema cavity; lung was well expanded; cavity formation had been obliterated; general condition excellent; patient had taken on weight. Weight on admission, 120 pounds; present weight, 147 pounds. Vital capacity reading, 3,100 c.c.

Factors to be combated were hemolytic streptococcus present; osteomyelitis with sequestration of ribs and angle of scapula; pleurobronchial fistula; diverticulum and secondary cavity; bullet tract through lung to be obliterated.

CASE 31.—W. R., age 28 years. February 1, 1917, developed pneumonia; complicated by empyema, right pleural cavity, hemolytic streptococcus type, February 11, 1917. Aspirated three times. February 14, 1917; operation; thoracotomy; resection of a portion of the ninth rib, posterior axillary line; and the institution of drainage. Patient healed March 6, 1918, and entered the military service May 28, 1918. Remained on active duty without recurrence until June 28, 1919, when he was discharged from the service. July 6, 1919, developed a recurrence of empyema. July 8, 1919, operation; incision and drainage, and irrigation with Dakin's solution daily. Had healed and been reopened at least 15 times. March 29, 1922, admitted to empyema service, Walter Reed General Hospital.

Condition on admission: Ambulatory case; well nourished; normal in weight; but slightly anemic and highly septic. Weight on admission, 180 pounds. Examination of chest revealed sinus discharging pus ninth interspace, midscapular line, right chest. Radiograph showed some collapse of the right lung and extensive thickening of the parietal pleura from apex to base, right lateral chest; cavity formation extending transversely from seventh to ninth rib, with a capacity of 250 c.c. Clinical laboratory examination: Wassermann double plus; sputum negative for tubercle bacilli; red blood count, 4,110,000; white blood count, 10,700; hemoglobin, 80 per cent; urine negative; culture from cavity showed hemolytic streptococci. Blood pressure: Systolic, 130; diastolic, 80; pulse pressure, 50. Vital capacity reading, 2,900 c.c.

March 31, 1922, resection of 20 cm. seventh, eighth, and ninth ribs, posterior axillary line, excision of thickened parietal pleura; entire cavity laid wide open; two diverticula draining into main cavity were excised; implantation of a portion of the serratus magnus into the anterior aspect of the cavity; skin inverted over superficial muscles and fixed; multiple scarification of skin to cause relaxation; preparation of cavity for active dakinization. April 17, 1922, resection of 10 cm. of the ninth and tenth ribs midaxillary line to remove osteomyelitic involvement; skin

inverted over superficial muscle; entire cavity left wide open for continued dakinization. May 31, 1922, excision of sinus tract draining into main cavity; removal of a sequestrum or detached particles of rib fragments in area of seventh rib; entire area left open for continued dakinization. June 21, 1922, plastic closure, muscle and skin; implantation of portion of superficial muscle body into remaining space; after maximum lung expansion had been obtained; all scar tissue excised; severed muscles and skin brought in apposition by means of silkworm gut sutures; rubber dam drainage for 48 hours; multiple scarification of skin to cause relaxation. June 28, 1922, all sutures removed and area healed by primary intention; lung was well expanded; general condition excellent; vital capacity, 3,400 c.c.

Factors to be combated were hemolytic streptococcus present; osteomyelitis with sequestration; diverticula and numerous sinus tracts draining into remaining cavity; syphilis, tertiary, manifested by double plus Wassermann; profuse acne.

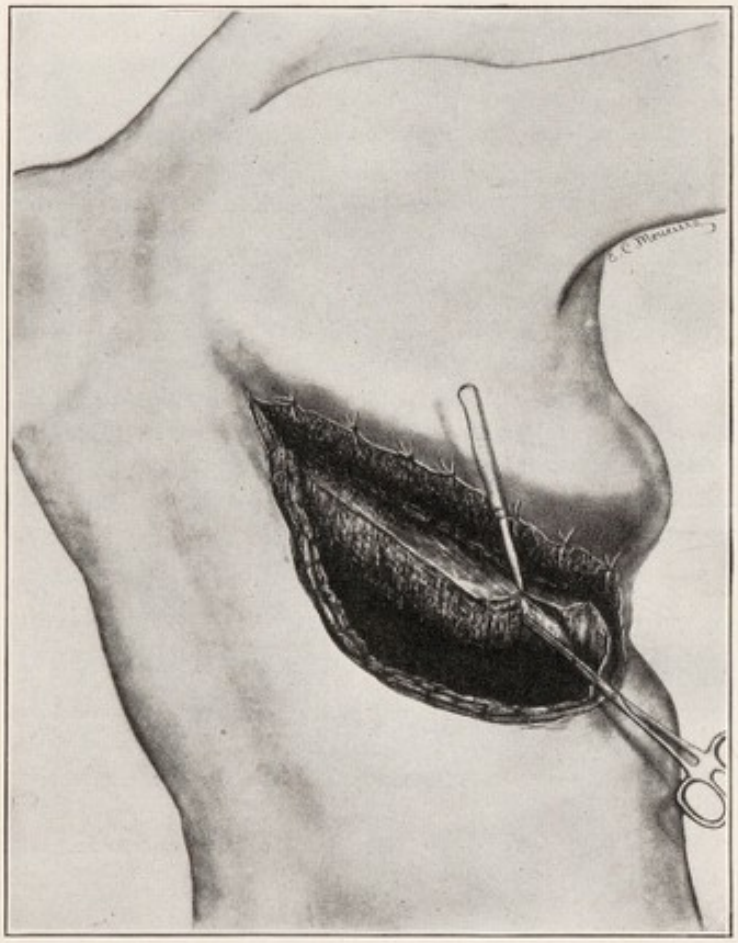

FIG. 124.—Case 33: A stage in the plastic closure by muscle implantation.

CASE 32.—J. M. P., age 28 years. October 12, 1921, developed pneumonia; complicated by empyema, right pleural cavity, hemolytic streptococcus type, November 12, 1921. Aspirated once. Received two operations prior to admission to Walter Reed General Hospital, with resection of the seventh and ninth ribs and the institution of drainage, and the instillation of Dakin's solution once daily to cleanse cavities. February 14, 1922, admitted to empyema service, Walter Reed General Hospital.

Condition on admission: Ambulatory case; fairly well nourished but highly septic and showing some anemia; normal weight, 150 pounds; present weight, 133 pounds. Examination of chest revealed two sinuses discharging pus, one in the seventh interspace and the second in the ninth interspace, posterior axillary line, left chest. Radiographs showed some collapse of the right lung and considerable thickening of parietal pleura from the third rib to base, and a cavity formation, hour glass in character, extending from the sixth to tenth rib, with a capacity of 350 c.c. Clinical laboratory examination: Wassermann negative; sputum negative for tubercle bacilli; red blood count, 4,180,000; white blood count, 18,950; hemoglobin, 70 per cent; urine showed trace of albumin, many pus cells; culture from cavity showed hemolytic streptococcus. Blood pressure: Systolic, 136; diastolic, 88; pulse pressure, 48. Vital capacity reading, 2,200 c.c.

This case was treated by the sterilization method due to its short duration; but under the most rigid Carrel-Dakin technique the cavity infection failed to clear up, hence this method of treatment was abandoned and surgical intervention instituted.

