REVIEW ARTICLE

Management of Children with Community-acquired Pneumonia: A Review of Literature

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Abstract

Community-acquired pneumonia in children is a common infection but can be potentially serious in some, leading to hospitalization in those with severe or complicated pneumonias. Diagnosis can be made with appropriate history and relevant clinical examination. Viral and *Streptococcus pneumoniae* infections remain the most common cause of CAP in preschool children, whereas *Mycoplasma pneumoniae* can present more commonly in older children. Treatment with the appropriate antibiotics is crucial, especially with the increasing prevalence of viral and bacterial co-infections as well as emerging antibiotic resistance. Appropriate dosage and duration of antibiotics are determined by the severity or complications involved. In addition, immunization is extremely important for prevention of CAP in children.

Keywords: Children, Community-acquired pneumonia, Management.

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Introduction

Pneumonia is an acute respiratory tract infection (ARTI) that affects the lung parenchyma. It causes significant morbidity and mortality in children less than 5 years of age, accounting for one-fifths of the total childhood deaths worldwide.[1] Approximately 50% of children with community-acquired pneumonia (CAP) whore are below the age of 5 years, 20% between 5 and 10 years, and 10% beyond 10 years[2] require hospitalization. Thus, CAP poses a significant burden and an increasing challenge to healthcare resources.

We have reviewed the existing literature for diagnosis and management of children with CAP—for children who are otherwise healthy and have no underlying comorbid conditions.

This review excludes neonates, immuno-compromised, and children with various chronic pulmonary, cardiac, genetic, and neurological disorders.

Definitions

World Health Organization CAP Classification

The new classification by WHO[1] includes only two categories of pneumonia:

"Pneumonia" with fast breathing and/or chest indrawing, which requires home therapy with oral amoxicillin.

"Severe pneumonia"—pneumonia with any general danger sign that requires referral and parenteral therapy.

Pediatric CAP is defined as "the presence of symptoms and signs of pneumonia in a previously healthy child due to an infection which has been acquired outside hospital"[3].

Clinical Features

Severe pneumonia is defined by the clinical parameters summarized in Table 1.[3]

The clinical presentation of CAP varies in infants and older children.

The clinical features of CAP has been summarized according to severity (Table 1).

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Children with CAP may present with fever, fast breathing, breathlessness or difficulty in breathing, coughing, wheezing, or even chest pain.

Tachypnea is a nonspecific clinical sign for respiratory distress and/or hypoxemia. Other causes of tachypnea like fever, dehydration, and concurrent metabolic acidosis must be ruled out.

Children can also present with abdominal pain, shoulder pain, vomiting, and headache.

It is imperative to differentiate by history and examination—those presenting with only upper respiratory tract symptoms and those with generalized wheezing and low-grade fever who may not qualify as pneumonia.

Other indicators of respiratory distress/potential respiratory insufficiency are increased work of breathing (evident by retractions [subcostal, suprasternal or intercostal], flaring of alae nasi and use of accessory muscles), apneas, and grunting. Grunting denotes impending respiratory failure.

Focal crackles on auscultation may not always be present.[3] However, focal crackles are neither sensitive nor specific for pneumonia. Other signs such as bronchial breathing, a pleural rub, or wheeze can further aid in the clinical diagnosis. If pleural effusion

Table 1: Severity assessment of CAP in children

	Mild to moderate	*Severe*
Infants	• Temperature <38.5°C • Respiratory rate <60 breaths/min for <2-month old, <50 breaths/minute for <1 year old and <40 breaths/min for those older than 1 year • Mild recession • Taking full feeds	• Temperature >38.5°C • Respiratory rate >70 breaths/minute • Moderate to severe recession • Nasal flaring • Cyanosis • Intermittent apnea • Grunting respiration • Not feeding • Tachycardia • Capillary refill time >/=2 seconds
Children	• Temperature <38.5 C • Respiratory rate<50 breaths/minute • Mild breathlessness • No vomiting	• Temperature >38.5°C • Respiratory rate>50 breaths/minute • Extreme difficulty in breathing • Nasal flaring • Cyanosis • Grunting respiration • Signs of dehydration • Tachycardia • Capillary refill time ≥2 seconds

