Article

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Pathogenic Detection of Alveolar Lavage Fluid in Children with Lobar Pneumonia

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Background: Lobar pneumonia seriously endangers children's respiratory tract health and affects their growth and development, so it is very important to identify pathogenic microorganisms and use appropriate antibiotics early.
Objective: To analyze the significance of pathogenic detection of alveolar lavage fluid in children with lobar pneumonia.
Methods: The clinical data of 80 children with lobar pneumonia who were hospitalized from March 2019 to March 2022 were analyzed for pathogenic characteristics in bronchoalveolar lavage fluid (BALF) detected by fluorescence quantitative PCR (FQ-PCR), and serum mycoplasma pneumoniae-specific antibody (MP-IgM) levels were measured by enzyme-linked immunosorbent assay (ELISA). The differences in clinical lung infections in children with different age groups, mycoplasma pneumoniae (MP) pneumonia versus non-MP pneumonia, and mixed versus single infections were compared.
Results: There were 15 cases of pathogenic MP infection in the 1–3 years old group, 34 cases of MP infection in the 4–6 years old group, and 6 cases of pathogenic MP infection in the 7–14 years old group. Statistically significant differences were observed in the detection rate of MP between each age group ($p < 0.001$), and the highest MP detection rate was found in the 7–14 years old group. The differences in the detection rates of single and mixed infections between the age groups did not come up to the statistical standard ($p > 0.05$). The mean age of patients with a single infection was slightly older than that of patients with mixed infection, but no statistical difference was found between the groups ($p > 0.05$). The duration of disease was shorter than that of patients with mixed infection, but the difference between the two groups was not statistically significant ($p > 0.05$). The positive rate of MP detection in BALF by FQ-PCR (55, 73.75%) was higher than that of serum MP-IgM detection (38, 47.5%).
Conclusion: The detection rate of MP was the highest in children with lobar pneumonia, followed by Streptococcus pneumoniae (SP) and adenovirus (ADV), and the pathogens of infection varied in different age groups. MP is the main pathogen of most mixed infections, and mixed infections are more prone to severe or refractory cases. Further studies are required prior to clinical promotion.

Keywords: children; lobar pneumonia; alveolar lavage fluid; pathogenic detection; significance analysis; clinical analysis

Introduction

Pneumonia is an inflammation in the terminal airways, alveoli, and interstitial spaces of the lungs caused by different pathogens or other factors (physicochemical factors, immune damage, allergies, and drugs). Clinical manifestations are mainly fever, cough, shortness of breath, dyspnea, and persistent wet rales in the lungs [1]. According to the World Health Organization (WHO), there are 1.55 billion cases of pneumonia in children worldwide each year, and more than 2 million children younger than 5 years of age die from pneumonia, accounting for about 1/5 of all deaths in this age group and being the leading cause of death in children [2,3]. Pneumonia is clinically classified into bronchopneumonia, lobar pneumonia, and interstitial pneumonia according to the pathological pattern, among which lobar pneumonia, characterized by a large area of infection and rapid onset, is a serious health risk for children [4]. Lobar pneumonia in children is a serious lung infection with sudden onset of fever, chest pain, lack of appetite, fatigue, and irritability, and is a serious pediatric disease with complications such as lung abscess, abscess chest, pleural effusion, and myocarditis, and infectious shock may develop in severe cases [5]. Currently, Streptococcus pneumoniae is the main pathogen of lobar pneumonia, with a higher prevalence among older children, and its pathogenesis may be associated with direct pathogen invasion and immunological pathogenesis [6]. The pathogenic bacteria invade the organism and activate the immune response, causing functional limitations and metabolic disturbances in systemic organs, whereas the maturing defenses of the organism in older children confine the lesion to a certain lobe or lung segment and prevent its spread, thereby exhibiting the pathological features of lobar pneumonia [7]. For the management of lobar pneumonia in children, penicillins or cephalosporins are mostly used in Western medicine to actively control the infection. However, since lobar pneumonia in children