April 10, 1922, resection of 15 cm. of the seventh and eighth ribs, posterior scapular line, and resection of 10 cm. of the ninth and tenth ribs, midaxillary line; excision of thickened parietal pleura forming roof of cavity; entire area laid wide open for active dakinization; skin inverted over severed superficial muscles and fixed to preserve them for final closure; multiple scarification to cause relaxation along suture line. May 25, 1922, resection of necrotic rib stumps of seventh

and eighth ribs, previously resected; excision of small sinus tract draining into main cavity; entire area left open for continued dakinization. June 20, 1922, plastic closure by muscle and skin, with implantation of superficial muscle body into remaining space after maximum lung expansion had been obtained; all scar tissue excised; muscle and skin brought in apposition by means of silkworm gut sutures. Rubber dam drainage for 48 hours; multiple scarification of skin to cause relaxation and prevent future slough. June 28, 1922, all sutures removed and area found healed by primary intention. Lung was well expanded; general condition was excellent; weight, 144 pounds; vital capacity reading, 3,400 c.c.

Factors to be combated were hemolytic streptococcus; osteomyelitis with rib sequestration; diverticulum or secondary cavity.

Case 33.—J. W. S., age 26 years. February 19, 1919, developed pneumonia; complicated by empyema, right pleural cavity, hemolytic streptococcus type, April 1, 1919. Aspirated three times. April 9, 1919, operation; thoracotomy; resection of 5 cm. of eighth rib, posterior axillary line; and the institution of drainage. October 19, 1919, operation; resection of 15 cm. of seventh, eighth, and ninth ribs, posterior axillary line, with removal of parietal pleura and decortication of visceral pleura; lower aspect of wound left open for drainage. November 27, 1920, admitted to empyema service, Walter Reed General Hospital.

Fig. 125.—Case 33: Second stage in the muscle implantation.

Condition on admission: Ambulatory case; fairly well nourished and about normal in weight (175 pounds). Examination of chest revealed sinus discharging pus ninth interspace, posterior axillary line, right chest. Radiographs showed ribs resected as enumerated above and a marked thickening of the parietal pleura, right lateral chest, with a partial collapse of right lung and a cavity formation with a capacity of about 200 c. c. Clinical laboratory examination: Wassermann negative; sputum positive for tubercle bacilli; white blood count, 8,600; red blood count, 4,620,000; urine negative; culture from cavity showed hemolytic streptococcus and bacillus proteus. Blood pressure: Systolic, 118; diastolic, 82; pulse pressure, 36. Vital capacity reading, 2,600 c. c. January 13, 1922, operation; resection of 20 cm. of seventh, eighth, and ninth, and tenth ribs, posterior scapular line, cavity being laid widely open; discission of visceral pleura; active dakinization followed and the cavity was obliterated by re-expansion of the lung until it was about one-fifth its original size. Seven consecutive daily cultures showing no growth were obtained and maximum amount of lung expansion occurred. April 6, 1921, operation; plastic closure of defect by muscle implantation; severed superficial muscles brought in apposition and sutured; skin closed with silkworm gut and rubber dam drainage instituted between the sutures along the suture line. May 15, 1921, patient entirely healed; general condition good; weight, 180 pounds; vital capacity reading, 3,100 c. c. June 14, 1921, transferred to General Hospital No. 19, Oteen, N. C., for active pulmonary tuberculosis. Empyema healed.

Factors to be combated in this case were hemolytic streptococcus organism present; primary drainage was not dependent; active pulmonary tuberculosis; osteomyelitis of resected rib stumps.

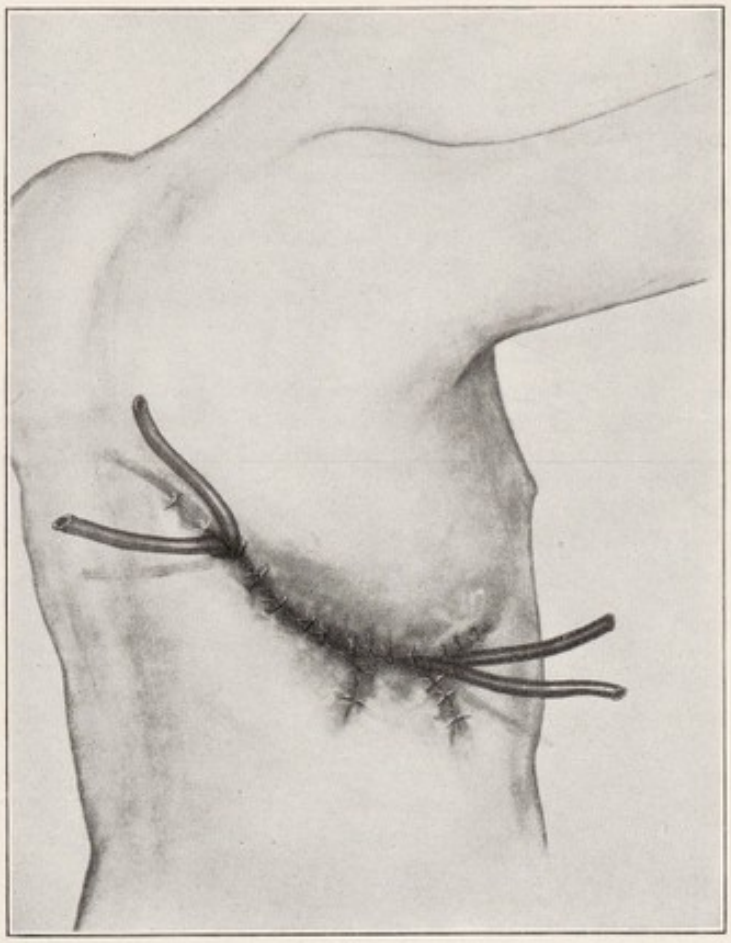

FIG. 126.—Case 33: Final skin suture.

