Original Article

Efficacy of bronchoalveolar lavage in treating mycoplasma pneumonia and bacterial pneumonia with atelectasis in children

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Background: Pulmonary atelectasis (PA) is a severe complication of pneumonia in children. Despite the growing use of fiberoptic bronchoscopy, the effectiveness of bronchoalveolar lavage (BAL) in treating PA caused by various pathogens remains uncertain. This study aims to evaluate the efficacy of BAL in PA associated with different pathogens and to identify factors influencing treatment outcomes.

Methods: We conducted a retrospective analysis on 185 children with PA between 2017–2021. Clinical data were collected and compared between different groups using a propensity score-matching analysis.

Results: A total of 185 patients were included in the study, divided into two groups based on whether BAL was performed (BAL group, n=146; non-BAL group, n=39). The patients in the BAL group had a longer fever duration, a higher proportion of neutrophils, elevated lactate dehydrogenase (LDH) levels, and a longer duration of antibiotic use prior to admission (all P<0.05). After applying propensity score matching (PSM), 35 cases were enrolled in each group. We further stratified the patients based on the pathogens identified. Furthermore, we found that patients in the *Mycoplasma pneumoniae* pneumonia (MPP) subgroup had shorter time of C-reactive protein (CRP) recovery and higher incidence of lung recruitment after BAL (all P<0.05), while these results were not observed in the bacterial pneumonia subgroup (P>0.05).

Conclusions: BAL could increase the incidence of lung recruitment and shorten the CRP recovery time in MPP patients with PA, but it could not make any improvement in PA patients caused by the bacterium.

Keywords: Bronchoalveolar lavage (BAL); atelectasis; *Mycoplasma pneumoniae* pneumonia (MPP); bacterial pneumonia; children

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Introduction

Pulmonary atelectasis (PA) is defined as the collapse of lung tissue, resulting in a reduction in lung aeration and significantly impairing gas exchange (1). Atelectasis can result from various mechanisms, including airway obstruction, compression due to extrinsic or intrathoracic factors, and alterations in alveolar surface tension (2). PA is commonly regarded as a complication of underlying respiratory diseases like asthma, pneumonia, sickle cell disease, respiratory muscle weakness in children (3). The clinical manifestations of these effects depend on the degree of lung collapse and the underlying disease. In addition, atelectasis has many complications, such as dyspnea, changes in local ventilation and blood flow ratio, irritant cough, sputum, and pulmonary infection (4). Current treatment

strategies for atelectasis include intrapulmonary percussion ventilation, mechanically assisted coughing, etiological therapy, antibiotic treatment, chest physiotherapy, and bronchoalveolar lavage (BAL) (5).

BAL is a diagnostic and therapeutic procedure used to remove mucus, secretions, and inflammatory factors from the lungs. It improves lung ventilation by clearing airway obstructions and helps reduce inflammation. BAL can also provide valuable diagnostic information by analyzing the retrieved fluid for pathogens, inflammatory cells, and other markers of lung injury, aiding in the management of various pulmonary conditions (6,7). It has recently become more widely used to diagnose, monitor, and treat children's respiratory diseases. Our previous studies (8,9) have found that BAL was effective and safe in the treatment of refractory *Mycoplasma pneumoniae* pneumonia (MPP). However, several studies have indicated that children with atelectasis typically experience normalization of lung expansion within 3 months after receiving antibiotic treatment (5,10,11). Therefore, the necessity of BAL for the treatment of PA remains a topic of debate. In this retrospective analysis, a case-matched design was used to evaluate the role of BAL in managing PA, particularly in cases of bacterial pneumonia and MPP. We present this article in accordance with the STROBE reporting checklist (available at https://tp.amegroups.com/article/view/10.21037/tp-2024-593/rc).

Highlight box

Key findings

- Bronchoalveolar lavage (BAL) could increase the incidence of lung recruitment and shorten the C-reactive protein recovery time in *Mycoplasma pneumoniae* pneumonia patients with pulmonary atelectasis (PA), but it could not make any improvement in PA patients caused by the bacterium.

What is known and what is new?

