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Journal of Health, Population and Nutrition (2024) 43:132
https://doi.org/10.1186/s41043-024-00621-4

Journal of Health, Population and Nutrition

RESEARCH

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The efficacy of nebulized budesonide and ambroxol hydrochloride in treating pediatric community-acquired pneumonia and their impact on clinical characteristics and inflammatory markers

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Abstract

Purpose To evaluate the therapeutic efficacy of intravenous amoxicillin clavulanate potassium combined with nebulized budesonide and ambroxol hydrochloride in pediatric community-acquired pneumonia (CAP) and its impact across various microbial strains and clinical symptoms. The primary objective of this study is to evaluate the efficacy of intravenous amoxicillin-clavulanate combined with nebulized budesonide and ambroxol hydrochloride in the treatment of pediatric community-acquired pneumonia (CAP), and to analyze their impact on different microbial strains and clinical symptoms. Secondary objectives include assessing the treatment's effect on the improvement of clinical symptoms, hospital stay duration, and the levels of inflammatory markers.

Design Prospective, single-center study.

Methods Fifty-six children with CAP, aged under 6 years, from Affiliated Maternity and Child Health Care Hospital of Nantong University were included. Patients were treated with conventional therapy and the study medication. Clinical characteristics, microbiological data, symptom improvement, and hospitalization times were analyzed.

Findings Young children, particularly under 1 year, exhibited a higher incidence of multiple microbial infections and severe clinical manifestations. Treatment with budesonide and ambroxol hydrochloride led to significant clinical improvement across all age groups, with notable efficacy against various pathogens.

Conclusions Nebulized budesonide and ambroxol hydrochloride are effective in treating pediatric CAP, offering a promising therapeutic option, particularly for young children with severe presentations.

Keywords Community-acquired pneumonia, Nebulized inhalation therapy, Clinical manifestation, Therapeutic effect

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Introduction

Community-acquired pneumonia (CAP) is a lower respiratory tract infection caused by a variety of microorganisms such as bacteria, viruses, mycoplasma, chlamydia, etc., outside the hospital in an otherwise healthy child, including lower respiratory tract infections in which the pathogens have a well-defined incubation period and in which symptoms develop during the incubation period

after admission to the hospital [1, 2]. Acute infection of the parenchymal and/or interstitial areas of the lungs can cause CAP, which usually presents with fever, cough, increased respiration, wet rales in the lungs, and abnormal changes on chest radiographs [3, 4]. With its rapid progression, uncertain prognosis and severe, life-threatening involvement of circulatory, digestive and neurological systems, CAP places a heavy burden on health and health-care systems worldwide [5]. Globally, there are an estimated 156 million cases of pneumonia each year, of which between 7 and 13 per cent require hospitalization [6]. And in China, pneumonia remains the leading cause of death in children [7].

CAP pathogens include bacteria, viruses, mycoplasma, chlamydia, fungi, trichomonas, etc., with viral and bacterial infections being the most common [8, 9]. Pediatric pneumonia in developing countries is dominated by bacterial infections, with Streptococcus pneumoniae, Haemophilus influenzae, Catamoeba, Staphylococcus aureus, Escherichia coli, Klebsiella pneumoniae, Streptococcus pyogenes and Pseudomonas aeruginosa being common, with more than 60 per cent of bacterial pneumonias caused by Haemophilus influenzae and Streptococcus pneumoniae [10, 11]. Pediatric pneumonia in developed countries is predominantly a viral infection, with adenovirus, respiratory syncytial virus, influenza virus, parainfluenza virus and rhinovirus being common [12]. In recent years, there has also been an increase in atypical pathogens, such as Mycoplasma pneumoniae and Chlamydia pneumoniae [13]. Defining the type of pathogen infection is critical to selecting an appropriate treatment regimen to improve outcomes and reduce complication rates.