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progresses rapidly and is prone to other systemic malfunctions, simple anti-infective therapy is unfavorably effective and therefore requires supplementation of glucocorticoids. When severe infections are present, high-dose gammaglobulin is administered intravenously to improve the immune level of the child and enhance resistance to disease [8,9]. Fiberoptic bronchoscopy allows direct access and manipulation of the lesion under visualization operation, which can rapidly control infection, relieve clinical symptoms and restore pulmonary ventilation [10]. Fiberoptic bronchoscopy has both therapeutic and diagnostic effects, allowing direct microscopic observation of the lesion, bronchoalveolar lavage (BAL), and bronchoalveolar lavage fluid (BALF) for pathogen detection. Bronchoalveolar lavage via fibrinoscopy has a wide sampling range to reach the distal lung parenchyma, and the collection of BALF specimens from a wide range of lung parenchyma for pathogen detection reveals the lung pathogenesis of lobar pneumonia in children and improves the diagnostic yield of respiratory pathogens [11,12]. Alveolar lavage is considered an important treatment modality for pulmonary diseases due to its simple operation, safety and reliability, and mild pain to the patient. Traditional Chinese medicine (TCM) suggests that the physiological functions of the internal organs are not well developed in children, so they are susceptible to the attack of the six externally induced evil elements. The external warm-heat evil causes the lung qi to be irregularly dispersed, which affects the normal distribution of water and fluids and coagulates into phlegm [13,14]. The warm-heat evil consumes fluid and blood, damaging the blood vessels, and phlegm evil blocks the airways and lungs, causing the obstruction of the lung channels, so clinical symptoms such as fever, cough, phlegm, shortness of breath, and in severe cases, stasis signs such as cyanosis of the lips and tortuous veins under the tongue are observed [15,16].

In view of the epidemiological, etiological, clinical symptoms and new features of the treatment of the disease, this study was undertaken to understand the main pathogenic types and clinical features of lobar pneumonia in children in this region and to provide insights into the clinical diagnosis and treatment of lobar pneumonia. In the present study, eight common pathogenic bacteria in BALF of children with lobar pneumonia were detected by fluorescence quantitative PCR (FQ-PCR), and the clinical data including pathogenic characteristics and clinical features of children with lobar pneumonia were analyzed.

Materials and Methods

Patient Characteristics

Eighty children with lobar pneumonia in our pediatric department were included in this study. All eligible patients provided written informed consent, the study protocol was approved by ethics committee of the Fourth Clinical College of Xinxiang Medical University (Approval No. NIUI20200201), and all processes conformed to the Declaration of Helsinki ethical guidelines for clinical research (Table 1).

Table 1. Patient characteristics.

Basic information	Included patients
N	80
Sex (Male/Female)	46/34
Age (year)	7.16 ± 3.46 (1–14)
1–3	24
4–6	49
7–14	7
Disease condition	
Mild	18
Moderate	56
Severe	6
WBC	
Elevated (≥10 × 10^9/L)	68
Not elevated (<10 × 10^9/L)	12
	12.9 ± 1.36
CRP	
Elevated (≥10 mg/L)	59
Not elevated (<10 mg/L)	21
	0.3 ± 0.12
PCT	
Elevated (≥0.5 ng/mL)	48
Not elevated (<0.5 ng/mL)	32
	41.2 ± 3.64

Note: WBC, white blood cell; CRP, C reaction protein; PCT, procalcitonin.

Diagnostic Criteria

The diagnostic criteria for lobar pneumonia are as follows: ① Recent cough, sputum, or aggravation of symptoms of an existing respiratory disease with purulent sputum, with or without chest pain, dyspnea, and hemoptysis; Fever; Signs of lung consolidation and/or smell of wet rales; WBC >10 × 10^9/L OR <4 × 10^9/L; ② Chest imaging examination shows shadow consolidation of the lung lobes or segments with or without pleural effusion. It can be diagnosed when meeting ② and anyone of ①, except pulmonary tuberculosis, lung tumor, non-infectious pulmonary interstitial disease, pulmonary edema, atelectasis, etc. [10].