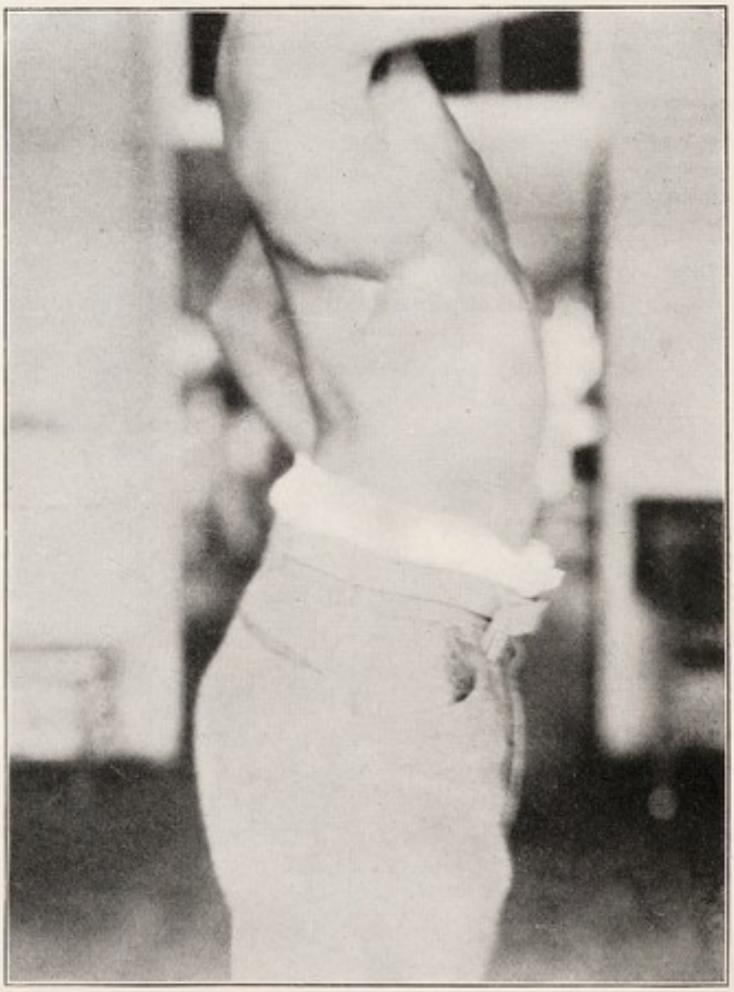

FIG. 127.—Case 33: Final result.

Case 34.—P. F. H., age 30 years. September 10, 1918, developed influenza, American Expeditionary Forces, France. Discharged from service July 8, 1919. Second attack of influenza August 2, 1920; complicated by empyema, right pleural cavity, hemolytic streptococcus type, September 1, 1920. Aspirated five times. September 9, 1920, operation; thoracotomy; resection of 10 cm. of sixth rib, midaxillary line, with the institution of drainage. October 3, 1921, admitted to empyema service, Walter Reed General Hospital.

Condition on admission: Ambulatory case; poorly nourished; weight, 125 pounds (normal weight, 145 pounds), fingers clubbed; anemic. Examination of chest revealed sinus discharging pus sixth interspace midaxillary line with a large cavity formation filled with pus. Radiographs showed marked collapse of right lung with extensive thickening of parietal pleura, right lateral chest, from apex to base, and a cavity formation, with a capacity of 500 c. c., extending from second rib to eighth rib; osteomyelitis with sequestration of sixth and seventh ribs, midaxillary line. Clinical laboratory examination: Wassermann negative; sputum negative for tubercle bacilli; white blood count, 16,150; red blood count, 4,120,000; urine negative; culture from cavity showed hemolytic streptococci. Blood pressure: Systolic, 108; diastolic, 78; pulse pressure, 30. Vital capacity reading, 1,700 c. c.

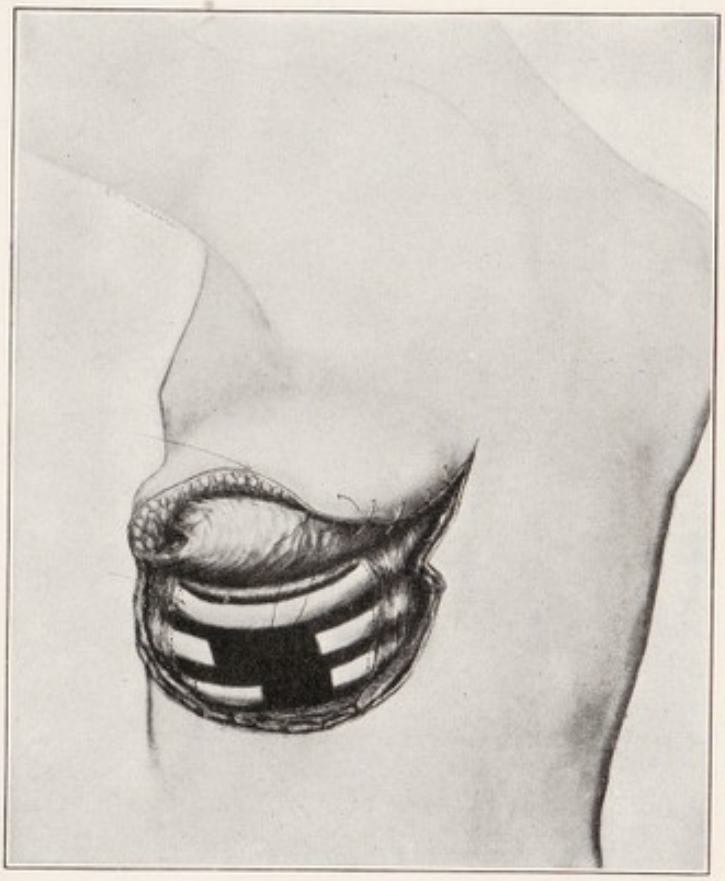

Fig. 128.—Case 35: The first fractional operation in the treatment of a chronic empyema cavity.

October 12, 1921, resection of 15 cm. of sixth, seventh, and eighth ribs, posterior axillary line, right chest, excision of thickened parietal pleura forming roof of cavity; evacuation of about 500 c. c. of pus; skin inverted over muscles that were severed; and cavity left open for active dakinization. October 16, 1921, patient on active dakinization and improving. With the thickening of the parietal pleura and the fixation of the lung in such a firm state of collapse, this case evidently had some pleural involvement with his first attack of influenza. This was not noticed or at least did not receive surgical attention. November 29, 1921, operation; resection of 20 cm. of fourth, fifth, sixth, seventh, and eighth ribs, anterior axillary line; excision of roof of cavity and preparation of cavity for active dakinization. December 30, 1921, operation; resection of 10 cm. of fourth, fifth, sixth, seventh ribs, posterior scapular line, right chest; excision of thickened parietal pleura; discission of visceral pleura; skin brought over muscle and fixed to prevent retraction and to preserve it for future closure; multiple scarifications of skin to cause relaxation; cavity left open for dakinization. February 3, 1922, operation; resection of 5 cm. of fourth and fifth ribs which showed some necrosis; cavity left wide open for active dakinization. March 8, 1922, patient improving; lung expanding and cavity cleaning up. March 13, 1922, resection of necrosed rib previously resected; removal of a portion of the fifth rib, anterior aspect; excision of sinus tract; preparation of entire cavity for active dakinization. May 17, 1922, plastic closure by muscle and skin, anterior aspect of cavity; posterior aspect left open for continuation of dakinization; multiple scarifications of skin to cause relaxation; rubber dam and Carrel tube drainage for 48 hours.

Factors to be combated in this case were osteomyelitis of rib stumps; hemolytic streptococcus present.

