Pneumonia

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Objectives

After completing this article, readers should be able to:

1. Describe the findings of pneumonia on physical examination of preschool children.
2. Name the most important cause of bacterial pneumonia in children older than 6 months of age.
3. Delineate the differential diagnosis of atypical pneumonia in school-age children and adolescents.
4. Describe the treatment of pulmonary abscesses, generally caused by *Staphylococcus aureus* (primary) or anaerobic species (secondary).
5. Characterize the circumstances under which a follow-up chest radiograph is required for pneumonia.

Introduction

Pneumonia is an inflammation or infection of the lungs. Some have considered any lower (sublaryngeal) respiratory tract infection to be pneumonia, including viral croup, bronchitis, and bronchiolitis of viral etiology. This review, however, focuses on infections of the gas exchange units (terminal and respiratory bronchioles, alveoli, and interstitium) commonly seen in pediatric practice. Note that croup, bronchiolitis, and pneumonia can occur simultaneously.

Worldwide, more than 2 million children die of pneumonia annually. However, mortality is extremely rare in the United States and other parts of the developed world. Dowell and coworkers recently reported a 97% decline in annual mortality from pneumonia in the United States between the years of 1939 and 1996. The steepest rate of decline coincided with the initiation of Medicaid and was proportional to the number of children covered by the program. In the United States, 35 to 40 episodes of community-acquired pneumonia occur per 1,000 children per year. Rates are on the order of three-fold higher or more in the developing world.

Pathophysiology

If all normal host defense mechanisms function properly, pneumonia will not occur. These normal functions include: nasopharyngeal air filtration; laryngeal protection of the airway from oral and gastric fluid; mucociliary clearance of particles and pathogens from the upper and lower airways; normal cough reflexes and strength; anatomically normal, unobstructed airway drainage; normal humoral and cellular immune function; and normal innate biochemical and redox-based host defense. A range of new mechanisms involved in innate host defense has been identified in the past decade, including internalization of pathogens by epithelial cells, secretion of intrinsic and microbial peptides such as beta-defensins, and modulation of elements of airway redox chemistry—analogous to that which occurs in the stomach—such as pH.

Pathology

Classically, lobar pneumonia has four stages. Congestion lasts approximately 24 hours and is characterized by vascular engorgement with fluid and neutrophils in the alveoli. Red hepatization involves fibrin deposition in the alveolar spaces, with strands of fibrin crossing

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pores of Kohn, and extravasation of red blood cells. Gray hepatization is characterized by contracting fibrinous plugs containing degraded cells in the alveolar spaces. Resolution begins after approximately 1 week and involves digestion and macrophage-mediated phagocytosis of fibrinous material.

In interstitial pneumonia, by contrast, the walls of the alveoli and interstitial septae are involved, and the alveolar space is spared. There is an interstitial cellular infiltrate that predominantly includes lymphocytes, macrophages, and plasma cells. It is not uncommon for lobar pneumonia, interstitial pneumonia, bronchial inflammation, and bronchiolar inflammation to coexist in the same child.

Management

Neonates

Bacterial pneumonia in the first day of life may be impossible to distinguish from hyaline membrane disease or transient tachypnea of the newborn. Therefore, respiratory distress in newborns generally should be treated as bacterial pneumonia until proven otherwise. When associated with chorioamnionitis, it is caused most commonly by *Escherichia coli* or by group B streptococci (GBS). However, *Haemophilus influenzae*, *Streptococcus pneumoniae* (pneumococcus), group D streptococci, *Listeria*, and anaerobes also have been described as pathogens in this setting. Infants infected with these organisms are often preterm and have very early onset of respiratory distress. Of note, infants also may develop bacterial pneumonia transnatally in the absence of maternal chorioamnionitis. Here, the causative organism is likely to be GBS, and the onset of symptoms tends to occur 12 to 24 hours after birth.

