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Original Article

Clinical characteristics of pediatric pneumonia: a retrospective study

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Abstract: Objectives: To explore the clinical characteristics of pneumonia in infants and children and to provide robust clinical evidence for its prevention and treatment. Methods: This retrospective study analyzed the clinical data from pediatric patients diagnosed with pneumonia who were admitted to The Third Affiliated Hospital of Anhui Medical University (The First People's Hospital of Hefei) between March 2023 and September 2023. Collected variables included sex, age, pneumonia vaccination rates, clinical diagnosis, severity of pneumonia, presence of fever, levels of C-reactive protein (CRP) and procalcitonin (PCT), incidence of anemia, use of ventilator-assisted breathing, length of hospitalization, and results of pathogen detection. Results: The incidence of rhinovirus, bocavirus, respiratory syncytial virus, and influenza A virus was significantly higher in children with severe pneumonia, who also showed a greater prevalence of mixed infections. These patients exhibited higher rates of fever, elevated CRP and PCT levels, more frequent anemia, increased reliance on ventilatory support, and prolonged hospital stays. Compared with patients with non-mixed infections, those with mixed infections showed lower pneumonia vaccination rates, significantly higher CRP and PCT levels, increased need for ventilatory support, and longer durations of hospitalization. Conclusions: In pediatric patients with pneumonia, severe cases were associated with a higher incidence of multiple viral infections and more frequent mixed infections, which correlated with more pronounced clinical symptoms. Patients with mixed infections also demonstrated lower vaccination coverage and greater disease severity. These findings underscore the need for enhanced surveillance, targeted prevention, and optimized treatment strategies, particularly for severe and mixed infection cases in the pediatric population.

Keywords: Pediatric pneumonia, pathogens, clinical characteristics, mixed infection

Introduction

Pneumonia is one of the most common respiratory infections in children and remains a leading cause of death in those under five years of age [1]. According to the World Health Organization (WHO), pneumonia accounted for approximately 740,180 deaths among children under five years old in 2019, representing 14-22% of all deaths in this age group [2]. The disease has a severe impact on children and families worldwide, with the vast majority of childhood pneumonia-related deaths occurring in developing countries [3]. Most pneumonia cases occur before the age of three, and the prevalence of pediatric pneumonia in China is significantly higher than in other middle- and high-income countries [4]. A large cross-sectional study involving 39,782 children aged 3-6 years from seven cities across China reported an average pneumonia prevalence of 32.0%, with Urumqi and Changsha showing the highest rates at 40.0% and 38.2%, respectively [5]. Childhood pneumonia is a complex disease influenced by host susceptibility, pathogen virulence, and environmental exposure, and it imposes a considerable economic and social burden on both families and public health systems [6].

Severe pneumonia, a more serious clinical form of the disease, is particularly prevalent in pediatric populations and poses heightened risks of morbidity and mortality [7, 8]. Studies have reported that the clinical manifestations of severe pneumonia caused by pathogens such as influenza virus and adenovirus differ significantly from those seen in non-severe cases [9].

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Moreover, evidence suggests that mixed infections involving multiple pathogens may play a critical role in the pathogenesis of severe pneumonia [8]. The clinical features of pneumonia with mixed infections caused by multiple pathogens may be more complex compared to those caused by a single pathogen [10]. Despite these observations, there remains a critical knowledge gap regarding mixed-pathogen infections and their distinct clinical characteristics in severe pneumonia compared to conventional pneumonia cases. Systematic investigations are urgently required to fill this gap.

Recently, The Third Affiliated Hospital of Anhui Medical University (The First People's Hospital of Hefei) experienced a notable increase in pediatric pneumonia admissions, including a substantial proportion of severe and fatal cases. In response to this trend, we conducted a retrospective analysis of the clinical data of pediatric pneumonia patients admitted to the The Third Affiliated Hospital of Anhui Medical University (The First People's Hospital of Hefei) from March 2023 to September 2023, aiming to characterize the clinical features of pediatric pneumonia and to provide evidence-based insights to inform effective prevention and treatment strategies.

Methods

Case selection

Between March 2023 and September 2023, a total of 249 pediatric patients (aged < 12 years) admitted to The Third Affiliated Hospital of Anhui Medical University (The First People's Hospital of Hefei) were enrolled in this retrospective study. All patients met the diagnostic criteria for pneumonia. This study was approved by the Ethics Committee of The Third Affiliated Hospital of Anhui Medical University (The First People's Hospital of Hefei).