Inclusion and Exclusion Criteria

Inclusion criteria: ① met the diagnostic criteria for lobar pneumonia in children; ② met the indications for fiberoptic bronchoscopy, and BALF could be collected during the operation; ③ all children were admitted to the hospital for routine blood tests, blood gas analysis, electrocardiogram, blood mycoplasma antibodies (MP-IGM) tests, chest X-ray, and lung computed tomography (CT); ④ Parents and children were informed and willing to participate in this study; ⑤ without massive pleural effusion in the lungs; ⑥

Table 2. Primers sequences for eight pathogens.

	Forward primer	Reverse primer
Mycoplasma pneumoniae	5′-GCAAGGGTTCGTTATTTG-3′	5′-CGCCTGCGCTTGCTTAC-3′
Chlamydia pneumoniae	5′-CTGTTAGCCATGCTCTTGTC-3′	5′-AGCTTCGTCCAGGTAAGAGG-3′
Streptococcus pneumoniae	5′-TCAGCAAATGCATCACAAAGAC-3′	5′-CGTAAATGCACTTGCTTCAGG-3′
Klebsiella pneumoniae	5′-AGTGCTGACCTGAGAACTGT-3′	5′-GGAGTGGTGTTTGCAGTGTT-3′
Haemophilus influenzae	5′-AGATGACAGACGGGTGCTAA-3′	5′-GTAGCTCTTTGAGCTCCGTT-3′
Legionella pneumophila	5′-AGGGTTAACGCTTGAGATGA-3′	5′-GTTCTTCAGCCGTTCTCCTT-3′
Adenovirus	5′-CGCGGCGCGGTCTATGTTGT-3′	5′-CGCGGCGCGGTCTATGTTGT-3′
Respiratory syncytial virus	5′-AGCAGCGAACTGTGTTAGCC-3′	5′-TTTGCGCGCGTAGTAGTAGG-3′

with a disease duration ≤1 week, or with high fever lasting >1 week and ≤2 weeks that does not subside.

Exclusion criteria: ① with hospital-acquired pneumonia; ② with bronchial foreign bodies; ③ with contraindications to or intolerance of fibrinoscopy; ④ with hospital referral or abandonment of treatment or without complete data; ⑤ with serious complications of other organs; ⑥ whose parents refused to complete the relevant examination; ⑦ whose parents refused to sign the relevant informed consent form.

Clinical Data Collection

Clinical data were collected to record the clinical manifestations of the included children before fiberoptic bronchoscopy lavages, such as fever duration, fever peak, nature of cough, presence of sputum, sputum volume and color, auscultatory signs, presence of complications, and season of onset. Laboratory tests such as routine blood tests, C-reactive protein (CRP) tests, procalcitonin (PCT) tests, and macrobiochemical tests were performed. Imaging data included chest X-ray (GE Healthcare, Wauwatosa, WI, USA), lung CT scan (GE Healthcare, Wauwatosa, WI, USA), and thoracic ultrasound (Siemens Healthineers AG, Henkestrasse, Erlangen, Germany).

Alveolar Lavage Fluid Collection

Main instruments ① Olympus fiberoptic bronchoscope (Olympus Corporation, Shinjuku, Tokyo, Japan): Japan Olympus tracheal intubation fiberoptic endoscope LF-DP (3.1 mm outer diameter); ② Olympus image imaging system (Olympus Corporation, Shinjuku, Tokyo, Japan): Olympus, Japan.

BALF Specimen Collection

Preoperative preparation: routine examination, CRP assay, PCT assay, liver and kidney function tests, cardiac enzyme tests, blood coagulation analysis, electrocardiograph (ECG) (Royal Philips, Amsterdam, Netherlands), chest X-ray, lung CT and other relevant examinations were performed. With the patient in the supine position and after local surface anesthesia with sedation, oxygen, ECG, and oxygen saturation monitoring were routinely administered intraoperatively by face mask. Fiberoptic bronchoscopy was inserted transnasally to observe the areas where imaging suggested abnormalities. Bronchoalveolar lavage was performed in the inflamed areas, and in the event of extensive inflammation, left lingual branch and right middle lobe lavage were used. The lavage fluid was saline at a temperature of 37 °C, generally 5 mL/time, and lavage was performed at least 3 times in the more inflamed lung segments. The lavage fluid recovery was ≥2 mL indicating adequate lavage, and the total amount of lavage fluid was 5–10 mL/kg. The BALF was obtained by negative pressure suction, and the specimen was placed in a disposable sterile siliconized collector for examination. The BALF specimens were collected and partially tested immediately, and partially placed in an insulated box with an ice pack and placed in a –80 °C refrigerator for freezing and storage to be examined.

