34 Acute Pneumonia and Its Complications

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Pneumonia (Greek word meaning "inflammation of the lungs") is one of the most common illness affecting infants and children globally, causing substantial morbidity and mortality.[1] Community-acquired pneumonia (CAP) designates acquisition in the community whereas hospital-associated or nosocomial pneumonia (HAP) is acquired during or after hospitalization.

ACUTE PNEUMONIA

Acute pneumonia is defined as inflammation of the alveoli and interstitial tissues of the lungs by an infectious agent resulting in acute respiratory symptoms and signs.[2] Over 155 million cases of pneumonia and 1.8 million deaths occur annually worldwide, especially affecting children <5 years of age in resource-poor countries.[3] Children in the United States have considerably less morbidity and mortality due to CAP. In the U.S., rates of outpatient visits for CAP are reported to be 74 to 92 per 1000 cases for children <2 years of age and 35 to 52 per 1000 cases in children 3 to 6 years of age;[4] the rate of hospitalization is about 200 per 100,000 cases, with the highest rate seen in infants (>900 cases per 100,000).[5] There were 525 reported deaths due to pneumonia in children <15 years of age in the U.S. in 2006.[6]

Etiologic Agents and Epidemiology (see Table 34-1)

Multiple microbes, predominantly viruses and bacteria, cause lower respiratory tract infection (LRTI) in infants and children. Establishing microbial diagnosis of pneumonia has been problematic in infants and children due to difficulty in distinguishing infection from colonization of the upper airways and lack of availability of dependable diagnostic laboratory tests.[7] In two studies of pneumonia in immunocompetent children, specific etiologic agents were confirmed in only 43% to 66%.[8,9] Identification of more than one pathogen makes it difficult to assign primary pathogenicity.[2] While bloodstream infection (BSI) confirms etiology, BSI occurs in only 1% to 10% of hospitalized children

TABLE 34-1. Microbial Causes of Community-Acquired Pneumonia in Childhood

Age	Etiologic Agents[a]	Clinical Features
Birth–3 weeks	Group B streptococcus	Part of early-onset septicemia; usually severe
	Gram-negative enteric bacilli	Frequently nosocomial; occurs infrequently within 1 week of birth
	Cytomegalovirus	Part of systemic cytomegalovirus infection
	Listeria monocytogenes	Part of early-onset septicemia
	Herpes simplex virus	Part of disseminated infection
	Treponema pallidum	Part of congenital syndrome
	Genital *Mycoplasma* or *Ureaplasma*	From maternal genital infection; afebrile pneumonia
3 weeks–3 months	*Chlamydia trachomatis*	From maternal genital infection; afebrile, subacute, interstitial pneumonia
	Respiratory syncytial virus (RSV)	Peak incidence at 2–7 months of age; usually wheezing illness (bronchiolitis/pneumonia)
	Parainfluenza viruses (PIV), especially type 3	Similar to RSV, but in slightly older infants and not epidemic in the winter
	Streptococcus pneumoniae	The most common cause of bacterial pneumonia
	Bordetella pertussis	Primarily causes bronchitis; secondary bacterial pneumonia and pulmonary hypertension can complicate severe cases
3 months–5 years	RSV, PIV, influenza, HMPV, adenovirus, rhinovirus	Most common causes of pneumonia
	Streptococcus pneumoniae	Most likely cause of lobar pneumonia; incidence may be decreasing after vaccine use
	Haemophilus influenzae	Type b uncommon with vaccine use; nontypable stains cause pneumonia in immunocompromised hosts and in developing countries
	Staphylococcus aureus	Uncommon, although CA-MRSA is becoming more prevalent
	Mycoplasma pneumoniae	Causes pneumonia primarily in children over 4 years of age
	Mycobacterium tuberculosis	Major concern in areas of high prevalence and in children with HIV
5–15 years	*Mycoplasma pneumoniae*	Major cause of pneumonia; radiographic appearance variable
	Chlamydophila pneumoniae	Controversial, but probably an important cause in older children in this age group

CA-MRSA, community-acquired methicillin-resistant Staphylococcus aureus; *HIV, human immunodeficiency virus; HMPV, human metapneumovirus.*

[a]*Ranked roughly in order of frequency. Uncommon causes with no age preference: enteroviruses (echovirus, coxsackievirus), mumps virus, Epstein–Barr virus, Hantavirus,* Neisseria meningitidis *(often group Y), anaerobic bacteria,* Klebsiella pneumoniae, Francisella tularensis, Coxiella burnetii, Chlamydophila psittaci. Streptococcus pyogenes *occurs sporadically or especially associated with varicella-zoster virus infection.*

with bacterial pneumonia.[10–12] Pathogens vary according to age, underlying illnesses, and maturation and function of the immune system.[13] Certain pathogens, particularly respiratory syncytial virus (RSV), rhinoviruses, influenza viruses, and *Mycoplasma,* are seasonal. In other instances, the pattern of family illness provides a clue to the causative agent. Extensive or invasive testing usually is not necessary.

Neonates and Young Infants

Pneumonia in neonates can manifest as early-onset disease (within the first week of life) or late-onset disease (≥7 days of life). Aspiration of either infected amniotic fluid or genital secretions at delivery is the cause of most early-onset infections. Group B streptococcus is the most frequent cause of early-onset pneumonia,[14] but *Listeria monocytogenes, Escherichia coli,* and other gram-negative bacilli can cause severe respiratory distress resembling hyaline membrane disease, usually as a part of a widespread systemic infection. Prenatal and perinatal risk factors, including preterm delivery, maternal chorioamnionitis and prolonged rupture of membranes, increase the risk for development of neonatal pneumonia. Hematogenous dissemination also can occur from an infected mother.

Chlamydia trachomatis pneumonia can occur 2 to 3 weeks after birth in 10% of neonates born to mothers colonized with the organism in their genital tract. *Bordetella pertussis* infection can cause secondary bacterial pneumonia or pulmonary hypertension (simulating pneumonia). Viruses are a less common cause compared with older infants. Congenital or perinatal infection with cytomegalovirus (CMV), herpes simplex virus (HSV), or *Treponema pallidum* can cause severe pneumonia. Genital *Mycoplasma* species and *Ureaplasma urealyticum* can cause LRTI in very-low-birthweight infants.

Infants, Children, and Adolescents

Viruses have been considered to be the most common cause of acute LRTI in children 1 to 36 months of age. In a study published in 2004 of acute pneumonia in hospitalized, immunocompetent children 2 months to 17 years of age, bacteria were identified in 60%, viruses in 45%, *Mycoplasma* species in 14%, *Chlamydophila pneumoniae* in 9%, and mixed bacterial-viral infections in 23%.[11]

Viruses

Viruses account for approximately 14% to 35% of childhood CAP[11] but for 80% of CAP in children <2 years.[12] RSV is the predominant respiratory tract viral pathogen. Other viruses include human metapneumovirus (HMPV), parainfluenza viruses (PIV) types 1, 2, and 3, influenza viruses (A and B), adenoviruses, rhinoviruses, and enteroviruses.[15] Rhinoviruses have been recovered in 2% to 24% cases of childhood pneumonia.[10,16,17] Varicella-zoster virus (VZV), CMV, and HSV can cause LRTI in immunocompromised children. Human parechovirus 1 (HPeV-1) was identified in the early 2000s, to cause LRTI in young children.[18] In 2003, coronavirus was recognized as the causative agent of severe acute respiratory syndrome (SARS) in adults; however, it caused milder disease with no documented deaths in children.[19–21]

RSV, HMPV, and influenza viruses cause infection during the winter season whereas PIV and rhinoviruses are more common in spring and autumn; adenovirus infections can occur throughout the year. A novel strain of influenza virus (H1N1) in 2009 resulted in a less severe infection in healthy infants and children compared with seasonal influenza virus.[22]

Mycoplasma pneumoniae and *Chlamydophila pneumoniae*

In one study, *Mycoplasma pneumoniae* was detected in 30% of children with CAP.[23] Harris et al.[24] found that children >5 years of age had a higher rate of *Mycoplasma* infection (42%) compared with children <5 years of age (15%). Coinfections with either *Streptococcus pneumoniae* (30%) or *Chlamydophila pneumoniae* (15%) are common.[25] Infections due to *M. pneumoniae* occur in 2- to 4-year epidemic cycles. Transmission between family members is slow (median interval 3 weeks).[26,27] *C. pneumoniae* was the causative organism of 9% to 20% of CAP in children of all ages (median age 35 months).[11,28] Asymptomatic carriage of *C. pneumoniae* is well documented and confounds assessment of pathogenicity.

