The Medical and Surgical Treatment of
Staphylococcal Pneumonia

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STAPHYLOCOCCAL PNEUMONIA IS A PROBLEM of increasing importance for two reasons: (1) the frequent development of antibiotic resistance by the etiologic organism, and (2) the impression that staphylococcal infections of the lungs and pleura are more frequent now than in the pre-antibiotic era.1

Until recently, primary staphylococcal pneumonia was an infrequent disease in adults and a rare form of pneumonia in children. Several reports2-5 during the past five years indicate a higher incidence of staphylococcal pneumonia in children, but only a slight increase in the incidence of adult cases.6-9 Approximately 60 per cent of cases of staphylococcal pneumonia in the pediatric group occur under the age of six months.7,8 Although the incidence of the disease in childhood reaches a definite peak during the winter and early spring, there is no such seasonal variation in adults.

ETIOLOGY

Staphylococcal pneumonia is caused by hemolytic coagulase-positive Staphylococcus aureus. This organism is characterized by growth on solid media in colonies with golden pigmentation, by the ability to hemolyze rabbit blood, to liquefy gelatin, and to produce acid from mannitol.10 The biochemical environment in which staphylococci may survive, proliferate, and cause disease is less important than with other organisms, since the Staphylococcus can synthesize amino acids from available nitrogen-containing salts.11 The physiochemical environment immediately surrounding staphylococcal colonies may be altered by the organism's intense glycolytic activity which produces a local accumulation of lactic acid and carbon dioxide and a fall in pH.12 Some investigators suggest that this altered physiochemical state may inactivate antimicrobial agents locally and may account, in part, for antibiotic resistance.13,14

The pathogenicity of the Staphylococcus is probably related to its ability to produce coagulase.15-18 This thrombin-like substance forms clots in small blood vessels surrounding the infection, thus producing a relatively avascular area where blood-borne antibodies and antimicrobial agents penetrate poorly. Previous infections do not confer appreciable immunity to subsequent staphylococcal infections. This may be the result of avascularity of the local lesion,19 filtration of antibodies by fibrin,20 or to the intracellular locus of the organism.21-23

PATHOLOGY

The characteristic staphylococcal lesion is a well-localized abscess surrounded by a capillary bed filled with thrombi. Fibrin is abundant in and around the lesion, presumably the result of the coagulase factor. A fibroblastic wall, which sharply demarcates the lesion, surrounds a central area filled with polymorphonuclear leukocytes, bacteria, and necrotic debris.

The first change in the development of the pulmonary lesion is a non-specific, peribronchiolar inflammation, with invasion of mononuclear and polymorphonuclear cells and fibrin. This exudative process leads to obstruction of small bronchioles, resulting in local consolidation. The consolidated lung parenchyma then becomes riddled with multiple suppurrative foci—the earliest stage in the development of the multiple pulmonary abscesses which characterize the gross pathologic and radiologic picture of this disease. If these abscesses lie close

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STAPHYLOCOCCAL PNEUMONIA

FIGURE 1: Premature white boy developed poor feeding at age three weeks. X-ray film revealed tension pneumothorax, collapse of left lung with marked mediastinal shift, and depression of left diaphragm.

fever. This may last as long as eight to nine days, although occasionally a fulminating course lasts only 18 to 24 hours. During this period, anorexia and irritability appear, followed by the insidious onset and progression of difficult respiration. The respiratory difficulty frequently begins with only occasional grunting respirations, but progresses to frank dyspnea and cyanosis. As the disease advances, the cough becomes more severe, anorexia becomes pronounced, and fever increases.

On physical examination, the respiratory signs naturally dominate the picture. The respirations are rapid and shallow, and frequently are characterized by the open-mouthed breathing of "air-hunger." Cyanosis is frequently present, and the pulse rate is rapid. Pallor, lethargy and abdominal distention are prominent. Examination of the chest, however, is highly unreliable in the childhood form of the disease. Changes in fremitus and percussion note may be due to the presence of a large amount of pleural fluid and, under these circumstances, other signs may be obscured.