Chest radiographs of infants who have bacterial pneumonia may exhibit a diffuse reticular nodular appearance, but in contrast to hyaline membrane disease, they tend to show normal or increased lung volumes with possible focal or coarse densities. There also may be pleural effusions, particularly with GBS pneumonia. In the newborn who has bacterial pneumonia, blood cultures obtained before the initiation of antibiotics commonly grow the offending organism. Cultures of urine and cerebrospinal fluid should be obtained at the time of the blood culture. Empiric treatment should be initiated as soon as possible with ampicillin 100 mg/kg per day divided every 12 hours (infants <1.2 kg) or every 8 hours (infants >1.2 kg) and cefotaxime 100 mg/kg per day divided every 12 hours or 150 mg/kg per day divided every 8 hours (infants >1.2 kg and >7 d old). Gentamicin is an alternative treatment, particularly when there is no evidence of meningitis. Treatment should be continued for at least 10 days, although 14 to 21 days may be required, particularly for gram-negative infections.

An unusual or unresponsive neonatal presentation of pneumonia warrants further evaluation. The maternal history may offer important clues. Neonatal pneumonia involving cytomegalovirus (CMV) or other viruses may be transmitted transplacentally. CMV pneumonia usually does not require treatment in the otherwise healthy infant. However, neonatal respiratory distress in the setting of perinatal exposure to herpes simplex virus, particularly if there is primary maternal genital infection, warrants treatment with acyclovir 30 mg/kg per day divided every 8 hours for 14 to 21 days until all cultures are negative. *Ureaplasma urealyticum* is another important consideration that can lead to chronic lung disease. Treatment of *Ureaplasma* infection in the newborn should include erythromycin 50 mg/kg per day divided every 6 hours.

Neonates may develop nosocomial pneumonia, particularly if they require prolonged intubation. These infections may involve viruses (eg, respiratory syncytial virus [RSV] or adenovirus) or bacteria (eg, *S aureus*, *Pseudomonas aeruginosa*, *Klebsiella*, and *Serratia* sp). A tracheal aspirate culture that grows more than 10^5/mL organisms may be helpful, including for identification of *Ureaplasma* infection. Bronchoalveolar lavage is occasionally helpful.

Infants

In the infant who is younger than 6 months of age and has pneumonia, it is important to decide whether a bacterial infection is likely. Bacterial infections in this age group usually are characterized by fever or recent history of fever of abrupt onset (generally >101.3°F [38.5°C]) and a productive-sounding cough. There may be signs of systemic toxicity (decreased peripheral perfusion with delayed capillary refill, lethargy, and tachycardia). In a 1998 meta-analysis, Margolis and Gadomski identified tachypnea (respiratory rate >50 breaths/min at rest) as the most sensitive sign of pneumonia in infants. However, tachypnea is not specific for bacterial pneumonia; it can reflect a variety of other pathologic processes in infants, including bronchiolitis, heart failure, sepsis, fever, and metabolic acidosis. Infants who have bacterial pneumonia generally have retractions, but not necessarily auscultatory evidence of either focal or diffuse lung disease. Cyanosis, nasal flaring, and expiratory grunting are worrisome signs suggestive of a severe bacterial or viral pneumonia in infants this age, but they may not be present.

In this age group, as in older children, pneumococcus

is the most common cause of bacterial pneumonia. Other common organisms include *S aureus*, *Moraxella catarrhalis,* and *H influenzae*. Although *H influenzae* type b (Hib) once was a common and aggressive pathogen, the widespread use of Hib vaccine has rendered it an uncommon cause. *Bordetella pertussis* may cause radiologic abnormalities, but its presentation differs from that of other bacterial pneumonias.

Infants in whom bacterial pneumonia is suspected, particularly those who are febrile, tachypneic, and toxic-appearing, require immediate attention. Blood and urine specimens should be obtained for cultures as well as a complete blood count. It should be noted, though, that blood cultures are less likely to be revealing in the older infant who has pneumonia than in the neonate. Cerebrospinal culture analysis is advisable in many infants, particularly those younger than 3 months of age. A chest radiograph should be obtained; focal consolidation is characteristic of, but not required for, the presumed diagnosis of bacterial pneumonia. Commonly, oxygen therapy is appropriate, particularly because children at this age have a hemoglobin concentration of about 10 to 11 g/dL (100 to 110 g/L) and will require relatively profound oxyhemoglobin desaturation to appear cyanotic (to achieve 4 to 6 g/dL [40 to 60 g/L] of deoxyhemoglobin). Fluid resuscitation should be undertaken unless there are signs of heart failure (cardiomegaly, hepatomegaly). Vigilance for signs of impending respiratory failure (changes in mental status, respiratory alternans, apnea, respiratory rate >90 breaths/ min with increased work of breathing) is important because oxygen demand by the muscles of respiration can outstrip supply in the setting of poor lung compliance, decreased blood oxygen content, hypovolemia, and fever. Endotracheal intubation and mechanical ventilation are advisable in the setting of impending respiratory failure.

