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The Practical Guide for Emergency Physicians

Emergency Medicine Reports™

1st Place Winner
Best Single Topic Health Newsletter
Newsletter Publishers Association

Volume 19, Number 20 **September 28, 1998**

The clinical challenge of diagnosing and treating viral and bacterial pneumonia in children is familiar to every practitioner of emergency medicine. Unlike adults, in whom the diagnosis of pneumonia is usually straightforward and for whom quantitative triage criteria have been established, in children the clinical picture is frequently less than straightforward. For example, in infants and toddlers, the auscultatory findings may not be helpful in making the diagnosis, and the x-rays frequently are equivocal. Even when an infiltrate is present, the distinction between viral, atypical, and bacterial pneumonia can be difficult, thereby undermining the approach to pharmacotherapy.

Outcome-effective management of pneumonia in infants and children requires a meticulous understanding of etiologic organisms responsible for producing pneumonia in the pediatric age groups. For example, whereas neonates with lower respiratory tract infections are likely to be infected with Group B streptococci or gram-negative enteric bacteria, the toddler or preschooler is more likely to be affected by Streptococcus pneumoniae, Haemophilus influenzae, or atypical organisms. Not surprisingly, these etiologic patterns govern initial selection of empiric antibiotic therapy, both in the hospital and in the outpatient setting.

With these clinical issues in mind, the purpose of this review is to outline a systematic, diagnostic approach to children suspected of having pneumonia. In addition, the authors provide an age group-by-age group analysis of etiologic agents repsonsible for pneumonia in the pediatric population, and highlight antitibiotics of choice for these infections, reviewing the role of newer macrolide agents—such as azithromycin and clarithromycin—in patient management.

Finally, because the season for bacterial infections in children is rapidly approaching, and because management of acute otitis media (AOM) continues to be a therapeutic challenge for emergency department (ED) physicians, we are pleased to enclose a "Critical Pathways In Pediatric Emergency Medicine" guideline monograph outlining an outcome-sensitive strategy for selecting antibiotics for AOM. The combination of these articles is designed to prepare the emergency practitioner for a wide range of infections that are likely to be encountered in the winter months.

—The Editor

Pneumonia in Infants and Children: Systematic Assessment and Outcome-Effective Treatment Guidelines

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Introduction

Acute respiratory tract infections are the most common ill-

nesses in pediatrics[1] and account for the majority of pediatric emergency department (ED) visits.[2] It is estimated that children may have as many as 10 or more respiratory infections yearly in early childhood.[2] Pneumonia accounts for approximately 15% of all respiratory tract infections.[1] Worldwide, about 3 million children die each year from pneumonia, with the majority of these deaths occurring in developing countries.[1]

In spite of antibiotics and other treatment modalities, pneumonia remains a significant cause of morbidity.[3]

The highest incidence of pneumonia is in the youngest patients with the incidence decreasing gradually with increasing age. The attack rates for pneumonia are: infants (< 1 year), 1 per 100; preschool age, 4 per 100; school age (5-9 years), 2 per 100; and ages 9-15 years, 1 per 100.[4] In infants (age < 2 years) with a fever without source, pneumonia, as diagnosed by positive chest roentgenogram, was found in 13%.[5]

Pneumonia is an inflammation of the lung parenchyma. Although pneumonia is almost always caused by a microorganism, there are a few noninfectious etiologies.[6,7] *(See Table 1.)* Since the infectious etiology and antibiotic treatments may differ, pneumonia is often divided into categories: pneumonia in the immunocompromised patient (such as the patient with HIV) and in the immunocompetent patient (the otherwise normal infant and child). Community-acquired pneumonia is pneumonia not acquired in a hospital or an extended care facility.[8,9] Our focus will be on community-acquired pneumonia in the nonimmunocompromised pediatric patient.

Table 1. Noninfectious Causes of Pneumonia

- Hypersensitivity reactions
- Drug-induced pneumonitis
- Radiation-induced pneumonitis
- Hydrocarbons/lipoid substance
- Aspiration of food and/or gastric acid
- Foreign bodies

Pathogenesis: Normal Pulmonary Defense Mechanisms

The lungs are protected by various mechanisms.[10-13] *(See Table 2.)* Inspired air is filtered by the nares. Warming, humidification, and filtration occurs in the upper airway. The trachea and bronchi are lined with ciliated epithelial cells and goblet cells. The goblet cells and the mucous glands of the airway secrete a mucous layer. The action of the cilia moves the mucous layer toward the pharynx so the mucous layer with entrapped particles can then be expectorated or swallowed.

Particles larger than 10-15 mcg are filtered by the coarse nasal hairs. Particles 5-10 mcg land on the nasal surface and are removed by mechanisms including the ciliary action of the epithelium and by sneezing. Particles 1-5 mcg land on the tracheobronchial mucosal blanket and are removed by ciliary action. Particles smaller than 1 mcg may reach the respiratory bronchioles and air spaces, where some may be exhaled. Particles in the alveoli may be removed by the mucociliary system, phagocytosis by alveolar macrophages, or via the lymphatics or bloodstream.

Opsonins and small lymphocytes act to enhance the phagocytosis and killing of living particles. Secretory immunoglobins, especially secretory IgA, can neutralize some viruses and toxins and assist in the lysis of bacteria. IgG and IgM are secreted when lung inflammation occurs. Other substances including interferon, lactoferrin, and lysozymes may also be a part of the defensive mechanisms of the lung.

Pathogenesis: Impaired Pulmonary Defense Mechanisms

Any process that adversely affects any of the pulmonary defense mechanisms predisposes to pneumonia.[14,15] *(See Table 3.)* Factors that impair host defenses can be congenital (ranging from anatomic abnormalities to impaired immunity) or acquired (generalized disorders such as human immunodeficiency virus [HIV] or pulmonary diseases such as pulmonary fibrosis) or even iatrogenic (drugs, anesthetics, intubation, and tracheostomy). *(See Table 4.)*

Emergency Medicine Reports™ (ISSN 0746-2506) is published biweekly by American Health Consultants, 3525 Piedmont Road, N.E., Six Piedmont Center, Suite 400, Atlanta, GA 30305. Telephone: (800) 688-2421 or (404) 262-7436.

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GST Registration No.: R128870672

Periodical postage paid at Atlanta, GA. **POSTMASTER:** Send address changes to ***Emergency Medicine Reports***, P.O. Box 740059, Atlanta, GA 30374.

Back issues: $21. Missing issues will be fulfilled by customer service free of charge when contacted within one month of the missing issue's date.

Multiple copy prices: One to nine additional copies, $87 each; 10 or more additional copies, $58 each.

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2 years *with* 104 ACEP/AMA/104 AAFP Category 1/Prescribed credits (104 AOA Category 2B credits):$814
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Table 2. Defense Mechanisms of the Lung

SPECIFIC PULMONARY MECHANISMS

- Filtration of inhaled particles
- Humidification, warming of inspired air
- Absorption of noxious fumes/gases by the vascular upper airway

PULMONARY REFLEXES

- Reflex mechanisms to expel foreign particles: reflexly shallow breathing, temporary cessation of respiration, laryngospasm, bronchospasm
- Closure of epiglottis (prevents aspiration of food, secretions, foreign bodies)

MUCOCILIARY SYSTEM

CELLULAR MECHANISMS

- Phagoycytosis of particles by alveolar macrophages
- Phagocytosis of particles by lymphocytes then transport into regional lymph nodes or bloodstream
- Enhancement of phagocytosis-killing process by: opsonins, small lymphocytes

HUMORAL MECHANISMS

- Secretory immunoglobulins (IgA, IgG, IgM)
- Other substances: interferon, lactoferin, lysozymes

Table 3. Impaired Pulmonary Defense Mechanisms Predisposing to Pneumonia*

LOSS OF/DEPRESSED REFLEXES

- Neurologic diseases
- Muscle weakness
- Drugs that impair cough reflex
- Anesthesia, sedation