**Adult Type**

In adults, the disease most often follows a previous respiratory infection or generalized debilitation. The onset is insidious; the symptoms may include progressive cough, pleuritic chest pain, chills, malaise, and occasionally hemoptysis. Physical examination of the chest is more reliable in adults than in children and usually reveals decreased breath sounds and dullness to percussion suggestive of fluid in the pleural space; rales are commonly heard. Physical findings suggestive of cavitation are rare.

**Laboratory Findings**

The laboratory findings are highly variable. Anemia, usually of the normochromic and normocytic type, is common, especially in an infection of some days' duration. The erythrocyte sedimentation rate is moderately to markedly elevated. The leukocyte and differential counts are notoriously variable. Leukocytosis with a

**Signs and Symptoms**

The clinical picture of staphylococcal pneumonia, while highly variable, generally falls into two categories—a childhood type and an adult type.

**Childhood Type**

There is a mild prodromal syndrome of rhinorrhea, moderate cough, and low grade

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predominance of granulocytes is the usual picture. In infants, the leukocyte count may be 25,000 to 30,000 per cmm., with values up to even 50,000.\textsuperscript{24} In adults, the count usually varies between 10,000 to 25,000;\textsuperscript{3} however, granulocytopenia may be seen.\textsuperscript{32,33} Pryles\textsuperscript{5} states that leukopenia and granulocytopenia indicate a poor prognosis. Throat cultures frequently are positive for hemolytic Staphylococcus aureus. Approximately 50 per cent of patients with staphylococcal pneumonia have positive blood cultures. The most valuable laboratory test for diagnostic purposes is positive culture of aspirated pleural material.

X-ray Findings

The single most reliable clinical criterion in the diagnosis of staphylococcal pneumonia is the appearance of the x-ray film of the chest. The characteristic radiographic feature of staphylococcal pneumonia is the presence of multiple cavities in consolidated areas.\textsuperscript{5} In the early stages of the disease, areas of patchy infiltration and consolidation dominate the picture. Soon translucencies appear in the consolidated areas. The later stages are marked by costophrenic angle density, pleural effusion, empyema and pyopneumothorax.\textsuperscript{34} Finally, pneumatoceles develop and become increasingly prominent. These evolutionary stages in radiographic appearance follow one another in rapid succession. Staphylococcal pneumonia is typically a disease with a rapidly changing x-ray picture in the presence of an unchanging clinical picture.\textsuperscript{35}

The rapidly changing x-ray appearance serves to distinguish this as an acute pneumonia. Acute pneumonia with multiple cavities and pneumatoceles is almost certainly of staphylococcal origin. Although empyema occurs in other acute pneumonias,\textsuperscript{37} especially pneumococcal, this complication raises the strong suspicion of staphylococcal etiology, particularly in children.\textsuperscript{38,39} When empyema develops into a pyopneumothorax, one must regard a staphylococcal etiology as very probable.

Diagnosis

The diagnosis\textsuperscript{40} of staphylococcal pneumonia must be based on a high index of suspicion derived from the clinical picture of a progressive, severe pneumonitis which does not respond to the sulfonamides, standard doses of penicillin, or the tetracycline drugs. The diagnosis must rest ultimately on one of two examinations: (1) the appearance of the chest roentgenogram, and (2) the demonstration of pathogenic staphylococci from aspirated pleural fluid.

Treatment

The most important consideration in the medical therapy of staphylococcal pneumonia is the choice of antibiotic agents. The results with sulfonamides are poor.\textsuperscript{41-44} Most workers agree that the early uniform success of penicillin\textsuperscript{45,46} was followed by a period of increasing staphylococcal resistance.\textsuperscript{31,32,47,48} It became evident that organisms cultured from hospital ward environments showed a much greater resistance to penicillin than organisms obtained elsewhere, either from hospital clinic patients or at random.\textsuperscript{31,32} Most clinicians feel that resistance develops more slowly when
penicillin is used in combination with other agents.\textsuperscript{34,35} More recently, some clinicians have advocated the use of massive doses (20 to 50 million units per day intravenously), even in the face of evidence of \textit{in vitro} resistance of the organism to penicillin.\textsuperscript{34,35}

\textit{Streptomycin} has been used widely, almost always in combination with penicillin or one of the other agents, to prevent the rapid emergence of resistant strains.\textsuperscript{34,35}