Preoperative, intraoperative, and postoperative precautions: ① Preoperative preparation of the child was performed. ② The patient's oxygen saturation, blood pressure, heart rate, respiration, mouth and lip color, facial color, and other general conditions during the operation were closely monitored. The oral and nasal secretions of the child were timely removed. The operation was immediately suspended in the case of reduced oxygen saturation (below 80%), and low-flow oxygen and back-patting were performed for the return of oxygen saturation. ③ To avoid contamination of the upper respiratory fluid, the tip of the fiberoptic bronchoscope should not be suctioned before entering the lesion site. ④ During saline irrigation, the fiberoptic bronchoscope must be tightly pressed against the bronchial orifice, quickly perfused with pressure, and then slowly absorbed. ⑤ The lavage duration was maintained within 10 min. In the event of intraoperative hemorrhage, 1:10,000 epinephrine was administered for local hemostasis. ⑥ To protect the specimen from contamination, the lavage solution was immediately injected into a 15 mL sterile centrifuge tube, part of the specimen was collected for immediate assay, and part of the specimen was stored in the insulation box with ice bags and transferred to the –80 °C refrigerator.

Detection of BALF Pathogen by FQ-PCR Method

The FQ-PCR method was used to examine eight pathogens in BALF: Mycoplasma pneumoniae (MP),

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Chlamydia pneumoniae (CP), Streptococcus pneumoniae (SP), Klebsiella pneumoniae (KP), Haemophilus influenzae (HI), Legionella pneumophila (LP), adenovirus (ADV), and respiratory syncytial virus (RSV). The primers sequences for eight pathogens are shown in Table 2. The nucleic acid extraction reagent (silica gel membrane-centrifuge column method) and nucleic acid amplification fluorescence detection kit (PCR fluorescent probe method) were provided by Zhongshan University Daan Genetics Co. (Cat. No. DA0591, Guangzhou, China). The PCR instrument was an American ABI7500 real-time fluorescence quantitative PCR instrument (Thermofisher Scientific, Waltham, MA, USA). The appropriate amount of nucleic acid sample and PCR reaction system were added to a 0.2 mL centrifuge tube according to the instructions (a pair of specific primers, a specific fluorescent probe, corresponding PCR reaction Buffer, Hot-StartTaq enzyme, nucleotide monomers, Mg2+, etc.), then centrifuged at 8000 r/min (1.5 cm radius) for 10 s and placed in the instrument sample slot.

Detection of Serum MP-Specific Antibodies by Enzyme-Linked Immunosorbent Assay (ELISA)

2.0 mL of venous blood was collected from the children and centrifuged to obtain the serum for assay. The ELISA kit provided by Thermo Fisher Scientific (R24229, Waltham, MA, USA) was used to determine the serum MP-specific antibody (MP-IgM), and the result was judged as positive with $\geq$0.8.

CPIS Scoring

The CPIS scoring was performed on the day of bronchoscopy. The clinical lung infection score includes 6 items: temperature, white blood cell count, airway secretions, oxygenation, radiographic chest infiltrative shadow, and airway aspirate culture, each with a score of 0–2 and a total score of 0–12. The higher the score, the more severe the disease.

Statistical Analysis

SPSS 23.0 statistical software (SPSS Inc, Chicago, IL, USA) was used to process the data. The count data were expressed as N (%) and analyzed using the chi-square test. The measurement data were expressed as mean $\pm$ standard deviation (Mean $\pm$ SD); an independent sample *t*-test was used for intergroup comparison and paired sample *t*-test was used for intra-group comparison. Differences were indicated as statistically significant at $p < 0.05$.