BYPASS OF UPPER AIRWAY

- Intubation
- Tracheostomy

CONGENITAL ANATOMIC ABNORMALITIES

- Cleft palate
- Tracheoesophageal fistula
- Sequestration

ALTERATIONS IN PULMONARY PARENCHYNA

- Noninfectious inflammatory conditions: aspiration
- Changes in pulmonary blood flow
- Damage to respiratory epithelium (certain lung diseases: pulmonary fibrosis, etc.)
- Fluid in the lungs (congestive heart failure, pulmonary edema)
- Anatomic abnormalities: pulmonary sequestration

IMPAIRMENT OF MUCOCILIARY SYSTEM

- Viral infection(s)
- Bronchial obstruction (foreign body, etc.)
- Chemical/physical agents (smoke, ethanol ingestion, steroids, hypoxemia, starvation, narcotics, some anesthetics)
- Cystic fibrosis
- Bronchitis
- Ciliary dyskinesia
- Alpha 1 antitrypsin disease

IMMUNOSUPPRESSION

- Malignancies
- Drugs: steroids, others
- Chemotherapeutic agents
- Radiation therapy
- HIV

IMMUNODEFICIENCY DISORDERS/DISEASE

- Cellular
  - Alveolar macrophage: steroids, chemotherapy, chronic granulomatous disease
  - Leukocytes: decreased numbers: chemotherapy, congenital neutropenia; Decreased mobility-WBC motility disease; Lymphocytes: decreased number/fiction

* *Impaired defense mechanism with some examples of disorders that predispose to pneumonia are listed.*

There are also environmental factors that are associated with an increased incidence and severity of respiratory infections. These include cigarette smoke, crowded living conditions, poverty, malnutrition, daycare attendance, and inhalation of pollutants from wood-burning stoves.[16-18] *(See Table 5.)*

In children, probably the most common factor that renders the lung susceptible to pneumonia is a preceding viral infection. At least 50% of the time, a viral upper respiratory infection (URI) precedes the onset of pneumonia.[19] Such a viral URI impairs host defenses by disrupting the normal epithelium of the respiratory tract that impairs the mucociliary system, altering normal secretions, modifying the native bacterial flora, and even inhibiting phagocytosis.

Organisms can gain access to the lungs by several routes. Most often, organisms colonizing the upper respiratory tract are aspirated into the lungs.[20] Less commonly, organisms access the lung via the bloodstream during a primary bacteremia or from a distant focus of infection.[20] Once the microorganism invades the lung, an inflammatory response occurs. This results in the migration of polymorphonuclear leukocytes, the release of oxidative enzymes and mediators of inflammation, the loss of surfactant, and the leakage of plasma. These pathophysiologic changes interfere with respiration and lead to the clinical signs and symptoms of pneumonia.

Clinical Presentation by Age

The clinical signs and symptoms depend primarily on the age of the patient, the causative organism, and the severity of the disease.

Neonates. Neonates generally present with nonspecific signs and symptoms including lethargy, irritability, poor feeding, isolated fever or hypothermia, vomiting, and poor muscle tone.[21] Neonates often do not have the usual signs and symptoms such as a cough or rales as found in older children, adolescents, and adults.[21]

Neonates do not have fully developed immunologic capabilities and, thus, are highly susceptible to any infection.[22] A diagnosis of pneumonia in a neonate mandates an appropriate diagnostic evaluation including initiation of antibiotics and hospital admission. A septic workup in a neonate includes a chest roentgenogram even if pulmonary findings, such as tachypnea and rales, are not present.[23]

Infants. Classic findings of pneumonia that occur in adults and older children, such as cough and rales, are often absent in infants and toddlers.[24] Infants may also have the same nonspecific signs and symptoms that can occur in the neonates.[25-27] Pneumonia in infants, including neonates, may also present as sepsis or as a "fever without a source."[28-30]

Table 4. Clinical Conditions that Predispose to Pneumonia

DISORDERS OF IMMUNE SYSTEM
Congenital/Acquired defects/deficiencies in cellular immunity; Congenital/Acquired defects/deficiencies in humoral immunity
IMMUNOSUPPRESSED PATIENTS
Malignancies; Patients on chemotherapeutic agents; Patients on radiation therapy; Patients on steroids, other drugs; Transplant patients; HIV
PULMONARY DISEASES
Bronchopulmonary dysplasia; Cystic fibrosis; Asthma
CERTAIN NEUROLOGIC OR NEUROMUSCULAR DISEASES
GASTROINTESTINAL DISEASES
Tracheosophageal fistula; Severe reflux; Aspiration
SICKLE CELL DISEASE
CERTAIN CONGENITAL HEART DISEASES

Table 5. Environmental Factors Associated with Increased Incidence and Severity of Pulmonary Infections

- Cigarette smoking in household
- Crowded living conditions
- Daycare attendance
- Poverty
- Malnutrition
- Inhaled pollutants from wood burning stoves

Infants with chlamydia pneumonia often are afebrile with only a cough and a surprising lack of physical examination findings, while those with a bacterial pneumonia may have a fever and signs of respiratory distress, such as tachypnea and retractions.

Toddler or Young Child. The young child with pneumonia usually has a fever and a cough.[31] However, gastrointestinal symptoms are common and may be the presenting complaint. Vomiting and anorexia are common as is abdominal pain, especially with lower lobe infiltrates. Occasionally, the abdominal pain may be mistaken for appendicitis or an acute abdomen.[2]

Older Children and Adolescents. In older children and adolescents with pneumonia, the presentation is similar to that of adults with pneumonia.[31] Cough is often, but not always, present.[32] Chest pain may occur and is usually pleuritic.

Clinical Presentation Based on Etiology

The typical presentation of a pediatric patient with bacterial pneumonia is the sudden onset of high fever with lower respiratory symptoms (e.g., cough) with rales on the lung examination indicative of pulmonary consolidation.[31,32] The usual history in a child with a viral pneumonia is a gradual onset of respiratory symptoms, which may include wheezing, along with a low-grade fever. Unfortunately, children with pneumonia (viral or bacterial) may have a varied presentation.[31,32] Therefore, one cannot always predict whether the pneumonia is bacterial or viral.[33] However, given the clinical signs and symptoms, laboratory findings, the chest radiograph, epidemiologic factors (the time of year or seasonal variation and an outbreak of the pathogen in the community or within a family), and patient factors (e.g., age, comorbidity, past medical history), a reasonable prediction of the etiology *(see Table 6)* or pneumonia syndrome usually can be made. *(See Table 7.)*

History

The history is important since it may determine the patient management. Are there any underlying diseases or conditions that make the infant or child more susceptible to a severe and/or more frequent pneumonia? This includes bronchopulmonary dysplasia, cystic fibrosis, asthma, sickle cell disease, congenital heart disease, malignancies, immunosuppressed patients (such as those with HIV and congenital disorders of the immune system), some neurologic diseases, certain gastrointestinal disorders, (e.g., tracheoesphageal fistula, significant reflux, aspiration, etc). *(See Table 4.)* If the patient has had a recent infection with measles or varicella, the pneumonia may represent a serious complication of the initial infection. Infants (younger than 3-6 months of age) with pneumonia may have apnea, so admission is recommended in these patients.

Has the child been able to take oral fluids and/or medicines? Is the child having symptoms of dehydration or respiratory distress? Has the child been on treatment as an outpatient and failed to respond? Are there psychosocial issues complicating the child's care, whether it be concerns about compliance with therapy or follow-up? Such issues or concerns may affect the decision for hospital admission. *(See Table 8.)* History should also recognize any exposures, travel, or other risk factors for pneumonia caused by unusual organisms *(see Table 9)* or even for the possibility of tuberculosis.

Physical Examination

The first step in the physical examination is an assessment of the general appearance and level of activity or behavior of the child. This is to determine if the child has any complications of pneumonia such as sepsis, shock, or respiratory failure, and if emergent resuscitation is needed. Is the child toxic and ill appearing or nontoxic, smiling, playful, and behaving appropriately?