The WHO has updated its guidelines for the classification and diagnosis of pediatric pneumonia. According to these guidelines, children presenting with cough or dyspnea are classified into three groups: no pneumonia, pneumonia, and severe pneumonia, based on clinical signs and symptoms [11]. Imaging findings, pathogen detection, and serological testing are important components of the diagnostic process. A diagnosis of severe pneumonia is made when any of the following features are present: dehydration, poor general condition, feeding refusal, impaired consciousness, significantly elevated respiratory rate, central cyanosis, respiratory distress (including grunting, nasal flaring, and three concave signs), multilobar or ≥ 2/3 unilateral lung involvement, pleural effusion, oxygen saturation ≤ 92% on pulse oximetry, or extrapulmonary complications [12].

Inclusion criteria were as follows: Diagnosis of pneumonia confirmed by nucleic acid testing for respiratory pathogens (pharyngeal and/or nasal swabs), imaging studies, and typical clinical symptoms (such as fever, shortness of breath, or cough); age < 12 years; availability of complete clinical data. Exclusion criteria included: Presence of comorbid conditions such as tuberculosis, lung tumors, pulmonary vasculitis, pulmonary oedema, or other diseases; coexistence of congenital or secondary immune system diseases; congenital organ dysfunction; incomplete clinical information.

Data collection

Clinical data were extracted from the Hospital Information System (HIS). Variables collected included sex, age, pneumonia vaccination status, clinical diagnosis, presence of severe pneumonia, presence of fever, levels of C-reactive protein (CRP) and procalcitonin (PCT), presence of anemia, use of ventilator-assisted breathing, length of hospitalization, and results of pathogen detection.

Respiratory specimens (nasal and/or pharyngeal swabs) were analyzed using multiplex real-time PCR capillary electrophoresis with an 18-pathogen detection panel, which included: 2019 novel coronavirus and other coronaviruses (HCoV-NL63, HCoV-229E, HCoV-OC43, and HKU1); Parainfluenza virus types I-III; Influenza A and B viruses; Respiratory syncytial virus, Chlamydia pneumoniae, Mycoplasma pneumoniae, Adenovirus, Rhinovirus, Human parvovirus, Bocavirus, Bordetella pertussis, and other common pediatric respiratory pathogens.

Statistical methods

Statistical analyses were performed using SPSS 26.0. The normality of the measurement data was tested. All measurements did not follow a normal distribution and were expressed

Table 1. General characteristics of all patients

Characteristic	Total patients (n = 249)
Sex [n (%)]	
Female	107 (43.0)
Male	142 (57.0)
Age [n (%)]	
< 1 month	4 (1.6)
1-3 months	15 (6.0)
4-6 months	9 (3.6)
7 months-1 year	39 (15.7)
2-3 years	63 (25.3)
4-6 years	75 (30.1)
> 6 years	44 (17.7)
Pneumonia vaccination [n (%)]	
No	108 (43.4)
Yes	141 (56.6)
Severe pneumonia [n (%)]	
No	219 (88.0)
Yes	30 (12.0)

as medians and interquartile ranges [M (P25, P75)]. Counting data were described as frequencies and percentages. The chi-square test (χ^2) test was used for comparison of counting data, and Fisher's exact test was applied when the expected frequencies were too low to meet the assumptions of the χ^2 test. A *P-value* of < 0.05 indicated that the difference was significant.

Results

General characteristics of all patients

Table 1 presents the general characteristics of the 249 pediatric patients included in this study. Among them, 142 were male and 107 were female. The age distribution was as follows: 4 patients were ≤ 1 month old, 15 were between 1-3 months, 9 were between 4-6 months, 39 were aged 7 months to 1 year, 63 were between 2-3 years, 75 were between 4-6 years, and 44 were older than 6 years. With regard to vaccination status, 141 patients had received the pneumonia vaccine prior to hospitalization, whereas 108 had not. In terms of disease severity, 219 cases were classified as mild pneumonia, and 30 cases met the criteria for severe pneumonia.