Table 2: Criteria for hospitalization for CAP

Hypoxemia (oxygen saturations <90% in room air)
Infants (3–6) months of age with suspected bacterial CAP
Tachypnea:
Infants <2 months of age- respiratory rate > 60 breaths per minute Infants <12 months of age: respiratory rate >70 breaths per minute
Children: respiratory rate >50 breaths per minute
Respiratory distress: apnea, grunting, difficulty breathing, and poor feeding
Signs of dehydration or inability to maintain hydration or oral intake
Capillary refill time >2 seconds
Infants and children with toxic appearance
Suspected or confirmed to have infection with a virulent organism (community-acquired methicillin-resistant *Staphylococcus aureus* or group A *Streptococcus*)
Underlying conditions/comorbidities that
May predispose patients to a more serious course (e.g., cardiopulmonary disease, genetic syndromes, neurocognitive disorders, neuromuscular disorders)
May be worsened by pneumonia (e.g., metabolic disorder)
May adversely affect response to treatment (e.g., immunocompromised host, sickle cell disease)
Complications (e.g., effusion and/or empyema)
Failure of outpatient therapy (48–72 hours with no clinical response)
Caretaker unable to provide appropriate observation or to comply with prescribed home therapy

and empyema are present, there will be concomitant decreased air entry and dullness to percussion.

Ominous or warning signs include worsening respiratory distress, cyanosis, hemodynamic instability, excessive irritability, and altered level of consciousness.

Management

Outpatient and Inpatient

Consider hospitalization for an infant or a child with suspected CAP if clinical features are evident as listed in Table 2.[4]

An infant or a child with CAP should be admitted to an ICU or intermediate care unit (IMCU) with continuous cardiorespiratory monitoring if the illness is associated with any manifestation presented in Table 3.

Etiological Agents

Both bacteria and viruses can cause CAP, but viral pneumonias occur more frequently than bacterial infections.[5] Viruses account for majority (30–67%) of cases of CAP, and viral causes account for a majority of pneumonias in infants.[5,6]

Table 3: Admission criteria for IMCU/ICU[4]

A child should be admitted to an IMCU/ICU:
Child acutely requires use of noninvasive positive pressure ventilation (e.g., continuous positive airway pressure (CPAP), or bi-level positive airway pressure (BIPAP).
If the child has impending respiratory failure).
If the child has sustained tachycardia, inadequate blood pressure or need for pharmacologic support for blood pressure or perfusion.
If the child has altered mental status, whether due to hypercarbia or hypoxia, because of pneumonia.
A child should be admitted in ICU:
Pulse oximetry measurement of <92% on fractional inspired oxygen concentration of >0.50.
If the child requires invasive ventilation via a non-permanent artificial airway (e.g., endotracheal tube)

There is increasing evidence that a significant number of cases of CAP are mixed infections. Various detailed studies indicate a mixed viral–bacterial infection in 22–33% of cases.[6]

Viruses

The commonest virus implicated in children less than 5 years old is the respiratory syncytial virus (RSV). Other viruses causing pneumonias are rhinovirus, parainfluenza, influenza, adenovirus, rhinovirus, enterovirus, varicella zoster virus, cytomegalovirus, and herpes simplex virus.

Several new viruses have been identified including, Human metapneumovirus, human bocavirus, and coronavirus.

Bacteria

Streptococcus pneumoniae remains the commonest cause of bacterial CAP across all ages.[7] Other important bacterial causes include, *Streptococcus pyogenes*, *Staphylococcus aureus*, *Haemophilus influenzae*, and *Moraxella catarrhalis* in children less than 5 years.

Atypical pneumonia, caused by *Mycoplasma pneumoniae*, usually affects children between the ages of 6 and 18 but must be considered in children of all age-groups.[8] It is characteristically slowly progressive with low-grade fever, intermittent cough, malaise, and sore throat developing over 3 to 5 days. Children may also present with chest pain, fatigue, and wheeze. Characteristically, the symptoms may be worse than the clinical signs. Children may also manifest with nonrespiratory symptoms such as arthralgia, malaise, and headaches.[8]

Another important bacterial cause of pneumonia is *Mycobacterium tuberculosis*. History of contact or other important clinical signs such as fever and weight loss have to be elicited.