The vital signs should be assessed. Pediatric patients with bacterial pneumonia generally have a fever except for the septic infant who may be hypothermic or the infant with the afebrile pneumonia syndrome. The blood pressure and pulse may reflect the child's hydration status and rarely shock.

Tachypnea may be the only sign of pneumonia in an infant or young child and is reported to be the best single parameter for pneumonia, but it is not always present.[34-37] Since fever can cause tachypnea, the respiratory rate should be rechecked after the patient has defervesced. Is the respiratory rate elevated to an extent that cannot be explained just by the fever or persists after the fever has dissipated?

Table 6. Likely Etiologic Organisms for Various Pediatric Age Groups

Age	Most Common Etiologic Group	Most Common Specific Organisms in the Given Age Group		
		Bacterial	Viruses	Atypical
Neonate (< 1 month)	1. Bacterial 2. Viruses	Group B streptococci Gram-negative enteric bacteria *(E. coli, Klebsiella)* *Listeria monocytogens* Other gram-positive cocci Staphylococci	Cytomegalovirus Herpes simplex Measles	
Infant (1-4 months)	1. Atypical (Chlamydia) 2. Viruses 3. Bacteria	Same as for neonates plus *Streptococcus pneumoniae* *Haemophilus influenzae* *Staphylococcus aureus*	Respiratory Syncytial virus (RSV)	Chlamydia
Toddler/ Preschooler	1. Virus 2. Bacteria 3. Atypical (Mycoplasma)	*S. pneumoniae* *H. influenzae* *S. aureus*	RSV Parainfluenza Adenovirus Influenza Other (enterovirus, rhinovirus)	Mycoplasma
School-aged children and adolescents	1. Atypical (Mycoplasma) 2. Viruses 3. Bacteria	*S. pneumoniae*	Parainfluenza Adenovirus Influenza Others	Mycoplasma

Signs of respiratory distress may or may not be present depending on the severity of the disease. Indeed, no one sign or symptom or group of signs and symptoms can always predict pneumonia.

Findings typical of pneumonia in an adult including rales, wheezing, decreased breath sounds, dullness to percussion, and decreased fremitus may sometimes be found in the older child or adolescent but are often absent in the young child or infant. Rales may not be heard in the infant or young child. This is because the transmission of sounds throughout the chest prevents localization, or there may be a poor inspiration, or noisy upper airway sounds may be present.

The abdomen may appear distended due to gastric dilatation from swallowed air or to an ileus. Downward displacement of the right diaphragm may give the false impression of hepatomegaly. Children with pneumonia in the upper lobes may have meningismus without meningeal infections.

A thorough physical examination should be done in order to find clues to the possible source of the pneumonia or to the etiologic agent. Other infections, such as otitis media, sinusitis, meningitis, pericarditis, and bone, soft tissue, or skin infections, may be implicated in the hematogenous spread of a microorganism to the lungs. Extrapulmonary findings may suggest a specific infectious agent. Various skin exanthems are associated with viral and bacterial pathogens. Pharyngitis may indicate a mycoplasma or streptococcal infection. Conjunctivitis is present in about half of the infants with *Chlamydia pneumonia*.[38] Rhinorrhea and other findings may implicate a previous or co-existent URI.

Laboratory Data

With a viral pneumonia, the white blood cell count may be normal or mildly elevated, often with a lymphocytosis. In bacterial pneumonia, there is generally a leukocytosis in the range of 15,000-40,000 cells/mm^3, with an increased percentage of polymorphonuclear leukocytes and band forms. Leukopenia (WBC < 5000/mm^3) may indicate a poor prognosis. A markedly elevated WBC count (> 30,000 mm^3) almost always denotes a bacterial pneumonia, often with bacteremia and a higher risk of complication.[7] Eosinophilia may be present with *C. pneumonia*[38] or a parasitic infection. Leukocytosis, with severe lymphocytosis, occurs with pertussis,[7] although this may not be present in infants younger than 6 months old.[39] A normal WBC count is typical of mycoplasma, or *C. pneumonia*. The erythrocyte sedimentation rate and C-reactive protein are usually elevated but are so non-specific that they are not helpful in management.[7]

The use of sputum cultures is limited since children (especially younger than 10 years of age) rarely produce sputum, and it is difficult to get a good quality sputum sample that is not contaminated by the indigenous flora of the mouth and pharynx.[40] High-quality sputum samples should have more than 25 polymorphonuclear cells per field, 40 squamous cells per field, and the presence of mucous.[41] Sputum samples and morning gastric aspirate samples are helpful to confirm tuberculosis. Nasopharyngeal and throat cultures are not usually helpful and are often misleading in establishing an etiologic agent for bacterial pneumonia because of a high rate of false-positive tests.[2,20]

Overall, blood cultures are positive in about 10-30% of patients with bacterial pneumonia.[19,40] However, a much higher yield occurs with certain bacterial pneumonias such as pneumococcal (25%)[41,42] or *Haemophilus influenza* type B (up to

Table 7. Differential Diagnosis of Pneumonia by Etiologic Category/Pneumonia Syndromes*

SIGNS AND SYMPTOMS	BACTERIAL	VIRAL	CHLAMYDIA	MYCOPLASMA	TUBERCULOSIS
History			Afebrile pneumonia of infancy		
Age	Any, especially neonates	Any, especially toddlers/preschoolers	1-4 months (3-16 weeks)	School age adolescent	Any age > 4 months
Onset	Sudden (> 50% occur after URI)	Gradual	Gradual	Gradual	Usually gradual may be acute
Cough	Often productive	Dry cough	Dry cough can be only symptom	Usually dry cough	Cough often productive, sometimes hemoptysis
Other signs	Sometimes pleuritic chest pain	Sometimes coryza sore throat, rash	Conjunctivitis in ~ 50% (may precede or occur with pneumonia)	Sometimes sore throat, rash, bullous otitis media, headache, myalgias	Weight loss, night sweats
PHYSICAL EXAMINATION					
Appearance of Fever	May be toxic usually high (> 39°C)	Nontoxic usually low grade	Nontoxic usually afebrile	Nontoxic usually low grade	Usually nontoxic variable
Lung Auscultation	Rales, decreased breath sounds	Rales, wheezing rhonchi	Rales wheezing	Sometimes rales	Variable
LABORATORY	**BACTERIAL**	**VIRAL**	**CHLAMYDIA**	**MYCOPLASMA**	**TUBERCULOSIS**
White Blood Cell**	Increased WBC	Normal or slightly increased	Normal or slight increase WBC up to 15,000 range; May have eosinophia	May have atypical lymphocytes, lymphocytosis	Variable
Other laboratory tests	Obtain blood culture	Nasal washing for RSV may be helpful	Nasal washings may be helpful	Cold agglutinins often positive, bedside test	Sputum, gastric aspirates for skin testing (ppd)
Chest Roentgenogram	Consolidation Pleural effusion Think *S. aureus* if Pneumatoceles pleural effusions, lung abscess	Hyperinflation Interstitial infiltrates	Hyperinflation Interstitial infiltrates	Variable patchy Interstitial infiltrates are most common	Variable, often adenopathy, Other: infiltrates cavitation, effusions

* *These are the generally observed characteristics for a given category of pneumonia. Any given patient may have all, some, or none of the given characteristics even when proven to have a specific infection. This is a general guide, not an absolute for every patient.*

** *Pertussis characteristically has an elevated WBC usually 15,000-40,000/mm^3 with a marked lymphocytosis, although this may not be present in infants.*

95%),[41] or *Staphylococcus aureus* (33% and up to 89% if disseminated disease is present).[42] There are differences in opinions concerning whether or not blood cultures should be obtained. Those in favor feel that blood cultures will provide a specific bacteriologic diagnosis; those against state that blood cultures almost never alter the treatment or outcome for previously healthy children presenting with pneumonia.[43]

Rapid screening tests to detect bacterial antigens in serum or urine using latex particle agglutination or countercurrent immunoelectrophoresis (CIE) generally have had a low sensitivity and specificity,[40,41,45,46] but some studies have found better results.[47,48] With improved techniques, bacterial antigen testing

