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Research on Risk Prediction Model for Multiple Bronchoalveolar Lavage in Children with Mycoplasma Pneumoniae Pneumonia

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Abstract: *Objective*: To study the risk prediction model for multiple bronchoalveolar lavage in children with mycoplasma pneumoniae pneumonia (MPP). *Methods*: 151 pediatric patients with MPP admitted in our hospital from July to December 2023 were selected, the incidence rate of multiple bronchoalveolar lavage was recorded. A logistic multivariate regression model was employed to analyze relevant factors and construct a risk prediction model for multiple bronchoalveolar lavage in children with MPP. *Results*: Among 151 children with MPP, 64 cases underwent multiple bronchoalveolar lavage, accounting for 42.38%. The Logistic multivariate model analysis revealed that the pleural effusion, sepsis, and abnormally elevated serum levels of LDH and D-D were independent influence factors for multiple bronchoalveolar lavage in children with MPP ($p < 0.05$), based on this, a Nomogram prediction model can be established. The *ROC* analysis results showed that the *AUC* of the model to judge the multiple bronchoalveolar lavage in MPP patients was 0.828 (*SE* = 0.035, *95% CI* = 0.760–0.896, $p < 0.001$), the sensitivity was 0.813 and the specificity was 0.759. *Conclusion*: The multiple bronchoscopic bronchoalveolar lavage in MPP patients are associated with the levels of LDH and D-D, as well as the presence of pleural effusion and sepsis complications, the risk prediction model established, which based on this has high accuracy.

Keywords: Mycoplasma pneumoniae pneumonia; Bronchoalveolar lavage; Risk prediction model

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1. Introduction

Mycoplasma pneumoniae pneumonia (MPP) is a common respiratory disease in children, which can cause fever and chest pain. In severe cases, it can lead to respiratory failure and even endanger the life of affected children. Antibiotics are the primary treatment method for MPP. However, with the widespread clinical application of antibiotics, the issue of drug resistance caused by antibiotic abuse has gradually become prominent, reducing their therapeutic effectiveness [1]. Bronchoscopic alveolar lavage refers to the procedure of injecting sterile saline into the bronchial alveoli under the guidance of a bronchoscope and then aspirating the lavage fluid to remove foreign bodies from the airways, thereby achieving therapeutic purposes. Recent studies have shown that bronchoscopic

alveolar lavage has minimally invasive characteristics and can directly obtain specimens from respiratory tract lesions, enabling precise diagnosis and treatment of MPP [2]. However, with the widespread clinical application, studies have revealed that multiple bronchoscopic alveolar lavages in children can damage the airways and may also cause glottic edema and bronchial spasm, affecting the prognosis of affected children [3]. Therefore, clinical practice should avoid multiple bronchoscopic alveolar lavages as much as possible. This study constructed a risk prediction model for multiple bronchoscopic alveolar lavages through retrospective analysis to guide early clinical intervention. The report is as follows.

2. Materials and methods

2.1. General information

A total of 151 children with Mycoplasma pneumoniae pneumonia (MPP) admitted to our hospital from July to December 2023 were selected as the study subjects. This study was approved by the hospital's ethics committee.

2.1.1. Inclusion criteria

(1) All children were confirmed to have MPP through respiratory pathogen detection, aged between 1 and 12 years, with complete clinical data [4]
(2) All received standardized diagnosis and treatment in our hospital
(3) Guardians of the children were informed and consented to the study content

2.1.2. Exclusion criteria

(1) Children with mixed infections
(2) Children with comorbid conditions such as complement deficiency diseases, nephrotic syndrome, leukemia, or severe malnutrition
(3) Children currently taking immunosuppressants
(4) Children with comorbid psychiatric conditions such as depression or autism. Based on whether they received multiple bronchoscopic alveolar lavages, the children were divided into an observation group (receiving multiple bronchoscopic alveolar lavage treatments, n = 64) and a control group (not receiving multiple bronchoscopic alveolar lavages, n = 87)