Diagnostic and Ancillary Testing

Pulse Oximetry

This is a simple, noninvasive, easily available test and should be done in all children with suspected pneumonia. Saturation of less than 94% in room air is considered abnormal.

Complete Blood Count

Complete blood count is not routinely indicated in all cases of suspected CAP managed in an outpatient setting but required for patients needing hospital admission, more serious disease, and aids in further clinical management. It has to be interpreted in the context of the history, clinical examination, and other corroborative laboratory or imaging studies.

Acute-phase Reactants

Acute-phase reactants such as ESR, CRP, and procalcitonin do not clearly distinguish bacterial from viral infections when used as the sole diagnostic test.[9,10]

Serum procalcitonin (PCT) can be used to complement clinical, epidemiological, and other diagnostic testing.[11] PCT concentrations <0.25 ng/mL are strongly associated with a decreased likelihood of detecting common typical bacteria and reduced disease severity.[12,13] PCT concentrations <0.1 ng/mL have a high negative-predictive value and hence can efficiently exclude typical bacterial CAP.[12]

These tests are indicated at baseline for children requiring hospitalization or those with clinical worsening/complications. Declining trends of CRP or procalcitonin may correlate with improvement in clinical symptoms and thus serve as objective measures for disease resolution/response to therapy.

Blood Culture

Blood culture (outpatient): A blood culture is not routinely recommended in patients who are fully immunized and managed on outpatient basis as the rate of positivity is 2%[14] in this clinical scenario.

Blood culture is indicated in all children who require hospitalization/who have progressive symptoms or clinical deterioration after initiation of antibiotic therapy.

Repeat blood culture is indicated in *Staphylococcus aureus* infections to ensure sterility after successful treatment.[15]

Respiratory Viral Studies

Available rapid validated tests for influenza virus and other respiratory viruses should be used in the evaluation of children with CAP. A positive influenza test may decrease both the need for additional diagnostic studies and unwarranted antibiotic usage, while guiding appropriate use of antiviral agents in both outpatient and inpatient settings.

Nasopharyngeal Swab for Polymerase Chain Reaction

It is not routinely indicated in children with suspected pneumonia; however, it can be done in atypical cases to establish diagnosis of pertussis, viral pneumonia-like Influenza H1N1, RSV, Coronavirus, and *Mycoplasma pneumoniae*. It is also useful in detecting viruses during pandemics, such as the COVID-19 pandemic caused by SARS-CoV-2.

Other Microbiologic Testing

Sputum culture and Gram stain are useful if feasible.

Paired serology (rising titers in antibody complement fixation tests) remains the mainstay for diagnosing atypical infections caused by *Mycoplasma pneumoniae* and *Chlamydia pneumoniae*.[8]

Urinary antigen detection tests are not recommended for the diagnosis of pneumococcal pneumonia in children as false-positive tests are common.

It is important to attempt to establish microbiological diagnosis in children with severe pneumonia or complicated pneumonia. In these children, samples from pleural fluid, tracheal aspirates, bronchoscopic or blind-protected specimen brush sampling, and bronchoalveolar lavage (BAL) may be drawn for Gram stain,

cultures, PCR, and other relevant tests to establish the causative agent for pneumonia.

Investigations to rule out tuberculosis must be performed if clinically indicated.

Chest Radiography

Chest imaging is most useful when the diagnosis of pneumonia is uncertain or when the findings from history and physical examination are inconsistent. It may be normal in early cases of CAP. It is not routinely recommended for children being treated for pneumonia on outpatient basis, as it rarely changes the course of management.[16]

Chest radiographs are recommended for all patients hospitalized with CAP to outline the size and characteristics of parenchymal infiltrates. In addition, it helps in corroborating the clinical lack of response and complications of pneumonia that require additional interventions or imaging.

Follow-up Chest Radiographs

Repeat chest imaging is mandated for those children who do not exhibit improvement within 48 to 72 hours following initiation of appropriate antimicrobial therapy or those with complicated pneumonia showing clinical worsening. However, for complicated pneumonia with parapneumonic effusion (status post-therapeutic intervention), repeated chest imaging is not recommended daily if the patient is clinically stable.

It may also be indicated in recurrent pneumonia involving the same lobe or in case of suspicion of an anatomic anomaly, chest mass or foreign body aspiration.

