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Objectives

After completing this article, readers should be able to:

1. Discuss the major pathogens of childhood pneumonia, including the usual age groups affected and clinical features.
2. Recognize the major findings that distinguish children who have pneumonia from those who have other respiratory tract infections.
3. Outline the antibiotic regimens used to treat pneumonia in ambulatory children.
4. Describe the clinical circumstances that warrant radiographic and laboratory studies and consideration of hospitalization.
5. Explain the hospital management of pneumonia, lung abscess, and empyema.
6. Identify preventive measures for reducing the risk of pneumonia.

Introduction

Pneumonia (infection of the lung parenchyma) in children is encountered commonly in daily practice, and otherwise healthy children typically do well with outpatient treatment. It is important, however, to recognize those children who are at risk for or who already are experiencing severe or complicated pneumonia and to monitor and treat them. Pneumonia usually can be diagnosed clinically, although radiographs may be useful to corroborate the clinical findings or identify complications. Antibiotic selection is important, and the treating clinician should consider prevalent organisms, the child's age, and the presence of risk factors for atypical or resistant organisms. Occasionally, in more severe or complicated cases, hospitalization may be necessary to provide intravenous (IV) antibiotics, fluids, oxygen, and other supportive measures and to facilitate necessary invasive procedures to diagnose and treat complications. Fortunately, appropriate immunization and proper personal hygiene can go far in preventing pneumonia.

Epidemiology

About 150 million cases of pneumonia occur worldwide each year in children younger than age 5 years, according to the World Health Organization, with up to 20 million cases classified as sufficiently severe to require hospital admission. In North America, the incidence of disease in children younger than age 5 years is estimated to be 35 to 40 cases per 1,000, with a decrease to 7 per 1,000 among adolescents ages 12 to 15 years. Thus, a practitioner who has 500 children younger than age 5 years and 500 adolescents under his or her care is likely to encounter 17 to 20 cases of pneumonia per year in young children and 3 to 5 cases in adolescents. This figure does not include the much larger number of children who have other viral lower respiratory tract infections (LRTIs), such as bronchiolitis, or children who have exacerbations of asthma. Mortality among children in developed countries is low, at less than 1 per 1,000 annually, but is substantial in the developing world, with 4 million cases per year making it the number one killer of children, ahead of malaria and gastroenteritis accompanied by dehydration.

In temperate climates, pneumonia is more common in cold months, presumably reflecting enhanced person-to-person droplet spread of respiratory pathogens due to crowding, along with diminished host resistance due to impaired mucociliary clearance from dry indoor air. Children exposed to cigarette or wood stove smoke and children from lower socioeconomic levels have a higher incidence of pneumonia, as do boys compared

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with girls. Adolescents who smoke cigarettes or drink alcohol are at higher risk for acquiring pneumonia as a result of impaired mucociliary clearance and increased risk of aspiration. Children who have underlying medical disorders such as sickle cell disease, bronchopulmonary dysplasia, gastroesophageal reflux, asthma, cystic fibrosis, congenital heart disease, and immunodeficiency syndromes are at higher risk for pneumonia and its complications. Similarly, children who have neuromuscular disease or seizure disorder are at risk for aspiration pneumonia.

Pathogenesis

Pneumonia typically follows an upper respiratory tract infection. Organisms that cause LRTIs usually are transmitted by droplet spread directly from close personal contact or indirectly by contaminated fomites. Following initial colonization of the nasopharynx, organisms may be inhaled, leading to a pulmonary focus of infection; less commonly, bacteremia results from the initial upper airway colonization, with subsequent seeding of the lung parenchyma. The normal pulmonary host defense system consists of multiple mechanical barriers, including saliva, nasal hair, the mucociliary apparatus, the epiglottis, and the cough reflex. Humoral immunity, including secretory immunoglobulin A (IgA) and serum IgG, defends against pneumonia, and other airway constituents such as surfactant, fibronectin, and complement play roles in microbial killing. Phagocytic cells, including polymorphonuclear cells and alveolar macrophages, play important defense roles, and cell-mediated immunity is important in the defense against certain pathogens, especially viral agents and other intracellular organisms.

Causes

Studies of the etiologic agents of pneumonia in children are hampered by the impracticality of obtaining specimens of lung tissue to identify the precise pathogen. Thus, most of the data about etiologic agents are indirect, obtained either by using secretions (usually from the upper respiratory tract) for culture, antigen, or nucleic acid detection or by measuring host serologic responses. Another problem is the generalizability of data from one region and one season to other settings because there are considerable geographic and seasonal variations in pathogens. Dual infection, with viral and bacterial agents isolated from the same patient, is reported frequently. However, up to 50% of patients who have pneumonia, even when exhaustively investigated, have no specific microbe identified. Fortunately, discoveries of new agents (eg, human metapneumovirus this decade) continue, making it possible to identify the pathogen more frequently.

Pneumonia pathogens in children (Table 1) often are discussed in reference to age groups, with infants, toddlers, and school-age children representing broad categories. In the first postnatal month, neonatal bacterial pathogens (eg, group B *Streptococcus*, gram-negative bacilli) account for many respiratory tract infections. From 1 month to 3 to 4 months of age, viruses are the most common pathogens. Respiratory syncytial virus (RSV) leads the list, with its highest attack rate in the first 6 postnatal months. Children who have RSV disease typically present with symptoms of bronchiolitis, but pneumonia with focal infiltrates and absence of wheezing is seen occasionally. Parainfluenza virus can cause similar lower respiratory tract disease in young infants and usually is detected earlier in the fall than is RSV. *Chlamydia trachomatis* causes a distinctive respiratory tract illness typically at about 6 weeks of age (range, 2 to 8 wk). Children present with tachypnea, and radiographs show interstitial infiltrates, but the children are strikingly afebrile and usually do not appear ill. Pneumococcal pneumonia is the most common pyogenic lung infection throughout childhood, starting at this age, with important therapeutic implications and concern for suppurative complications.