2.2. Treatment methods

A 2% lidocaine aerosol inhalation was used for local anesthesia of the throat. After the anesthesia took effect, a fiberoptic bronchoscope (Shanghai Outai Medical Equipment Co., Ltd., Shanghai Medical Device Registration Number 20192060363, Model: OIF-BC66P) was used to perform alveolar lavage. The bronchoscope was inserted through the nasal cavity into the trachea, and the child's vital signs were monitored. Sterile tubes were used to aspirate bronchial secretions, and a portion of the secretions was subjected to drug sensitivity testing. Alveolar lavage was performed using 0.9% saline at 37°C, with repeated lavage of the lesion 2–3 times, 10–20 mL per time. After the lavage fluid became clear, 2 mg of budesonide suspension was injected through the bronchoscope, and the bronchoscope was then removed. The treatment was administered once daily for a continuous week.

2.3. Observation indicators

Clinical characteristics and laboratory parameters of children with MPP were collected. Clinical characteristics included gender, age, disease duration, lesion location, duration of fever, blood oxygen saturation (SpO_2), and pleural effusion status. Laboratory parameters included C-reactive protein (CRP), hemoglobin (Hb), serum albumin (Alb), D-dimer (D-D), lactate dehydrogenase (LDH), and erythrocyte sedimentation rate (ESR) levels. Within 3 days of admission, 3.0 mL of blood was drawn from the median cubital vein of the children. After routine centrifugation, the serum was retained. A fully automated biochemical analyzer (Shanghai Kehua Experimental Systems Co., Ltd., Shanghai Medical Device Registration Number 20172220195, Model: Excellence 300) was used to detect serum CRP and Alb levels. Serum D-D and LDH levels were detected using immune turbidimetric assay and rate assay, respectively. Plasma fibrinogen (Fib) was measured by immune turbidimetry. A fully automated blood cell analyzer (Shenzhen DiMai Biotechnology Co., Ltd., Guangdong Medical Device Registration Number 20172220016, Model: DH73CRP) was used to detect whole blood Hb levels, and the Westergren method was used to detect whole blood ESR levels.

2.4. Statistical methods

The SPSS 24.0 software package was selected for statistical analysis of data related to the clinical characteristics of the patients. Measurement data were described using (mean ± standard deviation), and count data were described using [n (%)]. *t*-tests or chi-square tests were conducted accordingly. Logistic multivariate regression models were used to analyze relevant factors. Predictive models were drawn using R language, and the predictive value was analyzed using the Receiver Operating Characteristic (ROC) curve, with the results expressed as the area under the curve (AUC). A *p*-value less than 0.05 was considered statistically significant.

3. Results

3.1. Comparison of clinical features and laboratory indicators among different patients

Among the 151 children with MPP, 64 underwent multiple bronchoscopic alveolar lavage procedures, accounting for 42.38%, and were designated as the observation group, while the remaining 87 cases were the control group. Statistically significant differences were observed between the two groups in the incidence of pleural effusion, sepsis, and heart failure ($p < 0.05$). Similarly, significant differences were found in age, albumin (Alb), lactate dehydrogenase (LDH), erythrocyte sedimentation rate (ESR), D-dimer (D-D), and neutrophil-to-lymphocyte ratio (NLR) levels between the two groups ($p < 0.05$), as shown in **Table 1**.

Table 1. Comparison of clinical features and laboratory parameters among different patients

Indicator		Observation group (n = 64)	Control group (n = 87)	Statistical value (t/χ^2)	*p*-value
Gender	Male	36 (56.25)	39 (44.83)	1.924	0.165
	Female	28 (43.75)	48 (55.17)		
Age (years)		6.96 ± 2.34	6.45 ± 2.52	2.959	0.003
BMI (kg/m^2)		16.57 ± 2.28	16.20 ± 2.34	0.971	0.333
Lesion location	Right side	25 (39.06)	37 (42.53)	3.344	0.188
	Left side	21 (32.81)	36 (41.38)		
	Bilateral	18 (28.13)	14 (16.09)		

Table 1 (Continued)