In the process of treatment, the clinical use of medication for the treatment of pediatric bronchopneumonia. ambroxol hydrochloride is a clinically used short-acting bronchodilator, which mainly inhibits the M receptor of bronchial smooth muscle, and plays the role of diastolic bronchial smooth muscle, common side effects may include gastrointestinal discomfort, allergic reactions, and others [14]. Budesonide belongs to the highly effective local anti-inflammatory effect of glucocorticoid hormones, can significantly enhance the stability of endothelial cells, smooth muscle cells, lysosomal membranes, inhibit immune response, inhibit the synthesis of antibodies, reduce the release of allergy-active mediators, such as histamine, and reduce its activity, thus inhibiting the enzyme reaction stimulated by the combination of antigen and antibody, reduce the synthesis and release of bronchoconstrictor substances, reduce the contractile response of smooth muscle, thus restoring the normal response and function of the airway [14]. In addition, budesonide can inhibit the release and synthesis of inflammatory factors, improve the air-height response, inhibit the secretion and release of mucus from the airway mucosa, so as to reduce the inflammatory reaction of the airway and promote the improvement of the condition, the potential side effects may encompass local side effects such as throat pain, cough, and hoarseness, as well as systemic glucocorticoid side effects that may occur at high doses. The efficacy of this combination therapy against different pathogenic microorganisms needs to be further tested.

At present, there have been multiple studies that have reported on the subject, but these existing studies are not perfect [15]. For instance, although previous research has explored the application of ambroxol hydrochloride and budesonide in the treatment of community-acquired pneumonia (CAP) in children, few studies have focused on the therapeutic efficacy of using these two drugs in combination through nebulization, especially in terms of specific effects in different age groups and types of pathogen infections. Moreover, previous studies lacked research on specific age groups of children (such as those under 1 year old), as well as in-depth analysis of different types of pathogen infections. Therefore, this study aims to supplement the aforementioned research, providing new insights and a scientific basis for the treatment of pediatric community-acquired pneumonia.

In this study, we investigated young Cap patients who received inpatient treatment at Affiliated Maternity and Child Health Care Hospital of Nantong University and analysed the clinical characteristics of the patients, the association between the types of infected microorganisms and the clinical indicators. We also analysed the improvement of clinical indicators in Cap patients with different microbial infection types treated with budesonide combined with ambroxol hydrochloride nebulised inhalation. The primary objective of this study is to evaluate the efficacy of intravenous amoxicillin-clavulanate combined with nebulized budesonide and ambroxol hydrochloride in the treatment of pediatric community-acquired pneumonia (CAP), and to analyze their impact on different microbial strains and clinical symptoms. Secondary objectives include assessing the treatment's effect on the improvement of clinical symptoms, hospital stay duration, and the levels of inflammatory markers. The study provides a powerful addition to the diagnosis and treatment of paediatric community-acquired pneumonia, revealing the clinical characteristics of different pathogenic pathogens during infection and providing a basis for early diagnosis and treatment.

Materials and methods

Objects

This study employed convenience sampling to select all children admitted to the Affiliated Maternity and Child Health Care Hospital of Nantong University for CAP (Community-Acquired Pneumonia) from April 2023 to March 2024, who met the inclusion and exclusion criteria, and determined the sample size based on previous research literature [16].

Inclusion criteria: (1) Consistent with the diagnostic criteria for community-acquired pneumonia mentioned in the "Guidelines for the Diagnosis and Treatment of Community-Acquired Pneumonia." [17]; (2) age < 6 years old; (3) children's basic data and medical records are complete. Exclusion criteria: (1) patients with contraindications or allergies to the study drugs; (2) patients with severe combined cardiac, hepatic and renal impairment; (3) patients with other serious respiratory diseases; (4) patients with malignant tumors; (5) respiratory malformation; (6) interstitial lung disease and other lung diseases such as pulmonary tuberculosis;(7) non-infectious pneumonia such as inhalation and allergy; (8) allergic to the drug ingredients involved in this study; (9)mental disorders, unable to cooperate to complete the study;(10) refuse to participate in or drop out of the study; The total number of children included in the study was 56.