Table 8. Indications for Hospital Admission with Pneumonia

- Neonate
- Young infant ≤ 3-6 months
- Inability to tolerate fluids or medications
- Lack of response to outpatient therapy
- Psychosocial issues (compliance with therapy, follow-up)
- Comorbidity (bronchopulmonary dysplasia, sickle cell disease, etc.)
- Respiratory distress
- Hypoxemia
- Complications of pneumonia (lung abscess, emphysema, fistula, etc.)
- Bacteremia
- Sepsis
- Dehydration
- Suspicion of specific virulent pathogens (e.g., *P. carinii, S. aureus)*

Table 9. Risk Factors/Association with Unusual Causes of Pneumonia

Pneumonia	Risk Factor Association
Coccidiomycosis	Location/recent travel to Southwestern U.S. (San Joaquin Valley, S. California, New Mexico, S. Arizona, SW Texas)
Histoplasmosis	Mississippi/River Valley
Hantavirus	SW U.S. (4 corner area of Arizona, New Mexico, Australia, SE Asia, Guam)
Meliodosis	South/Central America, W. Indies, Australia, SE Asia, Guam
Animal Exposure	
Psittaci	Exotic birds (parrots, cockatoos, etc.), turkeys, pigeons
Anthrax	Cattle, horses, swine, animal hides
Brucellosis	Unpasteurized dairy products, cattle, goats, pigs
Bubonic Plague	Lagomorphs (squirrels, rabbits, chipmunks, etc.), rats
Hantavirus	Rodent excretions, urine, saliva, droppings
Histoplasmosis	Soil with bird or bat droppings
Leptospirosis	Water contaminated with animal urine, wild dogs, cats, rodents, cattle, horses, pigs
Pasteurella multocida	Infected dogs, cats
Q Fever	Secretions of infected animals or contact with the animals (cattle, sheep, goats, other domestic animals)
Tularemia	Hunting, trapping, skinning of infected animals
Other Risk Factors	
Legionnaires' disease	Contaminated aerosols (hospital water supply, air coolers, etc.)
Tuberculosis	Exposure to someone with tuberculosis

of the urine may become useful in the future.[44,48] Generally, serologic testing has also not been useful since paired acute and convalescent serum are needed.[40]

However, in selected cases, such as mycoplasma, cytomegalovirus, or measles, a rise in the immunoglobulin M antibody may confirm the diagnosis.[44] Pneumonia caused by group A streptococci can be diagnosed by detecting an elevated level of streptococcal antibodies (e.g., Antistreptolysin O, streptozyme, or anti Dnase B titers), although an elevated titer may reflect a previous infection.[43] Rapid antigen detection tests, using the immunofluorescent antibody test (IFA) or the enzyme-linked immunosorbent assay (ELISA) on nasopharyngeal secretions has been helpful with the diagnosis of RSV.[20]

Mycoplasma infection results in a positive cold agglutinin titer (> 1:32) in about half (from 1/3 to 3/4) of infected patients. However, elevated titers can occur with other diseases; such as adenovirus, Epstein-Barr virus, measles, lymphoma, and some tropical diseases.[49,50] A "bedside" test for cold agglutinins is done by putting 0.3-0.4 cc of blood in a lavender hematology tube with ethylenediaminetetracetic acid (EDTA) or in a blue prothrombin tube with sodium citrate. The tube is put in ice water for 15-30 seconds then tilted on its side and examined. A positive test is indicated by the presence of coarse floccular agglutination that disappears when the tube is rewarmed. A positive test corresponds to a cold agglutinin titer of more than 1:64. No agglutination or fine granularity is a negative test.[49,50]

If tuberculosis is suspected, a mantoux tuberculin test with 5 units of purified protein derivative (PPD) should be done. Skin tests for candida and histoplasmosis can also be done in selected cases, although these skin tests can be positive with past exposure as well as with active infection.

Currently, the laboratory detection of the etiologic agent causing pneumonia is limited. However, the use of polymerase chain reaction (PCR) testing along with other technological improvements looks promising and may lead to more widespread use of serologic type tests for the diagnosis of pneumonia in the future.

Invasive diagnostic techniques are generally done only in patients who lack a definitive diagnosis (e.g., noninvasive tests have not yielded a diagnosis) and who are deteriorating clinically, especially if they are immunocompromised.

If there is a significant pleural effusion, then thoracentesis, with removal of pleural fluid, may be diagnostic and therapeutic. Pleural fluid should be sent for analysis including appropriate cultures. Flexible bronchoscopy with bronchoalveolar lavage has mostly been used in HIV-infected children who have pulmonary disease. It has been a fairly safe and effective procedure (27-75% diagnostic yield).[52] Transbronchial biopsy has not been widely used in pediatrics except in lung transplant patients because of the bronchoscope size. Open lung biopsy has been done in critically ill patients in whom noninvasive procedures have failed to yield a diagnosis.[53]

Radiograph Evaluation

Although the diagnosis of bacterial vs. viral pneumonia can not be made solely on the basis of a chest roentgenogram, the radiographic appearance can be helpful.[54] The accuracy of the chest radiograph in predicting the etiologic agent causing the

Table 10. Disorders that can Present as Pneumonia

CHRONIC INFECTIONS
Tuberculosis
Fungal diseases
Parasitic diseases
PRIMARY PULMONARY DISEASES
Alpha 1-antirysin deficiency
Acute respiratory distress syndrome
Atelectasis
Asthma
Bronchopulmonary dysplasia
Cystic fibrosis
Pleural effusions
Pulmonary infarction
Sickle cell vasoocclusive crisis
Pulmonary emboli
AUTOIMMUNE DISORDERS (COLLAGEN VASCULAR DISEASES)
Systemic lupus erythematous, etc.
Others
MALIGNANCIES/GROWTHS
CONGENITAL PULMONARY MALFORMATIONS
Bronchogenic cysts
Pulmonary sequestrations
Cystic adenomatoid malformations
OTHER
Pulmonary Hemosiderosis
RADIOLOGIC TECHNIQUES/FACTORS THAT MAY APPEAR AS PNEUMONIA ON CHEST ROENTGENOGRAM
Underpenetration
Uneven grid on the film
Poor inspiration
Thymus shadow
Breast shadow

pneumonia varies widely from 42-73% to more than 90%.[44,56]

Pulmonary infiltrates can be classified into three categories: interstitial, alveolar, or bronchopneumonia.[54] An interstitial pattern has increased bronchovascular markings, peribronchial cuffing, and hyperaeration. Occasionally, there may be patchy consolidation due to atelectasis. Viral and mycoplasmal pneumonia generally have this radiographic appearance.

Consolidation with air bronchograms is the radiographic pattern found with alveolar or air space disease. Bacterial infections, such as pneumococcal pneumonia, generally exhibit this radiographic appearance. The third radiographic pattern is bronchopneumonia. This is characterized by a diffuse bilateral pattern, increased peribronchial markings, and small fluffy infiltrates that extend into the periphery of the lung. Bacterial infections, including *S. aureus*, tend to have a bronchopneumonic pattern on the chest roentgenogram.

A nonlobar patchy infiltrate(s) or an interstitial pattern is the usual radiographic appearance with the atypical pneumonias. Thus, the chest roentgenogram with mycoplasma can be consistent with a viral or a bacterial infection. Bilateral diffuse interstitial infiltrates with hyperaeration can be seen with *C. pneumonia*.

Occasionally, the chest roentgenogram may reveal a "round" pneumonia. This is a consolidative pneumonia usually caused by a bacteria. It has a spherical shape, indistinct borders, can be large, and is a solitary lesion. Initially, it may suggest a tumor.