During evaluation and stabilization, the infant suspected of having bacterial pneumonia should be treated with parenteral antibiotics. Ampicillin/sulbactam provides reasonable coverage and may be given as 200 mg/kg per 24 hours divided every 6 hours. Cefuroxime (150 mg/kg per 24 hours divided every 8 hours) or ceftriaxone (75 mg/kg per 24 hours divided every 12 to 24 hours) are reasonable alternatives. For the ill-appearing infant who has lobar pneumonia, ampicillin alone is not satisfactory, both because of the possibility that the pneumonia is caused by *S aureus* and because of the increasing prevalence (currently approximately 5% to 10%) of pneumococcus that has intermediate sensitivity or resistance to beta-lactam antibiotics. Once the infant has defervesced and is clinically stable, he or she can be switched to amoxicillin/clavulanic acid to complete a 10-day course.

Hospitalization often is advisable for supportive management of the infant suspected of having a *B pertussis* infection who has oxyhemoglobin desaturation or abnormalities on chest radiography. This infection is characterized by paroxysmal cough, whoop, or posttussive emesis following a prolonged upper respiratory tract infection and a peripheral lymphocytosis. Children younger than 6 months of age may not have the characteristic whoop. The diagnosis ideally is confirmed by polymerase chain reaction (PCR) analysis of nasal secretions. Direct fluorescence assay or culture in Bordet-Gengou medium are about half as sensitive as PCR, depending on the phase of the illness. Erythromycin (40 mg/kg per day divided every 6 hours) should be administered for 14 days to prevent spread of the pertussis organism, although this therapy will not change the course of the disease. Azithromycin (10 mg/kg per dose for 1 day, then 5 mg/kg per dose daily for 4 days) is used commonly because of convenience and compliance, but it is more expensive and of less proven efficacy. The incubation period of *B pertussis* pneumonia is generally 7 to 10 days.

Infants who have *Chlamydia pneumoniae* and are not in distress should be managed with erythromycin 50 mg/kg per day (in four divided doses) for 10 days.

Several nonbacterial pathogens are also important in this age group. *Chlamydia trachomatis*, *U urealyticum,* and CMV acquired perinatally may present late. *Pneumocystis carinii* must be considered in the differential diagnosis, but with identification of children at risk for human immunodeficiency virus and use of prophylaxis, it is seen less commonly. RSV, influenza, parainfluenza, and adenovirus are other common causes of pneumonia in this age group. Infections with *C trachomatis*, *U urealyticum*, and CMV should be suspected in the infant who is not febrile or toxic and who does not have paroxysmal

coughing, but who does have a dry cough and quiet tachypnea. Chest radiography reveals peribronchial cuffing, regions of atelectasis, or interstitial changes. Infants who have *C trachomatis* infection often have a peripheral eosinophilic pleocytosis. Infants who are not in distress, are not hypoxemic, and have afebrile tachypnea should be managed with erythromycin 50 mg/kg per day divided every 6 hours for 10 days. Alternative therapy with azithromycin (10 mg/kg on day 1, followed by 5 mg/kg per day for 4 days thereafter) or clarithromycin (15 mg/kg per day divided every 12 hours for 10 days) frequently is used for convenience, but its efficacy has not been well studied in this setting. Infants who do not respond to this regimen are likely to have CMV pneumonia; treatment generally is not required for immunocompetent patients. Children should be followed closely. If tachypnea worsens or hypoxemia develops, children should undergo bronchoscopic evaluation, and an underlying immunodeficiency should be considered.

Infants who are ill-appearing and fail to respond to antibiotics are likely to have a viral pneumonia, particularly those caused by influenza and adenovirus. Influenza occurs in the winter months and is characterized by sudden onset of fever, lethargy, and dry cough as well as gastrointestinal symptoms. It also can present in this age range as a sepsis-like picture or as croup in association with pneumonia. Influenza, RSV, and parainfluenza can be documented readily by fluorescent antibody testing. Adenoviral infections are more cumbersome to diagnose, requiring viral cultures. A severe viral pneumonia in this age group may result in a secondary bacterial pneumonia, as may pertussis. Further, viral pneumonia in this age group may be extraordinarily slow to resolve and may result in a cough that lasts for several months. Infrequently it leads to bronchiolitis obliterans, particularly in the case of adenoviral pneumonia.

