236 Pneumonias

Erin R. Stucky · Meerana Lim

Definition/Classification

Defining pneumonia is particularly difficult in young children in whom other lower respiratory tract infections are common. The World Health Organization (WHO) defines pneumonia clinically, in the following stages: Stage I, fever $\geq$38°C and tachypnea (>50 breaths/min for 2–11 month olds and >40 breaths/min for 1–5 year olds); Stage II, with addition of chest indrawing; and Stage III, with addition of inability to drink and/or central cyanosis. The British Thoracic Society defines community-acquired pneumonia (CAP) as the presence of signs and symptoms of pneumonia in a previously healthy child due to an infection which has been acquired outside hospital. In the developing world, "acute lower respiratory infection" (ALRI) is used, given the limited access to obtaining a chest radiograph (CXR).

Etiology

The etiology of pneumonias in children outside the immediate newborn period varies based on age group, environment, exposures, and underlying comorbid risk factors.

Pneumonia can be caused by microorganisms, irritants, or unknown causes. Infectious etiologies include bacteria, viruses, atypical organisms, fungi, and parasites. The exact infectious etiology of the pneumonia is often not known because this would require an invasive procedure to obtain a specimen for culture. Without a culture, other clinical features and diagnostic study results are used to help make a clinical diagnosis and to guide appropriate therapy. The most commonly reported viral causes are biased due to available testing, but include influenza A or B, rhinovirus, respiratory syncytial virus (RSV), human metapneumovirus (hMPV), and parainfluenza. In the post-pneumococcal vaccine era in the United States, increased rates of invasive pneumococcal pneumonia during the respiratory viral infection season has been reported in association with RSV, influenza, adenovirus and hMPV. Viral causes that are of concern in countries without consistent immunization practices, or in immunocompromised hosts with cancer, primary immunodeficiency, or human immunodeficiency virus (HIV), are varicella and measles.

Epidemiology

According to the WHO, pneumonia is a significant cause of child mortality worldwide, responsible for approximately 2 million deaths each year, of which almost three-quarters are in developing countries. The WHO's Global Burden of Disease Update 2004 reports diarrhea and pneumonia as the leading causes of mortality in children under 5 years of age. In 2008, pneumonia accounted for 14% of deaths in infants less than 28 days of life according to the WHO. In Europe and Australia, incidence is reported at 3.6–6.8% of children less than 5 years of age, with similar hospitalization rates of 41–42%.

Although diagnostic testing is usually limited in practice, studies in the United States and Europe demonstrate that viruses are involved in up to two-thirds of CAP, of which approximately half are mixed viral–bacterial infections. In limited studies in developing countries, rates of the more broadly defined ALRI are reported, with viral causes at approximately 50%, the majority due to RSV. Influenza's impact worldwide varies with the yearly strain antigenic drift, with epidemics and pandemics seen when antigenic shift occurs. New viral etiologies continue to emerge, such as the coronavirus severe acute respiratory distress syndrome (SARS). The clinician must be attentive to outbreaks of respiratory diseases across the globe given the ease with which pathogens travel on human hosts (air travel) and through natural sources (global air streams).

Pathogenesis and Pathology

The most frequent histopathologic findings in major airways with viral pneumonia are congestion, inflammation, necrosis of bronchial epithelium, and hemorrhage. Viral pneumonias affect the lung through direct invasion, causing mucosal inflammation and damaging ciliary clearance allowing secondary bacterial infection to occur more readily.

In severe cases, extensive involvement of the bronchoepithelial cells and mucous glands of trachea, bronchi, and larger bronchioles, and submucosal mononuclear inflammatory infiltrates can be seen. Neutrophilic and monocytic inflammation and extensive secondary

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bacterial pneumonia is reported from autopsies of pediatric influenza patients.

Clinical Manifestations

Typical signs and symptoms include fever, diminished breath sounds, rales, retractions, tachypnea, hypoxemia, and cough. In general, higher fever with a rapid onset is seen in bacterial pneumonia; however, there are many exceptions to this. Viral pneumonia, particularly those caused by influenza, may present with high fevers and chills. *Chlamydia trachomatis* and *Bordetella pertussis* infections are frequently afebrile. A fever many days into a respiratory illness accompanied by worsening symptoms may suggest a secondary bacterial infection after a primary viral illness.

While the characteristic post-tussive inspiratory whoop of whooping cough may help make this diagnosis in school-age children, it is usually not present in very young infants and adults. A productive cough, particularly if associated with large volumes of purulent secretions, is suggestive of a bacterial pneumonia, whereas a dry, nonproductive cough is more likely to be a viral process. In very young children and infants, sputum characterization can be difficult as they are likely to swallow their sputum. If sputum can be expectorated, a culture of the expectorate may be helpful in the diagnosis and treatment of pneumonia.

Poor feeding or poor oral intake is common (~75%), as are vomiting (30–45%), abdominal pain (up to 20%), and dehydration (25%).