Results

Detection of Pathogens in Different Age Groups

There were 13 cases of pathogenic MP infection in the 1–3 years old group, 34 cases of MP infection in the 4–6 years old group, and 6 cases of pathogenic MP infection in the 7–14 years old group. There are is not statistically significant differences were observed in the detection rate of MP between each age group ($p > 0.05$), and the highest MP detection rate was found in the 7–14 years old group. There were 16 cases of pathogenic single infections detected in the 1–3 years old group, 37 cases of single infections detected in the 4–6 years old group, and 4 cases of pathogenic single infections detected in the 7–14 years old group. There were 5 cases of mixed pathogenic infections detected in the 1 to 3 years old group, 15 cases of mixed infections detected in the 4 to 6 years old group, and 3 cases of mixed pathogenic infections detected in the 7 to 14 years old group. The differences in the detection rates of single and mixed infections in each age group did not come up to the statistical standard ($p > 0.05$) (Table 3).

Infections in MP-Positive Children

The mean age of patients with a single infection was slightly older than that of patients with mixed infection, but no statistical difference was found between the groups ($p > 0.05$). The duration of disease was shorter than that of patients with mixed infection, but the difference between

Table 3. Pathogen detection by age group ($\bar{x} \pm s$).

Indices	1∼3 years (n = 24)	4∼6 years (n = 49)	7∼14 years (n = 7)	Infection rate (%)	χ^2	*p*
Positive detection rate				100	5.91	0.051
MP	15	34	6	73.75	0.346	0.556
CP	1	1	0	2.50	-	0.058
LP	0	0	0	0	-	0.134
SP	2	7	1	12.50	0.121	0.728
KP	0	1	0	1.25	-	0.135
HI	0	0	0	0	-	1.157
ADV	2	5	1	10.00	0.028	0.867
RSV	1	0	0	1.25	-	0.135
Single infection	16	37	4	71.25	06334	0.426
Mixed infections	5	15	3	28.75	0.775	0.379

MP, Mycoplasma pneumoniae; CP, Chlamydia pneumoniae; LP, Legionella pneumophila; SP, Streptococcus pneumoniae; KP, Klebsiella pneumoniae; HI, Haemophilus influenzae; ADV, adenovirus; RSV, respiratory syncytial virus.

Table 4. Duration of disease in MP-positive children with single and mixed infections ($\bar{x} \pm s$).

Group	n	Age (y)	Duration of disease (d)
Single infection	39	8.37 ± 3.14	14.76 ± 2.55
Mixed infections	16	7.18 ± 2.31	15.36 ± 2.77
t		1.369	0.773
p		0.177	0.443

Note: * indicates $p < 0.05$ when compared with before treatment.

Table 5. MP detection in BALF with serum MP detection by FQ-PCR method in children.

		Serum MP-IgM assay		Total	χ^2/t	*p*
		(+)	(-)			
Detection of MP in BALF by FQ-PCR	(+)	38	17	55	0.300	0.584
	(-)	13	12	25		
	Total	51	29			

BALF, bronchoalveolar lavage fluid; FQ-PCR, fluorescence quantitative PCR.

the two groups was not statistically significant ($p > 0.05$) (Table 4).

Detection of MP

The duration of disease was shorter than that of patients with mixed infection, but the difference between the two groups was not statistically significant ($p > 0.05$). The positive rate of MP detection in BALF by FQ-PCR (55, 68.75%) was higher than that of serum MP-IgM detection (51, 63.75%), but that was not statistically significant ($p > 0.05$) (Table 5).

Intrapulmonary and Extrapulmonary Manifestations of MP Pneumonia Versus Non-MP Pneumonia

Compared with the non-MP pneumonia group, children in the MP pneumonia group had a high proportion of pleural effusion, abnormal liver function, Myocardial damage, Digestive system involvement, neurological involvement, and Skin rash ($p < 0.05$) (Table 6).