Preschool-age Children

As in the infant, pneumococcus is still the most common cause of bacterial pneumonia in preschool-age children, although there is hope that use of the conjugated pneumococcal vaccine will have an impact on the incidence of pneumococcal pneumonia in the future. *Moraxella*, Hib, and *Neisseria meningitidis* each cause a small fraction of bacterial pneumonias in this age group. The febrile, tachypneic (>40 breaths/min at rest) child who has a cough, particularly in the presence of focal crackles with no coryza, wheezing, or history of asthma, should have a chest radiograph. Radiography likely will reveal a lobar or segmental consolidation. Rounded, circular-appearing infiltrates are common in bacterial pneumonia at this age (Figure). Particularly for those younger than 2 years of age, a complete blood count and blood culture should be obtained.

If the child is hypoxemic, in respiratory distress, or hemodynamically unstable, he or she should be admitted to the hospital and treated initially with supportive therapy and parenteral antibiotics. Ampicillin/sulbactam (200 mg/kg per 24 hours divided every 6 hours) or cefuroxime (150 mg/kg per 24 hours divided every 8 hours) are appropriate antibiotics until the patient is more stable and can be switched to amoxicillin/clavulanic acid. Patients who are not hypoxemic, in distress, or unstable and who have reliable caretakers at home can be treated with amoxicillin/clavulanic acid 40 mg/kg per day divided every 8 hours for 10 days as an outpatient, although there is evidence that an initial dose of parenteral antibiotic may be of benefit. Twice-daily, higher-dose amoxicillin/clavulanic acid is effective for pneumococcal otitis, but its role in pneumonia has not been established. Macrolide antibiotics (particularly azithromycin and clarithromycin) may be of some advantage if the pneumonia is suspected of being caused by *Mycoplasma pneumoniae* or if the patient is living in an area that has a high prevalence of penicillin-insensitive pneumococcus. However, therapy with these agents is generally less cost-effective than with amoxicillin/clavulanic acid. Outpatient management of lobar, bacterial pneumonia in preschool-age children should include daily follow-up clinic visits until the fever and tachypnea have resolved.

As reported by Denny and Clyde, the majority of pneumonia in preschool children is not caused by bacteria. RSV, influenza, parainfluenza, adenovirus, picornaviruses, and *Mycoplasma* are, as a group, more common causative organisms, although *Mycoplasma* is substantially less common than in older children. Patients who have nonbacterial pneumonia present with cough, often accompanied by wheezes or crackles on physical examination. When these patients are not toxic or in distress, particularly in the context of upper respiratory tract symptoms such as coryza or sore throat, they frequently can be evaluated by history and physical examination alone and followed with regular outpatient visits. Worsening of symptoms, especially the development of recurrent fever or hypoxemia, suggests either a more severe viral pneumonia or a bacterial superinfection. Failure of symptoms to resolve or development of parainfectious symptoms such as rash or arthropathy should prompt consideration of *Mycoplasma* infection. As in infants, paroxysmal cough following upper respiratory tract symptoms should prompt consideration of pertussis.