Indicator		Observation group (n = 64)	Control group (n = 87)	Statistical value (t/χ^2)	*p*-value
Pleural effusion	Present	38 (59.38)	20 (22.99)	20.637	< 0.001
	Absent	26 (40.63)	67 (77.01)		
Extrapulmonary complications	Sepsis	34 (53.13)	18 (20.69)	17.182	< 0.001
	Heart failure	30 (46.88)	12 (13.79)	20.099	< 0.001
CRP (mg/L)		12.22 ± 12.53	15.71 ± 22.22	-1.131	0.260
Hb (g/L)		110.53 ± 6.82	111.89 ± 8.57	-1.044	0.298
Alb (g/L)		38.75 ± 3.90	40.67 ± 3.77	-3.042	0.003
LDH (U/L)		349.30 ± 110.52	306.98 ± 83.70	2.678	0.008
ESR (mm/h)		30.09 ± 3.96	25.87 ± 3.86	6.567	< 0.001
D-D (mg/L)		0.39 ± 0.93	0.18 ± 0.10	2.034	0.044
Fib (g/L)		3.59 ± 0.57	3.40 ± 0.46	2.193	0.030
NLR		2.25 ± 0.55	1.49 ± 0.43	9.497	< 0.001

3.2. Factors associated with multiple bronchoscopic alveolar lavage procedures in children with MPP

Factors potentially influencing multiple bronchoscopic alveolar lavage treatments in children with MPP were assigned values, as shown in **Table 2**. These assigned factors were treated as independent variables, and whether the children underwent multiple bronchoscopic alveolar lavage treatments was considered the dependent variable. Logistic multivariate regression model analysis revealed that pleural effusion, sepsis, LDH, and D-D levels were independent influencing factors for multiple bronchoscopic alveolar lavage procedures in children with MPP ($p < 0.05$), as shown in **Table 3**.

Table 2. Assignment of factors associated with multiple bronchoscopic alveolar lavage procedures in children with MPP

Indicator		Assignment status
Pleural effusion	X1	Yes = 1, No = 0
Sepsis	X2	Yes = 1, No = 0
Heart failure	X3	Yes = 1, No = 0
Age (X4), Alb (X5), LDH (X6), ESR (X7), D-D (X8), and NLR (X9) are included with their original values.		

Table 3. Analysis results of factors associated with multiple bronchoscopic alveolar lavage procedures in children with MPP

Indicator	β	SE	Wald χ^2	*p*-value	OR	95% CI
Pleural effusion	1.031	0.343	9.041	0.003	2.805	1.432–5.494
Sepsis	1.340	0.278	23.169	< 0.001	3.819	2.213–6.590
Heart failure	1.721	0.984	3.061	0.080	5.591	0.813–38.449

Table 3 (Continued)

Indicator	β	SE	Wald χ^2	*p*-value	OR	95% CI
Age	1.337	1.004	1.773	0.183	3.806	0.532–27.229
Albumin (Alb)	-0.218	0.496	0.193	0.660	0.804	0.304–2.126
LDH	0.910	0.413	4.858	0.028	2.484	1.106–5.579
ESR	1.166	0.874	1.781	0.182	3.209	0.579–17.785
D-dimer (D-D)	1.253	0.436	8.252	0.005	3.501	1.489–8.232
NLR	1.584	0.869	3.320	0.068	4.875	0.887–26.793

3.3. Predictive model for multiple bronchoscopic alveolar lavage procedures in children with MPP

Based on the results of multivariate analysis, pleural effusion, sepsis, LDH, and D-D were included in the R software analysis to construct a Nomogram predictive model, and calibration curves were plotted, as shown in **Figure 1** and **2**. The mean absolute error between the predicted probability and the actual probability was 0.001. DCA was also plotted, as shown in **Figure 3**, indicating that the threshold probability for multiple bronchoscopic alveolar lavage procedures in children with MPP ranged from 10% to 92%, and the model could achieve a high clinical net benefit. The patient scores were calculated based on the predictive model and used as the test variable, while whether the patient underwent multiple bronchoscopic alveolar lavage procedures was used as the state variable to plot the ROC curve. The results showed an AUC of 0.828 (SE = 0.035, 95% CI = 0.760–0.896, $p < 0.001$), with a sensitivity of 0.813 and a specificity of 0.759, as shown in **Figure 4**.