In the next age group, from a few months of age through preschool, viruses continue to predominate, notably RSV and parainfluenza. Other agents such as the human metapneumovirus, rhinovirus, influenza, and adenovirus may cause pneumonia. Newly recognized agents such as coronaviruses and bocaviruses also may be responsible for LRTIs in this age group. The major bacterial pathogen in this age group is the pneumococcus, and related suppurative complications (especially empyema) have occurred more commonly in the past decade than in prior decades. Group A *Streptococcus* and *Staphylococcus aureus* (including methicillin-resistant strains) are rare causes of invasive pneumonia in children, and *Haemophilus influenzae* type B (Hib) has been virtually eliminated as a cause of pneumonia in the United States with the introduction of vaccine in the early 1990s. *Mycoplasma pneumoniae* and *Chlamydophila pneumoniae* infections occasionally are seen in preschool-age children and may be increasing in incidence in this age group.

Once children reach school age, *M pneumoniae* becomes an important pathogen, and C *pneumoniae* also appears to be a significant cause of illness, especially in teenagers. *S pneumoniae* remains an important cause, and tuberculosis must be considered in populations at

Table 1. Childhood Community-acquired Pneumonia: Common Pathogens by Age

Age	Pathogen	Comments
3 wk to 3 mo	*Chlamydia trachomatis*	• Vertical transmission • Afebrile • Interstitial infiltrates on chest radiograph
	Respiratory syncytial virus (RSV)	• Bronchiolitis with wheezing most common; focal pneumonia possible • Onset usually late fall
	Parainfluenza	• Bronchiolitis or pneumonia • Seen fall through spring
	Streptococcus pneumoniae	• Major bacterial cause throughout childhood
	Bordetella pertussis	• Tracheobronchitis with severe paroxysmal cough, no fever • Pneumonia occasionally seen, usually related to aspiration
3 mo to age 4 y	RSV, parainfluenza, human metapneumovirus, influenza, rhinovirus	• Most toddler pneumonia is viral
	S pneumoniae	• Major treatable pathogen in this age group
	Mycoplasma pneumoniae	• Possible in all ages • Increased incidence in children approaching school age
5 y through adolescence	*M pneumoniae*	• Major treatable cause in school-age children and adolescents
	Chlamydophila pneumoniae	• Also an important cause; similar clinical presentation to *Mycoplasma*
	S pneumoniae	• Still an important cause • Complications, especially empyema, often ensue
	Mycobacterium tuberculosis	• Primarily in areas or populations of high tuberculosis prevalence • Higher risk at puberty and in pregnancy

risk due to geography or other exposures. *S aureus* and group A *Streptococcus* are uncommon pathogens in this age group. Viral pathogens continue to be recovered but constitute a smaller percentage of cases.

Less common but important pathogens associated with pneumonia in children are listed in Table 2. This list is not exhaustive but does include most of the other agents seen in children in North America who have pneumonia syndromes. Additional discussion of these organisms is beyond the scope of this review; the American Academy of Pediatrics *Red Book* and other sources can be consulted for additional information on diagnosis and management of disease caused by these pathogens.

Clinical Features

The hallmark symptoms of pneumonia are fever and cough. Most children who have these two symptoms do not have pneumonia, but clinicians always should consider the possibility of pneumonia if these are present. The clinician should check the patient's temperature, pulse, respiratory rate, and pulse oximetry reading (if available) and can evaluate illness severity by observing the child while taking the history, evaluating the quality of the cough and degree of respiratory distress. The child's general demeanor, attention to the environment, willingness to drink, degree of hydration, color, and presence of cyanosis can be assessed readily while asking questions.

For the typical child who does not appear urgently ill, the history should focus on duration of illness, respiratory symptoms (eg, quality of cough, wheezing, difficulty with breathing), and extrarespiratory symptoms (eg, fever, headache, sore throat, myalgias, lethargy). Other important questions should address previous epi-

Table 2. **Other Miscellaneous Pneumonia Pathogens**

Source	Disease/Organism	Comments
Geographic tropism	Histoplasmosis	Ohio and Mississippi River valleys; Caribbean
	Coccidioidomycosis	California, Arizona, New Mexico
	Blastomycosis	Ohio and Mississippi River valleys; Great Lakes states
	Legionella	Infected water worldwide
	Severe acute respiratory syndrome	Asia
	Avian influenza	Southeast Asia
Animal-acquired	Tularemia	Rabbits, ticks
	Psittacosis	Birds, especially parakeets
	Hantavirus	Mouse dung
	Q fever	Sheep, goats, cows, cats
	Plague	Prairie dogs, squirrels, fleas
Recognizable exanthems with pneumonia	Varicella	Human-to-human spread via airborne droplet nuclei
	Measles	Human-to-human spread via airborne droplet nuclei
Bioterrorism Agents	Anthrax, inhalational	Fever, chest pain, hypoxia, widened mediastinum on radiography
	Plague, inhalational	Fever, chest pain, cough, hemoptysis, dense infiltrate on radiography
	Ricin	Respiratory distress, necrotizing pneumonitis
	Tularemia, inhalational	Atypical pneumonia, pleuritis, adenopathy
Aspiration	Mouth aerobes and anaerobes	Follows a seizure or other events leading to altered consciousness

sodes of respiratory illness, ill contacts, recent antibiotic therapy and other medications, and chronic illnesses.

The physical examination, following the general observations discussed previously, should focus on the respiratory system. Tachypnea, retractions (intercostal, subcostal, suprasternal), wheezing, nasal flaring, and grunting should be noted. Tachypnea (>50 breaths/min at 2 to 12 months of age, >40 breaths/min at 1 to 5 years, >20 breaths/min for those older than 5 years, subtracting 10 if the child is febrile) is the most sensitive and specific sign of pneumonia, found twice as frequently in children who have evidence of pneumonia on chest radiography than for those who have no such findings. Although most children who have pneumonia exhibit tachypnea, a few may not, requiring the clinician to consider the entire clinical presentation. Findings of increased work of breathing (retractions, flaring, grunting) and decreased oxygen saturation (<95%) also are predictive of LRTI. Grunting, in particular, may be a sign of pneumonia as well as of impending respiratory failure. New onset of wheezing usually is not associated with pyogenic bacterial pneumonias.