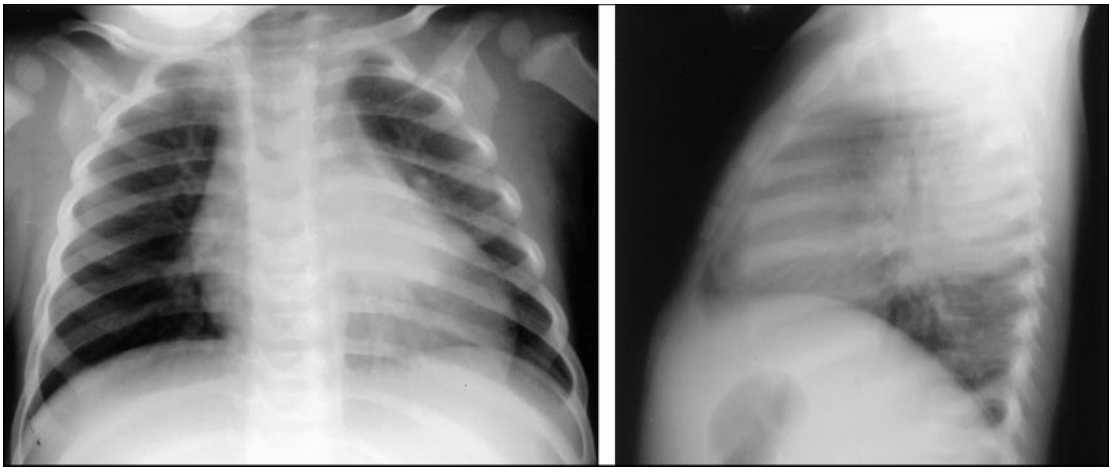

Figure. Rounded pneumonia. This 2-year-old girl, who had fever and tachypnea, did not have focal findings on physical examination. Her chest radiograph revealed a retrocardiac density. Although the round appearance is reminiscent of a thoracic mass lesion, in this setting it is most characteristic of a "round pneumonia," which is a particularly common appearance of bacterial pneumonia at this age. She was followed as an outpatient and recovered completely on amoxicillin. The most likely causative organism was pneumococcus.

School-age Children/Adolescents

In this population, *Mycoplasma* and *C pneumoniae* (often called TWAR, based on the abbreviations of the laboratory strain, to distinguish it from to *C trachomatis*) become substantially more important pathogens. Approximately 1 in 1,000 children between 10 and 15 years of age develop *Mycoplasma* pneumonia, and seroconversion rates for TWAR in this age group are approximately 20%. However, bacteria, particularly pneumococcus, continue to be important pathogens.

Physical examination of the chest can be a more refined and reliable tool for assessing pneumonia in older children. Extensive pulmonary consolidation is characterized by rales, dullness to percussion, increased tactile fremitus (eg, to the word "99") in the overlying intercostal spaces, and increased whispered pectoriloquy (transmission of whispered syllables on auscultation). In contrast, a pleural effusion generally has no rales, fremitus, or whispered pectoriloquy and may be either hyperresonant or flat. Obstructive disease or free air in the chest tends to decrease fremitus and pectoriloquy, but there is hyperresonance on percussion.

Bacterial pneumonia at this age generally is characterized by abrupt onset of high fever and cough productive of thick sputum that is rust-colored or frankly bloody if expectorated. Adolescents and some older children may be able to produce this sputum for Gram stain and culture. The sample is adequate for culture if there are more than 25 leukocytes and fewer than 25 squamous epithelial cells per low-power field.

Treatment can be with ampicillin (100 mg/kg per day divided every 6 hours) or intravenous penicillin G (150,000 U/kg per day divided every 6 hours) for patients who are hypoxic or have other reasons to require hospitalization. Of note, pneumococcus of intermediate sensitivity to penicillin responds reasonably well to these doses of penicillin or ampicillin. However, if there is substantial concern about resistance or about the patient's clinical status, ceftriaxone (80 mg/kg per day once daily or divided twice daily) or a macrolide can be used. Parenteral ampicillin/sulbactam or cefuroxime or oral ampicillin/clavulanic acid can be used if the sputum Gram stain suggests that *H influenzae* or *S aureus* is the causative organism. Healthy adolescents and older children who have bacterial pneumonia and are not hypoxemic or in distress can be managed with close follow-up on an outpatient basis.

Viruses, *Mycoplasma*, and *C pneumoniae* (TWAR) account for the majority of cases of pneumonia in adolescents. *Mycoplasma* infection often begins with the prodrome of headache or gastrointestinal symptoms as well as a low-grade fever. Importantly, rhinorrhea is not common. The cough frequently is productive, but the sputum is scant and generally nonbloody. The patient may have an erythematous macular rash or urticaria and can present with arthritis. TWAR infections may be difficult to distinguish from *Mycoplasma* infection, but they are characterized classically more by pharyngitis followed by cough and high fevers. Of note, *Legionella* infections are seen in this age group, but they are not

common. Their presentation generally is more severe than that of *Mycoplasma* or TWAR infections, with slight headache and dry cough progressing rapidly to high fever, chest pain, myalgia, abdominal symptoms, and prostration. Unlike *Mycoplasma* and TWAR infections, high white blood cell counts, peripheral leukocytosis, and evidence of hepatocellular damage are common.

