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Principles of Diagnosis and Treatment in Children with Acute Pneumonia

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ABSTRACT

Pneumonitis refers to the inflammatory response in the lung parenchyma, and when this inflammation is triggered by infectious microorganisms, it is termed pneumonia. The responsible microbial agents may include bacteria, viruses, or parasites. According to the definition provided by the World Health Organization (WHO) within the framework of the Integrated Management of Childhood Illness (IMCI) program, pneumonia in children is clinically characterized as a sudden onset of cough, which may or may not be associated with fever, accompanied by respiratory distress or an elevated respiratory rate (tachypnea). The present study aimed to investigate the principles of diagnosis and treatment in children with acute pneumonia. Following the effective execution of global strategies targeting the control and treatment of acute gastrointestinal infections and related gastroenteritis, in recent years, attention has increasingly shifted to acute respiratory infections, especially pneumonia, as the leading infectious cause of mortality among children in developing countries. The diagnosis of pneumonia is predominantly clinical and is usually categorized into bacterial pneumonia, viral pneumonia, and acute pneumonia. This classification is based on four essential criteria: clinical manifestations, epidemiological context, radiological imaging findings, and basic laboratory test results. In each category of pneumonia, diagnosis relies on the distinctive characteristics of the disease presentation, guiding the selection of an appropriate treatment plan. Accurate and up-to-date knowledge among physicians regarding the principles of diagnosing and managing pneumonia in children is essential. Optimizing clinical decision-making without imposing unnecessary healthcare costs can significantly contribute to reducing both the mortality and morbidity associated with this common and serious pediatric condition.

Keywords: Diagnosis, Children, Treatment, Acute pneumonia

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Introduction

Based on the 2000 report from the World Health Organization (WHO), acute respiratory infections (ARI) are responsible for approximately 1.4 million deaths globally each year, with nearly 90% of these fatalities attributed to acute pneumonia. Furthermore, the same report highlights that 1.9 million of these deaths occur in children younger than five years old [1]. The majority of these pediatric deaths are concentrated in developing countries, where malnutrition is considered a major predisposing factor contributing to this high mortality rate [2, 3]. Additionally, acute lower respiratory tract infections, particularly pneumonia, account for nearly 20% of childhood deaths worldwide. Statistically, in developing nations, this equates to 12 to 20 deaths from pneumonia for every 1,000 live births before children reach the age of 5 years [1, 4, 5]. Therefore, it is evident that acute respiratory infections, especially pneumonia among children, continue to impose a significant disease burden on global health systems [6, 7].

Medically, pneumonitis refers to an inflammatory process affecting the lung parenchyma. However, when this inflammation results from microbial invasion, it is classified as pneumonia. The causative microorganisms may be bacterial, viral, or parasitic. According to the WHO's Integrated Management of Childhood Illness (IMCI) guidelines, pneumonia is clinically defined as an acute onset of coughing, which may or may not be accompanied by fever, along with respiratory distress or an increased respiratory rate (tachypnea) [8]. It is important to note that this clinical definition overlaps with that of bronchiolitis — another major acute lower respiratory infection — since both conditions commonly present with tachypnea. The reason for this overlap lies in the fact that tachypnea is a highly sensitive clinical sign for diagnosing acute lower respiratory infections, particularly pneumonia. However, while fever and tachypnea provide high sensitivity, their specificity is low. In contrast, clinical findings such as pulmonary rales or pleuritic chest pain are highly specific but possess low sensitivity for the diagnosis of pneumonia [9, 10].

The present study aimed to investigate the principles of diagnosis and treatment in children with acute pneumonia.

Results and Discussion

Classification of Pneumonia

Pneumonia in the pediatric population can be categorized through various approaches, each serving an essential role in guiding clinical decisions regarding management and therapeutic strategies. The disease is classified based on several factors, including the source of infection, causative microorganism, clinical presentation, anatomical site of lung involvement, disease severity, and the presence or absence of complications.

Classification of Pneumonia According to Anatomical Site of Lung Involvement

One method of classifying pneumonia focuses on the specific lung region affected by the infection. In this system, localized pneumonia — such as lobar pneumonia, segmental pneumonia, or round pneumonia — is confined to a specific lung area or a single lobe. Another form, interstitial pneumonia, is characterized by involvement of the pulmonary interstitial tissue, often presenting with widespread and bilateral lung involvement. In contrast, bronchopneumonia features infection of the alveoli alongside inflammation of the bronchi, particularly the terminal bronchi, resulting in a mixed pattern of involvement across both airways and lung tissue.