Bacterial Pathogens

Bacterial pneumonia is more common in children living in developing countries, presumably due to chronic malnutrition, crowding, and chronic injury to the respiratory tract epithelium from exposure to cooking and heating with biomass fuels without adequate ventilation.[29] Evidence from multiple sources indicates that *S. pneumoniae* is the single most common cause of bacterial pneumonia beyond the first few weeks of life, occurring in all age groups and accounting for 4% to 44% of all cases.[8,10,28,30,31] The serotypes that cause uncomplicated pneumonia in the U.S. generally are similar to those that cause BSI and acute otitis media (AOM). The availability of protein conjugated vaccines against *Hemophilus influenzae* type b (Hib) and *S. pneumoniae* (PCV) has significantly reduced the morbidity and mortality associated with bacterial pneumonia in the U.S.[32,33] Pneumonia due to nontypable *H. influenzae* is uncommon in the U.S. except in children with underlying chronic lung disease, immunodeficiencies, or aspiration. Recently, a virulent strain of community-associated, methicillin-resistant *Staphylococcus aureus* (CA-MRSA) has emerged as an important agent of pneumonia, including life-threatening necrotizing pneumonia.[34–36] *Streptococcus pyogenes* (group A streptococcus or GAS) is not a frequent cause of acute pneumonia. However, both staphylococcal and streptococcal pneumonia are rapidly progressive and severe, frequently leading to hypoxemia and pleural effusion within hours. Other bacteria, especially gram-negative bacilli, are rare causes of pneumonia in previously healthy children. In one study, viral and bacterial coinfection was detected in 23% of the children with pneumonia.[11]

Occasional Pathogens

A variety of epidemiologic and host factors prompt consideration of specific organisms (Table 34-2). The most important of these is *Mycobacterium tuberculosis* (MTB), which should always be suspected if there is a history of exposure, presence of hilar adenopathy, or when pneumonia does not respond to regular therapy. In North America and Europe, risk factors for primary MTB in children are: birth to recent immigrants from countries with a high prevalence of infection, contact with infected adults, or HIV infection.[37]

Residence, and exposures lead to consideration of certain pathogens. *Coccidioides immitis* is endemic in the southwestern U.S., northern Mexico, and parts of Central and South America. *Histoplasma capsulatum* is endemic in the eastern and central U.S. and Canada. *Chlamydophila psittaci* and *Coxiella burnetii* are transmitted from infected birds and animals. *Pneumocystis jirovecii* causes pneumonia in untreated HIV-infected infants at 3 to 6 months of age, in severely malnourished children, and in other immunocompromised hosts. *Legionella pneumophila,* a rare cause of pneumonia in children, is considered with certain environmental exposures and in immunocompromised individuals.

TABLE 34-2. Occasional Causes of Pneumonia in Special Circumstances

Organism	Risk Factors	Diagnostic Methods
Histoplasma capsulatum	Exposure in certain geographic areas (Ohio and Mississippi River valleys, Caribbean)	Culture of respiratory tract secretions; urine antigen; serum immunodiffusion antibody test; and serum histoplasma complement fixation antibody test
Coccidioides immitis	Exposure in certain geographic areas (southwestern United States, Mexico, and Central America)	Culture of respiratory tract secretions; serum immunodiffusion antibody test
Blastomyces dermatitidis	Exposure in certain geographic areas (Ohio, Mississippi, St. Lawrence River valleys)	Culture of respiratory tract secretions; serum immunodiffusion antibody test
Legionella pneumophila	Exposure to contaminated water supply	Culture or direct fluorescent assay of respiratory tract secretions; antigen test on urine (type 1 only)
Francisella tularensis	Exposure to infected animals, usually	Acute and convalescent serology
Pseudomonas pseudomallei (melioidosis)	Travel to rural areas of Southeast Asia	Culture of respiratory tract secretions; acute and convalescent serology
Brucella abortus	Exposure to infected goats, cattle, or their products of conception; consumption of unpasteurized milk	Acute and convalescent serology
Leptospira spp.	Exposure to urine of infected dogs, rats, or swine, or to water contaminated by their urine	Culture of urine; acute and convalescent serology
Chlamydophila psittaci	Exposure to infected birds (often parakeets)	Acute and convalescent serology
Coxiella burnetii	Exposure to infected sheep	Acute and convalescent serology
Hantavirus	Exposure to dried mouse dung in a closed structure (opening cabins after winter closure)	Acute and convalescent serology; PCR test on the respiratory tract secretions

PCR, polymerase chain reaction.

Pathogenesis and Pathology

Pneumonia occurs in a child who lacks systemic or secretory immunity to a pathogenic organism. Invasion of the lower respiratory tract or lung usually occurs at a time when normal defense mechanisms are impaired, such as after a viral infection, during chronic malnutrition, or with exposure to environmental pollutants. Aerosol exposure or BSI occasionally can cause bacterial pneumonia.

The pulmonary defense mechanisms against LRTI consist of: physical and physiologic barriers, humoral and cell-mediated immunity, and phagocytic activity. Physical barriers of the respiratory tract include the presence of hairs in the anterior nares that can trap particles >10 μm in size, configuration of the nasal turbinates, and acute branching of the respiratory tract. Physiologic protection includes filtration and humidification in the upper airways, mucus production, and protection of the airway by the epiglottis and cough reflex. Mucociliary transport moves normally aspirated oropharyngeal flora and particulate matter up the tracheobronchial tree, minimizing the presence of bacteria below the carina. However, particles less than 1 μm can escape into the lower airways. Immunoglobulin A (IgA), is the major protective antibody secreted by the upper airways; IgG and IgM primarily protect the lower airways. Substances found in alveolar fluid – including surfactant, fibronectin, complement, lysozyme, and iron-binding proteins – have antimicrobial activity. The LRT has distinct populations of macrophages. Alveolar macrophages are the pre-eminent phagocytic cells that ingest and kill bacteria. Viral infection (especially due to influenza virus), high oxygen concentration, uremia, and use of alcohol and/or drugs can impair the function of the alveolar macrophages, predisposing to pneumonia. Cell-mediated immunity plays an important role in certain pulmonary infections such as those caused by *M. tuberculosis* and *Legionella* species.

Viruses

Viral respiratory infections can lead to bronchiolitis, interstitial pneumonia, or parenchymal infection, with overlapping patterns.[38,39] Viral pneumonia is characterized by lymphocytic infiltration of the interstitium and parenchyma of the lungs.[40] Giant cell formation can be seen in infections due to measles or CMV, or in children with immune deficiency. Viral inclusions within the nucleus of respiratory cells and necrosis of bronchial or bronchiolar epithelium can be seen in some fatal viral infections especially, adenoviral pneumonia.[41,42] Air trapping with resultant disturbances in ventilation–perfusion ratio can occur from obstructed or obliterated small airways and thickened alveolar septa.