- BAL is beneficial to the recovery of atelectasis caused by *Mycoplasma pneumoniae* in children and can shorten the length of hospital stay.
- BAL is not necessary for atelectasis caused by bacterial infection.

What is the implication, and what should change now?

- For patients diagnosed with bacterial pneumonia complicated by atelectasis, a full course of antibiotics may be sufficient, and BAL can be avoided.

Methods

Study population

A total of 185 children who were admitted to Zhejiang University Children's Hospital due to pneumonia complicated with atelectasis between January 2017 and December 2021 were enrolled in the study. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the ethics committee board of Children's Hospital (No. 2024-IRB-0166) and informed consent was taken from all the patients. All the data from patients were collected anonymously. All patients were admitted to the general ward. All cases enrolled in this study met the diagnostic criteria as follows: (I) individual symptoms, physical examination findings and chest radiograph satisfied the diagnostic standard of pneumonia (12,13); (II) in this study, the diagnosis of atelectasis was made based on the clinical experience of the attending physicians, followed by a double-blind review of chest X-rays or CT scans by two experienced radiologists. Chest imaging showed the presence of any of the following typical characteristics: radiography density, fissure displacement, mediastinal shift, diaphragmatic elevation, and compensatory hyperinflation (14). Children with chronic illnesses or immune-compromising diseases were excluded from the study (e.g., immunodeficiency, chronic corticosteroid use, chronic lung disease, malignancy, sickle cell disease, congenital heart disease, patients dependent on tracheostomy, and neuromuscular disorders impacting breathing).

Definitions

(I) C-reactive protein (CRP) recovery days: the duration from the peak CRP level to the time when CRP drops below 8 mg/L.

(II) Hypoxemia was defined as peripheral oxygen saturation (SpO_2) <95% on room air, measured using a pulse oximeter (15). The method of oxygen therapy varied according to the severity of hypoxia. In this study, all cases receiving oxygen therapy were administered oxygen via nasal cannula and face mask.

(III) Multiple lung lobes: atelectasis involves more than two lung lobes.

(IV) Complications refer to the dysfunction or abnormalities

of additional organs or systems, such as hepatic dysfunction, hypoalbuminemia, multiple serous cavity effusions, and myocardial injury.

Data collection

In this study, we retrospectively collected information from electronic medical records, including demographic data, clinical characteristics, laboratory results, and imaging findings. On admission, blood specimens were tested for complete blood cell count, CRP, procalcitonin (PCT), erythron sedimentation rate (ESR), cytokines including interleukin (IL)-2, IL-4, IL-6, IL-10, tumor necrosis factor (TNF)-α, interferon (IFN)-γ. During hospitalization, respiratory tract samples were routinely analysed for pathogens. The positive results of a serologic test [*Mycoplasma pneumoniae* (MP) IgM positive and antibody titer 1:160] or the positive results of MP polymerase chain reaction (PCR) tests of nasopharyngeal secretions were used to diagnose MP infection (16). The diagnosis of bacterial infections was based the positive results from a sputum culture or/and bronchoalveolar lavage fluid (BALF) (17). A chest computed tomography (CT) scan was performed before or during hospitalization and chest radiography was reviewed during follow-up. Two experienced radiologists who were blind to the patients' identities independently assessed the atelectasis area twice, and a reduction in the area of atelectasis of more than 50% was regarded as effective pulmonary recruitment (18).

BAL procedure

Sedation with midazolam (0.1–0.15 mg/kg) is administered 5–10 minutes prior to bronchoscopy. The choice of fiberoptic bronchoscope is determined based on the child's age. Following the passage of the bronchoscope through the vocal cords, lidocaine is sprayed for local anesthesia. The bronchoscope is then advanced to the lesion site while maintaining an anesthetic effect. Sterile saline at 37 ℃ is irrigated at a dose of 0.5–1.0 mL/kg/dose, followed by suction. Lidocaine application is employed to ensure local anesthesia and minimize discomfort during the procedure.