The lung examination should be performed when the child is cooperative, often while still in a parent's arms and before undertaking more threatening parts of the examination (eg, oral, aural, and abdominal). The most common signs of pneumonia detected by office-based clinicians are dullness to percussion, crackles, decreased breath sounds, and bronchial breath sounds (louder-than-normal tubular breath sounds often accompanied by egophony [E to A change]). Coarse-sounding upper airway breath sounds, often termed "rhonchi" and related to secretions in the large airways, are not necessarily indicative of pneumonia. The remainder of the physical assessment can follow the lung examination. In the absence of fever, tachypnea, increased work of breathing, and auscultatory abnormalities, bacterial pneumonia is unlikely.

It is important to review the overall severity of illness for children whose lung findings are consistent with pneumonia. Those who are ill-appearing, dehydrated, or in respiratory distress require rapid and aggressive management, including blood cultures, chemistry profiles, complete blood count (CBC), and chest radiography, as well as administration of IV fluids, oxygen, and antibiotics. Hospital admission often is indicated.

Outpatient management is sufficient for most children diagnosed with pneumonia in primary care practice. If the diagnosis is based on the lung findings and the child's condition does not warrant hospital admission,

Table 3. Community-acquired Pneumonia: Clues to Causes

- Age, season of year
- Fever
- Extrarespiratory symptoms (eg, headache, conjunctivitis, rash, myalgias, lethargy, sore throat, anorexia, vomiting, diarrhea)
- Nature of cough, congestion, chest pain, difficulty breathing, choking
- Underlying disorders (eg, seizure disorder, asthma, gastroesophageal reflux)
- Risk of foreign body aspiration
- Possible tuberculosis exposure (eg, contact with prisoners; homeless people; individuals from Asia, Africa, Middle East, or Latin America; or individuals who have chronic cough/weight loss/fever)
- Ill contacts/child care attendance
- Microbial agents in the community
- Travel history
- Immunization status
- Animal exposures/insect bites
- Previous episodes of lower respiratory tract infection/reactive airway disease

the clinician should obtain additional history to assess for clues to a possible causative agent (Table 3), paying particular attention to questions about travel, animal exposures, ill contacts, and tuberculosis exposure.

The next step in outpatient management is deciding whether to obtain laboratory studies or a chest radiograph. In most instances, blood tests such as a CBC, chemistries, or serology will not help to identify the cause or aid in management. For a highly febrile child, it is reasonable to obtain a blood culture, recognizing that even in documented pneumococcal pneumonia in children, the organism generally is recovered from the blood no more than 10% of the time. Erythrocyte sedimentation rate and C-reactive protein determinations are not useful. Diagnostic tests for bacterial pathogens with nucleic acid or rapid antigen detection performed on respiratory tract secretions are too expensive and impractical for most children in the community outpatient setting and generally do not affect therapy. In some settings, a rapid influenza test may help identify the cause of fever and reduce the subsequent use of antibacterial agents.

A chest radiograph also will not change clinical management for most children who are being treated as outpatients. For those who do not appear particularly ill but who do have impressive auscultatory findings, such as markedly diminished or altered breath sounds suggesting dense consolidation or significant effusion, a radiograph may help to determine whether a complicated pneumonia is present that requires more intense monitoring, parenteral therapy, or hospital management. Afebrile children normally do not require chest radiography.

A tuberculin skin test and close follow-up should be considered for any child who has known exposure or other risk factors for tuberculosis, chronic symptoms, or other unusual historical features. Primary tuberculosis in children may present with the picture of focal pneumonia.

A chest radiograph occasionally may be indicated for the febrile child who has no discernible source of infection if fever is prolonged, there is a history of multiple LRTIs or risk factors for pneumonia, or the physical examination raises suspicion for pneumonia.

The decision about antibiotic choice involves consideration of age, time of year, and other specific epidemiologic features. In addition to the afebrile pneumonia syndrome of infancy associated with *C trachomatis*, there are three child and adolescent pneumonia syndromes: bacterial (suppurative), atypical, and viral (Table 4). Classic bacterial pneumonia, usually caused by pneumococcus, has an abrupt onset (often following an upper respiratory tract infection [URI]), with fever and toxicity, mild respiratory distress, a cough that may be productive, and focal findings on examination. Occasionally, affected children present with emesis and abdominal pain and initially are evaluated for appendicitis. Other clues that suggest a bacterial cause include chest pain and the absence of wheezing or prominent extrarespiratory symptoms. If a chest radiograph is performed, it typically shows a unilateral focal infiltrate. Figures 1 through 6 show representative radiographs of pneumonia caused by various pathogens.

Children who have atypical pneumonia (resulting from *Mycoplasma* or *C pneumoniae*) usually are of school age or older and usually present with constitutional symptoms of myalgias, fever, malaise, headache, and gradual development of dry cough later in the illness as other symptoms improve. The chest radiograph often shows bilateral patchy infiltrates.

Children who have viral LRTIs generally present with URI symptoms, are not highly febrile or toxic, and often have bilateral auscultatory findings. Wheezing is common. Radiographs may show bilateral interstitial infiltrates.

Clinicians should remember that stereotypic presentations are not always encountered, the categories of pathogens often cause overlapping clinical features, and the chest radiograph may not distinguish the pathogens reliably. In addition, simultaneous infection with more than one agent (eg, bacterial and viral) occurs commonly.

Table 4. **Common Clinical Pneumonia Syndromes of Childhood**

Syndrome	Typical Cause	Age Group	Typical Clinical Features
Bacterial (suppurative)	Pneumococcus; others	All ages; younger children (<6 y) more common	Abrupt onset, high fever, ill/toxic appearance, more focal findings on examination, chest/abdominal pain, focal infiltrate if CXR is obtained
Atypical—infancy	*Chlamydia trachomatis*	<3 mo	Tachypnea, mild hypoxemia, lack of fever, wheezing, interstitial infiltrates on CXR
Atypical—older children	*Mycoplasma*	>5 y	Gradual onset, low-grade fever, diffuse examination findings, diffuse infiltrates if CXR is obtained
Viral	Multiple viruses	All ages; 3 mo to 5 y more common	Prominent URI symptoms, low-grade or absent fever, diffuse findings/wheezes on examination, possible diffuse interstitial infiltrates if CXR is obtained

CXR=chest radiograph, URI=upper respiratory tract infection.