Bacteria

Five pathologic patterns are seen with bacterial pneumonia: (1) parenchymal inflammation of a lobe or a segment of a lobe (lobar pneumonia, the classic pattern of pneumococcal pneumonia); (2) primary infection of the airways and surrounding interstitium (bronchopneumonia) often seen with *Streptococcus pyogenes* and *Staphylococcus aureus;* (3) necrotizing parenchymal pneumonia that occurs after aspiration; (4) caseating granulomatous disease as seen with tuberculous pneumonia; and (5) peribronchial and interstitial disease with secondary parenchymal infiltration, as seen when viral pneumonia (classically due to influenza or measles) is complicated by bacterial infection.[42] Bacterial pneumonia is associated with diffuse neutrophilic infiltration, resulting in airspaces filled with transudates or exudates, impairing oxygen diffusion. The proximity of alveoli and a rich pulmonary vascular bed increase the risk for complications, such as bacteremia, septicemia, or shock.

Clinical Manifestations

The symptoms of pneumonia are varied and nonspecific. Acute onset of fever, rapid breathing, and cough have been described to be the classic symptom complex of pneumonia.[43] Fever can be absent in very young infants and typically is absent in infections due to *Chlamydia trachomatis, B. pertussis,* and *Ureaplasma*. Some children have a prodrome of low-grade fever and rhinorrhea prior to developing LRT symptoms. No single sign is pathognomonic for pneumonia; tachypnea, nasal flaring, decreased breath sounds, and auscultatory crackles (crepitations or rales) are suggestive signs. Guidelines developed by the World Health Organization (WHO) for the clinical diagnosis of pneumonia in resource-poor regions highlight tachypnea (or shortness of breath) and retractions as the two best indicators of LRTI.[44] Palafox et al. observed that, in children <5 years of age, tachypnea (as defined by WHO) had the highest sensitivity (74%) and specificity (67%) for radiologically confirmed pneumonia, but it was less sensitive and specific in early disease.[45] Tachypnea can occur in other conditions such as asthma, cardiac disease, and metabolic acidosis. Crackles and bronchial breathing were reported to have sensitivity of 75% but specificity of only 57% for pneumonia.[46] Crackles can be absent early or in a dehydrated patient. Isolated wheezing or prolonged expiration is uncommon in bacterial pneumonia.[47] The value of clinical findings for predicting the presence of radiographically evident pneumonia has been evaluated in a number of studies.[48–51] In one study, the combination of a respiratory rate >50 breaths/min, oxygen saturation <90%, and presence of nasal flaring in children <12 months of age was highly associated with radiographically confirmed pneumonia.[52] About three-fourths of children with radiographically confirmed pneumonia appear ill. Severity of illness correlates with the likelihood of a bacterial cause. Approximately 6% to 25% of children <5 years of age with fever >39 °C without a source, and a white blood cell (WBC) count >20,000/mm^3 with no symptoms or signs of LRTI have radiographically confirmed pneumonia.[51,53] A systematic review of studies that considered observer agreement of clinical examination suggested that observed clinical signs were better than auscultatory signs;[54] interobserver agreement was low in recognizing crackles, retractions, and wheezing, but high in determining respiratory rate and cyanosis. However, neither respiratory rate nor cyanosis is a specific or sensitive indicator of hypoxia. Oxygen saturation should be measured in any child with respiratory distress, especially if the child has retractions or decreased level of activity.[55]

Neonates and Young Infants

The neonate with bacterial pneumonia usually develops tachypnea and respiratory distress in the first few hours of life with or without septicemia or meningitis or both. In very young, especially premature infants, apneic spells without fever and tachypnea can be the initial finding of LRTI.[54] Infants with *C. trachomatis* pneumonia present insidiously between 3 weeks and 3 months of age with staccato cough, tachypnea and crackles on auscultation.

Infants, Children, and Adolescents

Viruses. The onset of viral pneumonia is usually gradual and occurs in the context of an upper respiratory tract illness (URI) in the patient or family members. Irritability, respiratory congestion, cough, post-tussive emesis and fever follow. Although hypoxia can be marked, the patient may not appear toxic. Auscultation can reveal diffuse, bilateral wheezing and crackles. Adenovirus occasionally can cause severe pneumonia with findings similar to a bacterial infection, especially in immunocompromised hosts.

Bacteria. The onset of bacterial pneumonia usually is abrupt but can follow several days of mild URI. The patient usually is ill and toxic appearing with high fever, rigors, and tachypnea. Cough can occur later in the course of illness when the debris from the involved lung is swept into the upper airway. Unilateral pleuritic chest pain, or abdominal pain in the presence of radiographically demonstrated infiltrate, is a specific sign of bacterial pneumonia. Physical findings usually are focal, limited to an anatomic segment and include decreased tactile and vocal fremitus, diminished air entry, rales and dullness to percussion over the involved

area of the lung. Wheezing is an unusual finding in bacterial pneumonia.

Other pathogens. The major symptoms of LRTI due to *M. pneumoniae, C. pneumoniae,* and *C. burnetii* (Q fever) are fever and cough that persist for more than 7 to 10 days. The onset of pneumonia caused by *M. pneumoniae* usually is not well demarcated, but malaise, headache, sore throat, fever, and photophobia occur early, and sometimes subside when gradually worsening, nonproductive cough ensues. Although coryza is unusual, AOM with or without bullous myringitis can occur. Findings on physical examination and auscultation can be minimal, most commonly dry or musical crackles. In persons with sickle-cell disease, acute chest syndrome is common. *C. pneumoniae* infection usually causes bronchospasm and can cause an acute exacerbation of asthma. *C. burnetii* has an acute onset with intractable headache, fever, and cough with round parenchymal opacities on chest radiograph.

Differential Diagnosis

Pneumonia is highly probable in children with fever, cough, tachypnea, and shortness of breath in whom chest radiograph demonstrates pulmonary infiltrates. Alternative diagnoses are considered particularly in the absence of fever or with relapsing symptoms and signs, including foreign-body aspiration, asthma, gastroesophageal reflux, cystic fibrosis, congestive cardiac failure, systemic vasculitis, and bronchiolitis obliterans. Children who develop chemical pneumonia after ingestion of volatile hydrocarbons can have severe necrotizing pneumonia with high fever and leukocytosis as seen in bacterial pneumonia.

Laboratory Findings and Diagnosis

Radiograph

In a study evaluating ambulatory children >2 months of age with acute LRTI, routine use of chest radiography did not change clinical outcome in most cases.[56] Antibiotic was prescribed more frequently in those who underwent radiography (61% versus 53%).[57] However, chest radiograph is necessary in the following situations: children <12 months of age with acute LRTI; patients who are severely ill or hospitalized; those who have recurrent disease, fail initial antibiotic therapy, or have chronic medical conditions; those who develop complications; and those in whom the diagnosis is uncertain. Radiograph can appear falsely normal early in the course of pneumonia or in dehydrated patients.[48] Radiograph is insensitive in differentiating bacterial from nonbacterial pneumonia; however, combined with clinical findings, a normal radiograph accurately excludes bacterial pneumonia in most cases.[58,59]

Bilateral diffuse infiltrates are seen with pneumonia caused by viruses, *P. jirovecii, L. pneumophila,* and occasionally *M. pneumoniae. C. pneumoniae, C. psittaci, Coxiella burnetii,* and *M. pneumoniae* can cause patchy alveolar infiltrates, which are out of proportion to clinical findings (Figure 34-1). Distinctly confined lobar or segmental abnormality or a large pleural effusion suggests bacterial infection (Figure 34-2) and, rarely, *M. pneumoniae* or adenovirus infections.[60–62] Round appearance of infiltrate, common in children <8 years of age, most often is due to *S. pneumoniae.*

Hilar adenopathy suggests tuberculosis, histoplasmosis, or *Mycoplasma* pneumonia. Tuberculosis is highly likely in an adolescent with epidemiologic risk factors and apical disease or cavitation. Pneumatoceles (thin-walled air–fluid-filled cavities) resulting from alveolar rupture usually are associated with *S. aureus* and rarely, *S. pneumoniae, S. pyogenes,* Hib, other gram-negative bacteria, or anaerobic infections. Involvement of the lower lobes, particularly with recurrent infections, suggests aspiration pneumonia, or if confined to the same site, pulmonary sequestration. Recurrent bacterial pneumonia involving the same anatomic area suggests congenital anomaly or foreign body whereas recurrences in different areas suggest an abnormality of host defense, cystic fibrosis, or other causes.