Propensity score matching (PSM) analysis

We performed a propensity score-matching analysis to reduce the imbalance in baseline variables between patients with and without BAL. A one-to-one nearest neighbor caliper matching method was applied, with a caliper width set at 0.2 times the standard deviation of the logit of the propensity score. The matched groups were balanced for key baseline characteristics, including age, gender, days of fever and antibiotic use prior to admission, lung rales, reduced breath sounds, pleural effusion, involvement of multiple lung lobes, presence of complications, and hypoxemia. Logistic regression was used to estimate the propensity scores and facilitate the matching process.

Statistical analysis

The software SPSS 26.0 (IBM, Chicago, USA) was used to conduct the statistical analysis.

Normality tests were conducted for continuous variables. For normally distributed data, values were expressed as mean ± standard deviation and compared using *t*-tests. For non-normally distributed data, values were presented as median [interquartile range (IQR)] and compared using Mann-Whitney tests. Categorical variables were expressed as frequency (percentage, %) and compared using Chi-squared tests. To get rid of potential confounding factors, the BAL group was matched to the non-BAL group using a PSM analysis. $P < 0.05$ was considered statistically significant.

Results

Clinical characteristics before PSM

A total of 185 patients diagnosed with pneumonia complicated with atelectasis were enrolled in the study. There were 87 boys and 98 girls in the group, with a median age of 4.7 years. All patients had a fever, the average fever duration was 8.0 (IQR, 6.0–12.0) days, the incidence of hypoxemia was 20.5%, the proportion of multiple lung lobes involvement was 4.9%, and the ratio of complications was 18.4%. Among these patients, 146 patients had received BAL treatment, while 39 patients not. Yet there was no statistically significant difference in the gender distribution (P=0.81), but the BAL group's children are older than the non-BAL group's children (P=0.003). *Table 1* demonstrates that compared to the non-BAL group, children in the BAL group had a longer duration of fever before being admitted (P=0.003), a higher percentage of hypoxemia (P=0.03) and lower breath sounds (P=0.04). There was no statistical difference in the occurrence of pleural effusion and lung rales (P=0.07, P=0.73) between the two groups. As for laboratory indicators, the neutrophil ratio and lactate

Table 1 Demographic and clinical characteristics of patients between BAL group and non-BAL group before PSM

Characteristics	Total (n=185)	BAL (n=146)	Non-BAL (n=39)	P value*
Age, years	4.7 (3.2–7.2)	6.3 (4.4–7.8)	4.8 (0.8–7.2)	0.003
Sex				0.81
Male	87	68	19	
Female	98	78	20	
Duration of hospital stay, day	7.0 (5.0–9.0)	8.0 (6.0–10.3)	7.0 (5.0–9.0)	0.11
Duration of fever, day				
Before admission	5.0 (4.0–8.3)	7.0 (5.0–10.0)	5.0 (1.0–8.0)	0.003
After admission	2.0 (0.0–4.0)	3.0 (1.0–5.0)	2.0 (0.0–3.0)	0.02
Total	8.0 (6.0–12.0)	11.0 (8.0–13.0)	7.0 (2.8–11.3)	<0.001
Lung rales	90 (48.6)	72 (49.3)	18 (46.2)	0.73
Reduced breath sounds	64 (34.6)	56 (38.4)	8 (20.5)	0.04
Pleural effusion	95 (51.4)	80 (54.8)	15 (38.5)	0.07
Hypoxemia	38 (20.5)	25 (17.1)	13 (33.3)	0.03
Multiple lung lobes	9 (4.9)	5 (3.4)	4 (10.3)	0.08
Complication	34 (18.4)	28 (19.2)	6 (15.4)	0.59
WBC, $\times10^9$/L	7.38 (5.72–10.54)	7.40 (5.83–9.68)	7.74 (5.40–11.54)	0.58
Neutrophils, %	59.4 (46.2–68.8)	66.9 (55.1–73.8)	54.6 (39.0–63.0)	<0.001
CRP, mg/L	11.2 (2.6–38.2)	12.0 (3.4–41.9)	12.6 (3.2–38.2)	0.82
PCT, ng/mL	0.136 (0.072–0.289)	0.134 (0.072–0.301)	0.139 (0.070–0.269)	0.94
LDH, U/L	386 (297–524)	476 (346–681)	352 (282–452)	<0.001
ESR, mm/h	28.0 (16.5–42.5)	28.0 (20.0–41.0)	31.5 (14.5–49.3)	0.78
Cytokine, ng/L				
IL-2	1.3 (1.1–2.0)	1.4 (1.1–2.1)	1.3 (1.1–1.9)	0.60
IL-4	1.7 (1.4–2.3)	1.9 (1.5–2.4)	1.9 (1.5–2.4)	>0.99
IL-6	26.2 (11.7–89.5)	35.8 (15.1–87.9)	26.2 (12.2–65.5)	0.36
IL-10	7.5 (5.4–11.2)	7.9 (5.8–10.5)	7.5 (5.1–11.26)	0.68
TNF	2.3 (1.5–3.7)	2.1 (1.5–3.5)	2.3 (1.5–3.0)	0.80
IFN	5.4 (3.1–14.0)	6.7 (2.9–17.6)	4.6 (3.8–10.6)	0.47
Antibiotic use, days				
Before admission	4.0 (2.0–6.0)	5.0 (3.0–8.0)	4.0 (1.0–6.0)	0.002
After admission	6.0 (4.0–9.0)	7.0 (5.0–9.0)	7.0 (4.0–9.0)	0.94
Total	10.0 (7.8–14.0)	12.0 (9.8–16.0)	11.0 (8.0–14.0)	0.02