Treatment

Treatment must be directed initially at assessing whether the child needs to be admitted to the hospital or can remain at home. Typical indications for hospital admission include very young age (<3 mo) (because such patients can deteriorate rapidly and are more prone to hypoxemia and bacteremia), persistent hypoxemia requiring supplemental oxygen, complicating factors such as dehydration or severe vomiting requiring IV fluids, toxic appearance, or the presence of a serious concomitant chronic condition. Children who have none of these features almost always can be treated as outpatients.

Outpatient

Children in the 3-month to 5-year age group who have pneumonia most commonly have viral infections. Thus, infants and young children who are only mildly ill and

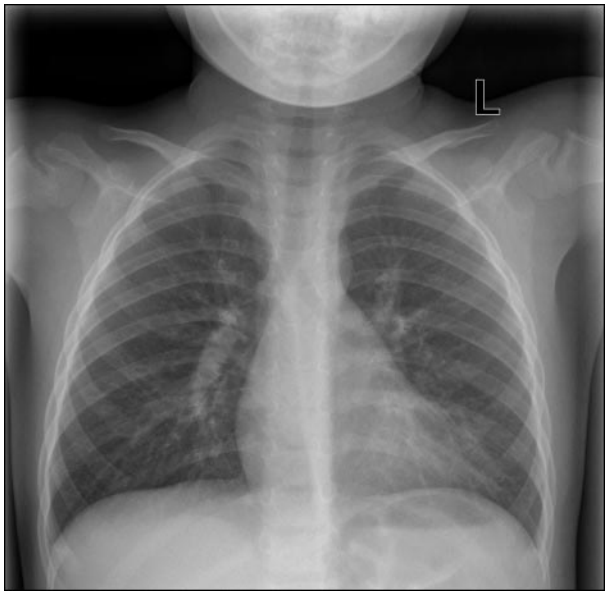

Figure 1. Radiographic findings of viral pneumonia caused by respiratory syncytial virus: Hyperinflation, mild peribronchial cuffing, increased parahilar markings, and patchy lingular opacity (note the loss of the left heart border on the frontal view), likely representing atelectasis.

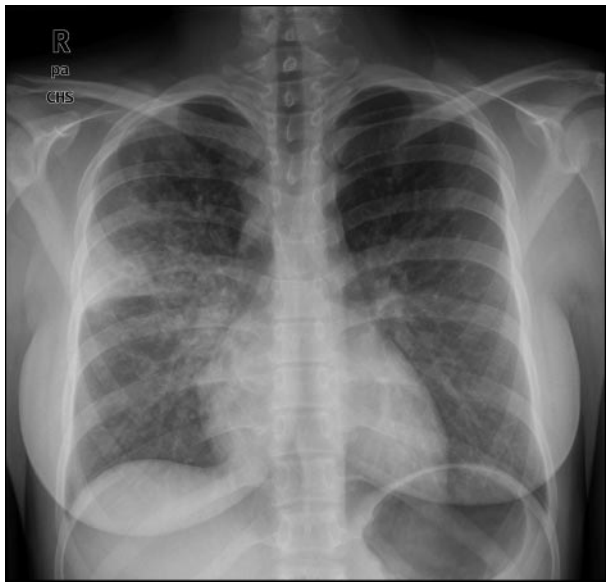

Figure 2. Radiographic findings of *Mycoplasma* pneumonia: Bilateral reticular/nodular interstitial infiltrates, with more focal patchy alveolar opacity in the right middle lobe, and opacity in the right upper lobe abutting the slightly elevated minor fissure, indicative of subsegmental right upper lobe atelectasis.

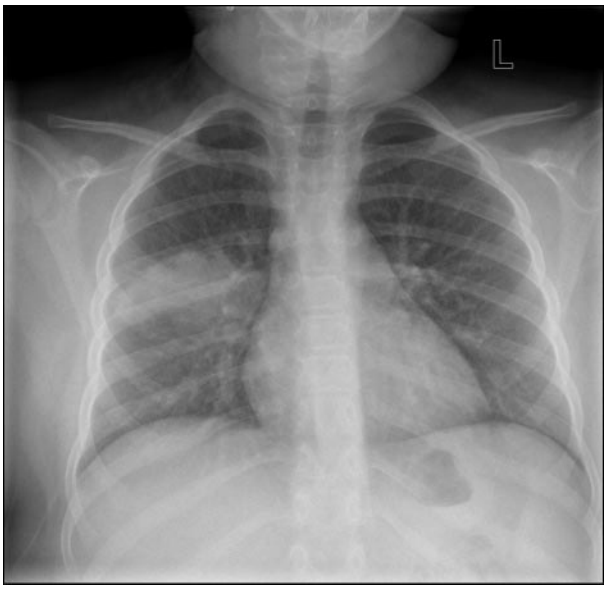

Figure 3. Radiographic findings of pneumococcal pneumonia: Rounded area of airspace consolidation in the superior segment of the right lower lobe. A few air bronchograms are seen medially.

afebrile and who have diffuse findings on chest examination generally need not receive antimicrobials. Agents are available for treating influenza, but there are no specific data on the efficacy of such drugs in pneumonia, and

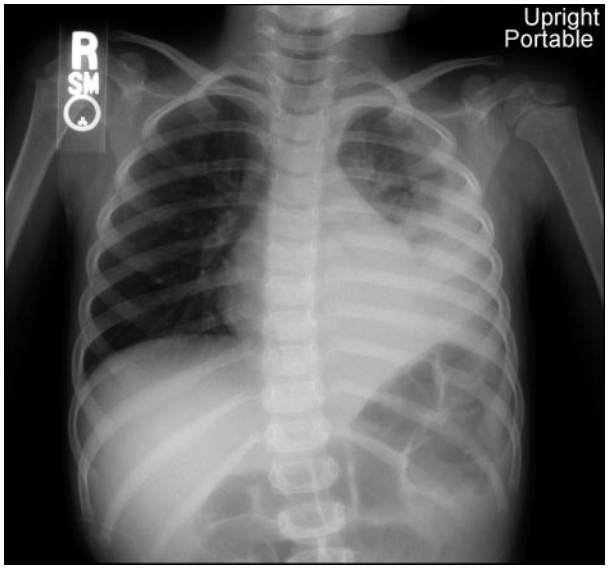

Figure 4. Radiographic findings of pneumococcal empyema: Left lower lobe and lingular consolidation (note loss of the left hemidiaphragm and lower left heart border) with associated large left pleural effusion tracking up laterally. Volume loss on the left also indicates a component of atelectasis.