Physical Exam

The physical exam for pneumonia may not be as helpful in an infant versus and older child or teenager. The most common findings include fever and tachypnea. Tachypnea has been associated with a sensitivity of 50–85% for diagnosis of lower respiratory tract infection with specificity of 70–97%. In children who have been symptomatic for over 3 days, tachypnea has a sensitivity of 74% and a specificity of 67% for pneumonia confirmed by chest x-ray.

Tachypnea age specific norms recommended for use:

- 60 breaths/min in infants younger than 6 months
- 50 breaths/min in infants 6–11 months old
- 40 breaths/min in children 12–59 months old
- 30 breaths/min in febrile children 5 years of age and older

Decreased breath sounds may occur in the area of a lobar pneumonia. Normal breath sounds may be auscultated in up to 20% of children due to transmission of normal breath sounds across the relatively small thorax; yet they may have complete collapse or consolidation on CXR. Crackles are frequently suggestive of bacterial pneumonia, which are not uncommon in infants with RSV pneumonia. This is the sound of alveoli opening and/or by air bubbling through fluid in the small airways during inspiration. Wheezing may be present; however this sign may be noted in many lower respiratory tract diseases. Dullness to percussion may be heard over an area of focal consolidation. Egophony or increased resonance can be auscultated over an area of consolidation or over a large effusion. The patient is asked to say "e" and what is heard by stethoscope is "a" due to altered transmission of noise through fluid versus air. Chest pain, usually pleuritic, worsened by deep breaths and cough, may also be present.

Diagnosis

Diagnosis of pneumonia in the ambulatory setting is often made clinically, especially where access to radiology services is limited. According to the British Thoracic Society, CXR should not be performed routinely in children with mild uncomplicated acute lower respiratory tract infection. Correlation between clinical assessment of diminished breath sounds and consolidation on CXR is overall poor at only 50–60%.

Neither clinical signs and symptoms nor CXR aid in differentiating between viral and bacterial pneumonias. However, some associations between CXR reports and infectious etiologies may be helpful in treatment decisions. Lobar consolidations are frequently associated with a bacterial pneumonia, whereas a bilateral diffuse interstitial appearance may be more suggestive of Pneumocystis pneumonia, Legionella, or a viral process. Pneumonia caused by Staphylococci in the pediatric population may be associated with pneumatoceles, bronchopleural fistulas, and empyema, although none of these should be considered pathognomonic. Mycoplasma pneumonia usually has a diffuse bilateral interstitial appearance on radiograph, although it can also be seen with lower lobe consolidations and effusions. The preferred imaging is for two views of the chest, frontal (usually posteroanterior), and lateral (to see the retrocardiac area) for initial evaluation. In cases where there is complete opacification of the hemithorax or when there is a complicated pneumonia, computed tomography and/or sonography may also be employed. Recurrent pneumonias and those that are resistant to therapy are candidates for further imaging.

Laboratory testing in ambulatory patients is not routinely indicated, but some studies may be helpful for hospitalized patients (Table 236.1). Lab testing for viruses by real-time (RT) PCR can be valuable in patients at risk for more severe complications of disease who may require more intense monitoring due to underlying cardiac, immune, or chronic pulmonary disorders. Routine laboratory testing for ambulatory children is not indicated. Inappropriate secretion of antidiuretic hormone (SIADH) may be more common than previously thought, found in up to 20% of patients (Table 236.2).

Patients with significant pleural fluid should have specimens sent for gram stain, viral testing, aerobic and anaerobic bacterial culture, with consideration for mycobacteria and fungal cultures at the direction of infectious disease consultation. Sensitivity of latex agglutination studies for *Streptococcus pneumoniae* and *Haemophilus influenzae* type b (Hib) on pleural fluid vary with method and range 77–91%.

For immunocompromised hosts, evaluation for invasive viral infections such as varicella, herpes simplex, and coronavirus should be considered along with parasitic, protozoal, and fungal infections, and in consultation with infectious-disease experts.

Table 236.1
Pneumonia-causing organisms by age

Neonates	Common organisms	Group B streptococcus, gram negative enteric bacteria, cytomegalovirus, *Ureaplasma urealyticum*, *Listeria monocytogenes*, and *Chlamydia trachomatis*
	Less common organisms	*Streptococcus pneumoniae*, group D streptococcus, and anaerobes
Infants	Common organisms	RSV, parainfluenza viruses, influenza viruses, adenoviruses, metapneumovirus, *Streptococcus pneumoniae*, *Hemophilus influenzae*, *Mycoplasma pneumoniae*, and *Mycobacterium tuberculosis*
	Less common organisms	*Bordatella pertussis* and *Pneumocystis jiroveci*
Preschool children	Common organisms	RSV, parainfluenza viruses, influenza viruses, adenoviruses, hMPV, *Streptococcus pneumoniae*, *Hemophilus influenzae*, *Mycoplasma pneumoniae*, and *Mycobacterium tuberculosis*
	Less common organisms	*Chylamydia pneumoniae*
School-age children	Common organisms	*Mycoplasma pneumoniae*, *Chylamydia pneumoniae*, *Streptococcus pneumoniae*, *Mycobacterium tuberculosis*, parainfluenza viruses, influenza viruses, and adenoviruses