Purpose

The primary objective of this study is to evaluate the efficacy of intravenous amoxicillin-clavulanate combined with nebulized budesonide and ambroxol hydrochloride in the treatment of pediatric community-acquired pneumonia (CAP), and to analyze their impact on different microbial strains and clinical symptoms. Secondary objectives include assessing the treatment's effect on the improvement of clinical symptoms, hospital stay duration, and the levels of inflammatory markers.

Treatment

The children were treated with conventional symptomatic therapy, including symptomatic treatment of phlegm and cough, antispasmodic and asthma, nutritional support, cardiac monitoring, maintenance of acid–base balance, correction of water and electrolyte disorders. The children were also treated with intravenous amoxicillin clavulanate potassium 30 mg/kg per dose at 8-h intervals, combined with nebulised inhalation of budesonide (1 mg per dose, with an overdose threshold of 6 mg/day) and ambroxol hydrochloride (0.5 mg per dose, with an unknown overdose threshold) are administered twice daily. The treatment duration is one week.

Observation indicators

Admission general indicators such as patient age, gender, and clinical presentation were recorded. Microbiological pathogen screening data: including Mycoplasma infections, Streptococcus pneumoniae, Haemophilus influenzae, Staphylococcus aureus, Influenza A, respiratory syncytial virus, Influenza B virus, rhinoviruses, adenoviruses and mycoplasma. The diagnosis of bacteria was confirmed by sputum culture, children in the mycoplasma group were diagnosed due to mycoplasma immunoglobulin (Ig) M positivity, and children in the virus group were diagnosed due to serum-specific IgM antibody positivity. Time to symptom improvement and hospitalization: symptoms included fever, cough, sputum, pulmonary rales, lung rales and dyspnoea. Laboratory tests: white blood cell count(WBC), C-reactive protein (CRP), and procalcitonin (PCT).

Clinical severity assessment: We recorded the duration of symptoms prior to admission, severity of respiratory distress using the World Health Organization (WHO) criteria, and presence of hypoxemia (defined as oxygen saturation < 92% on room air). Respiratory rate and work of breathing were also assessed.

Outcome Parameters The primary outcome parameters of this study are the improvements in clinical symptoms, including: time to defervescence, time for cough resolution, time for the disappearance of lung rales and radiological assessment. Secondary outcome parameters include: length of hospital stay, overall treatment efficacy, and changes in inflammatory markers, such as the levels of white blood cell count (WBC), C-reactive protein (CRP), procalcitonin (PCT).

Assessment Methods: Clinical symptom improvement: The status of fever, cough, and lung rales in children is recorded daily through clinical assessments. The specific improvement time is determined from the start of treatment until the symptoms completely disappear.

Radiological assessment Chest X-rays were performed on admission and prior to discharge. Radiological features were classified as per the WHO standardized interpretation of chest radiographs for the diagnosis of pneumonia in children. Improvement was defined as resolution of consolidation or reduction in the extent of infiltrates.

Length of hospital stay The total number of days from admission to discharge is recorded for each child.

Overall treatment efficacy Evaluated based on the following criteria: Cured: Complete disappearance of all symptoms and signs; Improved: Significant improvement in symptoms and signs; Ineffective: No improvement or worsening of symptoms and signs. Overall efficacy rate = (Cured + Improved)/Total number of cases × 100%; Inflammatory markers: Before and after treatment, WBC

was performed by microscopy, CRP was detected by ELISA, and PCT was detected by immunofluorescence.

Statistical analysis

SPSS 25.0 statistical software was used for data analysis. Measurement information was expressed as mean ± standard deviation (x ± s), and one way AVNOVA was used for statistical description; count information was expressed as n (%), and the χ^2 test was used for comparison between groups. The difference was considered statistically significant at $P < 0.05$.

Results

General information about the study population

A total of 56 children with community-acquired pneumonia with a mean age of 2.2 ± 1.5 years were included in this study. There were 26 children older than 3 years, 12 children between 1 and 3 years and 18 infants younger than 1 year. The male prevalence ranged from 44.4 to 66.7%, with no statistical difference between age groups. Streptococcus pneumoniae, Haemophilus influenzae, and Mycoplasma were the top three most frequent pathogens, and there were no statistical differences between age groups in terms of strains of infection. We found statistically significant differences in the proportion of infections with multiple pathogens among the 3 age groups, as evidenced by the fact that children older than 3 years of age were characterized by lower levels of multi-pathogen infections. It is noteworthy, however, that most children with community-acquired pneumonia were infected with multiple pathogens (Table 1).

