ORIGINAL RESEARCH PAPERS

Modified lung ultrasound score and related findings in children with Mycoplasma pneumoniae pneumonia

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ABSTRACT

Background: Different pathogens cause pneumonia with overlapping symptoms, labs, and imaging, complicating early diagnosis. The modified lung ultrasound score (MLUS) shows value in lung disease evaluation, but its ability to differentiate pathogens is unclear. This study assessed MLUS for early identification of mycoplasma, viral, and bacterial pneumonia in children.

Methods: We enrolled 186 children with suspected pneumonia (Jan–Dec 2023). Clinical data, labs, lung ultrasound findings (A-lines, B-lines, solid lesions, pleural effusion), and pathogens were recorded. MLUS was assigned. Based on pathogens, cases were grouped into mycoplasma (n=74), viral (n=63), and bacterial (n=49) pneumonia for comparison.

Results: 1. The median age of the mycoplasma pneumonia group was 6 (4.58,8) years, greater than that of the bacterial pneumonia group (3 [1.1,4.83] years) and the viral pneumonia group (3.41 [1.16,4.75] years) ($P< 0.05$). The mycoplasma pneumonia group had more febrile symptoms, extensive solid lung lesions, and fewer asthmatic symptoms than the other two pathogen groups ($P < 0.05$). 2. The median MLUS for mycoplasma pneumonia group was 15 (10,22), significantly higher than the median score of 9 (5,16) in the bacterial pneumonia group and 8 (5,15) in the viral pneumonia group ($P < 0.05$). 3. Coughing up sputum and small lung solid changes were significantly more common in the mycoplasma pneumonia group than in the bacterial pneumonia group ($P < 0.05$).

Conclusions: A high modified lung ultrasound score, extensive solid lung lesions, older age, fever, and fewer shortness-of-breath symptoms strongly suggest mycoplasma pneumoniae infection. These findings provide critical evidence for early, targeted clinical management.

Key words: mycoplasma pneumonia, ultrasound, modified lung ultrasound score, children

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Background

Pneumonia is the most common lung infection in children. Respiratory syncytial virus, parainfluenza virus, rhinovirus, influenza virus, *Mycoplasma pneumoniae*, adenovirus, and *Streptococcus pneumoniae* are the most common pathogens (1). *Mycoplasma* pneumonia is an atypical pneumonia and an interstitial lung disease that can affect other organs through localized respiratory infections. Mycoplasma pneumoniae infection occurs in major epidemics every 3–5 years. Its positive rate was approximately 15% before the COVID-19 pandemic, declined sharply to 0.3% during the pandemic, and rebounded to 25% in 2023–2024, representing a marked increase in incidence. (2). Early-stage diagnosis remains challenging, which can affect prognosis and pose greater risks to life and health. However, early diagnosis and standardized treatment can improve prognosis and increase survival rates (3).

Pneumonias caused by different pathogens share overlapping clinical symptoms, laboratory findings, and imaging characteristics, including specific features seen in lung ultrasound. Some studies have shown that mycoplasma pneumonia presents with greater lung solidity than viral pneumonia, and bacterial pneumonia shows greater lung solidity than viral pneumonia (4,5). However, there are fewer reports on using ultrasonography to differentiate mycoplasma pneumonia from bacterial pneumonia. Lung ultrasound as a quantitative tool has become more common in recent years, with the lung ultrasound score (LUS) used to assess the severity and progression of lung diseases. However, reports on its application in differentiating mycoplasma pneumonia from other types are limited. (6) used a lung ultrasound duodecimal scoring system to analyze 30 cases of severe acute respiratory syndrome pneumonia caused by coronavirus type 2 versus 10 cases of bacterial pneumonia, with a lung ultrasound score of 10 used as a cutoff value to identify bacterial and viral pneumonia. Our team previously applied the modified lung ultrasound score (MLUS) to quantitatively assess disease changes and treatment effects of neonatal respiratory distress syndrome, achieving favorable results (7,8). While some studies have used chest CT to differentiate between COVID-19 pneumonia from mycoplasma pneumonia—noting that COVID-19 pneumonia foci are typically located on the peripheral dorsal side, while mycoplasma pneumonia foci are mostly distributed along the bronchi (9) —few studies have explored the use of MLUS to differentiate mycoplasma pneumonia from viral and bacterial pneumonia. In this study, we hypothesized that MLUS, with its quantitative scoring, could be useful in identifying mycoplasma pneumonia, viral pneumonia, and bacterial pneumonia.