The older child and adolescent who has clinical evidence of *Mycoplasma* or TWAR pneumonia should be managed with either a macrolide antibiotic or a tetracycline. Azithromycin 500 mg on day 1, followed by 250 mg/d for four subsequent days is used commonly and has established efficacy. However, erythromycin or tetracycline (for children older than 8 years of age) is more cost-effective.

Additional Considerations

Aspiration Pneumonia

Aspiration of gastric contents or oral secretions can cause pneumonia in children of all ages. It is associated primarily with neuromuscular impairment, but it also is an important consideration in patients who have anatomic abnormalities of the proximal airway or digestive tract, a history of recent sedation or anesthesia, or a history of substance abuse. Close observation and supportive therapy, almost always in the hospital, are indicated for patients who have aspiration pneumonia. Antibiotics and corticosteroids typically do not have a role as initial therapy in otherwise healthy patients who have had a witnessed aspiration of gastric contents under sedation and who do not develop focal infiltrates. However, in patients who have poor dental hygiene or recent oral surgery and in patients who are coughing up putrid-smelling sputum or who have putrid-smelling pleural fluid, anaerobic coverage with penicillin 150,000 U/kg per day divided every 6 hours is appropriate. Hospitalized patients in the chronic care setting require broader coverage with the equivalent of ticarcillin/clavulanic acid or a quinoline. *Actinomyces* also can cause pneumonia following dental work; it develops into a persistent, destructive infection. This bacterium also responds to penicillin, but a substantially longer course is required. Of note, up to 50% of patients who have acute aspiration pneumonia develop a secondary infection with *S aureus, Klebsiella, Proteus,* or *Pseudomonas* sp or *Escherichia coli*. In this case, treatment is best guided by sputum, tracheal aspirate, or bronchoscopic culture.

Pleural Effusion

Small pleural effusions are common with pneumococcal and *Mycoplasma* pneumonias and can be seen with viral pneumonias. Because pneumococcus is the most common cause of pneumonia in children, it is also the most common cause of pleural fluid accumulation. Large pleural fluid collections and empyema are frequent in cases of *S aureus* pneumonia, particularly in infants.

Children who are stable and have only a small effusion (evident primarily on the lateral view of the chest) need not undergo thoracentesis. Children who are hospitalized, are hypoxic, and who have a large pleural effusion (particularly one that shifts when studied by decubitus radiograph), should undergo thoracentesis. Ultrasonographic guidance may be advisable if the effusion is smaller or loculated and the procedure is being performed because a culture is required.

A chest tube should be placed if the pleural fluid is frankly purulent, foul-smelling, has organisms evident on Gram stain, or has a pH less than 7.3. Often, an early empyema or complicated transudate will have a sterile culture because of pretreatment with antibiotics. Other markers for an exudate that are less clear determinants of the need for a chest tube include a white blood cell count more than 1×10^3/mL (1×10^9/L), a fluid glucose concentration less than that of serum, a fluid-to-serum lactate dehydrogenase ratio of more than 0.6, or a fluid-to-serum total protein ratio of more than 0.5. Only a small population of patients who have empyema and virtually no patients who have transudates on simple exudates require thoracoscopic decortication. Indications for decortication remain controversial, but include worsening symptoms, failure to defervesce spontaneously or on appropriate antibiotic coverage, and recurrence of systemic symptoms despite antibiotics and chest tube drainage. Ramnath and coworkers suggested that thoracoscopic decortication decreases the length of hospital stay in patients who have empyema and ultrasonographic evidence of loculation. Children who have empyema generally should not be changed to oral antibiotics until 48 hours after they have defervesced and the chest tube has been removed. Ordinarily, the course of antibiotics is at least 2 weeks.