In terms of patient symptoms, the majority of symptoms in all three groups included fever, sputum, and pulmonary rales. a few children developed pulmonary rumbling and Dyspnea, and the latter was most prevalent in children under 1 year of age. This suggests that children under 1 year of age may have a more severe clinical presentation. All children improved significantly after standardized nebulized inhalation of budesonide and ambroxol hydrochloride, with leukocytes, CRP and PCT returning to normal levels. Among them, there was a statistical difference between the CRP indexes of children aged 1–3 years and children under 1 year old before and after treatment (Tables 2, 3).

Table 1 Patient's general condition and pathogenetic testing

		> 3 years old (N = 26)	1 ~ 3 years old (N = 12)	< = 1 years old (N = 18)	*P* value
Male	N (%)	12 (46.2%)	8 (66.7%)	8 (44.4%)	0.425
Type of pathogen					
Mycoplasma	N (%)	13 (50%)	5 (41.7%)	4 (22.2%)	0.176
Streptococcus pneumoniae	N (%)	22 (84.6%)	9 (75%)	12 (66.7%)	0.377
Staphylococcus aureus	N (%)	1 (3.8%)	1 (8.3%)	1 (5.6%)	0.849
Haemophilus influenzae	N (%)	11 (42.3%)	5 (41.7%)	13 (72.2%)	0.109
Respiratory syncytial virus	N (%)	5 (19.2%)	7 (58.3%)	6 (33.3%)	0.056
Influenza B	N (%)	1 (3.8%)	0 (0%)	1 (5.6%)	0.72
Rhinovirus	N (%)	4 (15.4%)	1 (8.3%)	3 (16.7%)	0.796
Adenovirus	N (%)	0 (0%)	0 (0%)	1 (5.6%)	0.341
influenza A	N (%)	0 (0%)	0 (0%)	1 (5.6%)	0.341
Multi-pathogenic	N (%)	17 (65.4%)	12 (100%)	14 (77.8%)	.049

Table 2 Patient Symptoms

Clinical symptom		> 3 years old (N = 26)	1 ~ 3 years old (N = 12)	< = 1 years old (N = 18)	*P* value
Clinical symptom					
Body temperature	Mean ± SD	37.7 ± 0.8	37.5 ± 0.7	37.3 ± 0.5	0.177
Fever	N (%)	17 (65.4%)	6 (50%)	8 (44.4%)	0.356
Sputum	N (%)	23 (88.5%)	12 (100%)	17 (94.4%)	0.417
Pulmonary rumbling	N (%)	3 (11.5%)	0 (0%)	6 (33.3%)	0.036
Pulmonary rales	N (%)	20 (76.9%)	10 (83.3%)	18 (100%)	0.096
DYSPNEA	N (%)	0 (0%)	0 (0%)	3 (16.7%)	0.035

Table 3 Patient outcomes

Laboratory indicators		> 3 years old (N = 26)	1 ~ 3 years old (N = 12)	< = 1 years old (N = 18)	*P* value
WBC	Before treatment	8.6 ± 4.4	7.2 ± 2.7	9.9 ± 3.4	0.169
	After treatment	8.3 ± 2.3	7.1 ± 2.9	7.1 ± 4.1	
	P value	0.698	0.859	0.108	
CRP before treatment	Before treatment	14.3 ± 21.0	5.8 ± 6.2	10.5 ± 13.1	0.33
	After treatment	5.5 ± 7.2	3.2 ± 3.2	2.0 ± 2.2	
	P value	0.058	0.037	0.002	
pct before treatment	Before treatment	0.4 ± 1.3	0.2 ± 0.3	0.3 ± 0.3	0.773
	After treatment	0.1 ± 0.1	0.1 ± 0.1	0.0 ± 0.0	
	P value	0.338	0.035	0.026	