Occasionally, there are other factors that may give the appearance of pneumonia on the chest radiograph. These include radiologic technique and noninfectious causes. *(See Table 10.)* Radiologic techniques that may simulate a pneumonia are an underpenetrated film, an uneven grid on the film, poor inspiration, breast shadow, and thymus shadow.[57-59]

Atelectasis can also be confused as pneumonia.[57-59] Atelectasis has many causes. These include extrinsic compression of a bronchi (from a congenital malformation, lymphadenopathy, tumor, cardiovascular disease, web or ring), and intrinsic bronchial obstruction (foreign body, edema, inflammation, bronchomalacia or stenosis, tumor, and mucous plug secondary to cystic fibrosis or asthma). Noninfectious pulmonary diseases can also cause atelectasis from hyaline membrane disease to adult respiratory distress syndrome or pulmonary edema. External pulmonary compression for whatever reason from a growth or tumor to a pleural effusion can also result in atelectasis.

A chest roentgenogram can assist in the detection of complications of pneumonia, including a large pleural effusion, pneumatocoles, or a lung abscess. Such complications suggest a bacterial infection, particularly, *S. aureus* and, less commonly, *H. influenza*.

Although a positive chest radiograph is the gold standard for the diagnosis of pneumonia, an occasional patient with clinical symptoms and signs of pneumonia may have a normal chest roentgenogram.[20] The radiographic finding is said to "lag behind" the clinical picture.[7] If a child is dehydrated, especially early in the course of illness, an initial chest x-ray may be negative while a repeat film after therapy may then become positive.[20]

Likewise, the patient may have clinically recovered from the pneumonia, yet still have findings of pneumonia on the chest roentgenogram.[7] Thus, most clinicians will wait 6-8 weeks before repeating the chest roentgenogram in patients with lobar consolidation in order to confirm resolution of the pneumonia and to rule out an underlying anatomic abnormality of the lung.

Some physicians feel that a chest radiograph is not essential in a nontoxic well-appearing infant or child with no risk factors who appears to have a mild pneumonia and who has close follow-up, especially it if is during a viral outbreak or other family members have evidence of a viral infection.[32,36] However, other physicians disagree and feel that a chest roentgenogram is indicated in any infant or child seen in the ED in whom the diagnosis of pneumonia is suspected.[14,20]

Nevertheless, the practice of ordering radiographs on all febrile infants as part of a standard work-up deserves reflection. Febrile infants subsequently diagnosed with pneumonia generally will have evidence of pulmonary disease. Several studies

Table 11. Organisms Causing Pneumonia and Empiric Therapy in Pediatrics

Age Group	Bacterial	Viral	Empiric Therapy
Neonate (0-28 days)	Group B streptococcus, gram-negative enteric *(E. coli, Klebsiella, Listeria monocytogenes*, *S. aureus,* other gram-positive)	Cytomegalovirus Herpes simplex	Ampicillin and aminoglycoside (gentamicin or tobramycin or amikacin, or third-generation cephalosporin). *Note: Avoid ceftriaxone 2° to bilirubin*
Infants 3-16 weeks; afebrile pneumonia infancy		*Chlamydia trachomatis* *Ureaplasma urealyticum* Cytomegalovirus *Pneumocystis carinii*	Erythromycin Sulfonamide
Infants febrile or ill appearing age 1-3 months	Same organisms as for neonate plus *S. pneumoniae*, *H. influenzae, S. aureus*	Not applicable	Antibiotic (nafcillin, oxacillin, or methacillin) Broad-spectrum cephalosporin *(e.g., cefotaxime)*
Toddler or preschool age	*S. pneumoniae, H. influenzae M. pneumoniae, Chlamydia*	RSV Parainfluenza Adenovirus Influenza	Azithromycin Amoxacillin-clavulanate: not active against atypical organisms (Mycoplasma, Chlamydia)

The pathogens are listed in order of frequency, with the most common pathogen occurring first.

Whenever S. aureus is a pathogen, penicillinase-resistant penicillin is recommended. Depending on resistance patterns, methicillin may be used (if no resistance in community or vancomycin MRSA-methicillin-resistant S. aureus).

based on both meta-analysis prospective, and retrospective reviews of x-rays and patient records demonstrated that most infants less than 2-3 months with pneumonia had respiratory signs and symptoms such as tachypnea, rales, ronchi, retractions, wheeze, cough, or rhinorrhea.[60-62]

Pneumonia in Infants and Children: Etiologic Agents

Nonbacterial (e.g., viral) pneumonias account for about 60-80% of all pneumonias in pediatric patients. The most common viruses are respiratory syncytial virus (especially in infants), parainfluenza virus, adenovirus, and influenza virus. The atypical pneumonias are the most common pneumoniae in school age children and adolescents (age > 5 years). *Mycoplasma pneumoniae* is the most common atypical pneumoniae followed by *C. pneumoniae*, previously called the TWAR strain of *Chlamydia trachomatis*. The most common bacterial pneumonias are *Streptococcus pneumoniae*, *Staphylococcus aureus*, and *H. influenzae* type B. *(See Table 6.)*

Pneumonia in Various Pediatric Age Groups: Etiology and Therapy

Neonate. Pneumonia in neonates is usually due to an organism acquired during passage through the birth canal. The most common pathogens causing pneumonia in the first month of life are group B streptococci followed by enteric gram-negative bacteria, usually *Escherichia coli* and *Klebsiella pneumonia*. Other pathogens include *Listeria monocytogenes*, other gram-positive cocci, viruses (most commonly, cytomegalovirus and herpes simplex virus), and *S. aureus*.

Thus, antibiotic coverage should include group B streptococci, enteric gram-negative bacteria, and listeria. Generally, penicillin-type antimicrobials are the drug of choice for the gram-positive pathogens, with ampicillin being preferred because of better in-vitro activity against enterococcus, listeria, and some gram-negative bacilli.

If *S. aureus* is a possibility, then a penicillinase-resistant penicillin is indicated. Methicillin is the usual choice although methicillin-resistant *S. aureus* has been found in some neonatal nurseries. Antibiotic coverage for the gram-negative bacilli depends on recent antimicrobial susceptibility patterns for newborns in that community and hospital; an aminoglycoside is usually chosen. This could be gentamicin, tobramycin, or amikacin.

Another acceptable alternative to ampicillin plus an aminoglycoside is the third-generation cephalosporin, cefotaxime. Ceftriaxone is not recommended in the neonate because the drug may cause displacement of bilirubin.

Regardless of their clinical appearance, all neonates with pneumonia, fever without a source, or sepsis should have an evaluation (including a CBC, chest roentgenogram, and appropriate cultures of blood, urine, and cerebrospinal fluid) followed by an initial dose of antibiotics and hospital admission. The empiric therapy would be ampicillin plus an aminoglycoside or ampicillin plus a cephalosporin.

Infants. Pneumonia in infants (older than 1 month but younger than 1 year) can be categorized into two groups: afebrile well-appearing infant vs. the febrile and/or ill-appearing infant.

"Afebrile pneumonia of infancy" generally occurs at the age of 3-4 weeks up to 16 weeks or from 1-4 months of age. It is due to organisms that colonized the infant at birth. It is also referred to as "chlamydia pneumonitis" since the most common pathogen is *Chlamydia trichomatis*, followed by (in order of decreasing frequency) ureaplasma urealyticum, cytomegalovirus, and *Pneumocystis carinii*. Classically, the infant has a gradual onset of symptoms with nasal congestion

Table 12. Antimicrobial Therapy for Specific Pathogens

Organism	Antimicrobial
BACTERIA	
S. pneumoniae	Penicillin (if not resistant). Vancomycin (if resistant to penicillin)
H. influenzae	Azithromycin or Amoxicillin (if not resistant)
Beta lactamase	Cefuroxime or third-generation cephalosporin (if beta lactamase + and resistant)
S. aureus	Methicillin (if not resistant) Vancomycin (if MRSA-methicillin resistant *S. aureus*) if penicillin allergy: vancomycin, clindamycin
ATYPICAL	
Chlamydia	Azithromycin (other macrolides); alternative, sulfa drugs
Mycoplasma	Azithromycin (other macrolides); alternative, tetracycline (if older than 8 years)
VIRUSES	
RSV	Ribavirin (optional)
Influenza	Amantadine (if severe)

Table 13. Factors Influencing Antibiotic Choice

INDIVIDUAL (PATIENT) FACTORS

- Patient's condition (co-morbid factors, respiratory/overall status)
- Recent antibiotic use
- Allergies
- Age (drug metabolism, age-related side effects)

DRUG FACTORS

- Efficacy/side effect profile of particular antibiotic
- Drug resistance patterns in the community
- Frequency of administration
- Duration of administration
- Cost

followed by a dry cough. Conjunctivitis usually precedes or occurs with the respiratory symptoms and is present in about half the patients. The infant is usually afebrile. Rarely is a low-grade fever present. The cough is probably the most prominent feature of "afebrile pneumonia of infancy." Often, the infant is alert and active and looks well, with the only symptom being a cough and the only physical examination finding being conjunctivitis. The cough may or may not interfere with the infant's usual activities such as feeding or sleeping. The cough may be paroxysmal like pertussis. Respiratory distress with tachypnea and retractions may occur. Rales are often but not always present. Wheezing may be present. This is usually a mild disorder, but respiratory distress, hypoxia, and/or apnea may occur.