Chest radiography rarely is useful in following the clinical course of a child with acute pneumonia who is recovering as expected. Radiographic improvement significantly lags clinical changes; complete resolution is expected in 4 to 6 weeks after onset. Follow-up radiography is indicated for children with lobar collapse, complicated pneumonia, recurrent pneumonia, foreign body aspiration, and round pneumonia (to exclude tumor as the cause).[61,62]

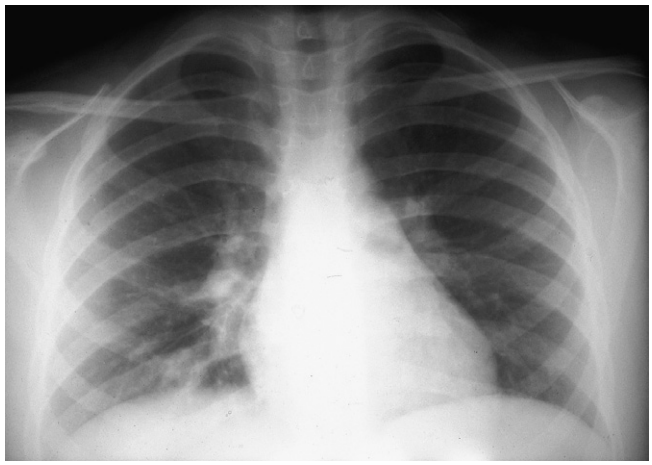

Figure 34-1. Chest radiograph of a 9-year-old girl with a 2-week history of fever, headache and hacking cough. *C. psittaci* infection was confirmed. (Courtesy of S.S. Long, St. Christopher's Hospital for Children, Philadelphia, PA.)

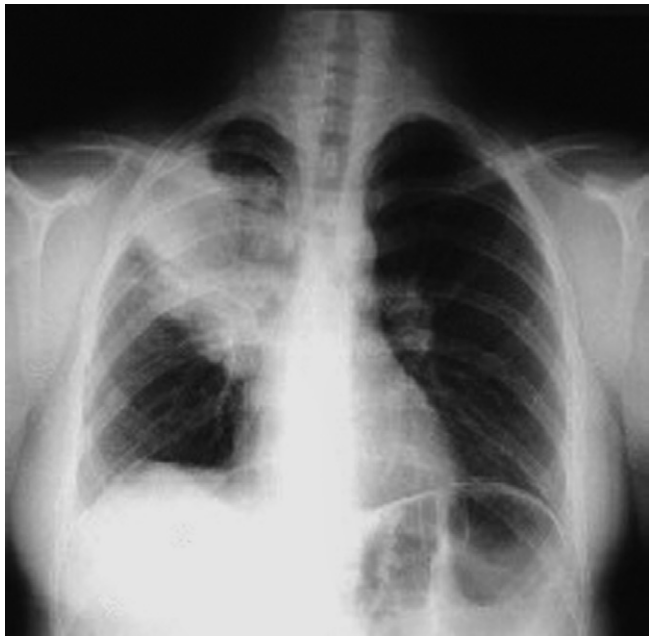

Figure 34-2. Plain radiograph showing consolidative pneumonia in the right upper lobe, typical of acute bacterial pneumonia.

Laboratory Tests

Peripheral WBC, white blood cell differential, erythrocyte sedimentation rate (ESR), and C-reactive protein (CRP) best detect invasive infections, particularly those caused by bacteria. Viral pneumonia comparatively is associated with a less brisk rise of acute-phase reactants, except with infections due to adenovirus, influenza, and measles virus. Conclusions of prospective study suggest that these tests do not stand alone as indicators of bacterial versus viral pneumonia.[63,64]

Diagnosis of Specific Agents

Viruses

Viral pathogens are best identified by isolation in tissue culture or detection of viral products (antigens or nucleic acid) in respiratory tract secretions. Combined real-time polymerase chain reaction (PCR) can rapidly detect common viral and atypical bacterial agents of CAP.[65] However, both false-positive and false-negative results can occur when specimens are obtained or transported improperly or tests are performed suboptimally. The best specimen is a nasopharyngeal aspirate or wash that contains epithelial cells. The presence of a virus in the upper respiratory tract does not exclude secondary bacterial pneumonia. Testing acute and convalescent sera for rising antibodies to various viruses usually is confined to research settings.

Bacterial Pathogens

In children >10 years of age, sputum is considered appropriate for microbiologic evaluation when Gram stain reveals <10 squamous epithelial cells and >25 neutrophils per low-power field, and a predominant microorganism. Culture of nasopharyngeal specimens does not confirm etiology because many bacterial pathogens also are common commensals. Further, noncommensal organisms residing in the upper airway may not be the cause of LRTI. Tracheal aspiration is useful for culture if performed with direct laryngoscopy. However, culture samples obtained via a catheter directly passed through a tracheostomy, endotracheal tube, or deep nasotracheal tube have limitations due to frequent contamination with upper respiratory tract organisms. (Specimen could be evaluated as for a sputum sample.) Quantitative culture performed on a bronchoalveolar lavage specimen is considered significant when the isolate colony count is $>10^4$/mL. Blood culture is specific but insensitive. A 2002 study demonstrated that transthoracic needle aspiration (lung tap) in hospitalized children with clinical pneumonia had a high microbiologic yield and was relatively safe; this procedure is not performed widely in the U.S.[32]

Other Pathogens

M. pneumoniae can be detected most effectively by PCR methodology but the test may not be readily available; culture may require 3 weeks. Cold agglutinins are found in 30% to 75% of individuals with *M. pneumoniae* pneumonia during the acute phase of the disease;[66] a titer of ≥1 : 64 has a high predictive value for *M. pneumoniae* infection. The cold agglutinin test can be falsely positive (certain viral infections and in lymphoma) or falsely negative (mild disease or in young children). Testing for serum IgM and IgA antibodies to *M. pneumoniae* is positive in 80% of cases during the early convalescent period but false-positive and false-negative results occur;[66,67] examining paired sera is the most definitive test.

C. trachomatis infection is associated with eosinophilia and elevated total serum IgM concentration.[68–70] *C. pneumoniae* infection is identified by isolation in tissue culture or PCR.[67] Serology also can confirm infections due to *C. pneumoniae, C. psittaci,* and *C. burnetii.*

When tuberculosis is considered, a tuberculin skin test (TST) is performed on the patient, immediate family members, and other significant contacts. In acutely ill patients, the TST can be nonreactive because of general or specific anergy to MTB antigen. When tuberculosis is suspected, multiple respiratory tract specimens, including sputum (spontaneous or induced), gastric aspirate, and/or bronchoalveolar lavage should be obtained for culture. Gastric aspirates are superior to bronchoscopic specimens in infants with primary or military tuberculosis.[71] The interferon-γ release assay (IGRA) on whole blood can be useful in diagnosis of latent infection (LTBI) and disease (TB). Data are limited on the use of IGRA in children <5 years of age, those recently infected, and in immunocompromised hosts.