Data are presented as median (IQR), n and n (%). *, comparison between BAL group and non-BAL group. BAL, bronchoalveolar lavage; CRP, C-reactive protein; ESR, erythrocyte sedimentation rate; IFN, interferon; IL, interleukin; IQR, interquartile range; LDH, lactate dehydrogenase; PCT, procalcitonin; PSM, propensity score matching; TNF, tumor necrosis factor; WBC, white blood cell.

dehydrogenase (LDH) values were comparatively higher in the BAL group, whereas cytokine levels were similar to those in the non-BAL group.

Clinical characteristics after PSM

We assembled PSM pairs of patients to reduce the gap in measured covariates between the two groups. As shown in *Table 2*, after PSM, 70 cases were analyzed in this study, and the baseline characteristics did not differ between patients treated with BAL and matched controls, proving proper matching quality. We also compared the auxiliary examination results after PSM between the two groups. The analysis revealed no significant differences in inflammatory

Table 2 Patient characteristics in the propensity score-matching sample

Characteristics	BAL (n=35)	Non-BAL (n=35)	P value
Age, years	4.4 (3.2–6.8)	4.9 (3.0–7.3)	0.80
Sex			0.34
Male	19	15	
Female	16	20	
Duration of fever before admission, day	5.0 (3.0–9.0)	5.0 (4.0–8.0)	0.90
Lung rales	11 (31.4)	14 (40.0)	0.45
Reduced breath sounds	9 (25.7)	8 (22.9)	0.78
Pleural effusion	11 (31.4)	15 (42.9)	0.32
Multiple lung lobes	4 (11.4)	4 (11.4)	>0.99
Complication	5 (14.3)	6 (17.1)	0.74
Hypoxemia	11 (31.4)	10 (28.6)	0.79
Antibiotic use before admission, day	4.0 (2.0–6.0)	4.0 (1.0–6.0)	0.49
MP/bacteria	26/9	25/10	0.79

Data are presented as median (IQR), n and n (%). BAL, bronchoalveolar lavage; IQR, interquartile range; MP, *Mycoplasma pneumoniae*.