Discussion

Lobar pneumonia is one of the most common forms of community-acquired pneumonia (CAP), mostly seen in adults. The incidence of lobar pneumonia in children has been gradually increasing in recent years, with rapid clinical onset, severe disease, long duration, and susceptibility to extra-pulmonary complications, while the typical characteristics of adult lobar pneumonia are mostly absent. Timely and accurate pathogenic diagnosis provides substantial clinical benefits for the diagnosis and treatment of lobar pneumonia in children [17,18]. The common pathogens of CAP include bacteria such as Streptococcus pneumoniae (SP), Klebsiella pneumoniae (KP), Haemophilus influenzae (HI), viruses such as respiratory syncytial virus (RSV), adenovirus (ADV), atypical pathogens such as Mycoplasma pneumoniae (MP), Chlamydia pneumoniae (CP), Legionella pneumophila (LP), fungi, and protozoa. Previously, SP was the main pathogenic organism in lobar pneumonia, and clinical manifestations were mostly rapid onset, chills and high fever, coughing rust-colored sputum, and pulmonary solid signs in the lungs. However, variations are identified in the pathogenic features and clinical manifestations of lobar pneumonia [19]. The key to the management of lobar pneumonia is the early and accurate identification of the pathogen and the administration of sensitive antimicrobial drugs to improve the cure rate and effectively reduce the occurrence of drug-resistant bacteria. Sputum culture, which is currently used in clinical practice, carries a high risk of contamination and poor specificity due to the influence of oral flora, and is of little significance in guiding drug therapy for lobar pneumonia [20]. Bronchoalveolar lavage is known as “liquid lung biopsy”, which is performed directly at the site of the lesion and may be less contaminated and more reflective of lung pathogenesis than sputum culture, providing an accurate pathogenic diagnosis for treatment and a basis for antibiotic selection. BALF is currently considered a more sensitive and reliable method for the diagnosis of pneumonia pathogens. The detection of pathogens in BALF by FQ-PCR allows for rapid and effective detection of pathogens [21].

A gradual increase in lobar pneumonia caused by MP and a gradual decrease in lobar pneumonia caused by SP infection have been reported. MP lobar pneumonia in the present study was mostly seen in school-aged children, which is consistent with previous reports. Recent studies have found that MP infection shows a trend toward a younger age and that children with MP lobar pneumonia are prone to fever with a long duration of fever, irritating dry cough in the early stage, and yellow-white mucous sputum in the late stage; chest radiographs or CT of the lungs present in multiple forms and single chest radiographic evidence is insufficient to support a definitive diagnosis of MP pneumonia [22]. Therefore, laboratory MP testing is

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Table 6. Intrapulmonary and extrapulmonary manifestations of MP pneumonia versus non-MP pneumonia.

Intrapulmonary and extrapulmonary manifestations	MP pneumonia (n = 55)	Non-MP pneumonia (n = 25)	χ^2	p
Pneumonia extending to ≥2 lobes of the lung	36	10	4.557	0.053
Pleural effusion	34	5	12.030	0.001
Pulmonary atelectasis	5	0	1.121	0.289
Abnormal liver function	28	2	13.502	0.001
Myocardial damage	35	10	3.902	0.048
Digestive system involvement	21	2	7.643	0.006
Neurological involvement	18	0	10.557	0.001
Renal impairment	6	0	1.586	0.208
Skin rash	14	0	6.051	0.014

recommended for children with lobar pneumonia who have a long fever, a prolonged irritant cough, unremarkable pulmonary signs and poor response to β-lactam antibiotic therapy. FQ-PCR detection of MP-DNA in BALF is superior to serum MP antibody detection and significantly improves the positive detection rate of MP infection, which is a reliable method for the early diagnosis of MP pneumonia. MP infection involves all systems of the body in addition to pulmonary symptoms, due to the presence of the same antigens as MP antigens and the human heart, liver, lung, brain, kidney, and smooth muscle tissues. After MP infection, the body produces autoantibodies to the corresponding tissues and forms immune complexes that cause lesions in target organs other than the respiratory system [23]. SP is an important pathogen causing bacterial pneumonia in children, and lobar pneumonia caused by Streptococcus pneumoniae infection has shown a gradual decrease in recent years. In the present study, children with SP infection accounted for 12.5%, and there were also combined MP, CP, and viral infections, resulting in a longer febrile course and more severe clinical symptoms and imaging manifestations [24]. ADV is a DNA virus that multiplies mainly in the pharynx, conjunctiva, and lymphoid tissues, causing respiratory tract (especially lower respiratory tract) infections in infants and children, as well as lobar pneumonia. The course of ADV pneumonia is frequently co-infected with other pathogens, leading to exacerbation and prolongation of the disease course [25]. In addition, mixed infections accounted for 28.75% of all cases in this study. The long duration and seriousness of the disease in children with mixed infections require active treatment measures, and the combination of β-lactam antibiotics and macrolides is strongly recommended for timely control of the disease and improvement of relevant tests.