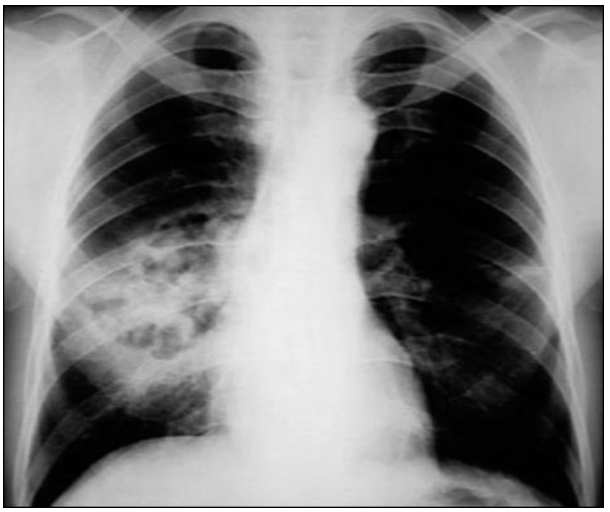

Figure 5. Radiographic findings of necrotizing pneumonia: Airspace consolidation in the right middle lobe with numerous central cavities.

there is no consensus for such treatment in the outpatient setting. For those who are suspected of having bacterial pneumonia, treatment for *S pneumoniae* is warranted. The first-line agent is amoxicillin, given orally at the dose of 80 to 100 mg/kg per day divided every 8 hours to provide effective coverage for penicillin-nonsusceptible

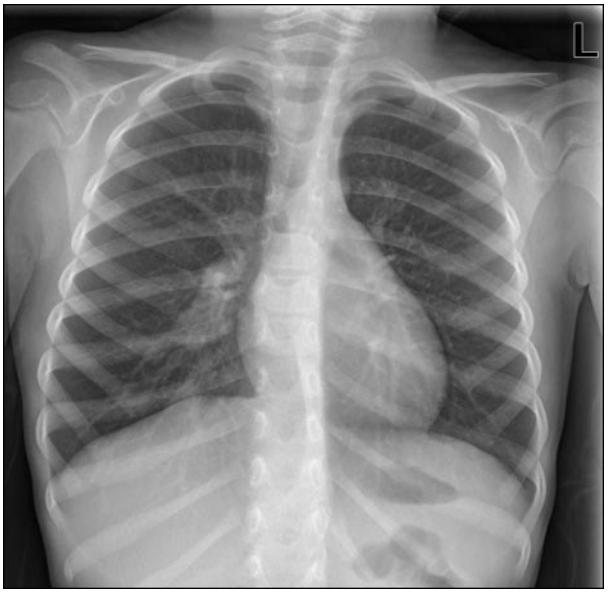

Figure 6. Radiographic findings of tuberculosis: Patchy airspace opacity in the right lower lobe and prominence of the inferior aspect of the right pulmonary hilum, consistent with hilar adenopathy, in a child whose purified protein derivative test result is positive.

Table 5. **Antimicrobials Used in Outpatients**

Agent	Dose (mg/kg per day)	Usual Maximum Dose
Amoxicillin	80 to 100 divided BID/TID	1 g TID
Cefdinir	14 divided QD/BID	600 mg QD
Cefuroxime	30 divided BID	500 mg BID
Cefpodoxime	10 divided BID	200 mg BID
Ceftriaxone	50 mg IM given QD	2 g QD
Azithromycin	10 mg QD day 1 5 mg QD days 2 to 5 OR 10 mg QD for 3 d	500 mg 250 mg daily 500 mg daily for 3 d
Doxycycline	4 mg divided BID	100 mg BID
Levofloxacin (not recommended for children <18 y)		750 mg daily
Clindamycin	20 to 40 mg divided TID	600 mg TID
Amoxicillin-Clavulanate	80 to 100 divided BID/TID	2 g BID

QD=once daily, BID=twice a day, TID=three times a day, IM=intramuscular.

organisms (Table 5). Some clinicians elect to administer one dose of ceftriaxone intramuscularly on the first day to achieve rapidly effective serum concentrations.

Although penicillin-nonsusceptible pneumococcal strains are present in most communities, high-level resistance to beta-lactam antibiotics still is relatively rare, and penicillins and cephalosporins administered at appropriate doses usually are sufficient to treat such organisms. Antibiotics such as vancomycin seldom are required for treatment of pneumonia. For children who have nontype 1 allergy to amoxicillin, a cephalosporin such as cefdinir, cefpodoxime, or cefuroxime may be used. For those who have a history of type 1 reactions, including hives, anaphylaxis, and other severe reactions, clindamycin or a macrolide such as azithromycin may be chosen. However, pneumococcal resistance to these last two agents, especially azithromycin, is increasing. Children who do not improve after 48 hours should be reassessed, with consideration given to performing a chest radiograph to rule out a complication of pneumonia such as a parapneumonic effusion. For children whose pneumonia is suspected of being due to atypical agents, treatment with azithromycin also can be considered.

The atypical organisms *M pneumoniae* and *C pneumoniae* are the most likely potentially treatable pathogens in children and adolescents 5 to 20 years of age, and a macrolide is the drug of choice. Azithromycin is recommended most often because of its ease of administration, with once-daily dosing for 5 days. For children older than age 8 years, doxycycline is an excellent alternative. These agents are not ideal for treating *S pneumoniae*; hence, children who have an abrupt onset of symptoms, ill appearance, high temperature, or focal pulmonary findings on examination and radiography probably should be treated with a beta-lactam antibiotic. The benefits of treating pneumococcal infections and complications of nontreatment are well established. In contrast, the need for antimicrobial treatment of atypical organisms is less clear, and complications from nontreatment are rare. In some situations, when it is more prudent to treat for both bacterial and atypical pneumonia, treatment with two agents (a beta-lactam and a macrolide or doxycycline) may be the best course of action, given the more severe consequences of inadequately treated bacterial pneumonia.