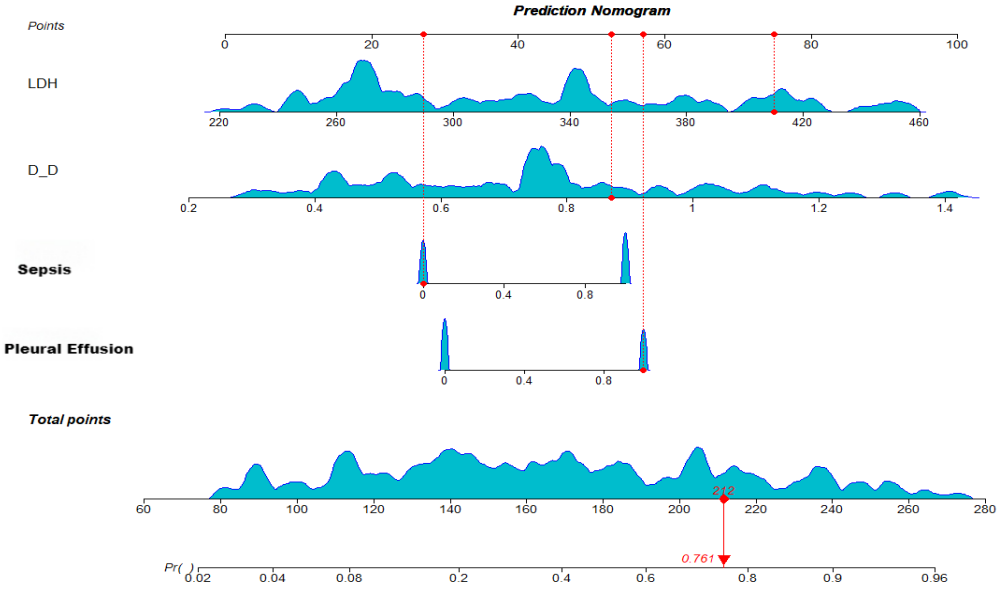

Figure 1. Nomogram predictive model for multiple bronchoscopic alveolar lavage procedures in children with MPP.

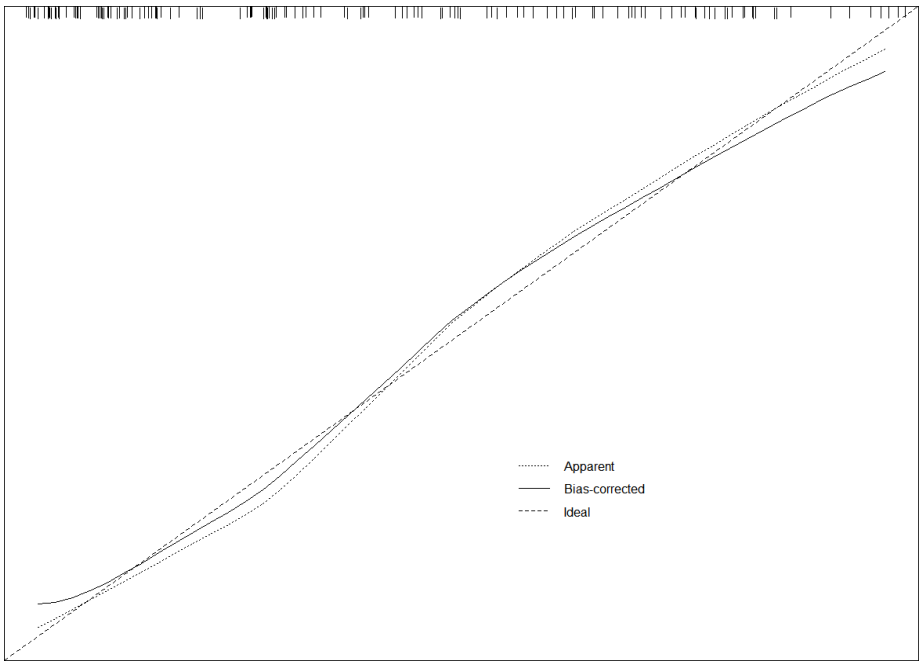

Figure 2. Calibration curve of the predictive model for judging multiple bronchoscopic alveolar lavage procedures in children with MPP.