Case 35.—H. J., age 28 years. December 8, 1919 developed influenza, complicated by empyema December 10, 1919. Aspirated once. January 6, 1920, patient was operated on at his

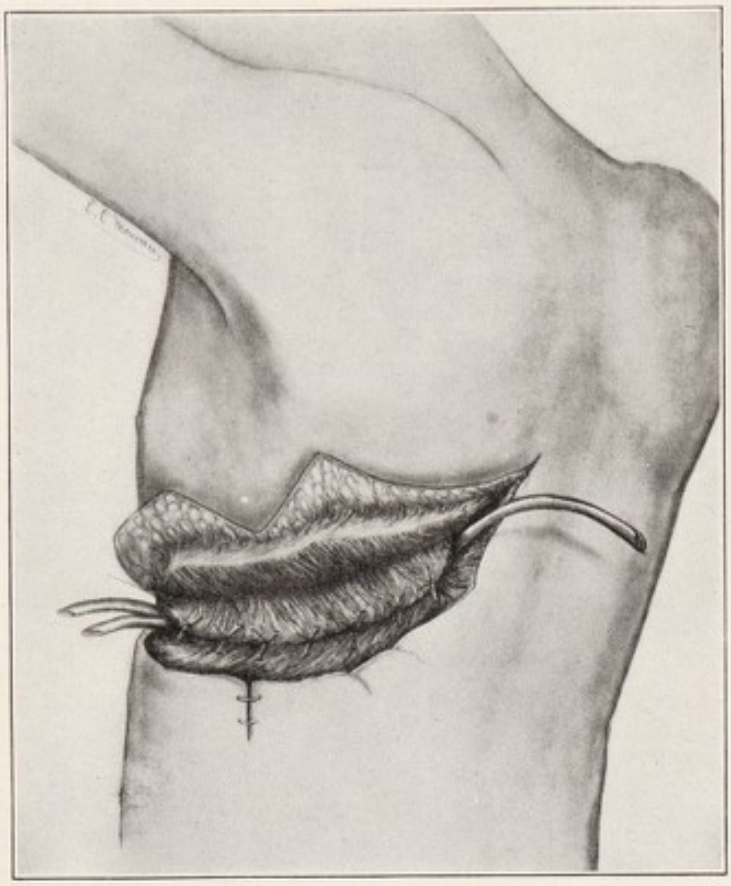

FIG. 129.—Case 35: Plastic implantation of muscle.

FIG. 130.—Case 35: The final suture and closure of the cavity.

home and a small section of the tenth rib resected. Drainage was instituted. Patient continued to drain. May 29, 1920, operation by civilian physician; resection of portion of ninth rib; drainage continued until date of admission. December 1, 1920, admitted to empyema service, Walter Reed General Hospital.

Condition on admission: General condition fairly good; weight, 145 pounds (normal weight, 160 pounds); fairly well nourished. Examination of chest showed two sinuses at the level of the ninth and tenth ribs, respectively, with exuberant granulations, and discharging heavy, thick pus; a probe could be inserted for a distance of about 20 cm. Radiograph showed a cavity extending from the point of resection of the ninth and tenth ribs from the midscapular line to the anterior axillary line at the level of the midportion of the lung. There was some collapse of the lung with a thickening of the pleura along the lower lateral chest wall. Clinical laboratory examination: Wassermann negative; urine negative; sputum negative for tubercle bacilli; red blood count, 4,300,000; white blood count, 7,100; hemoglobin, 80 per cent; culture from cavity showed streptococcus hemolyticus and staphylococcus aureus.

FIG. 131.—Case 35: The final result obtained by fractional procedures.

Drainage and active dakinization of the cavity was immediately started with a view to getting it as clean as possible before operation.

January 12, 1921, resection of the eighth, ninth, and tenth ribs overlying the sinus tract. On the removal of the intercostal structures and the parietal pleura, a cavity, 8 inches long and 1 inch wide was exposed with an accessory cavity draining through a small sinus into the first cavity and lying at right angles to it at its midportion. The secondary cavity was about 4 inches long and 2 inches wide. The cavity was completely exposed and after the severed muscle bodies on either side of the wound were tucked in and covered over by sliding the undermined skin forward and suturing it into place, the wound was packed with gauze in preparation for the usual Dakin treatment. After operation patient put on weight rapidly, the wound was obliterated in a short time and the lung expanded until only a superficial gutter was left with the visceral pleura forming the floor. March 31, 1921, plastic operation under local anesthesia; excision of all scar tissue; the skin and subcutaneous tissues covering the previously prepared muscle bodies undermined and dissected up; the muscle body was split and its lower half was implanted into the upper angle of the wound and sutured to the visceral pleura filling up the gap; the lower half of the wound was covered over by sliding forward the skin flaps from either side. Two Carrel tubes were inserted beneath the muscle implanted for the instillation of Dakin's solution for a few days and rather firm dressing was applied. All drainage was discontinued after a week and the wound healed by first intention. Just previous to the above plastic operation a small sinus was found leading forward from the anterior angle of the wound. The sinus was split open and one of the resected rib stumps found necrotic. May 18, 1921, patient discharged.

Factors to be combated were hemolytic streptococcus present; thickened pleura; faulty drainage; diverticulum or secondary cavity; scoliosis.

CASE 36.—G. M. A., aged 23 years. March 23, 1921, developed pneumonia; complicated by empyema, left pleural cavity, hemolytic streptococcus type, May 1, 1921. Aspirated three times. May 9, 1921, operation; thoracotomy; resection of 10 cm. sixth, rib, anterior axillary line, with the institution of drainage, and irrigation with Dakin's solution daily. June 9, 1921, admitted to empyema service, Walter Reed General Hospital.

Condition on admission: Ambulatory case; poorly nourished; anemic; showing some loss in weight; marked shortness of breath. Present weight, 111 pounds. Examination of chest revealed sinus discharging pus sixth interspace, anterior axillary line, left chest; pleurobronchial fistula present; and a cavity formation with a capacity of 200 c. c. Radiographs showed partial collapse of left lung with some thickening of the parietal pluera, left lateral chest, from the second to ninth rib, and a cavity formation running transeversely across the chest from the nipple line anterior to the posterior scapular line, the lower aspect of it being on a level with the seventh rib; heart slightly displaced to the right and posteriorly. Clinical laboratory examination: Wassermann negative; sputum negative for tubercle bacilli; white blood count, 19,300; red blood count, 4,720,000; urine negative; culture from cavity showed hemolytic streptococcus and staphylococcus aureus. Blood pressure: Systolic, 115; diastolic, 82; pulse pressure, 33. Vital capacity reading not taken.

June 30, 1921, operation; resection of 20 cm. of seventh rib, posterior axillary line, left chest; cavity laid wide open and lung freed about fistula and allowed to retract, thus mobilizing site of fistula; skin fixed over muscles which were severed to prevent retraction; cavity left wide open for active dakinization. July 25, 1921, lung well expanded; fistula closed and wound well granulated; cavity obliterated; seven consecutive sterile cultures having been obtained, cavity was allowed to close. September 15, 1921, patient entirely healed and feeling well; general condition excellent; weight, 135 pounds. Vital capacity reading, 3,200 c. c. Discharged from the service and hospital as cured December 8, 1921.

Factors to be combated in this case were hemolytic streptococcus present; pleurobronchial fistula present; drainage not dependent.

CASE 37.—O. C., age 22 years. December 20, 1919, developed influenza; complicated by empyema, right pleural cavity, hemolytic streptococcus type, January 25, 1920. Aspirated twice. February 3, 1920, thoracotomy; resection of 5 cm. of the sixth rib anterior axillary line, right chest. March 12, 1920, operation; incision and drainage. May 15, 1920, chest allowed to close. June 28, 1920, operation; incision and the institution of drainage. Chest was allowed to close and was reopened six times. October 2, 1920, admitted to the empyema service, Walter Reed General Hospital.