Pulmonary Abscess

Pulmonary abscesses are categorized as primary in otherwise healthy individuals and secondary in patients who have neuromuscular impairment or immunodeficiencies. *S aureus* causes approximately 75% of primary abscesses in children. Primary abscesses should be treated parenterally with ampicillin/sulbactam (200 mg/kg per 24 hours divided every 6 hours) or cefuroxime (150 mg/kg per 24 hours divided every 8 hours). Anaerobic infections are the principal cause of secondary

Table. **Unique Features: Clues To Unusual Causes For Pneumonitis**

Feature	Pneumonia	Comments
Exposure history to		
• Humans who have specific infections	Tuberculosis, varicella, measles	
• Animals and birds		
—Rabbits, other wild animals	Tularemia (*Francisella tularensis*)	Flu-like, painful skin lesions
—Rodents	Hantavirus	Flu-like, abrupt pulmonary edema
—Sheep and cattle, especially in childbirth	Q-fever (*Coxiella burnetii*)	
—Imported birds, poultry, plants	Psittacosis (*Chlamydia psittaci*)	Flu-like, headache, rash
—Pigeons	Psittacosis	
	Cryptococcosis (*Cryptococcus neoformans*)	
—Dogs and cats	Visceral larva migrans (*Toxocara canis* and *cati*)	1- to 4-year-olds who have pica, hepatomegaly
• Geography		
—American southwest	Coccidiomycosis (*Coccidioides immitis*)	May mimic tuberculosis
—American midwest and Mississippi valley	Histoplasmosis (*Histoplasma capsulatum*)	Flu-like
	Blastomycosis (*Blastomyces dermatitidis*)	May mimic tuberculosis; skin lesions common
—Developing countries	Typhoid (*Salmonella typhi*)	Gradual, systemic symptoms
	Measles	Giant cell pneumonia
	Paragonimiasis (*Paragonimus westermani*)	Hemoptysis
	Tuberculosis (*Mycobacterium tuberculosis*)	
Underlying disease		
• Cystic fibrosis	*Staphylococcus aureus*	
	Pseudomonas aeruginosa	
	Burkholderia cepacia	
	Aspergillus fumigatus	ABPA,* migratory atelectasis
• Asthma	ABPA	
• Sickle cell anemia	Acute chest syndrome	Children more commonly have infection than adults
• Neuromuscular disease	*Pseudomonas aeruginosa*	
	Klebsiella pneumoniae	
• Acquired immune deficiency syndrome	Lymphoid interstitial pneumonitis	
	Pneumocystis carinii	
	Cytomegalovirus	Often systemic
	Mycobacterial infections	Often systemic
	Fungal infections	Often systemic
Findings on complete blood count		
• Microcytic or acute anemia	Alveolar hemorrhage	Cough, infiltrates, and blood loss; may be idiopathic or secondary
• Eosinophilia	Eosinophilic pneumonia	Several types

*ABPA = allergic bronchopulmonary aspergillosis

abscesses. Secondary abscesses ideally are treated with clindamycin (30 mg/kg per day divided every 6 hours) or piperacillin/tazobactam (300 mg/kg per day divided every 6 hours). Parenteral therapy should be continued until the patient is asymptomatic and radiographic evidence of fluid in the abscess has resolved. Surgical drainage almost never is required. Bronchoscopic culture rarely is required or advisable unless the patient is not responding to empiric antibiotic coverage.

Follow-up Chest Radiography and Sequelae

In a longitudinal study of 129 children whose symptoms of uncomplicated, community-acquired pneumonia resolved completely, Grossman and colleagues demon-

strated normal chest radiographic findings in all children by 2 to 3 months after the acute infection. However, 20% still had residual changes 3 to 4 weeks after the initial infection. Asymptomatic children whose findings on physical examination are normal do not need a follow-up radiograph. Indeed, it is likely to be falsely concerning if performed in the first month.

On the other hand, children who have persistent cough, dyspnea, systemic symptoms, or abnormal physical examination findings should receive follow-up radiographs to rule out underlying problems, such as a retained foreign body, congenital lung malformation, or tuberculosis. Additionally, some community-acquired lung infections may be associated with specific, permanent pulmonary sequelae, such bronchiolitis obliterans following a viral pneumonia and bronchiectasis following pertussis. Other sequelae may merit a follow-up chest radiograph, including pneumatoceles following *S aureus* infections if air travel is anticipated.

Despite complete radiographic resolution of most cases of childhood pneumonia, there is evidence that adults who had an episode of pneumonia before age 7 years could have decreased lung function (average 6% to 7% lower FEV_1) compared with those who have not had pneumonia, even when asthma is analyzed as a confounding variable. It is not clear whether this difference reflects a predisposition of children who have decreased lung function to develop pneumonia or a permanent effect of the pneumonia episode on lung morphology. However, it suggests that follow-up of patients who have recovered completely from pneumonia might be more appropriate in the pulmonary function laboratory than in the radiology suite.