Ancillary studies usually reveal a normal WBC count with eosinophilia and an interstitial pneumonia on chest radiograph. A culture or fluorescent antibody stain of nasopharyngeal secretions is positive for Chlamydia. The drug of choice, erythromycin (or sulfonamide), decreases the symptom duration. Outpatient therapy is the rule except if there are complications such as hypoxia, respiratory distress, dehydration, or apnea.

Infants (Febrile or Ill-Appearing). Infants (1-4 months) who are febrile and/or ill-appearing are presumed to have a bacterial pneumonia. Empiric antibiotic therapy for the febrile infant in this age group should include coverage for the usual neonatal pathogens as well as for the three pathogens most common in the toddler age group (*S. pneumoniae*, *H. influenza*, and *S. aureus*). A broad spectrum cephalosporin, such as cefotaxime, would cover the common neonatal pathogens as well as *S. pneumoniae* and *H. influenza*. A penicillinase-resistant penicillin, such as nafcillin, methicillin, or oxacillin, is added to provide antistaphylococcal coverage. One choice for empiric therapy would be cefotaxime and an antistaphylococcal antibiotic (nafcillin, oxacillin, or methacillin).

There have been reports of resistance of *S. pneumoniae* to penicillin (up to 20%), macrolides (about 10% combined for erythromycin, azithromycin, and clarithromycin), trimethoprim-sulfamethoxazole (18%), and various cephalosporins (from 3-12%).[63] However, there has not yet been documented penicillin failures in pneumococcal pneumonia. If there is penicillin resistance, then other antibiotics such as vancomycin can be used.[64]

Toddler/Preschooler. In this age group, the majority of the pneumoniae are due to viral infections.[65] The usual pathogens are respiratory syncytial virus (RSV), parainfluenza, adenovirus, influenza, other viruses (enterovirus and rhinovirus), and mycoplasma.

There is a seasonal variation with the various organisms. RSV tends to occur in the winter months, parainfluenza in the late summer and autumn, and influenza in the winter during influenza epidemics.

Given an appropriate scenario (e.g., toddler with no risk factors who looks well, with an outbreak of a given virus in the community so there is an appropriate epidemiologic setting) and reliable follow-up, then some feel a chest radiograph is optional and the patient may be observed as an outpatient without instituting antibiotic therapy. However, daily outpatient follow-up is mandatory since an occasional bacterial pneumonia may initially have a benign presentation like that of a virus, and a more severe secondary bacterial pneumonia may occur following a viral pneumonia.

If the toddler or preschooler is febrile or appears ill, then a bacterial pneumonia is likely. *S. pneumoniae* is the most common bacterial pathogen followed by *H. influenza*. Other less common bacterial organisms causing pneumonia are *Neisseria meningitides* and *S. aureus*. When *N. meningitides* pneumonia is present, generally it is in the content of meningococcemia and sepsis, so other signs and symptoms (such as petechiae) are present.

In the hospitalized toddler or preschooler, a broad-spectrum parenteral cephalosporin is a reasonable choice. If the patient looks well, has no risk factors or co-morbid conditions, or complications and close follow-up is assured, then possible

antibiotic choices are a macrolide (azithromycin, clarithromycin, or erythromycin), amoxicillin/clavulanate, a broad-spectrum cephalosporin, or amoxicillin.[66] Although there is a 20-30% incidence of beta lactamase-positive resistance in most communities, amoxicillin remains an acceptable choice in those with mild disease because it is inexpensive as well as other factors.[66] *(See Table 12.)*

School Aged Children and Adolescents. Once children enter school (ages 5-18 years), the atypical organisms are the most common cause of pneumonia followed by viral then bacterial pathogens. Mycoplasma is responsible for about one-fifth of all cases of pneumonia in the general population. The incidence of *M. pneumonia* increases during childhood, about 9-16% in school-aged children (ages 5-12 years), 16-21% in adolescents (ages 12-18 years), and up to 30-50% in college students and military recruits.

The greatest incidence of pneumococcal pneumonia is in infants younger than 2 years. The macrolides (erythromycin, clarithromycin, and azithromycin) are the drugs of choice.[67] Those with severe disease should be hospitalized and also receive antibiotic coverage for other organisms including nontypeable *H. influenzae*. A third-generation cephalosporin plus a macrolide would be a good choice in these patients.

From the perspective of pediatric emergency medicine practice—with its primary emphasis on providing definitive, cost-effective, compliance-promoting, and drug-drug-interaction-minimizing therapy—the newer macrolide antibiotics, which include both azithromycin and clarithromycin, have recently emerged—along with amoxicillin-clavulanate—as drugs of choice for outpatient management of community-acquired pneumonia, as well as otitis media in children.[72] When used as oral agents, they play a central role in ED-based management of pneumonia in otherwise healthy children who do not require hospitalization. Unlike penicillins, cephalosporins, and sulfa-based agents, these drugs have the advantage of showing in vitro activity against both atypical and bacterial offenders implicated in pneumonia. The most common side effects include gastrointestinal upset and a metallic taste in the mouth, which are more common in clarithromycin.

These agents also have the advantage of a simplified dosing schedule, especially azithromycin, which is given once daily for five days. Clarithromycin requires a longer course of therapy and is slightly more expensive. In general, the decision to use a macrolide is based on weighing the cost of a course of therapy with azithromycin against its real-world advantages, which include a more convenient dosing schedule, its broader spectrum of coverage, its favorable drug interaction profile, and its decreased incidence of gastrointestinal side effects, which occur in 3-5% of patients taking a five-day, multiple-dose regimen.[73]

Azithromycin is approved in a palatable suspension formulation for the treatment of acute otitis media and pneumonia in children. The cost for a course of therapy is usually less than $30, and the once-daily, five-day course introduces compliance-enhancing features that, to a great degree, permit parental, day care, and grade school drug administration problems to be circumvented.[74] A well-accepted palatability profile, combined with an overall discontinuation rate of about 0.9%, are favorable as far as patient resistance is concerned.[75-77] When the five-day course of the suspension is used for treatment of otitis media, the reported incidences of side effects includes diarrhea/loose stools (2%), abdominal pain (2%), vomiting (1%), and nausea (1%).

From the perspective of drug resistance, the oral suspension of azithromycin is characterized by acceptable in vitro coverage of beta-lactamase-producing *H. influenzae* and *M. catarrhalis*, as well as in vitro coverage of *S. pneumoniae*, for which the overall resistance rate is estimated to be about 5-12%.[75-77]

The antimicrobial role of azithromycin and other macrolides in the ED, pediatric, and primary care setting is supported by rigorous otitis media studies that have been published comparing the safety and efficacy of azithromycin to amoxicillin-clavulanate for the treatment of acute otitis media in children.[75,78,79] In these large trials, clinical cure rates of up to 87.5% are reported, and azithromycin was as effective as, but better tolerated than, amoxicillin-clavulanate for the treatment of acute otitis media in the pediatric age group.[74,78-80] Although azithromycin does not affect a single IV dose of theophylline, caution is advised if multiple doses of theophylline are used. Accordingly, prudent clinical monitoring of theophylline levels is recommended in these patients.