Pathogen distribution

Figure 1A shows the clinical characteristics of all cases (n = 249). Streptococcus pneumoniae was the most frequently detected pathogen, identified in 47.0% of cases, followed by Mycoplasma pneumoniae (41.0%) and rhinovirus (21.3%). Other pathogens included parainfluenza virus (10%), coronavirus (10.4%), and respiratory syncytial virus (8.8%). In addition, 7 cases were associated with influenza A virus, and 98 cases were associated with Hemophilus influenzae. Less frequently detected pathogens included human metapneumovirus (12.0%), adenovirus (5.2%), bocavirus (1.2%), and chlamydia pneumoniae (0.4%). As shown in **Figure 1B**, 91 patients had single-pathogen infections. Dual-pathogen infections were observed in 86 cases, while 60 patients were infected with three pathogens. Mixed infections involving four pathogens were identified in 7 cases, and 5 cases were associated with complex co-infections involving 5 or 6 pathogens.

Clinical characteristics of all patients

Table 2 displays summarizes the clinical features of the 249 pediatric patients included in the study. Among them, 79 patients presented with fever, while 170 were afebrile. The CRP level was 15.38 mg/L [interquartile range (IQR): 10.84, 20.09], and the PCT level was 0.56 ng/mL (IQR: 0.28, 0.9). A total of 46 patients were diagnosed with anemia at the time of admission, whereas 203 had normal hemoglobin levels. Mechanical ventilation was required in 21 cases, while the remaining 228 did not. The median length of hospital stay for all patients was 11 days (IQR: 9, 15).

Comparison of general characteristics between severe and non-severe pneumonia cases

Patients were categorized into severe (n = 30) and non-severe (n = 219) groups based on disease severity. As shown in **Table 3**, there were no significant differences in sex or age distribution between the two groups ($P > 0.05$). However, the vaccination status differed markedly between groups. Only 5 patients (16.7%) in the severe pneumonia group had received the

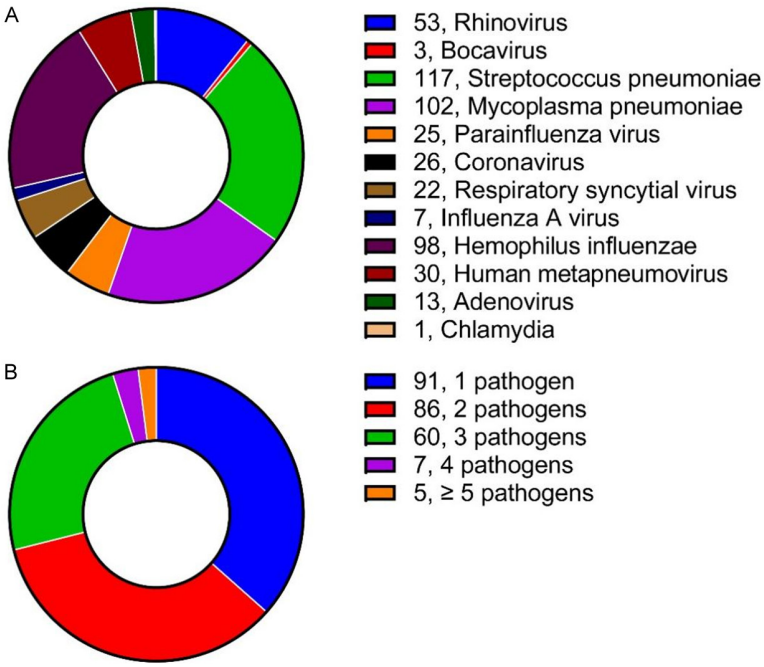

Figure 1. Pathogen distribution among all patients. A: Distribution of pathogen types identified in all patients; B: Number of pathogens infecting all patients.

Table 2. Clinical characteristics of all patients

Characteristic	Total patients (n = 249)
Fever [n (%)]	
No	170 (68.3)
Yes	79 (31.7)
C-reactive protein [mg/L, M (P25, P75)]	15.38 (10.84, 20.09)
Procalcitonin [ng/mL, M (P25, P75)]	0.56 (0.28, 0.9)
Anemia [n (%)]	
No	203 (81.5)
Yes	46 (18.5)
Ventilator-assisted breathing [n (%)]	
No	228 (91.6)
Yes	21 (8.4)
Length of hospitalization [d, M (P25, P75)]	11 (9, 15)

pneumonia vaccine compared to 136 patients (62.1%) in the non-severe group ($P < 0.001$).