Ultrasonography of the Chest

Lung ultrasonography, in combination with initial chest radiography, can demonstrate small pneumonic consolidations and allow early diagnosis of parapneumonic effusion and complicated pneumonia. Several studies have shown lung ultrasound to be an inexpensive, safe, widely available, and sensitive test for the diagnosis of pneumonia, which is defined by the presence of unilateral B lines or subpleural lung consolidation.[17] In low-income countries, there is also evidence that lung ultrasound is superior in terms of sensitivity when compared to chest X-rays.[17]

In addition, evaluation of parapneumonic effusion with chest ultrasonography may

- Aid in localization of the lesion;
- Demonstrate the presence of loculations or septations to further characterize empyema; and/or
- Guide thoracentesis and drain placement.

However, the presence or absence of septations on ultrasonography may not help predict response to specific therapy or indicate need for surgical intervention.[18]

Computed Tomography

Computed tomography (CT) of the chest is not routinely done in all patients with uncomplicated CAP. The indications for CT scan in a patient with CAP are suspicion of complications or when there are diagnostic dilemmas. It is useful in children with HIV and other immunocompromised states, can also help diagnose tuberculosis by evidence of typical lymphadenopathy, and can aid diagnosis of a missed foreign body.[19] Although useful, the high dose of radiation associated with a CT scan and the high cost are disadvantages. Because of these, chest X-rays continue to be the most commonly used imaging technique in patients with CAP.

Anti-infective Treatment

Practical Guidelines for Antibiotics

The following table (Table 4) is a recommendation for antibiotics based on organism, resistance of organism, and inpatient/outpatient treatment. A few important considerations are:

- Amoxicillin is recommended as first choice for oral antibiotic therapy in all children because it is effective against the majority of pathogens causing CAP and is well tolerated and cheap.
- Alternatives are to be considered in case of allergy to Amoxicillin. For non-serious allergic reactions, Cefpodoxime, Cefuroxime, or Cefprozil can be considered.
- Macrolide antibiotics may be added at any age if there is no response to first-line empirical therapy.
- In pneumonia associated with influenza, Co-amoxiclav is recommended.
- Influenza antiviral therapy should be administered as soon as possible to children with moderate to severe CAP consistent with influenza virus, especially during widespread local circulation of influenza viruses, particularly for those with clinically worsening disease documented at the time of an outpatient visit.
- Intravenous antibiotics should be used in the treatment of pneumonia in children when the child is unable to tolerate oral fluids or absorb oral antibiotics (eg, because of vomiting) or presents with signs of septicemia or complicated pneumonia.
- The empiric treatment of suspected bacterial pneumonia in a hospitalized child requires an approach based on local epidemiology, the immunization status of the child, and the clinical manifestations at the time of presentation.
- Combination therapy is not routinely recommended for children with pneumonia.
- Empiric therapy with a third-generation parenteral cephalosporin (Ceftriaxone or Cefotaxime) should be prescribed for hospitalized infants and children who are not fully immunized, in regions where local epidemiology of invasive pneumococcal strains documents high-level Penicillin resistance, or for infants and children with life-threatening infection, including those with empyema.
- Vancomycin or Clindamycin (based on local susceptibility data) should be provided in addition to β-lactam therapy if clinical, laboratory, or imaging characteristics are consistent with infection caused by *S. aureus*.
- Dosages of recommended drugs are mentioned in Table 5.

Supportive Treatment

Provide oxygen to keep SpO_2 more than 92% in room air.

IV fluids if child is unable to take orally.

Complications Associated with CAP

If a child remains febrile/symptomatic 48 hours after treatment has commenced, review is necessary for complications (Table 6).