The most common viral causes of pneumonia in this age group (5-18 years) are influenza, parainfluenza, and adenovirus. The most common cause of bacterial pneumonia in this age group remains *S. pneumoniae*.

Specific Pathogens

Streptococcus pneumoniae. *S. pneumoniae* is the most common cause of bacterial pneumonia in all pediatric age groups after the newborn period. The classic case of pneumococcal pneumonia is abrupt onset with fever, chills, cough, and dyspnea. Adolescents and adults with pneumococcal pneumonia may have hemoptysis or a blood tinged sputum. Asymptomatic carriage of *S. pneumoniae* in the nasopharynx occurs in up to 60% of individuals. The highest rates of carriage are in infants followed by families with children.

The greatest incidence of *S. pneumoniae* is in infants younger than 2 years old with the peak attack rate occurring at 3-5 months and peak hospitalization at 13-18 months. It is more frequent in the winter and spring months. Pneumonia from *S. pneumoniae* is greater in African-Americans and in males. There is a marked predilection for pneumococcal pneumonia in sickle cell disease, asplenia (whether congenital, surgical, or functional), and in immunosuppressed patients.

There is a 23 valent pneumococcal vaccine available, but it is poorly antigenic in young children (< 2 years of age), so it is currently used only in "at-risk" children older than 2 years of age, such as those with sickle cell disease or asplenia.[64] There are newer pneumococcal vaccines currently being evaluated that are promising.

Haemophilus influenzae. *H. influenzae* is still a cause of pneumonia, although there has been a marked decrease in disease secondary to *H. influenzae* since the advent of the hemophilus B conjugate (HIB) vaccine.[69,70] *H. influenzae* pneumonia is most prevalent in young children, with more than 80% of pneumonia occurring in children younger than 4 years of age. Like *S. pneumoniae*, *H. influenzae* may also colonize the nasopharynx and is more common in the winter and springs. Like the other bacterial pneumoniae, *H. influenzae* pneumonia usually begins with the abrupt onset of fever and cough. Extrapulmonary infections are

more frequent with *H. influenzae* than with *S. pneumoniae* pneumonia. Infections ranging from otitis media, meningitis, pericarditis, and epiglottitis have been found in almost half of the patients with *H. influenzae* pneumonia. Positive blood cultures occur in 75-90% of children with *H. influenzae* pneumonia.

If the *H. influenzae* is beta-lactamase negative, then ampicillin can be used. Since there is increasing resistance to ampicillin from B-lactamase producing strains (up to 36%),[71,72] chloramphenicol or a broad spectrum cephalosporin, such as, cefotaxime, ceftriaxone, cefuroxime, can be used.

There can be secondary transmission of invasive *H. influenzae* type B so rifampin prophylaxis is recommended. Rifampin prophylaxis is indicated for close (household) contacts, of all ages (including adults) if there is an immunocompromised child in the household (regardless of vaccination status); if there is an incompletely vaccinated or unvaccinated child younger than 4 years of age in the household; if there is an incompletely vaccinated or unvaccinated child younger than 2 years in a day-care setting; and if there is an incompletely or unvaccinated child (children) in a day-care setting where more than two cases of invasive disease has occurred within two months.[73]

Staphylococcus aureus. *S. aureus* is an uncommon but important cause of pneumonia that can occur in any age group. *S. aureus* is a rapidly progressive fulminant illness so patients with this disease should be hospitalized. *S. aureus* is found on the skin, nasal mucosa, and other mucous membranes. *S. aureus* pneumonia may be primary or secondary. Primary disease is defined as pneumonia with no extrapulmonary site of infection. Secondary pneumonia indicates the presence of one or more nonpulmonary sites of infection. Blood cultures are positive in 20-30% of patients with primary *S. aureus* pneumonia. The pleural effusions should be drained by thoracentesis or, if large, by a chest tube. Pneumatoceles are also common and are found in 45-60% of patients of patients with *S. aureus* pneumonia.

Antistaphylococcal penicillin (methicillin, oxacillin, or nafcillin) are the drugs of choice. In community-acquired pneumonia, methicillin-resistant *S. aureus* (MSRA) is rare. In hospitalized patients or patients in a long-term care facility, MSRA is more frequent, making vancomycin a better choice. If the patient has a penicillin allergy, then alternative antibiotics include vancomycin, clindamycin, or cefazolin.

Mycoplasma. Mycoplasma infections occur all year round with sporadic outbreaks in the fall and early winter. *M. pneumonia* generally has a gradual onset of symptoms that include a low-grade fever and a nonproductive cough. Headaches, myalgias, abdominal pain, and vomiting are other symptoms that can occur. Examination of the lungs may reveal rales or decreased breath sounds or a normal auscultation. The WBC count is usually normal. The cold agglutinins are positive, and the liver transaminase enzymes are often elevated. A small percentage of patients with mycoplasma pneumonia develop neurologic complications (about 7%) that range from meningoencephalitis to transverse myelitis, Guillan-Barré syndrome, to cerebellar ataxia. The preferred antibiotic for mycoplasma infection is the macrolides (erythromycin, clarithromycin, and azithromycin).[62,63]

Pertussis. Pertussis (whooping cough) usually occurs in infants younger than 6 months of age. It occurs in three clinical stages: catarrhal, paroxysmal, and convalescent stage.

The catarrhal stage lasts approximately 1-2 weeks. It begins with mild upper respiratory tract symptoms (coryza) and a cough. The paroxysmal stage, lasting 2-4 weeks, is characterized by a severe paroxysmal cough that may end with the classic inspiratory "whoop." Pertussis emesis often occurs. The characteristic whoop is frequently absent in infants. Generally, the patient is afebrile. The physical examination is fairly unremarkable between the paroxysms, which may be precipitated by gagging the patient. During the convalescent stage, the patient improves with the symptoms gradually disappearing.

The chest roentgenogram may be normal with clear lung fields or have a "shaggy" right heart border. Leukocytosis is generally present with a WBC count higher than 15,000/mm^3 up to 40,000/mm^3 and a marked lymphocytoses. The *Bordella pertussis* organism can be detected by culture or by fluorescent antibody staining of nasopharyngeal secretions during the catarrhal or early paroxysmal stages.

The antibiotic of choice for pertussis is erythromycin. In infants, pertussis is especially severe with frequent complications, therefore, all pediatric patients younger than 1 year of age should be hospitalized for monitoring and supportive care. Complications can include secondary bacterial pneumonia, apnea, seizures, encephalopathy, and death.

Respiratory Syncytial Virus. Respiratory syncytial virus (RSV) is the most common pediatric viral pneumonia, especially in infancy. RSV is most prevalent during the winter months, although epidemics may occur throughout the year. The hallmark of RSV infection is bronchiolitis. However, many infants with bronchiolitis (about one-third) will have pneumonia. Indeed, it is difficult to differentiate the two diseases (RSV bronchiolitis vs RSV pneumonia). Generally, if bronchospasm (e.g., wheezing) is present, the disease is classified as bronchiolitis, irrespective of whether or not pneumonia is also present.

The usual clinical signs of RSV infection include low-grade fever and signs of an upper respiratory infection. Generally, the temperature is less than that seen with bacterial pneumonia. A cough may be present. Wheezing and rales may be present simultaneously or may alternate during the 5-7 day course of the illness with wheezing present on one examination and rales on the next examination or vice versa. A normal or minimally elevated white blood cell count with a lymphocytosis is typical. The radiographic findings with RSV pneumonia are variable, but atelectasis is common.