Pathogen infections in severe versus non-severe pneumonia patients

As presented in **Table 4**, the prevalence of certain viral infections differed significantly between the severe and non-severe groups. Infections caused by rhinovirus ($P = 0.008$), bocavirus ($P = 0.039$), respiratory syncytial virus ($P = 0.034$), and influenza A virus ($P = 0.005$) were significantly more frequent in patients with severe pneumonia. In contrast, there were no statistically significant differences between the two groups regarding infections with streptococcus pneumoniae, mycoplasma pneumoniae, parainfluenza virus, coronavirus, Hemophilus influenzae, human metapneumovirus, adenovirus, or chlamydia infections ($P > 0.05$). Importantly the incidence of mixed infections was substantially higher among patients with severe pneumonia compared to those with non-severe disease ($P < 0.001$).

Clinical characteristics of severe versus non-severe pneumonia patients

Table 5 outlines the differences in clinical indicators between the severe and non-severe groups. Fever was significantly more common in patients with severe pneumonia ($P < 0.001$). Additionally, levels of both CRP and PCT were significantly elevated in the severe group ($P < 0.001$). The prevalence of anemia was also significantly higher in severe cases ($P = 0.001$), as was the need for mechanical ventilation ($P = 0.001$). Furthermore, patients with severe pneumonia experienced significantly longer hospital stays compared to those with non-severe illness ($P < 0.001$).

General characteristics of patients with mixed versus non-mixed infections

Patients were stratified into two groups based on the presence or absence of multiple pathogens: the mixed infection group (n = 158) and the non-mixed infection group (n = 91). As shown in **Table 6**, there were no significant dif-

Table 3. General characteristics of patients with severe versus non-severe pneumonia

Characteristic	Non-severe pneumonia (n = 219)	Severe pneumonia (n = 30)	χ^2	*P*
Sex [n (%)]			0.688	0.407
Female	92 (42.0)	15 (50.0)		
Male	127 (58.0)	15 (50.0)		
Age [n (%)]			--	0.059
< 1 month	4 (1.8)	0 (0.0)		
1-3 months	12 (5.5)	3 (10.0)		
4-6 months	9 (4.1)	0 (0.0)		
7 months-1 year	39 (17.8)	0 (0.0)		
2-3 years	54 (24.7)	9 (30.0)		
4-6 years	62 (28.3)	13 (43.3)		
> 6 years	39 (17.8)	5 (16.7)		
Pneumonia vaccination [n (%)]			22.176	< 0.001
No	83 (37.9)	25 (83.3)		
Yes	136 (62.1)	5 (16.7)		

Table 4. Pathogen infections in patients with severe versus non-severe pneumonia

Characteristic	Non-severe pneumonia (n = 219)	Severe pneumonia (n = 30)	χ^2	*P*
Positive pathogens [n (%)]				
Rhinovirus	41 (18.7)	12 (40.0)	7.130	0.008
Bocavirus	1 (0.5)	2 (6.7)	--	0.039
Streptococcus pneumoniae	102 (46.6)	15 (50.0)	0.124	0.724
Mycoplasma pneumoniae	90 (41.1)	12 (40.0)	0.013	0.909
Parainfluenza virus	19 (8.7)	6 (20.0)	--	0.095
Coronavirus	22 (10.0)	4 (13.3)	--	0.531
Respiratory syncytial virus	16 (7.3)	6 (20.0)	--	0.034
Influenza A virus	3 (1.4)	4 (13.3)	--	0.005
Hemophilus influenzae	85 (38.8)	13 (43.3)	0.226	0.635
Human metapneumovirus	24 (11.0)	6 (20.0)	--	0.225
Adenovirus	9 (4.1)	4 (13.3)	--	0.057
Chlamydia	0 (0.0)	1 (3.3)	--	0.120
Mixed infection [n (%)]			--	< 0.001
1 pathogen	87 (39.7)	4 (13.3)		
2 pathogens	78 (35.6)	8 (26.7)		
3 pathogens	49 (22.4)	11 (36.7)		
4 pathogens	3 (1.4)	4 (13.3)		
≥ 5 pathogens	2 (0.9)	3 (10.0)		

ferences in gender or age distribution between the two groups ($P > 0.05$). However, a significant difference was observed in vaccination status. Among patients with mixed infection, only 51.3% (81/158) had received the pneumonia vaccine, compared to 65.9% patients (60/91) in the non-mixed infection group ($P = 0.025$).