Management

Indications for Hospitalization

Hypoxemia with SaO_2 <92% is the single most important indication for hospitalization because of increased risk of death.[72] Other indications include cyanosis, rapid respiratory rate (RR >70 breaths/min in an infant or >50 breaths/min in a child), apnea, dyspnea, expiratory grunting, toxic appearance, poor oral intake, dehydration, recurrent pneumonia, underlying medical condition, or uncertain observation at home.

Cyanosis may not be noted in hypoxic infants and children until they are terminally ill. Irritability can be an indication. Sole reliance on pulse oximetry values is hazardous in ill patients because hypercarbia, an important sign of impending respiratory failure, is missed; blood gas should be evaluated in such patients. Rapid breathing, fever, and fatigue increase the fluid requirements in a child with acute LRTI. Frequent oral hydration with small volumes of fluids or intravenous hydration may be necessary. Hydration should be performed cautiously because the syndrome of inappropriate secretion of antidiuretic hormone (SIADH) occurs in approximately one-third of patients hospitalized with probable bacterial pneumonia.[73] Malnutrition has been associated with a worse prognosis of pneumonia. Infants and small children fare better when frequently fed small quantities to prevent pulmonary aspiration.[74] Intubated or very ill children may require enteral feeding tube or parenteral nutrition.

Antimicrobial Therapy

In previously healthy, preschool children with clinical symptoms most consistent with a viral infection, antibiotics are not helpful and may increase drug toxicity or promote the development of antimicrobial resistance.

Optimal antibiotic treatment of pneumonia in infants and children has not been determined by randomized, controlled, clinical trials. Recommendations are based on the most likely etiologic agents at different ages and in various settings. Therapy with ampicillin and gentamicin are appropriate in neonatal pneumonia because the pathogens are similar to those of sepsis. A macrolide antibiotic (preferably azithromycin in infants <1 month of age) is recommended for *C. trachomatis, Ureaplasma,* and pertussis.[75] The dose of azithromycin for pertussis is 10 mg/kg per day on each of 5 days.[76] Amoxicillin at 80 to 90 mg/kg per day is effective empiric therapy for pneumonia in febrile children >3 months of age; alternatives include amoxicillin-clavulanate (given 3 times daily), cefuroxime axetil, or cefdinir.[77–79] In older children (>5 years) suspected of having an infection with *Mycoplasma, Chlamydophila,* or *Legionella,* treatment with azithromycin, erythromycin, or doxycycline (at age ≥8 years) is recommended.[80] For a hospitalized child beyond the neonatal period with uncomplicated pneumonia, initial parenteral (intravenous) therapy with ampicillin is appropriate, even in areas with penicillin-nonsusceptible *Streptococcus pneumonia;* some experts recommend use of higher doses of cefuroxime, ceftriaxone, cefotaxime, or ampicillin-sulbactam.[77–79] While the use of vancomycin, clindamycin, or linezolid is not recommended for initial treatment of uncomplicated CAP, these agents may be considered for treating suspected CA-MRSA infection, if pneumonia is unresponsive to initial antibiotics, or in those patients allergic to beta-lactam agents.[81] Other antimicrobial agents may be chosen if a likely pathogen is identified, the case has clinical or epidemiologic features strongly suggestive of a particular infection, or the evolution of the disease suggests a more specific cause.

Opinions differ about the frequency with which viral pneumonia is complicated by bacterial superinfection.[11,82] There is a good deal of evidence, however, that withholding antibiotics from hospitalized children with pneumonia clinically compatible with or proven to be of viral origin is safe and is preferable to empiric antibiotic treatment.[83] Use of specific antiviral therapy depends on the pathogen, the severity of the clinical course, and availability of effective nontoxic therapy. Use of aerosolized ribavirin for the

TABLE 34-3. Antiviral Agents for Treating Influenza

Medication	Treatment	Chemoprophylaxis
OSELTAMIVIR		
Infants birth to <3 months	3 mg/kg/dose bid × 5 days[a]	Not usually recommended
Infants 3 to 12 months	3 mg/kg/dose bid × 5 days	3 mg/kg/dose once daily × 10 days
Body weight ≤15 kg	30 mg/dose bid × 5 days	30 mg/ dose once daily × 10 days
≥15 kg to 23 kg	45 mg/dose bid × 5 days	45 mg/ dose once daily × 10 days
≥23 kg to 40 kg	60 mg/dose bid × 5 days	60 mg/dose once daily × 10 days
≥40 kg	75 mg/dose bid × 5 days	75 mg/dose once daily × 10 days
Max dose	75 mg/dose bid × 5 days	75 mg/dose once daily × 10 days
ZANAMAVIR[b]	Only in children ≥7 years 10 mg (two 5 mg puffs) twice daily	Only in children ≥5 years 10 mg (two 5 mg puffs) once daily

[a]*Oseltamivir is not FDA approved in this age group; recommend discussing with an infectious diseases physician before use.*

[b]*Zanamavir cannot be used in individuals with asthma or chronic lung disease.*

From Centers for Disease Control and Prevention. Antiviral agents for the treatment and chemoprophylaxis of influenza. Recommendations of the Advisory Committee on Immunization Practices (ACIP). MMWR 2011;60(RR-1):1–25.

treatment of RSV is guided by recommendations from the American Academy of Pediatrics, although the value of such treatment has been questioned.[84–87]

Although therapy for influenza is most effective when antivirals are started early in the course of infection,[88] recent data, indicate benefit when therapy is begun >48 hours of onset of illness in seriously ill and rapidly deteriorating patients[89,90] (Table 34-3).

Prognosis and Sequelae

Mortality due to CAP is uncommon beyond infancy in Europe and North America because of improved and enhanced immunization rates, early access to medical care, and availability of antimicrobial and supportive therapy. Most healthy children with acute LRTIs recover without sequelae, but some patients, especially premature infants, immunocompromised hosts, or children with chronic lung, neuromuscular, or cardiovascular diseases can develop complications. Complications include necrotizing pneumonia, parapneumonic effusion, empyema, pneumatocele formation, and lung abscess. In the late 1990s, there was a significant increase in complications from bacterial pneumonia in infants and children in the U.S.[91,92] Since universal immunization with pneumococcal conjugate vaccine in children <2 years of age, frequency of complicated pneumococcal pneumonia due to vaccine strains and complications due to presumed bacterial pneumonia have decreased.[93,94]

Bacterial pneumonia usually is not associated with long-term sequelae. Epidemiologic studies have linked viral bronchiolitis, *C. trachomatis,* and *C. pneumoniae* with asthma and other respiratory problems in childhood.[95–100] A study of 35-year-old adults, with history of having pneumonia before age 7 years, demonstrated a significant reduction of forced expiratory volume and forced vital capacity.[97–106] However, several longitudinal studies of lung function in children with bronchiolitis have suggested that lung function abnormalities may have preceded the acute infectious illness.[102–106] It remains unclear whether childhood pneumonia causes subsequent pulmonary abnormalities.

Prevention

Most viral respiratory tract infections are transmitted by direct inoculation from hands contaminated with respiratory secretions onto conjunctival and nasal mucosa. Airborne spread by large droplets also can occur. Hand hygiene is the single most important method of preventing hospital-associated infections. Wearing facemasks and goggles can prevent large droplet transmission. Spread of infection by small droplets can be reduced by placing the patient in a negative-pressure room.