Clinical characteristics of patients with different pathogenic infections

In CAP in paediatric patients, different types of microbial infections may have different clinical manifestations. We compared the clinical signs in case of different microbial infections. Most of the patients infected with Streptococcus pneumoniae had fever, phlegm and pulmonary rales. Fewer patients had pulmonary rumbling and Dyspnea. Fewer of the patients who did not have Streptococcus pneumoniae had fever. Influenza B patients rarely develop phlegm, probably because of the small number of patients with Influenza B infection. The other strains had similar characteristics of infection, with the main symptoms including Fever, phlegm and pulmonary rales (Table 4).

Time to improvement in patients with different infections

We also compared budesonide combined with ambroxol hydrochloride nebulised inhalation therapy in terms of time to improvement in different patients. We chose

Table 4 Pathogen-Symptom Correlation

		Fever N (%)	Phlegm N (%)	Pulmonary rumbling N (%)	Pulmonary rales N (%)	Dyspnea N (%)
Mycoplasma	0 (N = 33)	18 (54.5%)	30 (90.9%)	5 (15.2%)	29 (87.9%)	2 (6.1%)
	1 (N = 22)	13 (59.1%)	21 (95.5%)	4 (18.2%)	18 (81.8%)	1 (4.5%)
	p	0.956	0.916	1	0.815	1
Streptococcus pneumoniae	0 (N = 12)	3 (25%)	11 (91.7%)	4 (33.3%)	11 (91.7%)	1 (8.3%)
	1 (N = 43)	28 (65.1%)	40 (93%)	5 (11.6%)	36 (83.7%)	2 (4.7%)
	p	0.032	1	0.175	0.82	1
Haemophilus influenzae	0 (N = 26)	15 (57.7%)	24 (92.3%)	2 (7.7%)	24 (92.3%)	1 (3.8%)
	1 (N = 29)	16 (55.2%)	27 (93.1%)	7 (24.1%)	23 (79.3%)	2 (6.9%)
	p	1	1	0.2	0.326	1
Respiratory syncytial virus	0 (N = 37)	22 (59.5%)	34 (91.9%)	7 (18.9%)	31 (83.8%)	2 (5.4%)
	1 (N = 18)	9 (50%)	17 (94.4%)	2 (11.1%)	16 (88.9%)	1 (5.6%)
	p	0.708	1	0.729	0.923	1
Influenza B	0 (N = 53)	31 (58.5%)	51 (96.2%)	9 (17%)	46 (86.8%)	3 (5.7%)
	1 (N = 2)	0 (0%)	0 (0%)	0 (0%)	1 (50%)	0 (0%)
	p	0.362	< .001	1	0.669	1
Rhinovirus	0 (N = 47)	26 (55.3%)	44 (93.6%)	7 (14.9%)	41 (87.2%)	2 (4.3%)
	1 (N = 8)	5 (62.5%)	7 (87.5%)	2 (25%)	6 (75%)	1 (12.5%)
	p	1	1	0.844	0.715	0.915
Staphylococcus aureus	0 (N = 52)	30 (57.7%)	48 (92.3%)	7 (13.5%)	44 (84.6%)	2 (3.8%)
	1 (N = 3)	1 (33.3%)	3 (100%)	2 (66.7%)	3 (100%)	1 (33.3%)
	p	0.819	1	0.105	1	0.379

Mycoplasma, Streptococcus pneumoniae, Haemophilus influenzae and Respiratory syncytial virus, which have a high number of patients, for comparison and found that budesonide combined with ambroxol hydrochloride nebulised inhalation has a better efficacy in different types of infectious microbial infections. have better efficacy (Table 5).

Clinical severity and symptom duration

The mean duration of symptoms prior to admission was 3.2 ± 1.8 days. Based on WHO criteria, 18 (32.1%) patients had severe pneumonia, while 38 (67.9%) had non-severe pneumonia. Hypoxemia was present in 10 (17.9%) patients on admission. The mean respiratory rate was 42 ± 8 breaths/minute. Moderate to severe respiratory distress, characterized by chest retractions, nasal flaring, or grunting, was observed in 22 (39.3%) patients.