There is considerable disagreement regarding the effectiveness of \textit{tetracyclines} in the treatment of staphylococcal infections. Chlortetracycline (Aureomycin) received initial good reports.\textsuperscript{35,40,41,43} A 1955 report stated that less than 10 per cent of staphylococci from nasal mucous membranes of hospital staff members were resistant to chlortetracycline,\textsuperscript{42} and the poor clinical results with tetracyclines corroborate the increasing \textit{in vitro} resistance of the organisms.\textsuperscript{44}

\textit{Erythromycin} has become one of the agents of choice in the treatment of deep-seated staphylococcal infection, in part because of the low rate of development of resistance when the drug is not used \textquotedblleft promiscuously\textquotedblright.\textsuperscript{34,44,64,65} It is considered, when used in combination, usually with chloramphenicol, as an effective agent in the treatment of staphylococcal pneumonia.\textsuperscript{31,58,67,71} The use of erythromycin as a prophylactic agent has been questioned.\textsuperscript{57,58}

\textit{Chloramphenicol} is generally conceded to be the most effective of the older antibiotic agents, chiefly because of the relatively low incidence of staphylococcal resistance. An editorial in 1958\textsuperscript{8} suggested that the preferred treatment of serious localized staphylococcal infections in adults should be 2 gm./day each of erythromycin and chloramphenicol.

\textit{Bacitracin} has been mentioned favorably,\textsuperscript{34} and its intrapleural administration has been used in children.\textsuperscript{7} Generally, there is justifiable reluctance to use this drug, because of its renal toxicity.

\textit{Novobiocin} (Albamycin, Cathomycin), vancomycin, kanamycin, and ristocetin (Spontin)\textsuperscript{32,71,74} have received enthusiastic reports. These agents now play an increasingly important role in the treatment of this disease, particularly in cases which

![Figure 3](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21382/)

**Figure 3**

**Figure 4**

**Figures 3, 4:** Three-month-old girl. First film shows large tension cysts in right lower lung and compression atelectasis of right upper lobe. Second film reveals cystic lesions amid patchy infiltrates.
Figures 5, 6, 7: Twenty-two year old white woman, seven months pregnant. First film shows right lower lungfield patchy infiltrates. Second film shows progression of infiltration and early effusion. The third film reveals bilateral infiltrates with a large, radiopaque lesion on the right suggesting early abscess formation.
do not respond to the older chemotherapeutic agents.

The guide to antibiotic therapy in this disease may be summarized: (1) never use a single antibiotic agent; 76-79 (2) obtain sensitivity tests; (3) treat twice as long as when treating a comparable disease caused by another organism. Important adjuncts in the medical therapy of staphylococcal pneumonia include the administration of oxygen, fluids, plasma, blood, and salt-poor human albumin.

**Surgical Treatment**

The *early* complications requiring surgical intervention are pleural effusion, empyema, pneumothorax (with and without tension), and occasionally acute respiratory insufficiency. Later complications include cyst formation, unresolved abscesses, and chronic empyema with fibroblastic membrane and “trapped lung.”

The timing for open drainage procedures in empyema secondary to pneumonia was well established by Graham and Bell 80-83 during World War I. They showed that, if the pus was thick and the lung adherent, open drainage with resection of a rib could be carried out with safety. However, if the fluid in the intrapleural space was thin and watery, the lung would not adhere to the chest wall; and a rapidly fatal pneumothorax might result.

Because of the unreliability of physical examination and of the early radiographic appearance, particularly in infants, early diagnostic thoracentesis is indicated. 84-88

*Thoracentesis* as a means of definitive treatment often proves inadequate. 84-88 Whenever frankly purulent material is obtained by thoracentesis, permanent drainage should be established. A small tube should not be used even in infants. The pus in a baby’s chest is just as thick as that of an adult. Lindskog 88 recommends that a small segment of rib be resected in the tiny infant in order to facilitate the insertion of a large catheter. If pneumothorax is present, a second tube should be placed into the second anterior intercostal space, lateral to the angle of Louis and connected to a separate drainage system.