The detection of pathogenic bacteria is partly affected by the detection method. Sputum culture is a routine test with poor specificity, while sputum specimens are not easily obtained in children, with potential contamination by oral colonizing bacteria. The fiberoptic bronchoscopy technique allows direct observation of lesions and the performance of bronchoalveolar lavage (BAL) and aspiration of alveolar lavage fluid for pathogen detection, and early fiberoptic bronchoscopic lavage in children with lobar pneumonia provides more effective clearance of airway secretions, alleviates symptoms, shortens the course of disease, and identifies the causative organism [26]. MP-IgM usually appears only after 7–10 days of infection and is affected by age, disease duration, immune status and other factors, resulting in limitations of serum MP-IgM examination. The FQ-PCR operation technique with high specificity and sensitivity and independent of the course of the disease is available for early diagnosis after MP infection [27]. The detection of MP in BALF by the FQ-PCR method can significantly increase the positive detection rate and is a reliable method used for early diagnosis of MP infection [28]. MP antigens have the same antigens as the human heart, liver, lung, brain, kidney and smooth muscle tissues, and the infection causes lesions in the respiratory tract and other organs, involving multiple systems such as cardiovascular, urinary, hematological and neurological [29]. The proportion of pleural effusion, abnormal liver function, and neurological involvement was significantly higher in MP pneumonia compared with non-MP pneumonia children in the present study. However, there was no statistically significant difference in the incidence of pulmonary atelectasis, myocardial damage, digestive system, urinary system, and rash between the two groups of children. Considering the small number of severe cases included and the possible coexistence of nosocomial infection in some cases, the relationship between extra-pulmonary symptoms and MP infection needs to be further investigated.

This study has the following limitations: Due to the limitations of research funding, study time, and other objective factors, this study is a single-center study with small sample size. Due to the differences in antibiotic use in different regions and population distribution, antibiotic resistance exhibits obvious regional characteristics. Accordingly, based on this study, future studies will continue to collect BALF by fiberoptic bronchoscopic lavage and apply FQ-PCR specific gene amplification to produce a rapid pathogenic diagnosis, while drug resistance gene testing will be used to understand the drug resistance and resistance mechanisms of common pathogens, to further clarify the epidemiological trends and antibiotic resistance of lo-

bar pneumonia pathogenesis in children in this region, and to better guide the rational clinical use of antibiotics.

Conclusion

The pathogens of childhood lobar pneumonia are diverse, including mycoplasma, chlamydia, bacteria, and viruses, among which MP is the most common, while SP and ADV infections also account for a significant proportion in the region. The positive rate of MP infection was higher in the 4–6 and 7–14 years old groups than in the 1–3 years old group. MP children with lobar pneumonia present with a high incidence of pleural effusion, pulmonary atelectasis, and restrictive pulmonary fibrosis in those with mixed infections, which warrants the attention of clinicians. In addition, the clinical characteristics of lobar pneumonia infected by different pathogens also differ, and some of the clinical characteristics are of assistance in predicting the etiology and providing a basis for empirical antimicrobial drug selection in children with lobar pneumonia.

Availability of Data and Materials

The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Author Contributions

The authors declare that this work was done by the authors named in this article and all liabilities pertaining to claims relating to the content of this article will be borne by them. All authors reviewed the manuscript. All authors have read and approved the manuscript.

Ethics Approval and Consent to Participate

This study has been approved by The Fourth Clinical College of Xinxiang Medical University ethics committee (Approval No. NIUI20200201) and Patients and their families were informed of the research content and voluntarily signed the informed consent consent. All the methods were carried out in accordance with the Declaration of Helsinki.

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Conflict of Interest

The authors declare no conflict of interest.

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