Both pulmonary and extrapulmonary manifestations are listed in Table 6:

Parapneumonic Effusion Management

The child's degree of respiratory compromise and the size of the effusion are important factors that determine the management

Table 4: Recommendations for antibiotics in CAP (adapted from Infectious Disease Society of America guidelines[20])

	Drugs of choice			
Suspected causative organism	*Intravenous*	*Oral*	*Duration*	*Comments*
Streptococcus pneumoniae (sensitive to penicillin), Group A streptococcus	Preferred: Ampicillin/Penicillin Alternate: Ceftriaxone/Clindamycin	Preferred: Amoxicillin Alternate: For *Strep. pneumoniae*-Cephalosporins Grp A *Strep*.- Clindamycin	5 days	Cephalosporins include Cefdinir, Cefixime, Cefpodoxime, Ceftibutin
Haemophilus influenzae (Hib)	Preferred: Ampicillin/Ceftriaxone	Preferred: Amoxicillin/Amoxicillin-clavulanic acid Alternate: Cephalosporins	5 days	Cephalosporins include Cefdinir, Cefixime, Cefpodoxime, Ceftibutin
Streptococcus pneumonia (resistant to penicillin)	Preferred: Ceftriaxone Alternate: Ampicillin HD, Clindamycin	Preferred: Linezolid Alternate: Clindamycin	5 days	
Methicillin-sensitive *Staphylococcus aureus* (MSSA)	Preferred: Cefazolin/Cloxacillin Alternate: Clindamycin	Preferred: Cephalexin Alternate: Clindamycin	5 days 2–4 weeks	
Methicillin-resistant *Staphylococcus aureus*(MRSA) (sensitive to) Clindamycin	Preferred: Clindamycin Alternate: Linezolid	Preferred: Clindamycin Alternate: Linezolid		
MRSA (resistant to Clindamycin)	Preferred: Vancomycin Alternate: Linezolid	Preferred: Linezolid No alternate suggested	 2–4 weeks	
Mycoplasma/Chlamydia	Azithromycin	Preferred: Azithromycin Alternate: Clarithromycin/Doxycycline	5 days	

plan. Chest radiography should be used to confirm the presence of pleural fluid. If the chest radiograph is not conclusive, then further imaging with chest ultrasound or Computed Tomography (CT) is recommended.

Pleural fluid analysis: Gram stain and bacterial culture of pleural fluid should be performed whenever a pleural fluid specimen is obtained. Antigen testing or nucleic acid amplification through polymerase chain reaction (PCR) increase the detection of pathogens in pleural fluid and may be useful for the management. Analysis of pleural fluid parameters, such as pH and levels of glucose, protein, and lactate dehydrogenase, rarely change patient management and are not recommended.[17]

Analysis of the pleural fluid white blood cell (WBC) count, with cell differential analysis, is recommended primarily to help differentiate bacterial from mycobacterial etiologies and from malignancy.

Small, uncomplicated parapneumonic effusions should not routinely be drained and can be treated with antibiotic therapy alone.

Moderate parapneumonic effusions associated with respiratory distress, large parapneumonic effusions or documented purulent effusions should be drained.

Both chest thoracostomy tube drainage with the addition of fibrinolytic agents and VATS have been demonstrated to be effective methods of treatment. The choice of drainage procedure depends on local expertise. Both of these methods are associated with decreased morbidity compared to chest tube drainage alone. However, in patients with moderate-to-large effusions that are free flowing (no loculations), placement of a chest tube without fibrinolytic agents is a reasonable first option.

VATS should be performed when there is persistence of moderate–large effusions and ongoing respiratory compromise, despite 2 to 3 days of management with a chest tube and completion of fibrinolytic therapy.

A chest tube can be removed in the absence of an intrathoracic air leak and when pleural fluid drainage is less than 1 mL/kg/24 hour, usually calculated over the last 12 hours.