When follow-up films indicate persistence of empyema, *enzymatic debridement* may be employed. Combined administration of streptokinase and streptodornase 89-91 is the method of choice. One ampule (100,000 units streptokinase and 25,000 units streptodornase) is dissolved in 15 to 20 ml. of isotonic saline solution and injected through the chest tube. Following this, the tube is clamped for a period of four to eight hours, then unclamped and suction resumed. Usually there is a good yield of secretions and improvement in the x-ray appearance. It may be necessary to repeat this procedure, but usually not more frequently than at 24-hour intervals. Enzyme therapy should be used only when there is a thoracostomy tube in place; if a febrile reaction occurs, the enzyme then can be promptly removed from the pleural space by suction.

Empyema in staphylococcal pneumonia has a tendency to loculate unless surgical drainage procedures are instituted promptly. The fluoroscopic localization of these intrapleural abscesses is extremely important for adequate drainage.

Samson and Burford 92 demonstrated the value of early *decortication* in patients with traumatic hemothorax and post traumatic empyema. Undoubtedly, decortication 93 is indicated in some cases of staphylococcal pneumonia.
empyema, especially those seen late in the course of the disease. Drainage with a large thoracotomy tube sharply reduces the number of cases requiring decortication.

If staphylococcal empyema is permitted to remain undrained, excision of the empyema sac and decortication will become necessary.\textsuperscript{19} When late decortication becomes necessary following staphylococcal empyema, it is likely that early management was not sufficiently vigorous since early drainage, with or without enzymes, will prevent the development of loculation in most cases. Even when loculations do occur, accurate localization and drainage will obviate the need for later decortication.

Pneumothorax may result from the rupture of a subpleural abscess which communicates with a bronchus. Tension pneumothorax may develop rapidly, especially in infants.\textsuperscript{16} Thoracentesis, followed immediately by the insertion of an intercostal catheter, is urgently indicated. Not only is there air under pressure within the pleural space, but purulent exudate as well; therefore, tension pneumothorax exists. Although this indicates the presence of bronchopleural fistula, removal of the exudate and expansion of the lung obviates the likelihood that the fistula will become a significant problem. Lobectomy has been advocated for removal of tension pneumothorax.\textsuperscript{19}

In contradistinction to putrid lung abscesses which, in the past, have required open drainage procedures, abscesses due to staphylococcal pneumonia do not require surgical drainage.

At an early stage,\textsuperscript{19} the appearance of pneumatoceles may simulate tension pneumothorax by producing radiolucent hemithorax, mediastinal shift and lowered diaphragm. This problem requires the same treatment as tension pneumothorax. In the convalescent phase of the disease, when the patient is asymptomatic, it is impossible to distinguish pneumatoceles from true congenital cysts radiographically.\textsuperscript{19} The distinction is important since few remain in the long-term follow-up series, although some of these pseudocysts persist for several months.\textsuperscript{19}

**Prognosis**

The outcome of staphylococcal pneumonia was previously nearly uniformly fatal; the mortality rate was not much decreased by sulfa compounds;\textsuperscript{4} it was not until the introduction of penicillin in 1941 that prognosis improved. In the ensuing years, the prognosis has improved greatly, but the outlook is still guarded. In part, this is a function of the occurrence of the disease in young infants and in old and debilitated persons. Furthermore, there is the obvious difficulty of antibiotic resistance. Finally, until recently, this disease was not diagnosed early because it was considered a rare form of pneumonia.

In children, the mortality rate has been reported as 29 per cent\textsuperscript{4} and 28 per cent.\textsuperscript{60} Factors indicating a poor prognosis are the occurrence in the first three months of life,\textsuperscript{90} a short fulminant course of the disease with little or no prodrome;\textsuperscript{90} and leukopenia on admission.\textsuperscript{28}

**Review of Cases**

The following 19 cases of staphylococcal pneumonia were diagnosed and treated on the wards of the 6407th USAF Hospital,
Tachikawa A.F.B., Japan. Seven of the patients were children, ranging from newborn to two years of age, while the remaining 12 were between 18 and 30 years of age. There were four boys and three girls among the children; eight men and four women among the adults. All of the children were Caucasians, eight of the adults were Caucasians, and two each were Negro and Oriental.