Older adolescents may be treated with fluoroquinolones, such as levofloxacin or moxifloxacin, which are active against both *S pneumoniae* and the organisms causing atypical pneumonia. These antibiotics provide simple, once-daily therapy. Increasing data suggest that these agents are safe in children and that they eventually may be approved for children younger than age 18 years. Again, there may be clinical situations where treatment for bacterial disease with amoxicillin or a cephalosporin is more prudent than treating only for atypical organisms with azithromycin or doxycycline, given the more severe consequences of inadequately treated bacterial pneumonia.

Patients who are suspected of having aspiration pneumonia, such as children who have seizure disorders or underlying neuromuscular disease, usually are given amoxicillin or amoxicillin-clavulanate to treat mouth organisms, including anaerobes. For those who have a penicillin allergy, clindamycin can be used.

The duration of therapy generally should be 7 to 10 days, in part depending on the clinical response. If the

Table 6. **Antimicrobials Used for Inpatients**

Agent	IV Dose (mg/kg per day)	Usual Maximum Daily Dose
Ceftriaxone	50	2 g
Ampicillin	200 divided QID	12 g
Vancomycin	40 to 60 divided BID	3 to 4 g
Clindamycin	30 to 40 divided TID	2.7 g
Levofloxacin	Not recommended for children	750 mg
Azithromycin	10 day 1 5 days 2 to 5	500 mg 250 mg
Doxycycline	Not recommended for children	200 mg
Nafcillin/Oxacillin	200 divided q 6 h	12 g
Linezolid	30 divided TID <12 y; 20 divided BID >12 y	600 mg BID
Ampicillin-Sulbactam	200 ampicillin component divided q 6 h	12 g
Piperacillin-Tazobactam	300 piperacillin component divided q 6 h	16 g
Meropenem	60 divided q 8 h	3 g

IV=intravenous, QID=once daily, BID=twice a day, TID=three times a day.

child's condition deteriorates or does not improve in 2 or 3 days, other pathogens should be considered, as should the possibility of a complication such as empyema or abscess. For children who improve with treatment, repeat chest imaging is not recommended unless there have been previous episodes of pneumonia (in which case, additional images are obtained to ascertain that there are no anatomic or functional abnormalities to account for recurrent infections).

Inpatient

As noted previously, although most children diagnosed with pneumonia can be treated as outpatients, there are instances in which hospitalization may be recommended. Infants between 3 weeks and 3 months of age who have pneumonia typically are admitted to the hospital, especially if they have fever, hypoxia, respiratory distress, or dehydration. Older infants, children, and adolescents who present with signs of ongoing respiratory distress, including tachypnea, grunting, increased work of breathing, or hypoxemia, should be admitted, as should children who are significantly dehydrated or highly febrile and toxic in appearance. Other children for whom admission should be considered include those who have underlying cardiac, pulmonary, metabolic, immunologic, hematologic (especially sickle cell disease), or neoplastic disease. In addition, children who worsen clinically despite appropriate outpatient therapy, including those who develop complications of pneumonia such as parapneumonic effusion or lung abscess, should be hospitalized.

When children are admitted to the hospital, chest imaging and laboratory tests should be performed, including CBC, blood culture, and a chemistry panel. It is important to attempt to determine the causative pathogen(s) to optimize antimicrobial therapy. For children who are able to expectorate, sputum should be obtained and tested for bacterial pathogens. A rapid diagnostic test performed on nasopharyngeal secretions can lead to a timely diagnosis of the major viral respiratory tract pathogens, with confirmation using traditional viral culture. In most clinical settings, the presence of *Mycoplasma*, *Chlamydophila*, and *Legionella* can be determined serologically; *Legionella* and pneumococcal infections are detectable with urine antigen tests.

Hospital management includes basic supportive care. Supplemental oxygen, suctioning, IV fluids, analgesics, and antipyretics should be administered as needed. Vital signs should be monitored and serial examinations performed.

The choice of antibiotic depends on the clinical scenario (Table 6). Infants younger than 3 months of age who have an illness suggestive of the atypical pneumonia syndrome of infancy (tachypnea, mild hypoxemia, absence of fever, and interstitial infiltrates on chest film) should be treated with a macrolide antibiotic. Azithromycin generally is recommended because of the once-daily dosing schedule. Initial empiric coverage for pneumococcus with a broad-spectrum antibiotic, such as ceftriaxone, is recommended if suppurative pneumonia (based on toxic appearance, leukocytosis, radiographic findings) is a concern.

For older infants and children, pneumococcus is the major pathogen of concern, and treatment with ceftriaxone or ampicillin is appropriate. These drugs also are effective against group A *Streptococcus*. Children who

have more fulminant or extensive disease, characterized by rapid onset of large pleural fluid collections or pneumatoceles, and children who have failed treatment with effective antipneumococcal therapy generally should be treated with broader-spectrum agents, such as clindamycin or vancomycin, that provide good coverage for *S aureus* (including methicillin-resistant *S aureus* [MRSA]) in addition to *S pneumoniae* and group A *Streptococcus*. Children who have aspiration pneumonia may be treated with ampicillin, ampicillin-sulbactam, or clindamycin.

Pneumonia caused by atypical agents usually is treated with a macrolide, most commonly azithromycin because of its once-daily dosing schedule and availability for IV treatment. This agent also covers *Legionella*, a rare but potentially serious cause of childhood pneumonia. For children older than age 8 years, doxycycline can be used for *Mycoplasma* and *Chlamydia*. Older teens may be given levofloxacin, which is active against pneumococcus, *Mycoplasma*, *Chlamydophila*, and *Legionella*. In some instances, therapy with two agents may be warranted (eg, a macrolide combined with a beta-lactam agent).

The length of therapy for children hospitalized with pneumonia that otherwise is uncomplicated depends on the clinical course. Once the child is afebrile and clinically stable, oral therapy should be sufficient, using the agents outlined in Table 5, for a total duration of 7 to 10 days (5 days for azithromycin because of its long half-life). Follow-up radiographs generally are not recommended for children who have had good clinical responses.

Complications

Major suppurative complications of pneumonia include parapneumonic effusion, lung abscess, and necrotizing pneumonia. Necrotizing pneumonia is a rare complication of bacterial pneumonia in which liquefaction and necrosis of lung tissue is caused by toxins of highly virulent organisms. Children who have this complication generally appear very ill. Routine imaging and chest computed tomography scan reveal a characteristic radiographic appearance. Treatment consists of a long course (typically 4 weeks) of antibiotics, usually administered parenterally. If no pathogen is identified, therapy generally should include coverage for *S pneumoniae*, group A *Streptococcus,* and *S aureus,* with vancomycin or clindamycin being first-line choices.