Classification of Pneumonia Based on the Source of Infection

Pneumonia can also be classified depending on where the infection was acquired. Community-acquired pneumonia (CAP) typically arises outside hospital settings and is generally associated with lower levels of antibiotic resistance. Conversely, hospital-acquired pneumonia (HAP) develops within healthcare facilities and is often linked to pathogens demonstrating significant antibiotic resistance. This is largely due to the transfer of resistant microorganisms, such as methicillin-resistant *Staphylococcus aureus* (MRSA), which colonize the skin or mucous membranes of hospital staff and can be transmitted to patients during hospitalization [11, 12].

Classification of Pneumonia Based on Clinical Presentation

Pneumonia may be categorized according to its clinical course into two primary forms. Typical pneumonia is characterized by a sudden onset of symptoms, most notably a high-grade fever, alongside localized infiltrates visible on chest radiography. This form is commonly caused by bacterial pathogens such as *Streptococcus*

pneumoniae (*pneumococcus*) and *Haemophilus influenzae*, and typically shows a favorable response to treatment with beta-lactam antibiotics. On the other hand, atypical pneumonia often develops gradually, with patients usually experiencing a milder fever, and radiographic findings reveal diffuse lung involvement rather than localized changes. This type is commonly attributed to non-bacterial organisms such as viruses, Mycobacteria, fungi, *Mycoplasma*, and *Chlamydia*, and generally does not respond well to beta-lactam antibiotics.

Classification of Pneumonia According to the Presence of Complications

Pneumonia can also be distinguished based on whether complications arise during the disease course. Uncomplicated pneumonia refers to cases where the infection resolves promptly without any significant complications. In contrast, complicated pneumonia involves additional clinical problems such as pleurisy, empyema, pneumothorax, extensive atelectasis, or lung abscesses, often resulting in a prolonged recovery period.

Pneumonia Classification Following WHO Guidelines in the MCI Program

The World Health Organization (WHO), within the framework of the MCI Plan, proposed a classification system based on clinical signs and symptoms. No pneumonia is defined by the presence of a cough or other upper respiratory tract symptoms without accompanying tachypnea or disturbed systemic regulation in the child. Mild pneumonia involves respiratory symptoms along with tachypnea but without evidence of respiratory distress. Severe pneumonia is identified when respiratory symptoms are present alongside tachypnea and signs of respiratory distress, such as the use of accessory respiratory muscles. Very severe pneumonia is diagnosed when the criteria for severe pneumonia are met, in addition to serious clinical features such as reduced level of consciousness, convulsions, or pronounced cyanosis.

Etiology of Pneumonia

As previously discussed, a range of infectious agents, including bacteria, viruses, and protozoa, are known to cause pneumonia. However, in approximately 25% to 33% of clinical studies, the exact infectious pathogen responsible for the pneumonia could not be identified [13-15]. Moreover, in certain cases, co-infection with two or more microbial agents has been documented. In fact, in about 41% of patients hospitalized with pneumonia, multiple microorganisms have been isolated as contributing etiological factors [16].

Major Etiological Agents of Pneumonia in Pediatric Patients

Viruses

Among young children, viruses represent the most prevalent causative agents of pneumonia, although their role tends to diminish with increasing age [17]. The most important viral pathogens in pediatric pneumonia include respiratory syncytial virus (RSV), influenza virus, and rhinoviruses. Other notable viral agents include adenoviruses, parainfluenza virus, enteroviruses, and coronaviruses. In recent years, human metapneumovirus (HPV) has emerged as a significant viral pathogen implicated in pediatric pneumonia [18]. Additionally, the measles virus, once regarded as one of the most severe causes of viral pneumonia, is now being effectively controlled in many regions due to widespread vaccination programs [19, 20].

Streptococcus Pneumoniae

Streptococcus pneumoniae, or pneumococcus, is the leading bacterial cause of pneumonia across all stages of life, except in infancy [21]. Pneumococcal pneumonia typically presents as a localized form, but can also manifest as pneumonia with pleural effusion or as interstitial pneumonia. The routine administration of the heptavalent pneumococcal vaccine in certain developed nations has resulted in a noticeable decline in pneumococcal pneumonia cases. A large-scale study demonstrated a 35% reduction in radiologically confirmed cases of pneumonia due to this vaccine [22].