Universal immunization with Hib conjugate vaccine and PCV has eliminated invasive Hib disease and has significantly reduced the incidence of pneumococcal pneumonia, respectively, in children and in contacts of other ages through herd immunity.[93,94,107,108]

RSV bronchiolitis and pneumonia can be reduced in high-risk infants by passive immunoprophylaxis using a monoclonal antibody (palivizumab).[109,110] Annual vaccination against influenza is recommended for all individuals ≥6 months of age.[111] It is anticipated that varicella and influenza vaccination programs will reduce incidence of bacterial pneumonia, especially that caused by *S. aureus* and *S. pyogenes*.

PLEURAL EFFUSION, PARAPNEUMONIC EFFUSION, AND EMPYEMA

Pleural effusion is the presence of demonstrable fluid between the visceral and parietal pleurae. It may be useful to characterize pleural effusions as a *transudate* or an *exudate* based on the relative concentration of pleural fluid protein to serum protein (>0.5 in an exudate versus <0.5 in a transudate), pH, glucose, and lactate dehydrogenase (LDH) concentrations (Table 34-4). Exudates more frequently have an infectious etiology and transudates a noninfectious etiology (Table 34-5).

Parapneumonic effusion (PPE) is a collection of inflammatory fluid adjacent to a pneumonic process. In prospective studies in children with CAP from Europe and the Americas, the incidence of PPE in children was 2% to 12%.[112–115] Hospitalizations for PPE have increased in the U.S. in recent years.[116–118]

Empyema is a purulent or seropurulent parapneumonic fluid. PPE can be complicated (CPPE) or uncomplicated. CPPE and empyema represent a continuum.[119] Estimated incidence of empyema in children is approximately 3.3 per 100,000.[120] Both CPPE and empyema are serious illnesses associated with significant morbidity but with infrequent mortality in the U.S.[121] Seventy percent of complicated pneumonia occurs in children <4 years of age; pneumatoceles occur predominantly in children <3 years of age.[121]

Etiologic Agents

Bacteria account for 40% to 50% of cases of PPE;[120] *S. pneumoniae, S. pyogenes,* and *S. aureus* are most common in countries where

TABLE 34-4. Biochemical Characteristics of Parapneumonic Pleural Effusions

Laboratory Value	Uncomplicated Effusion Transudate	Complicated Effusion Exudate
pH	>7.2	<7.1
Glucose level	>40 mg/dL	<40 mg/dL
Lactate dehydrogenase concentration	<1000 IU/mL	>1000 IU/mL
Pleural protein : serum protein	<0.5	>0.5

TABLE 34-5. Noninfectious Causes of Pleural Effusion in Children

Transudate	Exudate	
Hypoalbuminemia	Spontaneous chylothorax	Malignancy
Congestive heart failure	Posttrauma or postsurgical	Collagen vascular disease
Cirrhosis with ascites	Postoperative chylothorax	Pancreatitis
Myxedema	Pulmonary lymphangiectasia	Subphrenic or other intra-abdominal abscess
Peritoneal dialysis	Uremic pleuritis	Drug reaction
Central venous catheter leak	Sarcoidosis	Meig syndrome (pelvic tumor)
Fluid mismanagement	Dressler syndrome (postmyocardial infarction)	
Adult respiratory distress syndrome		

Hib vaccination rates are high.[11] During the latter 1990s, *S. pneumoniae,* especially serotype 1, emerged as the most common isolate from children with CPPE.[122] With the introduction of universal PCV in the U.S., the incidence of CPPE due to vaccine-serotype *S. pneumoniae* decreased, although serotypes 1, 19A and other nonvaccine serotypes have emerged.[117,118] CA-MRSA has become an important cause of pneumonia and CPPE in children.[123] In South Asia, *S. aureus* is the most common cause of CPPE or empyema.[124] Less frequently, *S. pyogenes, Pseudomonas aeruginosa,* mixed anaerobic pathogens, *Mycobacterium* species and, rarely, fungi can be etiologic agents.[120] About 20% of cases of PPE are due to *M. pneumoniae* and approximately 10% are due to viruses but such PPEs rarely are large enough to require intervention. In 22% to 58% of cases, PPEs are sterile and etiology is not defined.[116,124] Use of real-time PCR assay on culture-negative PPE significantly increases detection of *S. pneumoniae,* especially for serotypes other than 19A, and raises pathogen detection overall to >80%.[125]

Pathogenesis and Pathologic Findings

Usually the pleural space contains 0.3 mL/kg of fluid, maintained by a delicate balance between secretion and absorption by lymphatic vessels. Various infectious agents induce pleural effusion by different mechanisms including a sympathetic response to a bacterial infection by elaboration of cytokines, extension of infection, an immune-complex phenomenon or as a hypersensitivity reaction (e.g., rupture of tuberculous granuloma). Replication of microorganisms in the subpleural alveoli precipitates an inflammatory response resulting in endothelial injury, increased capillary permeability, and extravasation of pulmonary interstitial fluid into the pleural space. Pleural fluid is infected readily because it lacks opsonins and complement. Bacteria interfere with the host defense mechanism by production of endotoxins and other toxic substances. Anaerobic glycolysis results from further accumulation of neutrophils and bacterial debris. This in turn causes pleural fluid to become purulent and acidic (i.e., empyema). The acidic environment of the pleural fluid suppresses bacterial growth and interferes with antibiotic activity. With disease progression, inflammatory cytokines activate coagulation pathways, leading to deposition of fibrin.

Three corresponding clinical stages are: (1) exudative, in which the pleural fluid has low cellular content; (2) fibrinopurulent, in which pus containing neutrophils and fibrin coats the inner surfaces of the pleura, interfering with lung expansion and leading to loculations within the pleural space; and (3) organizational (late stage), in which fibroblasts migrate into the exudate from visceral and parietal pleurae, producing a nonelastic membrane called the pleural peel. Before the availability of antibiotics, spontaneous drainage sometimes occurred by rupture through the chest wall (empyema necessitans) or into the bronchus (bronchopleural fistula). At present, such events are rare.

Clinical and Radiographic Manifestations

PPE should be suspected by clinical examination, when the response of pneumonia to antibiotic therapy is slow, or if there is clinical deterioration during treatment. Initial symptoms can be nonspecific and include malaise, lethargy, fever, cough, and rapid breathing. Chest or abdominal pain can occur on the involved side, associated with high fever, chills, and rigors.[116,126] Difficulty in breathing (dyspnea) progresses as effusion increases. The patient usually is ill and toxic appearing, with fever and rapid, shallow respirations (to minimize pain). Breath sounds usually are diminished. The percussion note on the involved side is dull when the effusion is free-flowing; by contrast, dullness can disappear as the effusion organizes.

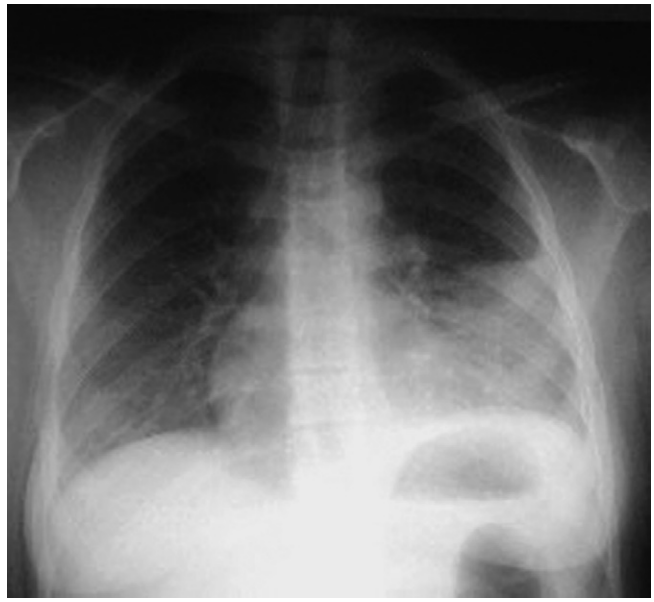

Figure 34-3. Plain radiograph showing left lower lobe pneumonia and a parapneumonic effusion, typical of acute bacterial pneumonia.