Clinical characteristics of patients with mixed versus non-mixed infections

As shown in **Table 7**, the incidence of fever and anemia did not differ significantly between the mixed and non-mixed infection groups ($P > 0.05$). However, CRP ($P = 0.016$) and PCT levels ($P = 0.002$) were significantly higher in

Table 5. Clinical characteristics of patients with severe versus non-severe pneumonia

Characteristic	Non-severe pneumonia (n = 219)	Severe pneumonia (n = 30)	Z/χ^2	*P*
Fever [n (%)]			47.531	< 0.001
No	166 (75.8)	4 (13.3)		
Yes	53 (24.2)	26 (86.7)		
C-reactive protein [mg/L, M (P25, P75)]	14.44 (10.29, 18.84)	25.73 (17.865, 38.895)	-5.572	< 0.001
Procalcitonin [ng/mL, M (P25, P75)]	0.5 (0.265, 0.765)	1.38 (0.8525, 1.5925)	-5.886	< 0.001
Anemia [n (%)]			10.494	0.001
No	185 (84.5)	18 (60.0)		
Yes	34 (15.5)	12 (40.0)		
Ventilator-assisted breathing [n (%)]			–	0.001
No	206 (94.1)	22 (73.3)		
Yes	13 (18.5)	8 (26.7)		
Length of hospitalization [d, M (P25, P75)]	11 (9, 14)	14.5 (10.25, 17.75)	-2.805	< 0.001

Table 6. General characteristics of patients with mixed versus non-mixed infection

Characteristic	Non-mixed infection (n = 91)	Mixed infection (n = 158)	χ^2	*P*
Sex [n (%)]			1.191	0.275
Female	35 (38.5)	72 (45.6)		
Male	56 (61.5)	86 (54.4)		
Age [n (%)]			–	0.496
< 1 month	3 (3.3)	1 (1.6)		
1-3 months	5 (5.5)	10 (6.0)		
4-6 months	1 (1.1)	8 (3.6)		
7 months-1 year	16 (17.6)	23 (15.7)		
2-3 years	24 (26.4)	39 (25.3)		
4-6 years	27 (29.7)	48 (30.1)		
> 6 years	15 (16.5)	29 (17.7)		
Pneumonia vaccination [n (%)]			5.058	0.025
No	31 (34.1)	77 (48.7)		
Yes	60 (65.9)	81 (51.3)		

the mixed infection group. Moreover, a greater proportion of patients in the mixed infection group required ventilator-assisted respiratory support compared to those in the non-mixed infection group ($P = 0.027$). Additionally, the length of hospitalization was significantly longer in the mixed infection group ($P = 0.021$).

Discussion

Pneumonia and sepsis remain the leading causes of mortality in children under five years of age, with pneumonia alone accounting for the highest number of deaths within this age group, as reported by the WHO [13]. Our findings indicate that rhinovirus, bocavirus, influenza A virus, and respiratory syncytial virus were more frequently detected in children with severe pneumonia, suggesting that certain viral pathogens may be closely associated with increased disease severity. The significantly higher rate of mixed infections in the severe group supports the hypothesis that co-infection with multiple pathogens may synergistically exacerbate pulmonary inflammation and compromise host immunity. This enhanced inflammatory response is reflected in the elevated levels of CRP and PCT observed in patients with severe or mixed infections. A noteworthy observation from this study is the lower pneumonia vaccination rate among

Table 7. Clinical characteristics of patients with mixed versus non-mixed infection

Characteristic	Non-mixed infection (n = 91)	Mixed infection (n = 158)	Z/χ^2	*P*
Fever [n (%)]			1.198	0.274
No	66 (72.5)	104 (65.8)		
Yes	25 (27.5)	54 (34.2)		
C-reactive protein [mg/L, M (P25, P75)]	13.55 (9.585, 18.325)	15.775 (11.455, 20.7025)	-2.420	0.016
Procalcitonin [ng/mL, M (P25, P75)]	0.37 (0.22, 0.77)	0.67 (0.3125, 0.965)	-3.042	0.002
Anemia [n (%)]			0.551	0.458
No	72 (79.1)	131 (82.9)		
Yes	19 (20.9)	27 (17.1)		
Ventilator-assisted breathing [n (%)]			4.901	0.027
No	88 (96.7)	140 (88.6)		
Yes	3 (3.3)	18 (13.3)		
Length of hospitalization [d, M (P25, P75)]	10 (8, 14)	11 (9, 15)	-2.316	0.021

patients with mixed infections, highlighting the potential protective effect of immunization in reducing either the incidence or severity of pneumonia. In addition, patients with mixed infections exhibited a greater need for ventilator-assisted respiratory support and experienced prolonged hospital stays, further underscoring the increased clinical burden posed by co-infections. These findings emphasize the importance of early detection, pathogen monitoring, and preventive strategies, particularly in patients presenting with risk factors for severe or mixed infections.