Haemophilus Influenzae

Another major bacterial pathogen, particularly in children under five, is *Haemophilus influenzae*. Its clinical presentation is similar to that of pneumococcal pneumonia, with symptoms ranging from mild to severe. The introduction of the *Haemophilus influenzae* type B conjugate vaccine in developed countries has significantly lowered the incidence of invasive infections, including pneumonia, caused by this pathogen [23]. However,

nontypable *Haemophilus influenzae* remains a common cause of pneumonia in these regions, particularly in developing countries. Unlike type B, which may lead to pneumonia following bacteremia, this strain often causes pneumonia after aspiration of upper respiratory tract secretions [24].

Staphylococcus Aureus

Staphylococcus aureus is a frequent cause of pneumonia, particularly in early infancy, often following a viral infection like influenza. This pneumonia tends to have a rapid onset and severe progression, commonly accompanied by complications such as empyema, abscess formation, and the development of pneumatoceles in the lungs. In older children, the clinical and radiological presentation may resemble other bacterial pneumonias. Approximately 75% of initial cases in infants involve an underlying health issue, with 65% of these being unilateral, typically in children under one year of age. Secondary pneumonia due to *Staphylococcus aureus* is usually bilateral, often resulting from the spread of infection from other sites in the body.

Group A Streptococcus

Pneumonia caused by Group A *Streptococcus* is uncommon in children. One of its distinctive features is the severe necrosis of the respiratory tract mucosa, leading to edema and bleeding, which prolongs fever in affected patients for several days, sometimes as long as ten days, even with appropriate treatment [25]. Following this type of pneumonia, complications such as pleurisy and pneumatoceles may occur.

Gram-Negative Intestinal Bacilli

Infections with gram-negative intestinal bacilli typically cause pneumonia in infants or children with underlying immunodeficiencies, although they are rare in otherwise healthy children. Klebsiella pneumoniae-induced pneumonia is characterized by severe symptoms, including high fever and chills, and may involve necrotizing pneumonia with extensive tissue damage. Pneumonia caused by *Pseudomonas aeruginosa* or, to a lesser degree, *Burkholderia cepacia*, is a significant concern for children with cystic fibrosis (CF).

Anaerobic Bacteria

Anaerobic bacteria are commonly implicated in aspiration pneumonia, particularly in children past the teething stage. These infections often exhibit a gradual clinical course and, if not appropriately treated, may lead to the development of lung abscesses.

Mycoplasma Pneumoniae

Mycoplasma pneumoniae stands out as one of the primary causes of acute pneumonia, particularly in children over 5 years of age [26]. It commonly shows up on chest X-rays as diffuse lung infiltration, sometimes appearing as bilateral interstitial pneumonia. In rare instances, it may occur alongside other conditions. A significant portion of children with *Mycoplasma* infections (about 25%) also present with symptoms outside of the lungs, affecting areas like the skin, nervous system, heart, and blood [27].

Chlamydial Infections

The *Chlamydia* genus includes organisms that are major contributors to acute pneumonia. *Chlamydia trachomatis* frequently leads to pneumonia in infants younger than four months, often causing a fever-free, bilateral infection, transmitted from mother to child during delivery. *Chlamydia pneumoniae* is another prominent pathogen responsible for pneumonia, particularly in school-aged children and adolescents, sharing similarities with *Mycoplasma pneumoniae*. Most of these cases remain asymptomatic [28]. *Chlamydia psittaci*, contracted through exposure to birds, can cause high fever, severe headaches, and tonsillitis, with an elevation in liver enzymes and alkaline phosphatase being characteristic of this rare pneumonia in children.

Clinical Presentation

The clinical manifestations of pneumonia depend on the causative organism, the child's age, and the severity of the infection. In young infants, symptoms may be vague, and the clinical signs might not be as obvious. These symptoms can be grouped into five categories: general symptoms, signs of lower respiratory involvement, pneumonia-specific symptoms, pleural-related symptoms, and signs beyond the lungs.

General symptoms include fever, chills, fatigue, irritability, and a lack of appetite. Symptoms that indicate lower respiratory involvement include cough (which may initially be dry but can become productive), rapid breathing (tachypnea), and signs of distress such as grunting (audible exhalation due to partial vocal cord closure). Additionally, the use of secondary respiratory muscles, seen in intercostal, subcostal, and supracostal retractions, or nostril flaring, is often noted.

Specific pneumonia signs include reduced breath sounds, bronchophony (the amplification of sound during lung consolidation), and fine crackles heard at the end of inspiration. Chest pain, which may cause shallow breathing, may prompt the child to press on the painful area of the chest. Wheezing is typically absent in pneumonia but may occasionally be heard in the early stages of the infection [29]. In some cases, young children may develop abdominal distention, which could result from swallowing air or an intestinal blockage.