Condition on admission: Ambulatory; patient anemic; weight, 149 pounds (normal weight, 160 pounds). Examination of chest revealed sinus discharging pus, anterior axillary line, sixth interspace, right chest. Radiographs showed partial collapse of right lung, with marked thickening of the parietal pleura, and a cavity triangular in outline and about 6 to 8 cm. deep, extending upward; heart, aorta and trachea displaced to the right. Capacity of cavity, 150 c. c. Clinical laboratory examination: Wassermann negative; sputum negative for tubercle bacilli; white blood count, 8,500; red blood count, 4,380,000; urine negative; culture from cavity showed heavy growth of hemolytic streptococci. Blood pressure: Systolic, 115; diastolic, 76; pulse pressure, 39. Vital capacity reading, 2,800 c. c.

October 21, 1920, resection of 20 cm. of sixth, seventh, and eighth ribs; posterior axillary line cavity laid wide open and prepared for active dakinization. December 1, 1920, secondary closure with plastic muscle flap using a portion of the latissimus dorsi muscle; superficial, severed muscles brought in apposition and skin sutured. March 20, 1921, patient entirely healed; general condition excellent; weight on admission, 149 pounds; weight on discharge, 160 pounds. Vital capacity reading, 3,400 c. c. Patient completely cured and discharged May 26, 1921.

Factors to be combated in this case were hemolytic streptococcus present; primary drainage was not dependent; cavity led directly into mediastinum.

CASE 38.—A. M., age 27, October 23, 1918, developed influenza, followed by pneumonia October 27, 1918, and complicated by empyema, left pleural cavity, hemolytic streptococcus type, November 2, 1918. There were four operations, prior to admission to Walter Reed General Hospital, with partial resection eighth and ninth ribs, left side.

Condition on admission to Walter Reed General Hospital: Patient anemic; weight, 131 pounds (normal weight, 168 pounds); poorly nourished; highly septic. Examination of chest showed sinus draining pus at the level of the ninth rib, mid scapular line, left chest. Radiograph revealed spindle-shaped cavity extending from the level of the ninth rib, posterior, to the third rib, posterior, about 4.5 cm. at its widest portion. There had been resection of parts of the eighth and ninth ribs, posterior, with regeneration of the bone joining the resected ends; marked collapse of left lung with thickened pleura from base to apex; pneumothorax most marked in the upper portion of the left chest; heart, aorta and mediastinal contents displaced markedly to the right. Clinical laboratory examination: Wassermann negative; urine negative; sputum negative for tubercle bacilli; red blood count, 4,000,000; white blood count, 7,000; hemoglobin, 85 per cent; culture from cavity showed streptococcus hemolyticus.

November 10, 1920, resection of 20 cm. of the third to sixth ribs, left sinus tract excised and the cavity laid wide open over this area; preparation for active dakinization. December 27, 1920, the lower part of the cavity was attacked and about 20 cm. of the seventh, eighth, and ninth ribs were resected. Crossbone formation with necrosis was found in this area. This part of the cavity being laid widely open, the whole of the cavity was now exposed to view. The cavity soon cleaned up under active dakinization, and the obliteration of the wound proceeded at a rapid rate. This obliteration was aided by linear scarifications of the visceral pleura at weekly intervals. The depth of the wound gradually increased largely by the re-expansion of the previously collapsed lung. April 27, 1921, the cavity was entirely obliterated in its lower aspect and the upper angle showed only a superficial wound, the floor of which was formed by the visceral pleura. A plastic operation was contemplated with excision of the scar tissue and the establishment of the continuity of the muscle bodies lying on either side of the old wound. The patient, however, considered himself practically well and requested discharge. Patient discharged June 3, 1921.

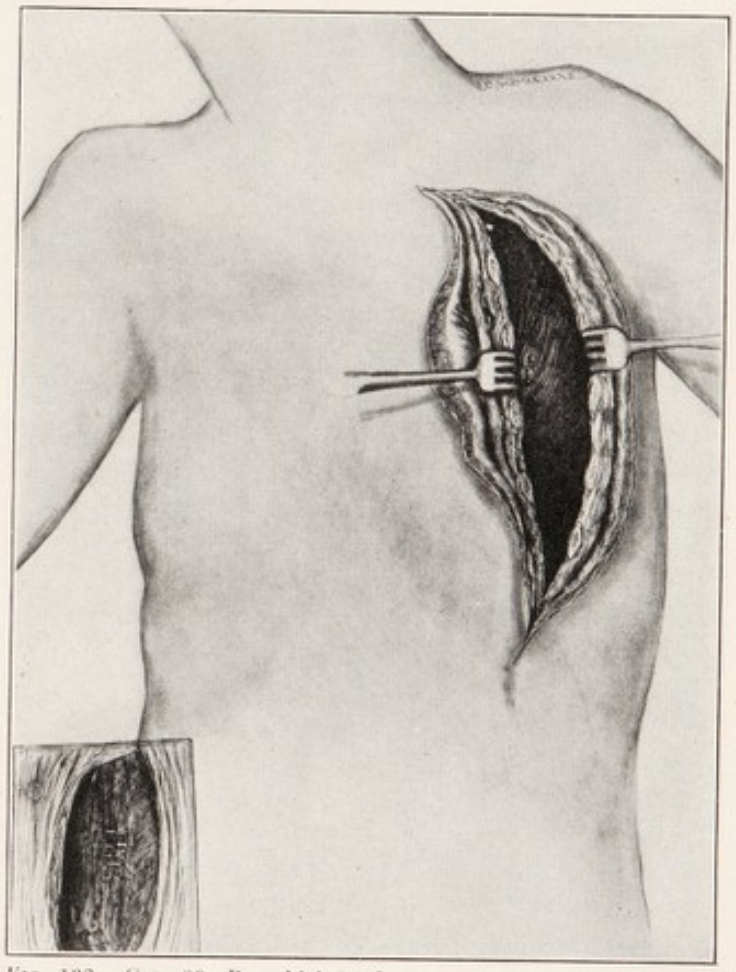

FIG. 132.—Case 39: Bronchial fistula persisting in a case otherwise prepared for closure.

Factors to be combated were hemolytic streptococcus present; osteomyelitis of rib stumps; marked collapse of left lung with thickened pleura from apex to base.

CASE 39.—R. L. S., age 21 years. February 26, 1920, developed influenza, complicated by bronchopneumonia March 5, 1920, and by empyema, left pleural cavity, hemolytic streptococcus type, March 18, 1920. Aspirated six times. March 24, 1920, operation; intercostal thoracotomy, eighth interspace, anterior axillary line, with the institution of drainage and irrigation with Dakin's solution. August 12, 1920, operation; thoracotomy; resection of 10 cm. of seventh and eighth ribs, anterior axillary line, cavity left open for irrigation with Dakin's solution. September 24, 1920, admitted to empyema service, Walter Reed General Hospital.