Chest radiography is more sensitive than physical examination, especially in detecting small pleural effusions. Blunting of the costophrenic angle, thickening of the normally paper-thin pleural shadow, or a subpulmonic density suggest pleural effusion (Figure 34-3). Movement and layering of fluid on lateral decubitus films differentiate free effusions from loculated collections, pulmonary consolidation, and pleural thickening. Effusions of >1000 mL compress the lung and shift the trachea. Ultrasonography or computed tomography (CT) aid differentiation of PPE from parenchymal lesion.[127–129]

Laboratory Findings and Diagnosis

Although the majority of PPEs in children are due to bacterial infection, only 25% to 49% of Gram stains or cultures are positive.[116,128] Several studies using nucleic acid or antigen detection methods demonstrate that most culture-negative empyemas, especially in patients pretreated with antibiotics, are due to penicillin-susceptible, non-vaccine serotypes of *S. pneumoniae*.[128,130-134]

Biochemical testing of pleural fluid in children with PPE associated with pneumonia rarely is necessary.[135]

Acid-fast and fungal stains and cultures for *M. tuberculosis* and fungi are performed on pleural fluid (and on sputum or gastric aspirate for TB) in suggestive or confounding clinical settings. TST and IGRA should be considered; anergy is unusual in the presence of pleural effusion.[136]

Management

The optimal management of PPEs in children depends on the size of the PPE. Small to moderate sized effusions, without significant mediastinal shift, rarely require drainage because most of these patients recover on antibiotics alone.[137] Most large effusions (defined as opacification of >½ of the thorax) fail simple aspiration and drainage, and require continuous pleural drainage.[137,138] While PPE without loculations can be treated with simple placement of a chest tube, loculated PPE is more effectively treated (shortening hospital stay) with chest tube placement, intrapleural fibrinolysis (using urokinase or tissue plasminogen activator), or video-assisted thoracoscopic surgery (VATS).[139–142] Patients with persistent large effusions (worsening respiratory compromise despite 2 to 3 days of chest tube placement and completion of fibrinolytic therapy) may require VATS or rarely, open thoracotomy with decortication; the latter procedure is associated with higher morbidity. Routinely obtained chest radiographs after chest tube placement or VATS are not useful, but re-imaging is indicated for worsening clinical status or if fever persists for >4 days after appropriate pleural drainage. The chest tube typically is removed when there is no intrathoracic air leak and drainage is <1 mL/kg per 24 hours.[139,140]

Antimicrobial Therapy

Probable pathogens, clinical circumstances, Gram stain of the pleural fluid, and radiographic appearance are considered when choosing antibiotic therapy for CPPE or empyema. Is infection community- or hospital-associated, is the patient immunocompetent or immunocompromised, is there an underlying medical condition? The empiric therapy should cover *S. pneumoniae*, CA-MRSA, and *S. pyogenes*. Therapy for anaerobic bacteria is considered if aspiration is likely. A macrolide (<8 years) or doxycycline (≥8 years) is added if atypical pathogens are suspected. Antibiotic therapy is narrowed when a pathogen is identified. Duration of parenteral therapy and total treatment is based on clinical response and adequacy of drainage; optimal duration of therapy is approximately 2 to 4 weeks, or 10 days after resolution of fever. When effusion persists and the microbial etiology is unknown, it is important to remember that fever, anorexia, and toxicity can be prolonged, even with optimal management and choice of antibiotics – due to inflammatory response within the pleural space. Therefore, additions or changes in appropriately selected antibiotic therapy should be avoided.

Prognosis

Most patients with uncomplicated PPE recover without major sequelae; although morbidity can be prolonged, the mortality rate for CPPE in previously healthy children is between 0% and 3%.[143] Mortality is highest in young infants and with *S. aureus* infection. Decortication rarely is indicated. Patients are usually asymptomatic at follow-up but radiograph can show pleural thickening which regresses only over months. Mild abnormalities occur with equal frequency in children treated with and without chest tube drainage.[144]

NECROTIZING PNEUMONIA AND LUNG ABSCESS

Necrotizing pneumonia usually occurs as a consequence of a localized lung infection by particularly virulent, pyogenic bacteria. Necrotizing pneumonia in an otherwise healthy child can resolve without further complications after antimicrobial treatment, or can lead to formation of a pneumatocele, lung abscess, or bronchopleural fistula. Lung abscess also can be the consequence of aspiration of heavily infected mouth secretions or a foreign body, secondary to BSI or septic emboli, chronic infection (e.g., cystic fibrosis, chronic granulomatous disease after prolonged intubation, or hospital-associated infection), or an underlying anomaly (e.g., congenital cystic adenomatoid malformation or pulmonary sequestration).

TABLE 34-6. Microbiology of Lung Abscesses in Children[a]

	Organisms	Percent Cases
Aerobic and facultative bacteria	*Staphylococcus aureus*	19
	Streptococcus pneumoniae	10
	Other streptococci	32
	Haemophilus influenzae	6
	Pseudomonas aeruginosa	13
	Escherichia coli	9
	Other gram-positive organisms	7
	Other gram-negative organisms	6
Anaerobic bacteria	*Bacteroides* species[b]	25
	Prevotella melaninogenica	9
	Peptostreptococcus species	21
	Fusobacterium species	5
	Veillonella species	8
	Other gram-positive organisms	8
	Other gram-negative organisms	3
Fungi		10
Mycobacteria		1

[a]*Note: more than one organism can be isolated from a lung abscess.*

[b]*Includes some* Prevotella melaninogenica *(formerly* Bacteroides melaninogenica*)*.

Data compiled from references 145–147, 149, 150.

Etiologic Agents (see Table 34-6)

Necrotizing pneumonia can complicate CAP;[145] the pathogen can be *S. pneumoniae, S. aureus* (especially CA-MRSA), or *S. pyogenes,* or no pathogen is identified. *S. pneumoniae* or *S. aureus* can cause pneumatoceles; *S. aureus* especially can progress to abscess.[146,147] Severe *M. pneumoniae* pneumonia rarely can result in lung abscess.[148] Lung abscess frequently is accompanied by PPE.

Pneumonia associated with aspiration of bacteria from the oropharynx, or from regurgitated stomach contents, is particularly likely to cause necrosis and abscess formation. Anaerobic bacteria can be isolated from 30% to 70% of lung abscesses, especially *Peptostreptococcus* spp., *Bacteroides* spp., *Prevotella* spp., *Veillonella* spp., and facultative aerobic pathogens including β-hemolytic streptococci (Lancefield groups C and G).[146]

Single or multiple lung abscesses due to *S. aureus, Streptococcus anginosus,* or *Fusobacterium necrophorum* can result from right-sided endocarditis, severe septicemia, or endovascular infarction or infection of the large veins in the neck (Lemierre disease).[149] Abscesses in intubated infants and children usually are due to hospital-associated pathogens.[147] Abscesses developing in the later stages of cystic fibrosis secondary to chronic bronchiectasis are caused by *Staphylococcus aureus, Pseudomonas aeruginosa,* or mycobacteria.[150] Necrotizing pneumonia in neutropenic and immunocompromised patients can have bacterial or fungal etiology.