Lung abscess is diagnosed based on characteristic chest imaging showing a thick-walled cavity with an air-fluid level in a child who has symptoms of pneumonia. Abscesses in the lung typically develop following an aspiration event, sometimes related to a seizure or underlying neuromuscular disease. Frequently involved microbes are mouth organisms, including *Streptococcus* and anaerobes; *S aureus* and gram-negative rods also may be involved. Tuberculosis always should be considered and an appropriate evaluation undertaken, including applying a skin test and obtaining acid-fast bacilli sputum smears and cultures. Treatment of lung abscess may be empiric, using clindamycin or another antibiotic effective against anaerobic organisms. However, needle aspiration of the abscess to obtain culture specimens often is recommended, especially in children who have underlying disorders or who do not respond to initial empiric therapy. Duration of treatment generally is several weeks, depending on the rapidity of the response and the radiographic resolution of the process; treatment may include a combination of parenteral and oral antibiotics.

In contrast to the previously noted complications, the development of simple sterile parapneumonic effusions in association with bacterial pneumonia is common. With therapy directed against the causative organism, such sympathetic effusions typically resolve without additional intervention. However, purulent effusions with a resultant empyema have become increasingly common. Children who have empyema typically present with persistent fever, diminished appetite, fatigue, chest pain, and some degree of respiratory distress. This may represent the initial presentation to the clinician for some children; in others, this picture develops over time while the child is receiving medical care and antibiotics. Affected children usually appear ill, with fever and tachypnea, and often with chest pain and splinting. Physical examination findings are striking, including dullness to percussion and markedly diminished air movement.

Imaging studies guide the clinical management of children who have parapneumonic effusions. Plain radiographs establish the diagnosis of an effusion, and decubitus views can help in determining whether the fluid is free-flowing, typical of an early effusion, or loculated. Ultrasonography often can determine the location, quantity, and quality of fluid (eg, thickness, fibrinous streaking, and presence of loculations) and identify an optimal location for chest tube insertion. Chest computed tomography scan can complement ultrasonographic evaluation and may enhance anatomic detail, but is not necessary in planning management.

Pleural fluid ideally should be analyzed before antibiotics are administered, but it is unusual for children who have significant effusions not to have received antibiotic therapy before pleural fluid is obtained. Children who have small, free-flowing effusions should be given a trial of antibiotics before considering a pleural fluid aspiration to see if the effusion resolves. When obtained, pleural

fluid should be sent for Gram stain and routine and anaerobic culture; cell count and differential count; pH, glucose concentration, and lactate dehydrogenase measurement (to help differentiate a transudate from an exudate); rapid antigen detection for pneumococcus; specific and broad-range polymerase chain reaction testing for bacterial pathogens (if available); acid-fast bacillus and fungal culture (if indicated); and cytology if malignancy is under consideration (eg, based on absence of febrile illness or mass on chest radiograph).

The approach to surgical intervention for infected parapneumonic effusions has been controversial, with a variety of methods advocated. Most institutions have developed their own preference, depending, in part, on the local experience and expertise. Options include medical management alone or in combination with thoracentesis, chest tube drainage, video-assisted thoracoscopic surgery (VATS) with chest tube drainage, intrapleural fibrinolytic therapy, and thoracotomy. A recent meta-analysis of studies in children showed that those receiving primary operative therapy (usually VATS) had a lower mortality rate, length of hospital stay, and duration of antibiotic therapy compared with those treated with antibiotics and thoracentesis or tube drainage alone.

Intrapleural fibrinolytic therapy has been promoted as a possible approach in centers where VATS procedures are not available. Data showing benefit from this procedure have been less impressive than the results of VATS, and a recent large study in adults demonstrated no benefit to patients who received intrapleural fibrinolytic therapy via chest tube compared with those who received intrapleural saline.

Based on these observations, one practical approach to surgical management of significant pleural effusions is to perform a simple thoracentesis under anesthesia in children whose imaging studies suggest free-flowing fluid. This procedure is undertaken for diagnostic and therapeutic reasons, with removal of as much fluid as possible and (usually) insertion of a chest tube. If the fluid is purulent or loculated, VATS then can be performed; otherwise, VATS can be delayed while awaiting clinical response to chest tube drainage. For children in whom noninvasive studies suggest more complex loculated effusions, VATS may be carried out initially. The VATS procedure also allows for lung biopsy in cases where the diagnosis is uncertain or the child is not responding to treatment.

Supportive care of children who have parapneumonic disease includes antipyretics, fluids, analgesia, and oxygen, if required. Chest physical therapy is not recommended, and bronchodilator therapy generally is contraindicated because it may worsen ventilation/perfusion mismatch by opening up nonperfused areas of the lung.

Antibiotic therapy is tailored to the characteristics of the patient, the local microbial epidemiology, and the results of microbiologic studies. In general, coverage for pneumococcus and *S aureus* is warranted; anaerobes and gram-negative rods typically are not involved in empyema in otherwise healthy children.

Potential empiric agents include ceftriaxone, often in combination with clindamycin or vancomycin. Vancomycin has the best activity against pneumococcus and MRSA, but does not achieve as high tissue concentrations as others and does not convert to an oral equivalent once parenteral therapy is stopped. Ceftriaxone is not ideal for methicillin-sensitive *S aureus* and is ineffective against MRSA, but is the easiest to administer and has a long and successful track record in treating serious pneumococcal infections, including strains that are penicillin-nonsusceptible. Clindamycin is active against most strains of pneumococcus and *S aureus*, including some, but not all, strains of MRSA.

For children in whom noninvasive studies suggest more complex loculated effusions, video-assisted thoracoscopic surgery may be carried out initially.

The duration of antibiotic therapy is not defined clearly. Following chest tube drainage or VATS, continuation of IV treatment (with adjustments based on susceptibility data) generally is recommended until the patient has been afebrile for a few days, followed by 2 weeks of high-dose oral therapy. Long-term parenteral therapy for children who undergo VATS typically is not required.