Condition on admission: Ambulatory case; poorly nourished; present weight, 115 pounds (normal weight, 130 pounds). Examination of chest revealed sinus discharging pus, anterior axillary line, left chest; pleurobronchial fistula present and a large cavity formation extending

up to second rib, anterior aspect of left chest; a large cavity formation noted extending from second rib to base with a capacity of about 500 c. c. Clinical laboratory examination: Wassermann negative; sputum negative for tubercle bacilli; white blood count, 6,250; red blood count, 4,700,000; urine negative; culture from cavity showed hemolytic streptococcus and proteus. Blood pressure: Systolic, 132; diastolic, 74; pulse pressure, 58. Vital capacity reading, 1,600 c. c.

November 5, 1920, operation; resection of 20 cm. of fourth, fifth, sixth, seventh, and eighth ribs, left chest, midaxillary line, with the roof of cavity excised and pleurobronchial fistula exposed; skin inverted over muscles that were severed, and fixed over rib stumps to preserve the muscles for final closure and to render dressing less painful; cavity left open for active dakinization; December 1, 1920, operation; resection of 10 cm. of second and third ribs, anterior axillary line, left chest with a plastic closure of the upper aspect of cavity with a portion of the pectoralis minor muscle; the several superficial muscles and skin brought in apposition and sutured; the lower aspect of the cavity left open for drainage and dakinization. December 22, 1920, operation; enlargement of drainage opening in lower aspect of cavity and preparation of cavity for active dakinization. January 31, 1921, operation; resection of 10 cm. of eighth and ninth ribs, anterior axillary line, left chest; bronchial fistula closed by suture and implanting muscle over it; sinus tract excised. April 28, 1921, operation; mobilization of lung about fistula and closure of fistulous tract by means of purse-string suture; plastic closure of lower aspect of cavity, leaving ample drainage. September 29, 1921, operation; excision of scar and superficial ulcer over lower aspect of plastic closure. November 20, 1921, patient entirely healed, general condition excellent. Had taken on weight since his first operation; X ray showed total obliteration of all cavity formation and the lung well expanded. December 6, 1921, healed and in excellent physical condition; weight, 125 pounds; vital capacity reading, 2,300 c. c. Granted 60 days' leave. March 1, 1922, condition steadily improving. May 15, 1922, discharged, completely cured, after having been healed five months.

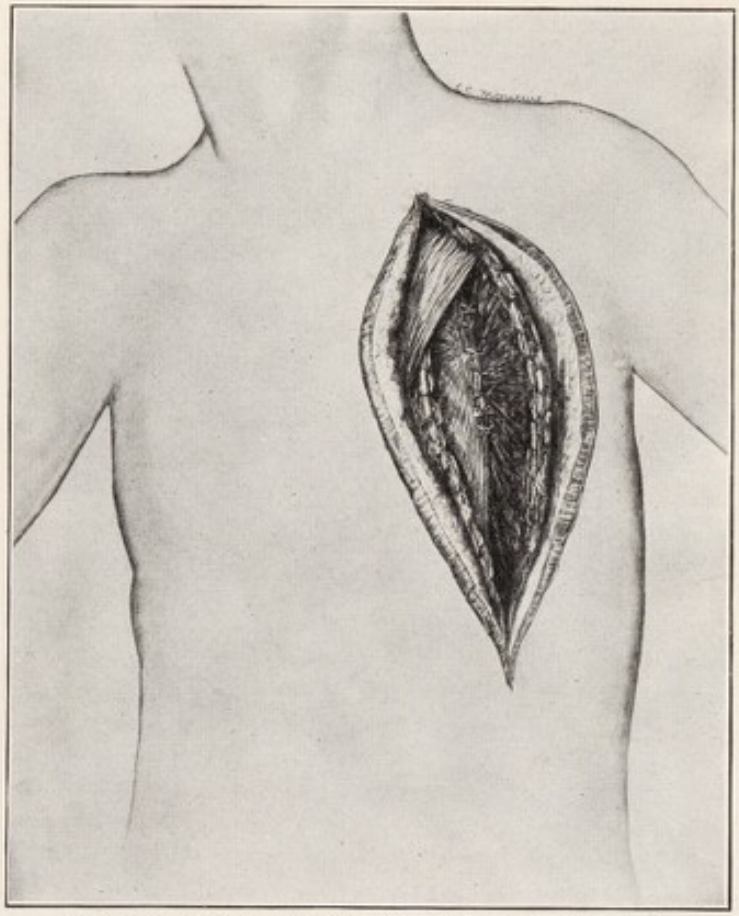

FIG. 133.—Case 39: A stage in the closure of the wound.

Factors to be combated in this case were hemolytic streptococcus present; osteomyelitis with rib sequestration; pleurobronchial fistula present.

CASE 40.—H. C. C., age 26 years. January 25, 1918, developed pneumonia; complicated by empyema, right pleural cavity, hemolytic streptococcus type, January 27, 1918. Aspirated three times. Received seven operations prior to his admission to this hospital with resection of the fifth to tenth rib, inclusive, right chest. Received active dakinization and continuous treatment. March 29, 1922, admitted to empyema service, Walter Reed General Hospital.

Condition on admission: Ambulatory case; fairly well nourished; quite septic; and slightly under weight. Examination of chest: Marked disturbance in contour of right chest, posterior lateral aspect, due to previous operative procedure. Sinus discharging pus seventh interspace, posterior axillary line and a narrow cavity formation extending from the fifth to the tenth rib, same line; a partial collapse of the right lung noted, and some osteomyelitis of the previously resected rib stumps; a regeneration with bridging and overlapping of the previously resected ribs.

Capacity of cavity, 300 c. c. Radiographic examination supported the above findings. Clinical laboratory examination: Wassermann negative; sputum negative for tubercle bacilli; white blood count, 13,700; red blood count, 4,280,400; hemoglobin, 75 per cent; urine negative; culture from cavity showed hemolytic streptococcus and staphylococcus aureus. Blood pressure: Systolic, 136; diastolic, 80; pulse pressure, 56. Vital capacity reading, 1,800 c. c.

April 10, 1922, operation; resection of regenerated rib stumps, from the fifth to the tenth rib, inclusive; entire cavity laid open; multiple fistulous tracts excised; skin inverted over covered superficial muscles and fixed; multiple scarifications of skin to cause relaxation along suture line; implantation of a portion of the deep fascia into the apex of the exposed tract; preparation of the entire cavity for active dakinization. May 17, 1922, operation; resection of a mass of regenerated bone in site of cavity and removal of an additional portion of the ninth rib, posterior aspect, with excision of sinus tract leading down under rib; entire cavity left open for continuous dakinization. June 7, 1922, operation; plastic closure by muscle and skin of entire space remaining following maximum lung expansion, with the implantation of a portion of the latissimus dorsi muscle into the space; muscle and skin brought into apposition by means of silkworm gut sutures; Carrel tube and rubber-dam drainage for 24 hours; multiple scarifications of skin to cause relaxation. June 20, 1922, entire structure healed; patient feeling well; lung well expanded and all cavity obliterated.