Differential Diagnosis

Alternate diagnoses may be both pulmonary and non-pulmonary. For young infants with wheezing and acute respiratory distress, bronchiolitis is the most common diagnosis. Acute respiratory distress may be the result of aspiration of a foreign body, inhalation lung injury, or spontaneous pneumothorax. Non-pulmonary considerations include leukemic infiltrates, congestive heart failure, metabolic acidosis with compensatory tachypnea, asthma, or in appropriate areas malaria. Failure to improve as expected with usual therapy should trigger consideration of both uncommon infectious organisms as well as underlying condition such as HIV or pulmonary anatomic abnormality. Recurrent pneumonia bears a further work-up, depending on the associated signs and symptoms. Underlying diagnoses to consider include: cystic fibrosis, congenital malformations (cystic adenomatoid malformations, pulmonary sequestrations, foregut duplication cysts), immotile cilia syndrome, right middle lobe syndrome, immunodeficiency (congenital or acquired), hemorrhage, vascular malformations, and dysfunctional swallow. In these cases, treatment of the underlying disease is an important part in the prevention of further pneumonias and long-term consequences of recurrent lung infections.

Treatment

Patients not hospitalized should be reevaluated by their primary care practitioner within 24–48 h. Admission should be considered for patients with need for supportive care (oxygen, intravenous hydration, suctioning) or at risk for progression of respiratory disease or potential instability of underlying chronic condition. Specific admission criteria suggested include oxygen saturation less than 92%; respiratory rate >70 breaths/min in infants/50 in

Table 236.2
Commonly performed laboratory testing

Study	Value	Comments
RT-PCR viral (NPA; tracheal)	Influenza treatment can be initiated; discontinuation of antibiotics can be considered	Nasopharyngeal aspirate (NPA) technique influences result; overall sensitivity 80–95%
RT-PCR atypical (NPA; tracheal)	Mycoplasma and Chlamydia pneumonia treatment can be initiated	Not available at many hospital sites
Viral culture (NP, tracheal most common)	Definitive diagnosis of active viral infection	Requires special transport media, processing time, not available at many hospital sites; rarely positive in face of a negative viral PCR
Paired acute and convalescent serology (blood)	Can detect acute infection of some viruses; more reliable result for *M. pneumoniae* than single IgM	Requires blood testing at presentation and at 3 weeks
RT-PCR (blood)	*S. pneumoniae* most often tested	May be negative when paired serology demonstrates acute exposure
C-reactive protein (CRP); Procalcitonin (PCT)	Higher levels seen in typical bacterial infection	Cutoff levels below which typical bacterial disease is not likely to have not been well documented for CRP or PCT
Complete blood count		White blood cell count and band forms do not correlate well with etiology
Electrolytes	For severely dehydrated or ill patients	Hyponatremia, acidosis, and hypoglycemia are not uncommon in severely ill patients
Blood culture	Supportive of more systemic disease	Rarely positive (1–10%); however, it is recommended in any patient with probable bacterial infection

children, grunting or apnea, poor feeding/inability to feed, and concern for caregiver ability to assess respiratory distress. Pulse oximetry should be performed on all hospitalized children.

Antibiotics will be given empirically despite the fact that this approach likely leads to overuse of antibiotics in the general population. Antibiotic choice is typically based on the patient's age and commonly encountered organisms causing infection in that age. It is important to remember that for neonates, early-onset GBS disease is usually severe and almost always includes pneumonia as part of the disease presentation. Treatment of suspected or proven viral pneumonia is typically supportive. Chest physiotherapy (postural drainage, percussion of the chest, or deep breathing exercises) does not affect length of hospital stay, duration of fever, or CXR findings in patients with pneumonia. Sitting upright may help to expand lungs and lessen respiratory symptoms in children with respiratory distress.

For patients with suspected or proven influenza pneumonia, antiviral therapy with oseltamivir is indicated to both treat the patient and to limit spread of the disease. Other pathogen-specific therapies include vitamin A for measles pneumonia, acyclovir for varicella, and ribavirin for SARS and severe RSV. Steroid use is controversial but has been used in severely ill patients in intensive care settings.

Prognosis

Duration of hospital stay is associated with clinical severity rather than etiology. Although acute inflammatory markers (CRP, PCT) are higher in bacterial disease, levels do not correlate with severity of disease.

Follow-up CXR is indicated only for lobar collapse or round pneumonia to document complete resolution and thereby confirm absence of anatomic abnormality or tumor.

Prevention

Primary prevention includes strict infection control measures, immunization, and avoidance of exposures and lung irritants that increase susceptibility to respiratory pathogens. Hand washing and covering the mouth while coughing continue to be significantly effective measures to reduce

spread of disease. Crowding and smoke exposure are associated with increased risk of viral infections, particularly in young infants. Chemoprophylaxis for certain types of pneumonia may be indicated in select populations such as immunocompromised patients, and those with asplenia and certain cardiac disorders. Guidelines for routine vaccination against Hib, *Streptococcus pneumoniae*, and varicella, as well as yearly influenza prevention should be followed. Immunoprophylaxis against RSV should be given to appropriate infants following national guidelines.

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