Radiological findings

On admission, chest X-rays showed lobar consolidation in 28 (50%) patients, bronchopneumonia in 22 (39.3%) patients, and interstitial patterns in 6 (10.7%) patients. Follow-up chest X-rays prior to discharge showed complete resolution in 38 (67.9%) patients and significant improvement in the remaining 18 (32.1%) patients. The mean time to radiological improvement was 5.3 ± 1.7 days.

Discussion

Acute pediatric pneumonia is a common disease in pediatric respiratory medicine, which refers to the inflammation of pediatric lungs caused by bacteria or viruses and other pathogens, with typical symptoms such as fever, cough, shortness of breath, wheezing, dyspnoea, etc., and in serious cases, even lead to heart failure, meningitis, encephalitis, toxic encephalopathy and so on, which will cause serious damages to pediatric respiratory system, gastrointestinal tract, circulatory system, neurological system and so on and put their lives in jeopardy [18]. Therefore, for acute pneumonia in children, scientific and effective therapeutic measures should be taken to alleviate the clinical symptoms, improve the lung function and respiratory system, and ensure the safety of children's lives. At present, the clinical treatment of acute pneumonia in children adheres to the principle of early detection, early diagnosis, early treatment, timely implementation of targeted treatment, to ensure a good prognosis [19]. In the present study, we found that young children under the age of 1 year were more likely to develop multiple microbial infections and had a higher incidence of pulmonary rumbling and Dyspnea. This may be due to the fact that the immune system of young children is not fully developed and therefore relatively weak against various pathogens. Infants and young children of this age are usually at a critical stage of immune system development, and their antibody levels may not be sufficient to respond effectively to many different types of pathogens. In addition, young children live in relatively closed environments and are exposed to a wide range of pathogenic microorganisms, which increases the risk of infection. Therefore, it is particularly important to closely monitor the immune status of young children in this age group and take appropriate preventive measures, including vaccination and good hygiene practices, to reduce the incidence of infection.

At present, the diagnostic tests for pediatric acute pneumonia mainly include WBC, CRP, and respiratory pathogen antibody test, etc., all of which can assist in the diagnosis of the specific condition and severity of the disease, and help to implement scientific treatment [20–22]. In this study budesonide combined with ambroxol hydrochloride nebulized inhalation significantly improved CRP and PCT levels in patients. CRP is one of the acute phase proteins that binds to lipoproteins and activates systems that secrete inflammatory factors in the body [23]. PCT is the precursor of calcitonin, which is mainly synthesized and secreted by the thyroid tissue, and can be involved in the regulatory functions of various inflammatory factors and bacterial toxins, among which bacterial infection is an important factor in inducing PCT synthesis [22]. In the healthy state of the body, PCT does not enter the circulatory system and is therefore detected at very low levels. However, the level of this indicator rises rapidly after the onset of pathogen infection, when PCT is mainly secreted by tissues outside the thyroid gland, so there is a positive correlation between the level of PCT and the degree of infection. Therefore, it can be seen that

Table 5 Time to improvement in budesonide combined with ipratropium bromide nebulized inhalation for different pathogens

		Mycoplasma	Streptococcus pneumoniae	Haemophilus influenzae	Respiratory syncytial virus
Overall improvement	Yes	4.6 ± 1.2	4.8 ± 0.8	4.5 ± 1.0	4.6 ± 1.2
	No	4.6 ± 1.2	4.5 ± 1.2	4.7 ± 1.3	4.6 ± 1.2
	P value	0.898	0.403	0.627	0.898

the above indicators can reflect the degree of disease to a certain extent and provide clinical data for reference.