Recurrent Pneumonia

Recurrent pneumonia is defined as more than one radiographically confirmed episode in a year or more than three episodes in a lifetime (with clinical or radiographic resolution between episodes). In general, the differential diagnosis includes anatomic lesions such as vascular rings, cysts, and pulmonary sequestration; respiratory

tract disorders such as cystic fibrosis, gastroesophageal reflux, and aspiration; and immunologic disorders such as human immunodeficiency virus (HIV) infection, chronic granulomatous disease, and hypogammaglobulinemia. In clinical practice, asthma is the most common lung disease for which children receive multiple courses of antibiotics (and are labeled as having recurrent pneumonia), but the radiographic changes that frequently are mistaken for pneumonia in such children usually represent areas of atelectasis. Most children whose recurrent pneumonia has been documented should be referred to a specialist for additional evaluation. Depending on the clinical scenario, referral to a pulmonary, infectious disease, or immunology/allergy specialist may be appropriate.

Prevention

Prevention of pneumonia can save lives and money. As with any type of infection that is spread by droplet or contact transmission, good hand washing along with good personal respiratory hygiene (including wearing a mask around others and covering one's mouth and nose during sneezing and coughing) are important. Breastfeeding and limiting exposure to ill individuals are helpful.

Immunization of young children with Hib, pertussis, and heptavalent pneumococcal vaccines is very important. Although recent serotype shifts have increased the prevalence of pneumococcal strains not contained in this vaccine in the community, the vaccine remains very effective in decreasing invasive bacterial disease. Recent studies from Africa have demonstrated a reduction in viral pneumonia in recipients of pneumococcal vaccine. Children older than age 2 years at high risk for pneumococcal disease, such as those who have sickle cell disease, chronic heart or lung disease, HIV disease, or diabetes mellitus, also should receive the 23-valent pneumococcal polysaccharide vaccine. Because viral infections usually are either the direct cause of pneumonia or predispose children to infection with bacterial or atypical pathogens, immunization against influenza is particularly helpful. Finally, prevention of exposure to cigarette smoke can decrease the occurrence of pneumonia in both infants and their parents.

Summary

Pneumonia in children and adolescents, although common, is encountered less frequently than are other lower respiratory tract illnesses such as bronchiolitis and asthma. Findings on the history and physical examination are sufficient to diagnose pneumonia in most cases, with the clinical hallmarks of fever, cough, tachypnea, increased work of breathing, and auscultatory abnormalities being most important. Radiographic and laboratory studies, although helpful in some cases, often are not needed. Uncomplicated pneumonia in children usually can be treated on an outpatient basis, with season and age group typically informing the decision about antibiotic choice, if any. Young infants, more severely ill patients, and those who have complications such as pleural effusions require laboratory and radiographic studies and aggressive hospital treatment. Prevention of pneumonia is paramount in children and adolescents and includes immunization, avoidance of cigarette smoke, and good hand washing and personal hygiene practices.

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PIR Quiz

Quiz also available online at www.pedsinreview.org.

1. Which of the following statements regarding pneumonia in children is true?

   A. A specific microbial pathogen usually can be identified.
   B. All children who have pneumonia should be hospitalized for observation and treatment.
   C. Pneumonia is a rare cause of child mortality worldwide.
   D. Radiographs of the chest always should be obtained to determine the cause.
   E. Viral agents are the most common causes of pneumonia in older infants and young children.

2. You are evaluating an 8-year-old boy who has a 7-day history of malaise and worsening cough. His mother reports that he has had a low-grade subjective fever. Physical examination reveals a well-appearing boy whose respiratory rate and pulse oximetry findings are normal. His lung examination documents bilateral crackles without wheezing. A chest radiograph shows bilateral interstitial infiltrates without effusion. Of the following, the *most* likely pathogen is:

   A. *Haemophilus influenzae.*
   B. *Mycobacterium tuberculosis.*
   C. *Mycoplasma pneumoniae.*
   D. Respiratory syncytial virus.
   E. *Streptococcus pneumoniae.*

3. An 8-week-old girl is brought to the emergency department because of increased work of breathing for the past day. She has a temperature of 101.1°F (38.4°C) and has had difficulty breastfeeding because of significant nasal congestion. Her respiratory rate is 70 breaths/min and pulse oximetry is 90% on room air. Lung examination reveals bilateral wheezes and crackles, and a chest radiograph shows increased perihilar markings bilaterally and a right middle lobe opacity. Of the following, the *most* likely cause of her symptoms is:

   A. Adenovirus.
   B. *Bordetella pertussis.*
   C. *Chlamydia trachomatis.*
   D. Group B *Streptococcus.*
   E. Respiratory syncytial virus.

4. A previously healthy 5-year-old girl is admitted to the hospital because of a temperature of 104°F (40.0°C), hypoxia, respiratory distress, and findings on a chest radiograph consistent with left lower lobe pneumonia. She is believed to have infection with *S pneumoniae* and is placed on intravenous ceftriaxone and maintenance fluid hydration. After 2 days of therapy, she remains febrile and complains of increased left chest pain and shortness of breath. Of the following, the *most* likely explanation for her symptoms at this time is:

   A. Aspiration of anaerobic organisms from the mouth.
   B. Concurrent presence of a viral infection.
   C. Development of an empyema.
   D. Inappropriate microbial therapy for *S pneumoniae.*
   E. Infection with *M tuberculosis* rather than *S pneumoniae.*

5. You are seeing a 4-year-old girl who has had a fever to 103.5°F (39.8°C), cough, and decreased appetite for 3 days. She is well hydrated and appears tired, with a pulse oximetry of 95% on room air. She has a normal respiratory rate but a frequent cough during the examination. Her lung examination reveals focal crackles in the right lower lobe, with mild dullness to percussion. She is able to tolerate oral fluids in your office, and she has no drug allergies. Of the following, the *most* appropriate management of this girl's illness is:

   A. Hospitalization and intravenous clindamycin.
   B. Hospitalization and intravenous vancomycin.
   C. Outpatient treatment with high-dose oral amoxicillin.
   D. Outpatient treatment with oral azithromycin.
   E. Placement of a tuberculin skin test and isolation until results are known.

Pneumonia

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