Table 3 Auxiliary examination results of patients between BAL group and non-BAL group after PSM

Laboratory Indexes	BAL (n=35)	Non-BAL (n=35)	P value
WBC, $\times 10^9$/L	7.27 (5.85–9.28)	7.47 (5.33–11.27)	0.90
Neutrophils, %	62.40 (47.90–71.30)	54.70 (40.90–63.80)	0.23
CRP, mg/L	7.19 (1.80–22.35)	16.27 (4.62–39.74)	0.15
PCT, ng/mL	0.141 (0.071–0.268)	0.113 (0.065–0.249)	0.55
LDH, U/L	444 (314–612)	377 (282–465)	0.20
ESR, mm/h	26.5 (16.5–41.5)	32 (16.0–49.5)	0.65
Cytokine, ng/L			
IL-2	1.3 (1.1–2.2)	1.3 (1.1–1.9)	0.50
IL-4	1.7 (1.4–2.2)	1.90 (1.5–2.3)	0.50
IL-6	27.8 (11.0–228.6)	24.6 (12.1–67.1)	0.75
IL-10	7.8 (5.7–11.8)	7.4 (5.1–10.9)	0.64
TNF	2.3 (1.5–4.1)	2.3 (1.4–3.2)	0.57
IFN	6.4 (1.9–15.8)	4.5 (3.8–10.9)	0.86

Data are presented as median (IQR). BAL, bronchoalveolar lavage; CRP, C-reactive protein; ESR, erythrocyte sedimentation rate; IFN, interferon; IL, interleukin; LDH, lactate dehydrogenase; PCT, procalcitonin; PSM, propensity score matching; TNF, tumor necrosis factor; WBC, white blood cell.

markers, including white blood cell (WBC) count (P=0.90), CRP level (P=0.15), PCT level (P=0.55), IL-2 (P=0.50), IL-4 (P=0.50), IL-6 (P=0.75), IL-10 (P=0.64), TNF (P=0.57), and IFN (P=0.86). None of these values indicated statistically significant differences between the groups (*Table 3*).

The effect of BAL

In order to compare the impact of BAL on patients, we evaluated the outcomes of patients between two groups, including the hospital days, antibiotic use time, CRP

Table 4 Clinical symptoms of patients between BAL group and non-BAL group after PSM

Clinical data	BAL (n=35)	Non-BAL (n=35)	P value
Duration of hospital stay, days	7.0 (5.0–9.0)	7.0 (5.0–9.0)	0.70
Total antibiotic use, days	10.0 (7.0–14.0)	10.0 (8.00–14.0)	0.64
Combining use of antibiotics	16 (45.7)	14 (40.0)	0.63
Total duration of fever, days	9.00 (6.0–12.0)	8.0 (5.75–12.00)	0.49
CRP recovery days	3.00 (0.00–4.00)	4.00 (2.00–4.00)	0.49
Pleural effusion absorption rate	2/2 (100.0)	4/6 (66.7)	0.35
Lung recruitment at discharge	23/31 (74.2)	14/32 (43.8)	0.01

Data are presented as median (IQR) or n (%). BAL, bronchoalveolar lavage; CRP, C-reactive protein; PSM, propensity score matching.

recovery time, pleural effusion absorption time. As can be seen in *Table 4*, the median hospital days and the median antibiotic use days were 7.0 (IQR, 5.0–9.0) days and 10.0 (IQR, 7.0–14.0) days in BAL group; while the median hospital days and the median antibiotic use days were 7.0 (IQR, 5.0–9.0) days and 10.0 (IQR, 8.0–14.0) days in non-BAL group (P=0.70, P=0.64). Interestingly, there was a higher rate of lung recruitment at discharge in BAL group than in non-BAL group (P=0.01).

Pathogens

Based on previous studies on MPP (8,19), we wanted to explore whether different pathogens would affect the role of BAL on lung recruitment. Consequently, we divided the matched patients into MPP and bacterial pneumonia groups. There were 51 MPP patients and 19 bacterial pneumonia (7 cases of S*treptococcus pneumoniae*, 4 cases of *Haemophilus influenza*, 4 cases of *Staphylococcus aureus*, 2 cases of *Moraxella catarrhalis*, 1 case of *Pseudomonas aeruginosa*, and 1 case of *Escherichia coli*) patients among the 70 cases. The median age of patients in MPP group was 5.0 (IQR, 3.9–7.3) years old, while the median age of patients in bacterial pneumonia group was 2.3 (IQR, 0.5–5.7) years old, which showed significant difference (P=0.003). Among MPP patients, 26 cases were in the BAL group, 25 cases in the non-BAL group. In bacterial pneumonia patients, 9 cases were in the BAL group, and 10 cases were in the non-BAL group.