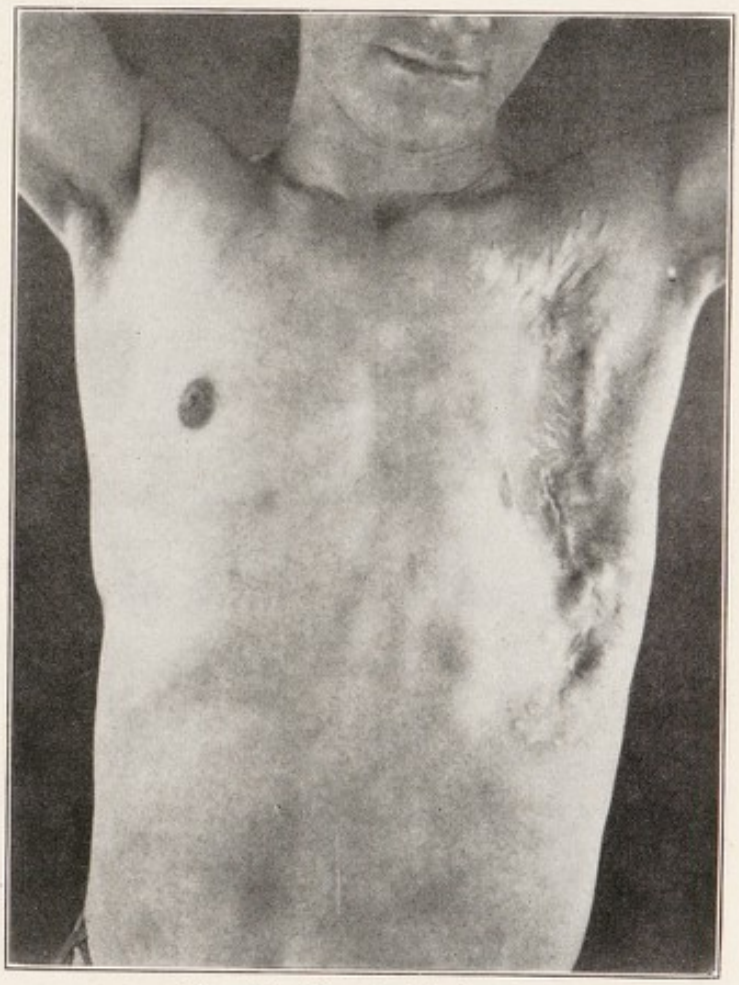

FIG. 134.—Case 39: Final result.

The illustrations following are photographs of some of the patients whose case records have been considered above. They are included in the chapter to show the degree of physical rehabilitation to which it was possible for them to attain.

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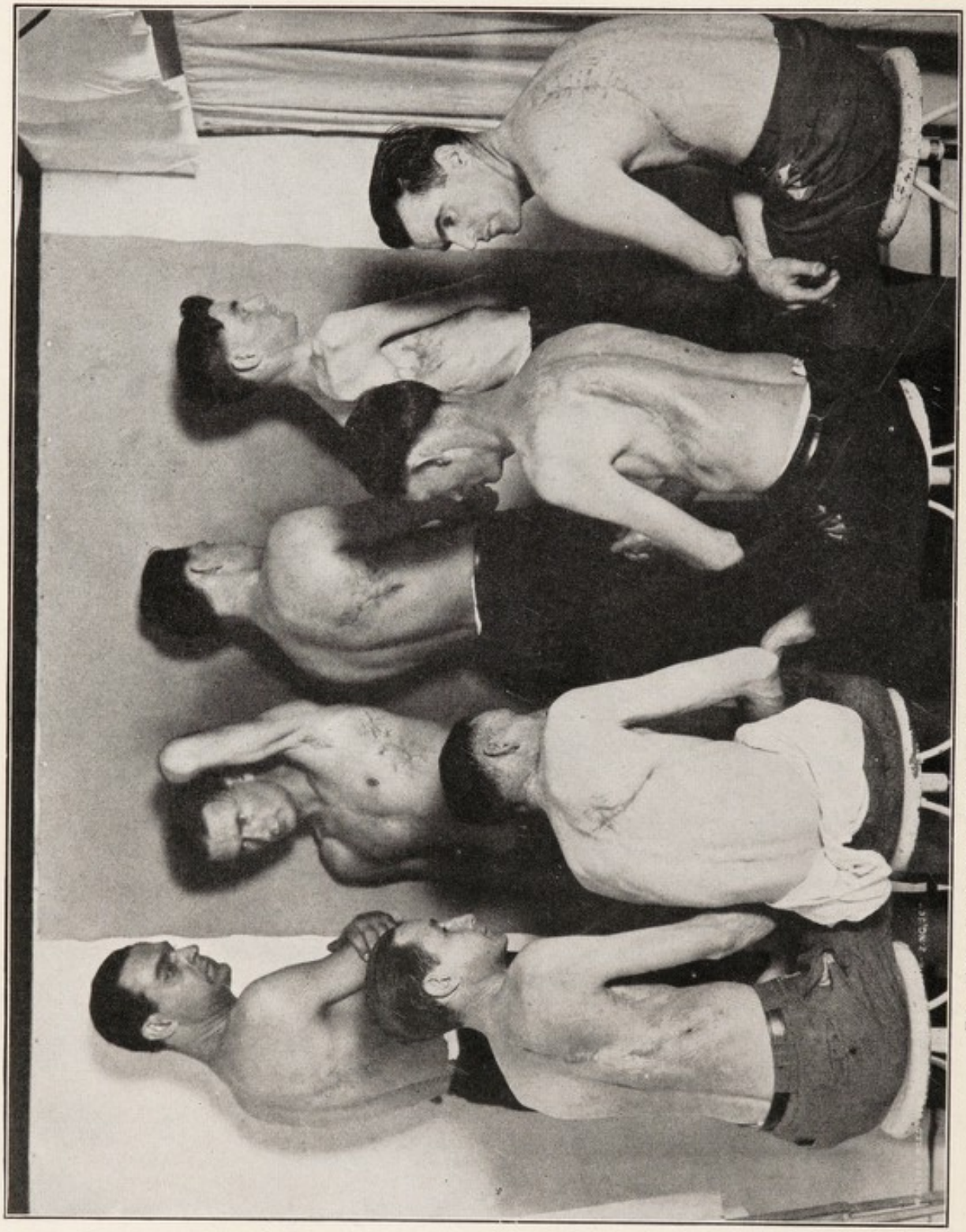

FIG. 135.—Showing degree of physical rehabilitation attained in some of the cases described.