Table 5: Recommended dosages of drugs

	Recommended dosage and interval	
Name of drug	*Intravenous*	*Oral*
Ampicillin	200 mg/kg/day every 6 hours	
Ampicillin HD (High Dose)	400 mg/kg/day every 6 hours	
Penicillin (Benzyl Penicillin)	2 lac units/kg/day every 6 hours	
Ceftriaxone	100 mg/kg/day every 12 hours	
Clindamycin	40 mg/kg/day every 6 hours	40 mg/kg/day every 6 hours
Amoxicillin		80 mg/kg/day every 12 hours
Cefdinir		<12 years-15 mg/kg/day every 12 hours ≥13 years old-600 mg/day every 12 hours
Cefixime		8 mg/kg/day every 12 hours (max dose 400 mg/day)
Cefpodoxime		10 mg/kg/day every 12 hours
Ceftibutin		9 mg/kg/day once daily (max dose 400 mg/day)
Amoxicillin-Clavulanic acid		Amoxicillin dose of 80 mg/kg/day
Linezolid	<12 years-30 mg/kg/day every 8 hours for children ≥12 years old-20 mg/kg/day every 12 hours for children	<12 years-30 mg/kg/day every 8 hours for children ≥12 years old-20 mg/kg/day every 12 hours for children
Cefazolin	150 mg/kg/day every 8 hours	
Cloxacillin	200 mg/kg/day every 6 hours	
Cefalexin		100 mg/kg/day in 4 doses
Vancomycin	40–60 mg/kg/day every 6 hour	
Azithromycin	10 mg/kg on days 1 and 2 of therapy (transition to oral therapy if possible)	10 mg/kg/day on day 1 once daily, followed by 5 mg/kg/day once daily
Clarithromycin		15 mg/kg/day in 2 doses
Doxycycline		4 mg/kg/day on day 1 in two divided doses, followed by 2.2 mg/kg/day once daily

Table 6: Complications of CAP[17]

Pulmonary	Pleural effusion or empyema
	Pneumothorax
	Lung abscess
	Bronchopleural fistula
	Necrotizing pneumonia
	Acute respiratory failure
	ARDS
Metastatic	Meningitis/Brain abscess
	Central nervous system abscess
	Pericarditis
	Endocarditis
	Osteomyelitis
	Septic arthritis
Systemic	Systemic inflammatory response syndrome or sepsis
	Hemolytic uremic syndrome
	Syndrome of inappropriate ADH secretion

When the blood or pleural fluid bacterial culture identifies a pathogenic isolate, antibiotic susceptibility should be used to determine the antibiotic regimen.

In the case of culture-negative parapneumonic effusions, antibiotic selection should be based on the treatment recommendations for patients hospitalized with CAP. The duration of antibiotic treatment depends on the adequacy of drainage and on the clinical response demonstrated for each patient. In most children, antibiotic treatment for 2 to 4 weeks is adequate.

Measures to Minimize Antibiotic Resistance

Limiting antibiotic exposure whenever possible is highly recommended.

Using the most narrow-spectrum antibiotic for the suspected or identified pathogen is a primary goal of therapy.

Treating for the shortest possible duration will minimize antibiotic exposure and chances of resistance.

Duration of Antimicrobial Therapy

Recommend treatment course for 5 days for most cases of mild, uncomplicated disease managed on an outpatient basis.[18]

Recommended treatment duration is for 7 to 10 days for more severe uncomplicated cases.

Infections caused by specific pathogens, especially community-associated methicillin-resistant *Staphylococcus aureus*, may require more prolonged treatment than those due to *Streptococcus pneumoniae*.

Two to 4 weeks of antibiotic therapy is typical for treatment of complicated pneumonia.

In lung abscess, the treatment can be for 4 to 6 weeks (or with at least 1 to 2 weeks of therapy after resolution of fever and until normalization of inflammatory markers).

Discharge Criteria

Patients are eligible for discharge when they have documented:

- Overall clinical improvement, including level of activity, appetite, and decreased fever for at least 12 to 24 hours;
- Pulse oximetry readings of >94% in room air for at least 12 to 24 hours;
- Tolerate their home anti-infective regimen, whether oral or intravenous;
- Parents are able to administer and children are compliant; and
- For those with chest tube ensure chest tube has been removed for 12 to 24 hours, with no clinical evidence of deterioration since removal or if a chest radiograph, obtained for clinical concerns, shows no significant re-accumulation of a parapneumonic effusion or pneumothorax.

Prevention

Prevention of CAP has been greatly enhanced by general improvements in public health. However, there are more efforts required to reduce overcrowding and exposure to smoke. Increase in the uptake of routine vaccines has had a major impact on pneumonia and child survival worldwide. Children should be immunized with vaccines for bacterial pathogens, including *S. pneumoniae*, *Haemophilus influenzae type B, Pertussis*, and for viral infections—measles and influenza.

Conclusion

CAP is a major burden on healthcare globally and therefore needs to be prevented with adequate vaccination and treated with appropriate antibiotics. This review highlights the clinical features and provides a pragmatic approach to treatment. Antibiotic stewardship policies must be kept in mind while treating bacterial pneumonias to decrease the rate of antibiotic resistance.

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