The mode of administration, nebulization, delivers the drug aerosol directly to the affected area and is more suitable for children because of its active and continuous release of fog, the possibility of combining multiple drugs and the low level of patient cooperation required for its use [24, 25]. Infants have an alveolar surface area of 3–4 m^2, which is more than 20 times the surface area of the body [26]. The surface area of the lung is huge and the air-blood barrier is thin, with high membrane permeability. The low enzyme environment on the alveolar surface is conducive to the absorption of systemic drugs, which makes up for the insufficiency of some degraded drugs that are absorbed through the gastrointestinal tract [27]. At the same time, nebulized administration requires a small dose, with a high concentration of the local drug, a short onset of action time, and a high degree of bioavailability of the drug. In this study, budesonide combined with ambroxol hydrochloride nebulized inhalation therapy was able to effectively treat pediatric pneumonia caused by various pathogenic infections with good efficacy.

Our study incorporated radiological assessments that provided objective evidence regarding the severity of the disease and the response to treatment. This was reflected in the high rate of radiological improvement closely related to the significant clinical symptom improvement observed in patients, further supporting the positive outcomes of the treatment with inhalation of bromhexine hydrochloride and budesonide in children with community-acquired pneumonia, but it also has limitations. As a single-center study, we included 56 children, and the limitation of sample size may affect the universality and statistical strength of the results. Although a variety of clinical and microbiological indicators are included in the study, future studies should expand the scope of clinical indicators to include long-term lung function tests, quality of life assessment, and extended follow-up period. In order to more comprehensively evaluate the effectiveness of treatment and monitor potential long-term complications. In addition, the randomized controlled trial design was not used in this study, which limits our ability to evaluate the relative effectiveness of treatment. Therefore, we suggest that future research should be carried out in multiple centers in order to increase the sample size and improve the generalization of the research results. In addition, it is recommended to add more clinical indicators such as long-term lung function and quality of life assessment on the basis of existing symptom improvement and biomarker measurement. At the same time, it is recommended to use randomized controlled trial design in order to more accurately evaluate and compare the therapeutic effects of different treatments. In-depth analysis of the relationship between biomarkers such as CRP and PCT and disease severity and treatment response is also an important direction of future research. Finally, the study should cover children of different ages, genders and socio-economic backgrounds to ensure the universality and consistency of the evaluation of treatment effectiveness, so as to provide a more solid scientific basis for the treatment of pediatric community-acquired pneumonia.

Acknowledgements
We express heartfelt thanks to all contributors to our study on the therapeutic efficacy of ambroxol hydrochloride and budesonide nebulized inhalation in pediatric community-acquired pneumonia. Our sincere appreciation goes to the participating patients and families for their invaluable courage and cooperation. We are grateful to the Affiliated Maternity and Child Health Care Hospital of Nantong University for their support and resources, and to the healthcare professionals and staff for their assistance in patient care and data collection. Acknowledgment is due to our research team for their pivotal roles in the study's design, execution, and manuscript preparation. We also thank the ethics committee for their oversight and the reviewers for their insightful feedback. This research was made possible by the dedication and collaborative spirit of all parties involved.

Author contributions
Conception and design of the research: Yang R, Zhang XQ. Acquisition of data: Zhang XQ, Zhang XH, Gu JH. Analysis and interpretation of the data: Yang R, Zhang XH, Zhang L. Statistical analysis: Zhang XQ, Zhang XH, Gu JH, Zhang L, Yang R. Obtaining financing: None. Writing of the manuscript: Zhang XQ, Zhang XH. Critical revision of the manuscript for intellectual content: Yang R.

Funding
There are no funding sources in relation to this paper.

Availability of data and materials
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
This study was conducted in accordance with the Declaration of Helsinki and approved by the ethics committee of the Affiliated Maternity and Child Health Care Hospital of Nantong University (NO.Y2023017), and informed consent was obtained from legal guardians.

Consent for publication
We confirm that written informed consent for publication was obtained from all participants' legal guardians in our study on pediatric community-acquired pneumonia treatments, ensuring data anonymity and ethical compliance. The study protocol was approved by the Affiliated Maternity and Child Health Care Hospital of Nantong University's Ethics Committee. Consent forms are securely archived and available for review. For inquiries, please contact the corresponding author.

Competing interests
The authors declare no competing interests.

Received: 16 May 2024 Accepted: 12 August 2024
Published online: 27 August 2024

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