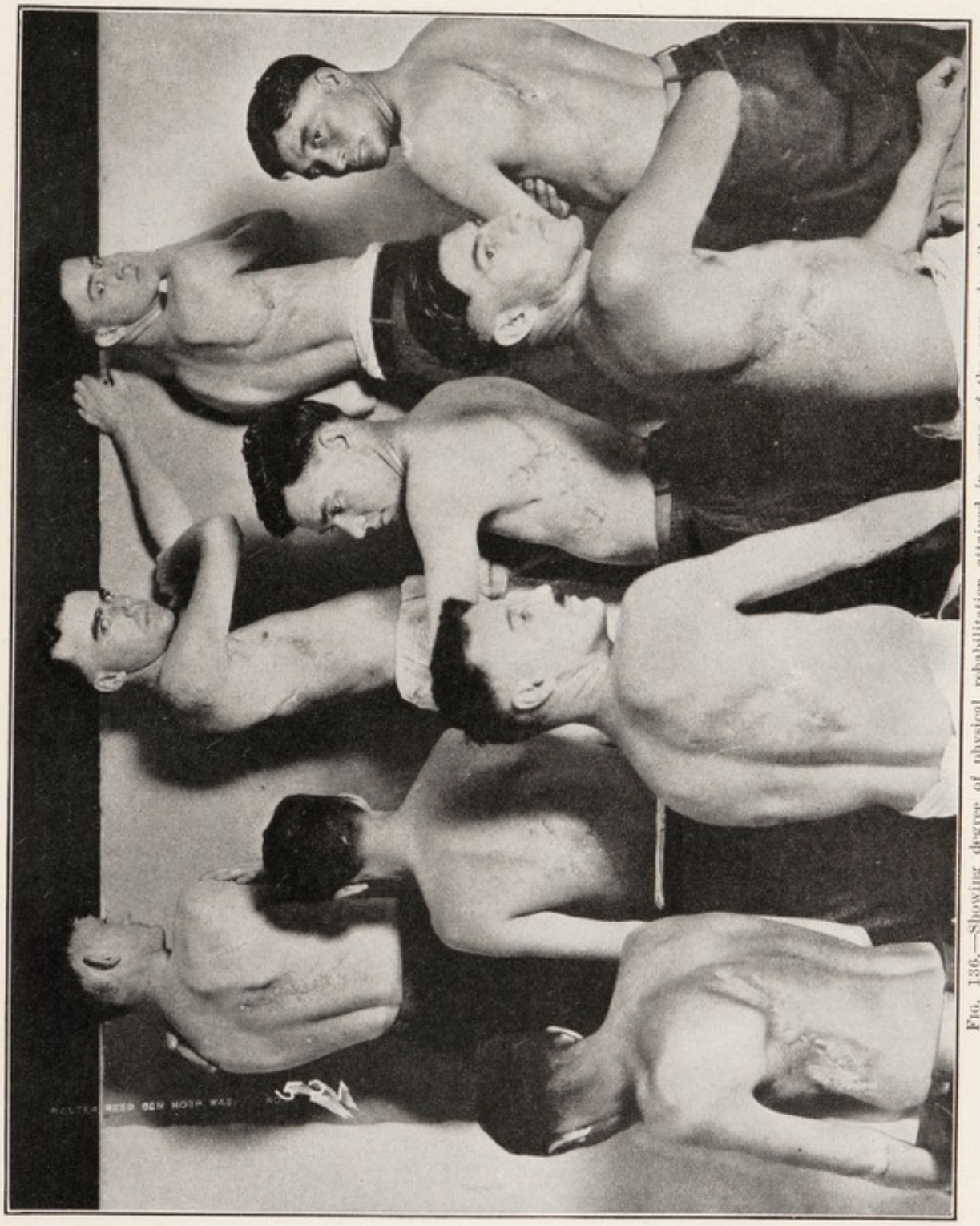


FIG. 136.—Showing degree of physical rehabilitation attained in some of the cases described.

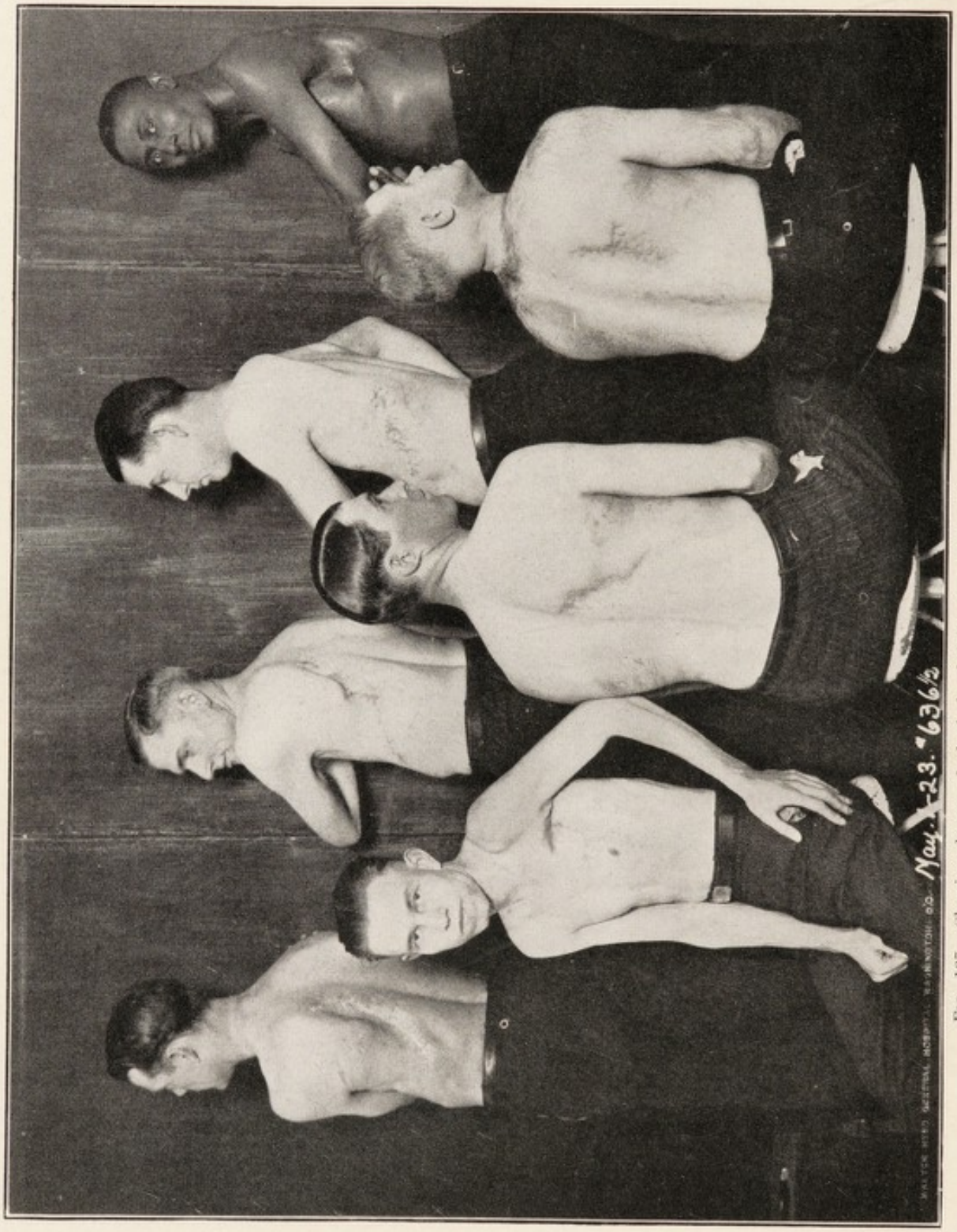


FIG. 137.—Showing degree of physical rehabilitation attained in some of the cases described.