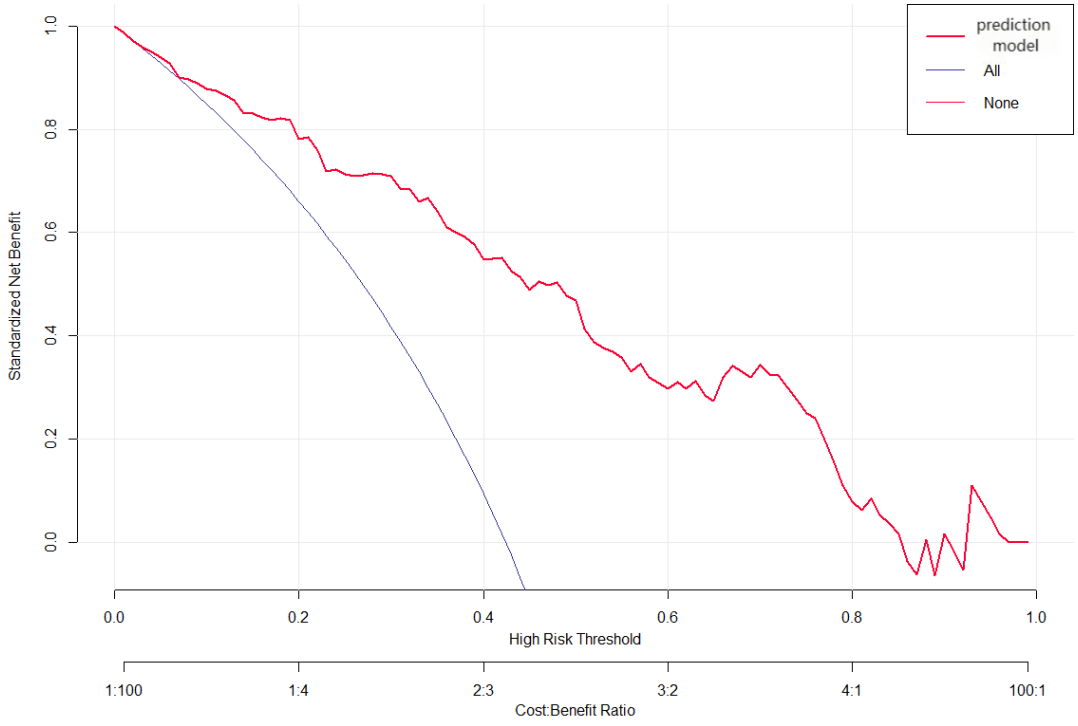

Figure 3. DCA analysis of the predictive model.

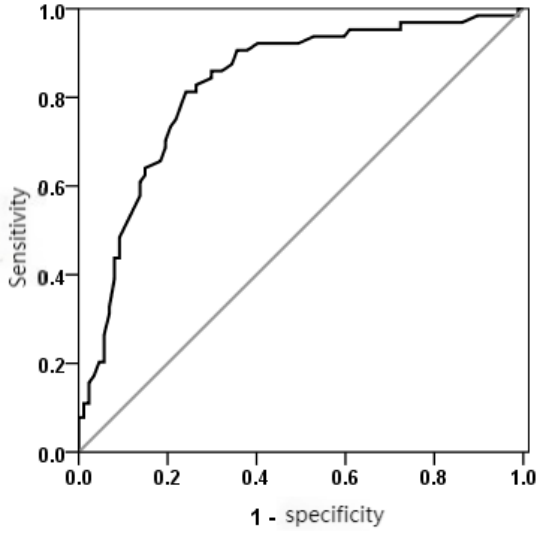

Figure 4. ROC analysis of the predictive model for determining the need for multiple bronchoscopic alveolar lavage procedures in children with MPP.