Treatment is somewhat controversial. Some clinicians use bronchodilators if wheezing is present. There have been conflicting results from clinical trials on ribavirin, prompting the Committee on Infectious Diseases of the American Academy of Pediatrics to revise its recommendations.[74,75] Ribavirin should be considered "based on the clinical circumstances and physicians' preferences."[76] Studies on the use of intravenous RSV immunoglobulin (RSV-IGIV) and intramuscular RSV monoclonal antibodies are in progress. Preliminary results suggest that RSV-IGIV is effective in preventing RSV infection in preterm infants but not effective in treating RSV infections.[76]

Unusual Causes of Pneumonia

Other unusual causes of pneumonia can be related to certain exposures, travel, or hobbies. *(See Table 9.)* Tuberculosis has a variable clinical presentation and radiologic findings and is in

the differential diagnosis of pneumonia. Histoplasmosis is endemic to the Mississippi river valley region. Coccidiomycosis is endemic to the Southwestern United States as is Hantavirus, which is especially associated with the "four corner" region of Arizona, New Mexico, Utah, and Colorado. *Chlamydia psittaci* pneumonia is transmitted via exotic birds. *Francisella tularensis* pneumonia could occur in a teenager or child who has been hunting with his/her parent.

Clinical Course of Pneumonia

Bacterial pneumonias generally resolve quickly once treatment including appropriate antibiotics is started unless complications occur. *(See Table 13.)* Generally, the patient will defervesce and feel significantly better within 24-48 hours of instituting therapy. Viral and atypical pneumonia have a more gradual onset and a slower resolution of symptoms.

Clearing of the abnormalities on the chest radiograph takes longer than resolution of the clinical symptoms and may not clear for weeks (up to about 6 weeks). In patients with an acute pneumonia discharged from the ED, follow-up especially in infants and young children may be in two stages: initial (24 hours) to check for deterioration or complications and delayed (about 6 weeks) in order to document radiographic resolution.

In the pediatric patient with nonresolving or recurrent pneumonia, other conditions need to be considered. These include: chronic infections, (tuberculosis is a major consideration, but fungal and parasitic infections may be present), primary pulmonary diseases (ranging from asthma to cystic fibrosis), aspiration (whether due to foreign body, chemicals, toxins, or anatomic/physiologic factors), malignancy, pulmonary infarction (pulmonary emboli or sickle cell vasoocclusion), congenital disorders (sequestration, cysts), autoimmune disease (lupus pneumonitis), and immunologic diseases. *(See Table 10.)*

When encountering such a patient with recurrent or nonresolving "pneumonia," treat for an acute infectious pneumonia with appropriate antibiotics until an infectious cause can be ruled out. Depending on the clinical situation, other studies (skin tests, laboratory tests, fungal or tuberculosis cultures, etc.) can be done.

Management. Management of pneumonia includes supportive care, the appropriate use of antimicrobials, *(see Tables 11 and 13)* and hospitalization in selected cases. The patient's age, the likely pathogen, *(see Tables 6 and 7)* and the severity of the illness direct the management. Hospital admission is mandatory in any patient with hypoxemia, respiratory distress, a neonate, or underlying disease (including: sickle cell disease, malignancy, immunosuppression, etc.). *(See Table 8.)* Hospitalization is warranted if complications of the pneumonia are present, such as empyema, lung abscess, a moderate to large pleural effusion, bacteremia, or sepsis. Other indications for hospital admission include: dehydration, inability to take oral fluids or medications, and/or failure to respond to outpatient therapy. Presumed or proven pneumonia due to certain highly virulent organisms, such as *S. aureus* or meningococcus warrants inpatient therapy. *(See Table 8.)*

If bacterial pneumonia is suspected (or proven), selection of an appropriate antibiotic is based on factors including: the patient's age, clinical presentation (signs and symptoms including their overall appearance, respiratory status, and vital signs), laboratory and radiographic findings, epidemiologic considerations, etc. Empiric antibiotic therapy may need to be chosen *(see Table 11)* and therapy modified when culture and ancillary laboratory results are available.

A determination of whether the pneumonia is bacterial, viral, or an atypical (e.g., mycoplasma or chlamydia) pneumonia is also based on the above factors since there is no one definitive test (or sign or symptom) that is pathognomonic (except perhaps for a positive blood culture that is not available when the patient is initially seen). Unfortunately, since a definitive diagnosis is not often available when the patient first presents to the physician, treatment is based on a presumptive etiology. *(See Tables 6 and 7.)*

Supportive care includes: hydration (sometimes intravenous), control of fever, management of complications, and respiratory support. Respiratory care may range from oxygenation, bronchodilators for wheezing, humidification or mist, suctioning, and postural drainage, intubation and mechanical ventilation.

An empyema and some pleural effusions (especially if interfering with respiration) of moderate to large size may need to be drained either by thoracentesis or a chest tube. Empyema usually requires a chest tube. Thoracentesis of a pleural effusion may also need to be done for diagnostic purposes.

Pneumonia secondary to a foreign body may require removal of the foreign body before the pneumonia will resolve. Apnea and respiratory failure may occur precipitously in infants with bacterial pneumonia (ages 3-6 months) consequently monitoring and hospitalization is appropriate.

Antiviral agents may be indicated in certain high-risk patients: former premature infants with bronchopulmonary dysplasia, chronic lung diseases (such as cystic fibrosis), certain congenital heart diseases, and immunodeficiencies. The two common antiviral agents are ribavirin (for respiratory syncytial virus) and amantadine for influenza. *(See Table 12.)*

Summary

Pneumonia in pediatric patients encompasses a wide spectrum of etiologies and illness from mild to severe and life threatening. Fortunately, most pediatric patients with pneumonia have mild disease and can be treated as an outpatient.

Outpatient therapy should include an antibiotic if a bacteria or atypical bacteria (chlamydia or mycoplasma) is suspected. No antibiotics are necessary for viral pneumonia. Outpatient supportive therapy also includes fever control and maintenance of hydration. Close follow-up is necessary in order to detect any secondary bacterial infection or the development of complications. Pediatric patients, especially infants and young children, diagnosed with pneumonia in the ED should have follow-up within 24 hours. Use of parenteral antibiotics (e.g., intramuscular ceftriaxone) may expand our ability to treat pediatric patients with pneumonia as outpatients.

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Physician CME Questions

49. Pneumonia in an adolescent is most commonly due to:
    A. *Streptococcus pneumoniae.*

B. Mycoplasma.
C. Chlamydia.
D. *Hemophilus influenzae.*
E. Adenovirus.

50. The drug of choice for the patient in question #1 is:
A. a macrolide.
B. amoxicillin-clavulanate.
C. penicillin.
D. ciprofloxin.
E. None of the above

51. A 10-year-old has the sudden onset of a fever (T = 40°C) and a cough, WBC count of 20,000 with a lobar consolidation on the chest radiograph. The most likely etiology (or pneumonia syndrome) is:
A. bacterial.
B. viral.
C. tuberculosis.
D. atypical (mycoplasma).
E. atypical (chlamydia).

52. A 3 year old has the gradual onset of upper-respiratory infection symptoms, with a low grade fever (T = 100.7°F), a cough, and an interstitial pattern on the chest radiograph. The most likely pathogen is:
A. *Streptococcus pneumoniae.*
B. *Hemophilus influenza.*
C. Mycoplasma.
D. Chlamydia.
E. respiratory synctival virus.

53. The antibiotic of choice for the patient in question # 4 is:
A. tetracycline.
B. erythromycin.
C. sulfonamide.
D. amoxicillin-clavulanate.
E. None of the above

54. The antibiotic of choice for "afebrile pneumonia of infancy" is:
A. tetracycline.
B. erythromycin.
C. sulfonamide.
D. amoxicillin-Clavulanate.
E. None of the above

55. An 8 year old has the sudden onset of fever (T = 40.2°C) with a cough, rales on the lung examination, and lobar consolidation on the chest radiograph. The most likely organism causing the pneumonia is:
A. Mycoplasma.
B. Chlamydia.
C. *Streptococcus pneumoniae.*
D. *Hemophilus influenza.*
E. Adenovirus.a

56. Assuming there is no antibiotic resistance (beta lactamase negative), which of the following antibiotic should be used in this patient?
A. Erythromycin
B. Sulfisoxazole
C. Penicillin
D. Tetracycline
E. Ribavirin

In Future Issues

Community-Acquired Pneumonia