When pleurisy develops, chest pain and a friction rub are often heard during auscultation, making breathing more difficult. As pleurisy progresses, respiratory sounds might diminish, and the irritation of the pleura can cause abdominal discomfort, sometimes mimicking an acute abdominal issue, or even lead to signs of meningeal irritation. The presence of pleural effusion is a strong indicator of bacterial pneumonia, raising the likelihood of bacterial infection sixfold [17].

Extrapulmonary manifestations of pneumonia, especially *Mycoplasma pneumonia*, may include sore throat, headache, skin reactions (such as erythema multiforme, erythema nodosum, urticaria, and Stevens-Johnson syndrome), ear infections (otitis media), and neurological symptoms (like aseptic meningitis, encephalitis, ataxia, and transverse myelitis). Hematologic signs such as anemia and thrombocytopenia, digestive system issues (e.g., elevated liver enzymes, diarrhea, and vomiting), and cardiovascular symptoms (myocarditis and pericarditis) may also present. Joint-related symptoms like muscle pain and polyarthritis can be observed as well.

An elevated respiratory rate (tachypnea) is an essential clinical sign for diagnosing pneumonia in children. This should be measured over one full minute while the child is calm and at rest.

Diagnosis

In the majority of community-acquired pneumonia (CAP) cases, identifying the causative organism is not necessary for diagnosis. The diagnosis is primarily based on clinical evaluation. However, in certain scenarios—such as hospital-acquired pneumonia (HAP), severe or fulminant pneumonia, pneumonia with complications, empyema, or pulmonary abscesses—determining the responsible microorganism is crucial. It is also important in cases where pneumonia does not respond to initial treatment, or in patients with underlying conditions like primary immunodeficiencies or cystic fibrosis [30].

Collecting sputum samples in children, particularly those under six years old, is often challenging. In some cases, hypertonic saline nebulization may help in obtaining a sputum sample. For a sample to be considered viable, it should contain more than 10 white blood cells (PMN) and fewer than 25 epithelial cells per 10x magnification (LPF) in each field [31].

Nasopharyngeal samples are not typically reliable for microorganism cultures or antigen testing due to the potential for natural colonization in that area. They are only useful in specific circumstances, such as when testing for certain viral infections like respiratory syncytial virus (RSV) and influenza. Throat and oropharyngeal samples are generally not effective for identifying the pathogen responsible for pneumonia [32]. In more complex cases, invasive procedures like bronchoscopy or bronchoalveolar lavage (BAL), and sometimes closed or open lung biopsy, are required for accurate diagnosis and appropriate treatment. Additionally, blood or pleural fluid cultures can aid in diagnosing pleurisy. Blood cultures, although highly specific, have low sensitivity and yield positive results in only around 15% of bacterial pneumonia cases. Consequently, it is recommended to perform a blood culture for any child suspected of having bacterial pneumonia.

Serological testing can detect certain pathogens like *Mycoplasma pneumoniae* and *Chlamydia pneumoniae*. However, these tests usually require delayed results, which makes diagnosis retrospective. Moreover, serological tests are less reliable in children under six months of age due to low immune responses and maternal antibody transfer. A rapid and simple immunochromatographic strip test for detecting bacterial polysaccharides in urine, especially for *Streptococcus pneumoniae*, is an efficient diagnostic tool in adults. However, its reliability in children is limited, as it can produce false positives due to pharyngeal or nasopharyngeal colonization, particularly in developing countries, where up to 60-90% of children may carry *S. pneumoniae* in their throats [33].

When diagnosing pneumonia in children, it is typically categorized into three groups: bacterial, viral, and acute pneumonia. This classification is based on an evaluation of four key elements: 1) clinical findings, 2)

epidemiological findings, 3) radiological results, and 4) primary laboratory tests such as erythrocyte sedimentation rate (ESR), complete blood count (CBC), and C-reactive protein (CRP).

Treatment of Patients

The MCI method outlines the management of pneumonia patients in four categories: 1) no pneumonia: antibiotics are not required for these patients; 2) mild pneumonia: treatment involves oral antibiotics, such as amoxicillin or cotrimoxazole, for a duration of 3 to 5 days (amoxicillin is preferred due to resistance concerns) [34]; 3) severe pneumonia: the patient is hospitalized and receives intravenous antibiotics; 4) very severe pneumonia: these patients are admitted to the intensive care unit (ICU) for intensive care and antibiotic therapy. The adoption of this treatment strategy in developing countries has led to a significant reduction in pneumonia-related mortality, particularly in children under five, with a decrease of approximately 40% [35].