Current ultrasound scoring methods, such as the six-zone, ten-zone, and twelve-zone methods, have improved the objectivity and clarity of disease assessment. These methods are widely used in clinical practice, offering guidance for diagnostic and therapeutic decisions. In this study, the MLUS was used to evaluate pneumonia in children using the fourteen-zone method, which increased the exploration of the bilateral lung bases compared to the twelve-zone method, enabling a more detailed evaluation of the overall condition of the lungs and refinement of solid lung lesion scoring. By comparing the MLUS, ultrasound signs, and related clinical manifestations in children with mycoplasma pneumonia, viral pneumonia, and bacterial pneumonia, this study can help physicians make faster, more accurate diagnoses. Therefore, this study aimed to use MLUS and related clinical and laboratory indices to identify mycoplasma pneumonia, viral pneumonia, and bacterial pneumonia at an early stage, promoting the broader application of MLUS in clinical settings.

Methods

Content of the study

Research target

This prospective study included 186 children admitted to our hospital between January 2023 and December 2023, who met the inclusion criteria and had a complete diagnosis and treatment course. Data on clinical presentation, laboratory tests, lung ultrasonography results, and pathogenetic findings were collected. Lung ultrasonography was performed within 24 hours

of admission. All participants enrolled in this study were hospitalized children. Compared with outpatient children, this population exhibited relatively more severe illnesses, more typical clinical manifestations, and represented a group with greater disease severity. Informed consent was obtained from all patients, and the study was approved by the Ethics Committee of our hospital [(2023) Lunar Review No. (102)].

Entry criteria

(1) The clinical diagnosis of pneumonia followed the "Diagnostic and Treatment Guidelines for Community-Acquired Pneumonia in Children (2019 Edition)"; (2) Pathogenic testing identified *Mycoplasma pneumoniae*-positive patients for the mycoplasma pneumonia group, virus-positive patients for the viral pneumonia group, and bacterial-positive patients for the bacterial pneumonia group. Diagnosis of mycoplasma pneumonia was confirmed through PCR testing pharyngeal swabs, sputum, or bronchoalveolar lavage fluid (for DNA/RNA detection) and serological testing for specific antibodies. Viral pneumonia was diagnosed through nucleic acid detection of respiratory viruses. Bacterial pneumonia was diagnosed based on positive blood or sputum cultures or bacterial cultures from bronchoalveolar lavage fluid; (3) All participants underwent lung ultrasonography; (4) The age range was from 29 days to less than 18 years old.

Exclusion criteria

Exclusion criteria included: (1) Pneumonia induced by the inhalation of a foreign body; (2) severe immunosuppression; (3) presence of complex congenital diseases; (4) presence of mixed infections with multiple pathogens; (5) special cases of severe obesity, subcutaneous emphysema, and thoracic deformities; and (6) extreme uncooperativeness during testing. (7) Patients with negative etiological test results.

Clinical information

General information

This included patient age, sex, clinical symptoms, laboratory findings, and pathogenetic findings.

Ultrasound information

Lung ultrasound signs of A-line, B-line, extensive lung solid lesions, small lung solid lesions, and pleural effusion were recorded for each child. A total of at least 14 static ultrasound images from the 14 lung zones were collected, and the MLUS score was documented for each patient.

Case selection process

The case selection process is shown in Figure 1.

Equipment and methods

Equipment

A GE Voluson E8 color Doppler ultrasound machine was used, equipped with an 11 MHZ line array probe and a 5 MHZ convex array probe. The depth was adjusted according to the size of the child and the thickness of the chest wall, with a fixed gain (60-70%) and a focal position at the level of the pleural line.

Sweeping methods

The child was positioned supine, lateral, prone, and sitting. The linear array probe was swept perpendicular to the intercostal space longitudinally and transversely, from top to bottom and right to left. The convex array probe was used to sweep the subcostal space along the rib margins. Each zone was swept one by one, and each region was scored based on the highest ultrasound score, including the presence of B-lines, small pulmonary solid lesion, large pulmonary solid lesion, and pleural effusion. Two sonographers with 5 years of experience in lung ultrasonography performed the examinations. In case of inconsistent results, a senior sonographer resolved the discrepancies.Lung ultrasound scoring was performed independently by two sonographers, and the intraclass correlation coefficient (ICC) was 0.836 (95% CI: 0.778–0.879, $P < 0.001$), indicating good inter-observer agreement.The sonographers were blinded to the clinical information of the pediatric patients and did not involve in any clinical care of the study subjects.