Seasonal Incidence

The seasonal incidence differed in the childhood and adult groups. Of the five children who were admitted with the disease (the other two children contracted the infection while still in the newborn nursery), all were admitted during January, February, and March, the months of the Japanese winter. The adult admissions were distributed evenly throughout the seasons of the year.

Predisposing Factors

One child was premature; the other had a history of generalized furunculosis. In the adult group, three had Staphylococcus aureus infections proved by culture at the time of onset of the pneumonia: a pilonidal cyst, endometritis, and pyelonephritis, respectively. Three other adults were debilitated because of measles, a severe attack of bronchial asthma, and a difficult pregnancy, respectively.

Prodrome

The duration of the prodromal period averaged four to five days in 72 per cent of the children, although one had a fulminant and rapid course and another had been ill for ten days. In 75 per cent of the adults, the prodromal period lasted for at least a week, although three were entirely well until 24 hours prior to admission.

Laboratory Findings

Blood cultures were positive for hemolytic Staphylococcus aureus in 50 per cent of the 19 cases; all but two sputa contained hemolytic Staphylococcus aureus. The leukocyte counts were characterized by marked variability and previously unreported leukemoid reactions. In the childhood group, the leukocyte counts fell into two categories. The first group of four children had initial counts between 10,000 and 14,000 per cmm.; two showed predominance of polymorphonuclear leukocytes; two who had a predominance of lymphocytes died. These were the only deaths in the childhood group. Two had leukocyte counts of 50,000 per cmm., with a leukemoid picture indistinguishable from acute leukemia which persisted for one week.

In the adult group, five showed leukocyte counts of 9,000 to 14,000 per cmm. with predominance of polymorphonuclear leukocytes, but few immature forms; five had leukocyte counts of 14,000 to 20,000 with polymorphonuclear predominance and a "shift to the left;" two showed peak leukocyte counts of 27,000 and 50,000. The adults did not show bizarre differential counts or leukemoid reactions. The only fatality in the adult group occurred in a patient who had almost no elevation in the total leukocyte count.

Physical Examination

Our experience confirms the unreliability of physical examination in staphylococcal pneumonia. In the childhood group, three patients, including the two newborn infants, had no abnormal chest findings on initial physical examination; the other four had dullness, decreased fremitus, and decreased breath sounds, but no rales. In the adult group, four had normal chest examinations; three had rales; one had slight dullness at the base and another decreased basal fremitus. Only four of the 12 adults revealed significant dullness or decrease in breath sounds or rales.

Early X-ray Findings

The initial chest x-ray findings in the children revealed pneumothorax in only one (Fig. 1). One child presented only with consolidation, radioluencies and a questionable fluid level in the large radio-
lucent areas (Fig. 2). Another child (Fig. 3) presented with a large multilobulated cyst in the right base as the only initial finding on x-ray; later infiltrates and a typical staphylococcal pneumonia pattern (Fig. 4) developed in the contralateral lung. Three children presented with massive pleural effusion and opacity of one hemithorax as the initial x-ray finding.

In adults, the common parenchymal pattern was one which demonstrated the several stages of the disease process, i.e., infiltrates, radiolucencies and fluid levels in the large radiolucent areas (Figs. 5, 6, 7). Nine presented with massive pleural effusion, but only one had pyopneumothorax. Following thoracentesis, the typical pattern of infiltrate with radiolucency was seen on x-ray.

**Diagnosis**

The diagnosis of staphylococcal pneumonia was based on: (1) the isolation and identification of coagulase positive hemolytic *Staphylococcus aureus* from the intrapleural space, or (2) the clinical and x-ray findings of a necrotizing pneumonitis with predominance of coagulase positive hemolytic *Staphylococcus aureus* in sputum cultures.

**Medical Treatment**

During the two years encompassed in this study, all species of *Staphylococcus aureus* which underwent sensitivity studies in the laboratory of the USAF Hospital, Tachikawa, were reported as resistant to penicillin in the standard therapeutic dosages. There was nearly uniform sensitivity to erythromycin, chloramphenicol, streptomycin and bacitracin and a variable response to chlorotetracycline (Aureomycin) and oxytetracycline (Terramycin).