Pneumonia diagnosis is determined based on clinical, epidemiological, radiological, and laboratory findings, and patients are categorized into one of three types: bacterial, atypical, or viral pneumonia. A key concern is the growing resistance of penicillin-resistant pneumococci. While resistance is a factor, if the infection is confined to the lungs, penicillins remain the first-line choice for treatment, and merely increasing the dosage can overcome resistance. In severe cases, third-generation intravenous cephalosporins are preferred, and vancomycin is added if initial treatments are ineffective or if the pneumococcal minimum inhibitory concentration (MIC) for penicillin exceeds 4 μg/dl [36].

Supportive Care

In addition to antibiotics, supportive care is crucial in managing pneumonia in children. These interventions include:

Oxygen Therapy: Hypoxia is a common issue in pneumonia, primarily due to an imbalance between ventilation and perfusion. In children, their softer sternum, more horizontal ribs, and weaker intercostal muscles make it harder for the body to compensate for this imbalance, potentially leading to hypoxia and acidosis. Preventing these complications is vital for the management of severe pneumonia in children [37]. The WHO recommends oxygen therapy for children exhibiting symptoms such as cyanosis, inability to feed, or a respiratory rate greater than 60 breaths per minute [38].

Adequate Nutrition and Hydration: Malnutrition significantly contributes to the morbidity and mortality of children with pneumonia. Early initiation of oral nutrition and ensuring proper hydration, especially in children with severe pneumonia, is essential for speeding up recovery. Vitamin A deficiency, for instance, significantly increases the risk of respiratory infections and mortality from pneumonia [39]. Furthermore, administering zinc supplements has been shown to reduce the prevalence of pneumonia by 40% and shorten hospitalization by 25% [40].

Rest and Proper Positioning: Ensuring the child receives adequate rest and minimizing stress are vital for recovery. Raising the patient's head to an angle of 30-45 degrees is recommended. Chest physiotherapy has also shown benefits, particularly in adults without underlying conditions. Studies suggest that chest physiotherapy improves outcomes for those with acute pneumonia and enhances recovery [41].

Duration of Antibiotic Therapy

As per the IMCI guidelines, a treatment period of 3 to 5 days is sufficient for mild pneumonia when oral antibiotics are used. However, the duration may vary based on the type of infection. For mild bacterial pneumonia, the treatment course lasts 5 to 7 days, while for more severe cases, it extends to 10 to 14 days. If the patient requires hospitalization and intravenous antibiotics are initiated, treatment may be switched to oral antibiotics once the patient's symptoms improve, fever subsides for 48-72 hours, and inflammatory markers like ESR and CRP decrease. The overall length of antibiotic therapy is influenced by factors such as the causative organism (e.g., *Staphylococcus aureus* may require 3 to 6 weeks of treatment), the patient's clinical response, and whether complications like pleurisy are present.

Prevention

Since its introduction in 2000, the seven-valent pneumococcal vaccine (Heptavalan) has led to a notable decline in invasive infections, including pneumonia, in developing countries, with a similar trend observed after the inclusion of the *Haemophilus influenzae* type B vaccine in 1990 [42, 43]. Currently, research is being conducted

on the administration of a 14-valent pneumococcal vaccine to pregnant women during the final months of pregnancy to help protect newborns from pneumococcal infections [44].
Following the Heptavalan vaccination, there has been a reduction of 20-88% in the occurrence of invasive pneumococcal infections. A study from Belgium found that replacing the seven-valent pneumococcal vaccine with a nine-valent version led to a decrease in these infections by 45% to 73%. Additionally, for children over six months old, receiving the influenza vaccine in recommended cases helps lower the likelihood of contracting the virus and reduces the chances of secondary bacterial infections [41, 45, 46].

Conclusion

Following the effective implementation of strategies for managing acute gastrointestinal infections and gastroenteritis, acute respiratory infections, particularly pneumonia, have become the primary infectious cause of death among children in developing regions in recent years. The diagnosis of pneumonia is predominantly clinical and can be categorized into bacterial, viral, and acute types, using four key criteria: clinical presentation, epidemiological data, radiological findings, and standard laboratory tests. Each diagnosis is refined according to the pneumonia's distinct characteristics, and treatment is adapted accordingly. A physician's comprehensive knowledge of diagnosing and treating this significant childhood illness, while avoiding unnecessary expenditures, is crucial in reducing both the fatality and impact of the disease.

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