Between different pathogens, we compared the hospital stay, antibiotic use days and proportion of combination, fever days, CRP recovery days, pleural effusion absorption time, and chest imaging manifestations. We found that in the MPP group, patients treated with BAL had a slightly quicker recovery of CRP than those who did not receive treatment (P=0.02). Meanwhile, we also demonstrated that in the MPP group, the proportion of effective lung recruitment was higher in the BAL group than in the non-BAL group (P=0.002). Nevertheless, in the bacterial pneumonia group, there were no statistically significant differences in the outcomes between BAL and non-BAL groups (P=0.50) (as shown in *Table 5*).

Discussion

In this study, we analyzed the clinical characteristics of patients with atelectasis and compared the clinical data of those who underwent BAL with those who did not. PSM and pathogen classification were performed to minimize bias. Our findings indicate that BAL was effective in improving outcomes in patients with MPP, but did not show significant improvement in cases of bacterial pneumonia.

Due to the relative smaller size of the airway, PA is more common in children than adults (20). In children, atelectasis can significantly affect respiratory function by reducing lung compliance, leading to hypoxemia and increased work of breathing (21). In severe cases, patients may experience dyspnea, pleural effusion, and multiple lung lobes damage (4). Among the patients enrolled in our study, all presented with fever, and the incidence of hypoxemia, pleural effusion, and multi-lobe involvement were 20.5%, 51.4%, and 4.9%, respectively. The pathogenesis of pneumonia, particularly when complicated by atelectasis, remains unclear, but is primarily thought to involve direct lung injury and immune damage (22,23). The persistence of atelectasis is influenced by changes in

Table 5 Clinical symptoms of patients in MP group and bacteria group after PSM

Prognosis	MPP (n=51)			Bacteria pneumonia (n=19)		
	BAL (n=26)	Non-BAL (n=25)	P value	BAL (n=9)	Non-BAL (n=10)	P value
Duration of hospital stay, days	6.5 (5.0–8.3)	6.0 (4.5–7.5)	0.61	6.5 (5.0–8.3)	7.0 (6.0–10.5)	0.84
Total antibiotic use, days	9.5 (6.0–12.3)	10.0 (7.0–13.5)	0.86	10.0 (6.5–12.5)	8.0 (6.8–12.0)	0.72
Combining use of antibiotics	13/26	10/25	0.47	3/9	4/10	0.57
Total duration of fever, days	10.5 (7.8–14.5)	11.0 (8.0–14.5)	0.52	9.0 (2.0–12.0)	2.0 (0.0–6.0)	0.06
CRP recovery days	3.0 (3.0–4.0)	4.0 (3.0–4.0)	0.02	1.0 (0.0–8.8)	0.0 (0.0–4.0)	0.80
Pleural effusion absorption	2/2	4/6	0.35	NA	NA	NA
Lung recruitment at discharge	20/25	8/23	0.002	3/6	6/9	0.46

Data are presented as median (IQR) or n. CRP, C-reactive protein; PSM, propensity score matching; BAL, bronchoalveolar lavage; MPP, *Mycoplasma pneumoniae* pneumonia; MP, *Mycoplasma pneumoniae*; NA, not applicable.

lung compliance, impaired regional ventilation, and the accumulation of secretions (24). Long-term atelectasis can result in complications such as recurrent infections, bronchiectasis, bronchiolitis obliterans, and even lung necrosis (4). In severe cases, lobectomy is even required, posing a great threat to children's health.