Analysis of antibiotic therapy (Chart 1) indicates no correlation between the antibiotic agents selected and the clinical results. All but three were treated with massive doses of penicillin, and most received erythromycin and chloromycetin. In every case the initial regimen was supplemented with additional antibiotics.

**Analysis of Surgical Treatment**

*Thoracentesis* was performed in nine. In only three of these was simple thoracentesis an adequate means of pleural drainage; in the other six cases, an intercostal tube was placed in the chest soon afterward. In our experience, simple aspiration of the chest is rarely sufficient and constant drainage is usually necessary. Although initially the pleural effusion may often be watery, it rapidly becomes thick and tenacious. The definitive treatment of empyema or effusion in five of six cases consisted of constant intrapleural suction at a negative pressure of 10 to 14 cm. of water. Greater negative pressure was thought to be undesirable, particularly in children because of the danger of causing or perpetuating a pre-existing bronchopleural fistula.

*Enzymatic debridement* was used in three cases. These patients exhibited a more rapid recovery.

*Tracheostomy* was performed in only one instance, in a terminal patient.
Two of the patients had residual Pseudocystis (Fig. 8). It required two months in each case for the disappearance of these cystic lesions.

A fibroblastic membrane (Fig. 9) was present, but disappeared in four cases. A reasonable time must elapse before the membrane disappears. In one case, five months were required for complete clearing. Three cases had frank abscess formation (Fig. 6, 7, 8).

**SUMMARY**

1. Staphylococcal pneumonia may be manifested in one of two characteristic fashions, the "juvenil" and the "adult" forms.

2. Nineteen cases, including both children and young adults, were seen among U. S. Air Force personnel and their dependents at the Tachikawa Air Force Base, Japan, during an 18-month period.

3. The diagnosis is based, first, on recovery of the *Staphylococcus aureus* organism and, second, on the characteristic roentgenographic picture.

4. The roentgenographic picture is a slowly changing one, in contrast to the rapid changes in the course of the clinical picture.

5. Medical treatment rests on the selection of chemotherapeutic agents on the basis of the *in vitro* sensitivity of the organism.

6. Surgical treatment includes drainage of pleural effusion by continuous suction, reduction of pneumothorax, and — only rarely—decortication for adhesive limitation of respiratory function.

**ACKNOWLEDGMENT:** The authors are deeply indebted to the following persons who read and criticized this paper: Dr. Charles Carman, Department of Medicine, University of California Medical Center, San Francisco; Dr. John A. Wilson, Department of Surgery, American University, Beirut, Lebanon; Drs. Albert Niden and Kathryn T. Sydnor, Department of Medicine, University of Chicago.

**RESUMEN**

1. La neumonía de estafilococos se manifiesta en dos formas características: la "juvenil" y la "adulta."

2. Se vieron 19 casos, incluyendo tanto niños como adultos, entre el personal de las Fuerzas Aéreas de los Estados Unidos, así como entre sus dependientes, en la Base Aérea de Tachikawa, Japón, durante 18 meses.

3. El diagnóstico se basó primero en el hallazgo de *Staphylococcus aureus* y después en el cuadro característico a los rayos X.

4. El cuadro radiológico cambia lentamente en contraste con los rápidos cambios observados clínicamente.

5. El tratamiento médico descansa en la base de la selección del agente quimioterápico que *in vitro* muestra la sensibilidad del organismo.

6. El tratamiento médico incluye la canalización pleural con succión continua, reducción del neumotórax, y sólo rara vez decorticación de la parte adherida que limita la función.

**ZUSAMMENFASSUNG**

1. Die Staphylococcen-Pneumonie kann sich manifestieren in einer von zwei charakteristischen Gestaltungen, der "juvenilen" und der "eswachsenen" Form.


3. Die Diagnose gründete sich in erster Linie auf den Nachweis von *Staphylococcus aureus*—Erregern und zweitens auf das charakteristische röntgenologische Aussehen.

4. Der röntgenologische Befund ändert sich nur langsam im Gegenstau zu dem raschen Wechsel im Ablauf des klinischen Bildes.

5. Die internistische Behandlung beruht auf der richtigen Auswahl chenotherapeutischer Stoffe an Hand *in vitro*—Sensibilität der Erreger.


*All references will appear in reprints.*