Pathogenesis

Necrosis of lung parenchyma as a consequence of inadequate or delayed treatment of severe lobar or alveolar pneumonia often results in abscess formation. Aspiration and obstruction of the airways also predispose to lung abscess, typically developing 1 to

2 weeks after the aspiration episode. Risk factors for aspiration include decreased level of consciousness, neuromuscular disorders depressing the gag reflex, esophageal abnormalities, gastroesophageal reflux, prolonged endotracheal intubation, periodontal disease predisposing to bacterial hypercontamination of aspirated material.[150] Obstruction of the airway can occur from extrinsic or intrinsic masses, lobar emphysema, pneumatoceles, aspirated foreign body, or abnormal drainage as seen in congenital pulmonary sequestration. Impaired immune responses, chronic airway disease, cystic fibrosis, congenital ciliary dysfunction, bronchiectasis, high-grade bacteremia, and pulmonary infarction secondary to septic embolization increase the likelihood of abscess formation.

Clinical Manifestations

Clinical manifestations of necrotizing pneumonia are similar to, but usually are more severe than those of uncomplicated; pneumonia evolution to abscess frequently is insidious.[151,152] Prolonged fever, toxic appearance, and persistent hypoxia despite appropriate antimicrobial therapy frequently are noted. Fever, cough, dyspnea, and sputum production are present in approximately half of patients while chest pain and hemoptysis occur occasionally.[145,152]

The differential diagnosis of typical bacterial lung abscess includes necrotizing infections such as tuberculosis, nocardiosis, fungal infections, melioidosis, paragonimiasis and amebic abscess. Lesions caused by certain noninfectious diseases (malignancy, sarcoidosis, or pulmonary infarction) can mimic abscess on chest imaging.

Diagnosis

Necrotizing pneumonia is suspected in a child when the symptoms do not respond to appropriate antibiotic treatment for pneumonia. Plain film can reveal a radiolucent lesion but CT is more discerning. Decreased parenchymal contrast enhancement on CT correlates with impending necrosis and cavitation.[152] Lung abscess appears as a cavity at least 2 cm in diameter with an air–fluid level and a well-defined wall. Lung abscesses usually are found in either lower lobes or right upper lobe (Figure 34-4).[152]

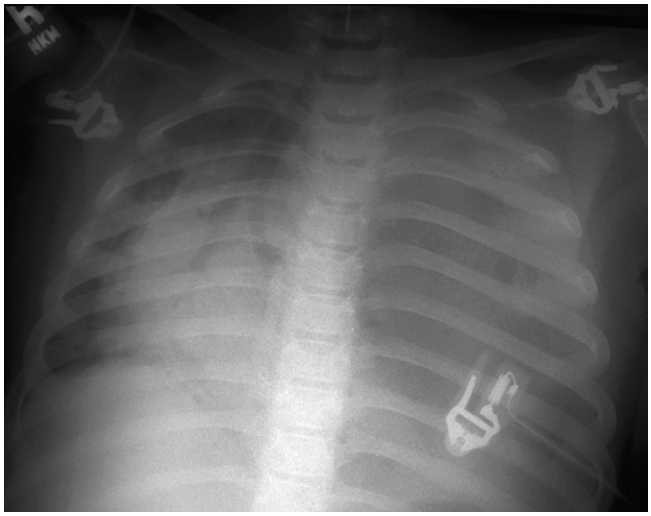

Figure 34-4. Anaerobic pleural empyema in a 5-year-old girl who came to medical attention because of a 1-month history of abdominal pain, tiredness, and constipation, but no history of an aspiration event, fever or respiratory symptoms. This radiograph was obtained after an acute respiratory event during evaluation for constipation. Note complete opacification of the left hemithorax with severe shift of the heart and trachea to the right. Three liters of putrid pus was drained, revealing a left lower lobe abscess. Gram stain and culture revealed polymicrobial anaerobic and facultative oropharyngeal flora. (Courtesy of E.N. Faerber and S.S. Long, St. Christopher's Hospital for Children, Philadelphia, PA.)

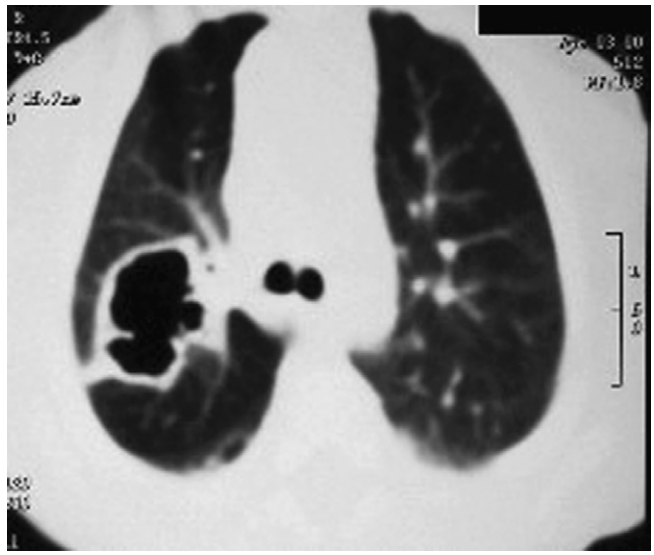

Figure 34-5. Lung windows of computed tomography study showing right sided lung abscess.

CT is useful to define the extent of disease, underlying anomalies, and the presence or absence of a foreign body (Figure 34-5). Bronchoscopy is diagnostic and therapeutic on many occasions to facilitate the removal of a foreign body or to promote the drainage of purulent fluid if this has not occurred spontaneously.[152] Specimens for culture, other than those obtained by bronchoscopy or direct aspiration of the lung, are of limited value. Quantitative culture of bronchoalveolar lavage fluid improves the accuracy of identification of aerobic and anaerobic bacteria as causes of lung abscess.[153] Ultrasound or CT-guided transthoracic aspiration of lung abscess performed on complex cases, successfully identifies the etiologic agent in >90% of cases.[154]

Management

Most cases of necrotizing pneumonia or lung abscess without substantial PPE can be effectively treated with antibiotics without surgical intervention. Parenteral therapy usually is initiated. Clindamycin was determined to be superior to penicillin for the treatment of anaerobic lung abscess in adult studies; however no difference between these two drugs was noted in a clinical trial involving children.[155–157] Parenteral clindamycin is an appropriate empiric therapy for children with suspected *S. aureus* (including MRSA) or anaerobic lung infection. Combination therapy with ticarcillin or piperacillin and a β-lactamase inhibitor, with or without an aminoglycoside, is considered when necrotizing pneumonia occurs in a hospitalized child or in a child for whom an Enterobacteriaceae (e.g., *Escherichia coli*, *Klebsiella*, etc.) or *Pseudomonas aeruginosa* infection is suspected. Duration of total antibiotic therapy is based on clinical response and usually is 4 weeks, or at least 2 weeks after the patient is afebrile and has improved clinically.

Necrotizing pneumonia or abscess is frequently complicated by PPE, which benefits from percutaneous drainage or other invasive procedures. However, percutaneous abscess drainage carries the hazard of bronchopleural fistula with prolonged morbidity or the necessity for surgical repair.[158] Percutaneous drainage is considered in patients with continued systemic illness 5 to 7 days after initiation of antibiotic therapy, in hosts with underlying conditions, and especially if lesions are peripheral or if bronchoscopy fails to drain a more central lesion. Drainage also may be necessary if an abscess is >4 cm in diameter, causes mediastinal shift, or results in ventilator dependency.[159] Surgical wedge resection or lobectomy rarely is required, and is reserved for cases in which medical management and drainage fail or bronchiectasis has occurred.

Prognosis and Complications

Necrotizing pneumonia in otherwise healthy children resolves in 80% to 90% of the cases with antibiotic treatment alone provided airway obstruction is removed.[145] Fever usually persists for 4 to 8 days. The most common complication of lung abscess is intracavitary hemorrhage with hemoptysis or spillage of abscess contents with spread of infection to other parts of the lung.[158] Other complications include empyema, bronchopleural fistula, septicemia, cerebral abscess, and SIADH.[158]

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