4. Discussion

Mycoplasma pneumoniae pneumonia (MPP) predominantly affects children. For those with severe or refractory MPP, bronchoscopic alveolar lavage can directly remove airway mucus plugs, reduce inflammatory mediators, relieve airway obstruction, alleviate clinical symptoms, and suppress inflammatory responses [5]. However, repeated bronchoscopic procedures can increase the risk of airway injury, leading to mucosal congestion and edema. In some children, it may even induce airway stenosis and fibrosis, resulting in permanent damage and affecting long-term prognosis [6]. Early identification of children requiring multiple bronchoscopic alveolar lavage procedures can guide clinical intervention, minimize injury, and improve prognosis.

This study revealed that pleural effusion is an independent risk factor for children with MPP requiring multiple bronchoscopic alveolar lavage procedures. This may be because the presence of pleural effusion indicates disease progression in children with MPP, with persistent inflammation leading to increased vascular permeability and fluid leakage into the pleural space [7]. Multiple bronchoscopic alveolar lavage procedures are thus necessary to accurately locate the lesion site and effectively flush out inflammatory exudates for precise treatment. Previous studies have also suggested that pleural effusion can compress lung tissue, obstructing the drainage of airway secretions [8]. Multiple bronchoalveolar lavages via bronchoscopy are beneficial in unblocking the bronchial lumen and facilitating the expulsion of secretions. Therefore, early identification of children with MPP complicated by pleural effusion plays a positive role in avoiding the need for multiple bronchoalveolar lavages.

This study also found that sepsis is a risk factor for multiple bronchoalveolar lavages in children with MPP. This may be because sepsis is a systemic inflammatory response syndrome, and the presence of sepsis in children with MPP often indicates a critical condition, with a large number of inflammatory secretions in the lungs and the accumulation of necrotic tissue in the bronchi and alveoli, thereby obstructing the airways [9,10]. In such cases, repeated bronchoalveolar lavages are often required to improve the airways and enhance oxygenation function. Additionally, the development of sepsis can affect the microcirculation in children with MPP, impair the alveolar-capillary barrier function, and lead to the accumulation of inflammatory secretions in the lungs, forming an

inflammatory storm [11]. Multiple bronchoalveolar lavages can suppress the secretion of inflammatory factors, promote gas exchange, and improve respiratory function in these children.

Furthermore, this study also revealed that lactate dehydrogenase (LDH) and D-dimer (D-D) are independent risk factors for multiple bronchoalveolar lavages in children with MPP. LDH is closely related to the severity of MPP, and elevated LDH levels can further exacerbate the inflammatory response, increasing the amount of necrotic material and fibrin exudate in the airways, making it difficult to completely clear with a single bronchoalveolar lavage [12]. Xie Youjun et al. also posited that an abnormal increase in LDH levels indicates that children with MPP are more prone to airway secretion obstruction, necessitating multiple bronchoscopic alveolar lavages to clear secretions and promote lung re-expansion [13]. D-D, as a fibrin degradation product, an elevated D-D level suggests that children with MPP are in a hypercoagulable state, which may be accompanied by vascular endothelial damage and widespread inflammatory responses. This can impair the barrier function between alveoli and blood vessels, allowing inflammatory exudate to infiltrate the alveolar space and even increasing the risk of pulmonary edema. Clinically, multiple bronchoscopic alveolar lavages are required to facilitate the drainage of inflammatory secretions, correct vascular and alveolar obstruction, improve blood oxygen function, and enhance prognosis.

This study constructed a predictive model based on the results of multivariate analysis, which also demonstrated that the model's AUC for predicting the risk of multiple bronchoscopic alveolar lavages in children with MPP reached 0.828, indicating high accuracy. Therefore, clinical monitoring of D-D and LDH levels, along with early prevention and treatment of sepsis and pleural effusion, can help avoid multiple bronchoscopic alveolar lavages. However, this study was a retrospective analysis with a limited sample size. Future research should expand the sample size and conduct multicenter studies to externally validate the model and provide more evidence for clinical promotion.

5. Conclusion

In summary, multiple bronchoscopic alveolar lavages in children with MPP are associated with their D-D and LDH levels, as well as the presence of sepsis and pleural effusion. The predictive model constructed based on these factors aids in determining the likelihood of multiple bronchoscopic alveolar lavages in children with MPP and is worthy of clinical promotion and validation.

Disclosure statement

The authors declare no conflict of interest.

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