Unusual History or Clinical Course

Recurrent or Persistent Pneumonia

Following a viral pneumonia or pertussis, cough may persist for as long as 3 to 4 months. However, there should be a gradual trend toward improvement. It is not uncommon for patients who have had bacterial lobar pneumonia or *Mycoplasma*, TWAR, or *Legionella* infection to have a cough for several weeks and moderate dyspnea on exertion for 2 to 3 months. Families and school officials should be made aware of this natural history and its effects on symptoms and physical activity.

A chest radiograph should be obtained if there is no gradual trend toward improvement or if there is a worsening or recurrence of symptoms or physical findings. Persistent consolidation in a distribution of a major bronchus, either a lobar distribution or right middle lobe and right lower lobe (bronchus intermedius), particularly when the lower lobes are involved, should prompt consideration of a retained foreign body. Intralobar sequestration also results in a persistent density in a lower lobe. Chronic focal disease can suggest bronchial narrowing, such as from stenosis, endobronchial tuberculosis, a tumor, or a bronchogenic cyst. If the history and distribution makes a retained foreign body a reasonable possibility, the patient should undergo immediate rigid bronchoscopy under general anesthesia in the operating room. Other diagnoses can be evaluated by chest computed tomography, chest magnetic resonance imaging, and flexible bronchoscopy.

Recurring pneumonias that are diffuse or multifocal, particularly associated with chronic cough, should alert the clinician to underlying diseases, such as cystic fibrosis, allergic bronchopulmonary aspergillosis (associated with asthma), immunodeficiency, laryngotracheal abnormality (eg, posterior laryngeal cleft or tracheoesophageal fistula), cardiac or pulmonary vascular abnormalities, or ciliary dyskinesia. Similarly, persistent symptoms with interstitial changes, systemic findings, extrapulmonary symptoms, or hilar or mediastinal adenopathy suggest opportunistic, chronic idiopathic, or autoimmune pneumonitis. In all of these cases, the patient should be referred for subspecialty evaluation.

Unusual Historical Features

When a child presents initially with symptoms of pneumonia, it is of paramount importance to be alert to the differential diagnosis (Table). Often, features of the chest radiograph (eg, diffuse, uniform interstitial changes; hilar or mediastinal adenopathy; or abnormalities of pulmonary vasculature) alert the clinician that the child may not have one of the common causes for pneumonitis or cardiovascular disease. Historical factors, particularly exposures to specific infectious diseases or animals, geographic locations, and clues suggesting a potential underlying disease, must be considered. Important clues to underlying infectious and noninfectious causes of pneumonitis frequently are provided by the complete blood count.

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PIR Quiz

Quiz also available online at www.pedsinreview.org,

11. A 3-day-old term infant develops respiratory distress. The pregnancy, delivery, and subsequent course were uncomplicated. Maternal chorioamnionitis was not present. Chest radiograph reveals multiple coarse densities and a small pleural effusion. The *most* likely etiology of pneumonia in this child is:

A. Anaerobes.
B. *Escherichia coli.*
C. Group B hemolytic streptococci.
D. *Haemophilus influenzae.*
E. *Listeria* sp.

12. The *most* sensitive clinical sign of pneumonia in infants younger than 6 months of age is:

A. Cough.
B. Crackles.
C. Ronchi.
D. Systemic toxicity.
E. Tachypnea.

13. A 3-year-old boy aspirated gastric contents on extubation following elective surgical repair of an inguinal hernia. A chest radiograph obtained 3 hours later appears normal. He is in no acute distress, and his oxygen saturation in room air is 97%. The *most* appropriate next step is administration of:

A. Corticosteroids.
B. No drug therapy.
C. Penicillin.
D. Quinolones.
E. Ticarcillin/clavulanic acid.

14. A 16-year-old boy developed pharyngitis followed by cough and high fever. Chest radiography reveals bilateral pulmonary infiltrates. The white blood cell count is normal, and there is no shift to the left. The *most* likely infectious etiology of pneumonitis in this adolescent is:

A. *Chlamydia pneumoniae.*
B. *Legionella* sp.
C. *Staphylococcus aureus.*
D. *Streptococcus pneumoniae.*
E. *Ureaplasma urealyticum.*

Pneumonia

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