The aim of treating atelectasis is to restore the lost lung volume. This re-expansion helps increase the regional functional residual capacity, reduces the intrapulmonary shunt, and enhances ventilation/perfusion (V/Q) matching, gas exchange, and overall lung mechanics (2,25). BAL has been widely implemented in cases of acute PA recently (26) and can help achieve microbiological diagnosis in infectious respiratory conditions, which allows antimicrobial treatment to be optimized (27). But at the same time, as an invasive examination, BAL may also bring adverse reactions to patients. In general, the use of BAL in children with infectious PA is still controversial, and the majority of previous studies on PA have focused on postoperative PA (28,29). We found that patients in the BAL group had a longer duration of fever, a higher incidence of hypoxemia, a longer antibiotic treatment duration, a higher neutrophil ratio, and elevated LDH levels. These findings suggest that the overall clinical condition of patients in the BAL group was more severe compared to those in the non-BAL group, which likely contributed to the increased frequency of BAL procedures. Therefore, in our retrospective study, PSM was employed to control for confounding factors, allowing us to explore these issues from the perspective of different underlying etiologies. However, after PSM and comparing the length of hospital stay, duration of fever, CRP recovery time, and other clinical parameters between the BAL and non-BAL groups, no significant differences were found. This prompted us to explore potential underlying reasons for these findings.

In a study of PA caused by MP, it was shown that BAL can directly remove the secretions to improve lung ventilation and clear various inflammatory factors (30). In our previous study, we also found BAL could ameliorate clinical symptoms, radiological as well as laboratory abnormalities rapidly in MPP with large pulmonary lesions (8). However, another study pointed out that PA was a common complication of respiratory infection in children, and could be self-absorbing after antimicrobial therapy (24). Marini *et al.* (14) showed that BAL is not required for the reversal of acute lobar collapse in most cases, and several patients might experience a striking deterioration in gas exchange after BAL. Since studies on the effectiveness of BAL in the treatment of PA have mostly focused on MPP, and there is still a controversy about BAL for the therapy of PA, we speculated that the necessity of BAL might be associated with different pathogens leading to respiratory infection. Thus, patients were divided into MPP subgroup and bacterial pneumonia subgroup in this study, and the effect of BAL on PA caused by different pathogens was evaluated.

In our study, we found that in the MPP subgroup, CRP recovery was marginally faster in patients treated with BAL than in untreated individuals. Furthermore, we demonstrated that the proportion of effective lung recruitment in the BAL group was higher than in the non-BAL group. Interestingly, another study also found that at 4 weeks after BAL, merely 15 children failed to

lung recruitment, and the partial or complete rate of lung recruitment reached as high as 85.29% (4). These results are to some extent consistent with our findings that BAL is effective in MPP patients with PA. On the contrary, our data demonstrated that there was no significant difference in the efficiency of lung recruitment with or without BAL in bacterial pneumonia patients with PA, implying that the implementation of BAL was not necessary for PA caused by bacterial infection and that adequate antibiotic therapy might be sufficient. Bacterial pneumonia is primarily caused by an excessive inflammatory response triggered by the pathogen, with inflammation mediating further lung injury and functional impairment. Therefore, the primary treatment goal for bacterial pneumonia is to control inflammation through the use of antibiotics (31).

The retrospective design and relatively small sample sizes are the limitations to the current study, so further clinical studies are still required to assess the importance of our findings. And the clinical follow-up in our study was short, and it is necessary to observe the long-term prognosis. Another limitation of this study is the use of chest X-rays for assessing atelectasis resolution, which may not provide the most precise evaluation of volume reduction. While X-rays are a useful clinical tool, they may be less sensitive to subtle changes compared to more advanced imaging methods such as CT scans. Furthermore, our study only focused on children with a single pathogenic infection, but many children would have concurrent infection with two or more pathogens, which might cause some confusion about whether to apply BAL.

Conclusions

In conclusion, pneumonia complicated with PA is a common disease in children. Our findings demonstrated that BAL was effective in PA patients caused by MP infection, which could increase the incidence of lung recruitment and shorten the CRP recovery time. However, in the PA patients caused by bacterial infection, BAL seemed to be not necessary. These findings might help physicians to have deeper insights into PA and provide proper treatment for PA caused by different pathogens.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://tp.amegroups.com/article/view/10.21037/tp-2024-593/rc

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the ethics committee board of Children's Hospital (No. 2024-IRB-0166) and informed consent was taken from all the patients.

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