Severe pneumonia constitutes a significant clinical challenge in pediatric populations, accounting for approximately 7% to 13% of all pediatric pneumonia cases [8, 12]. In this study, 30 out of 249 children diagnosed with pneumonia developed severe pneumonia, a proportion consistent with previous reports. Prior studies have shown that older children are more susceptible to severe pneumonia and have higher rates of readmission [14, 15]. Although our analysis did not reveal a statistically significant association between age and severe pneumonia incidence, the observed *P* value of 0.059 indicates a trend toward older age in the severe pneumonia group. It is well known that inflammatory biomarkers such as CRP and PCT are markedly elevated in pneumonia patients and correlate with disease severity and prognosis [16-18]. For instance, Yang et al. reported that patients with severe Mycoplasma pneumoniae pneumonia had higher levels of inflammatory factors and an increased requirement for mechanical ventilation compared to those with non-severe pneumonia [19]. Consistent with these findings, our study, which included pediatric pneumonia cases caused by diverse pathogens, demonstrated elevated CRP and PCT levels across the cohort. Notably, this is the first study to report a significantly greater elevation of these inflammatory markers in children with severe pneumonia compared to those with mild pneumonia.

Streptococcus pneumoniae is a leading bacterial pathogen responsible for community-acquired infections in children, particularly pneumonia, and remains a primary cause of morbidity and mortality among preschool-aged children [20]. Consequently, the prevalence and transmission of Streptococcus pneumoniae among pediatric populations constitute a critical public health concern. Consistent with this, our findings demonstrate that Streptococcus pneumoniae was the most frequently detected pathogen in infants and children with pneumonia, accounting for 47.0% of cases. Pneumonia vaccination is widely recognized as a key preventive measure targeting pneumonia caused by streptococcal pneumoniae [21]. Nonetheless, in this research, vaccination status did not significantly correlate with the incidence of streptococcus pneumoniae infection. Given the higher vaccination coverage observed in children without severe pneumonia, we hypothesize that although vaccination may not significantly reduce the acquiring Streptococcus pneumoniae infection, it likely mitigates disease severity and progression following infec-

tion [22-24]. These findings, together with prior evidence, reinforce the critical need to enhance pneumonia vaccination coverage.

Mixed infections involving multiple pathogens are common in pediatric pneumonia and other respiratory infections [8, 25]. A large-scale study involving over 18,000 Chinese patients with community-acquired pneumonia across all age groups reported higher rates of co-infection among severe cases compared to non-severe cases, with predominant pathogens including respiratory syncytial virus, streptococcus pneumoniae, influenza virus, and pseudomonas aeruginosa [26]. In this study, 63.5% of pediatric pneumonia patients harbored infections with two or more pathogens. Children with mixed infections exhibited a greater need for mechanical ventilation and experienced prolonged hospital stays relative to those with single-pathogen infections. Prompt and accurate pathogen identification is therefore critical for optimizing clinical diagnosis and treatment. Based on these findings, medical institutions may develop customized multi-pathogen detection panels or microfluidic chips targeting specific respiratory pathogens. Such tailored diagnostic approaches could improve pneumonia case detection efficiency, thereby facilitating prompt clinical intervention and optimized patient management.

Despite the valuable insights provided by this study for the clinical management of pediatric and neonatal pneumonia, several limitations should be acknowledged. First, as a retrospective study, incomplete patient data limited the scope of available information, potentially affecting the comprehensiveness and representativeness of the clinical characteristics analyzed. Second, the study population was drawn from a single medical center, which may restrict the generalizability of the findings. Future studies should include larger, multicenter cohorts to validate and extend these results. Lastly, this study focused primarily on the impact of pneumonia vaccination; however, the effects of other relevant vaccines, such as influenza vaccination, warrant further investigation to fully understand their roles in pneumonia prevention and disease severity.

Conclusion

Mixed infections were prevalent among children with severe pneumonia and were associated with more pronounced clinical symptoms. Additionally, lower vaccination rates were observed in this group, underscoring the importance of immunization. These findings highlight the need for enhanced pathogen surveillance and the implementation of targeted interventions, particularly for patients at risk of severe and mixed infections.

Disclosure of conflict of interest

None.

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