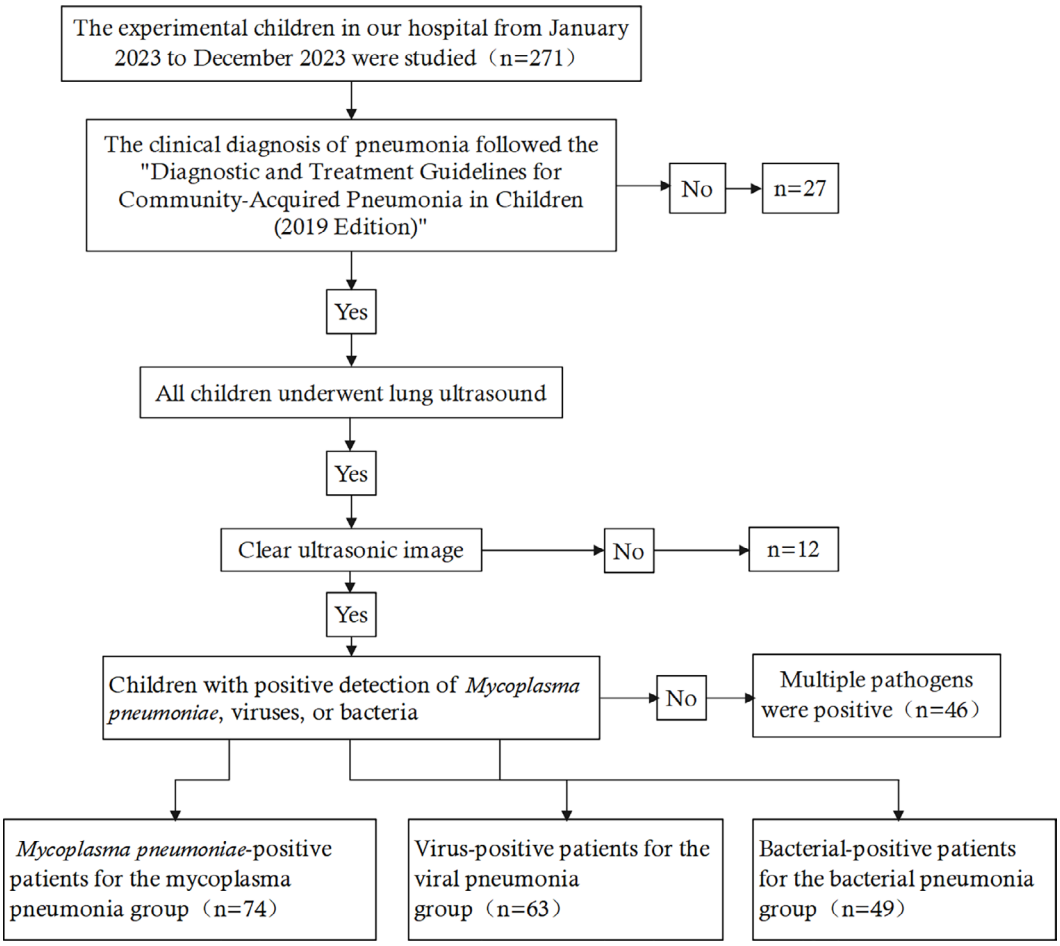

Figure 1. Flowchart of case selection.

The MLUS method was developed by our team using the fourteen-zone lung method, dividing the lungs into seven zones: anterosuperior, anterior-inferior, supra-axillary, axillary, axillary, postero-superior, posterosuperior-inferior, and the lung bases. This method covered both lungs, totaling of 70 points based on parasternal, anterior-axillary, post-axillary, posterior-midline, and bilateral nipple connecting lines. The scoring criteria were as follows: 0 points: predominantly A-lines with sporadic (<3) B-lines; 1 point: scattered, non-confluent B-lines; 2 points: dense, partially confluent B-lines; 3 points: fully confluent B-lines; 4 points: abnormal pleural lines with small (<1 cm depth) subpleural solid lung lesions; and 5 points: abnormal pleural lines with large (>1 cm depth) solid lung lesions) (Figure 2).

Statistical analysis

Statistical analysis was performed using SPSS 27.0. Data with non-normal distribution were expressed as M (IQR). Comparisons between two groups were made using the Mann-Whitney U test. Count data were expressed as n (%), with comparisons between groups made using the chi-square test or Fisher's exact test. A P-value <0.05 was considered statistically significant.

Results

Clinical baseline status and ultrasound indicators

A total of 186 children with pneumonia were enrolled, including 74 with mycoplasma pneumonia, 49

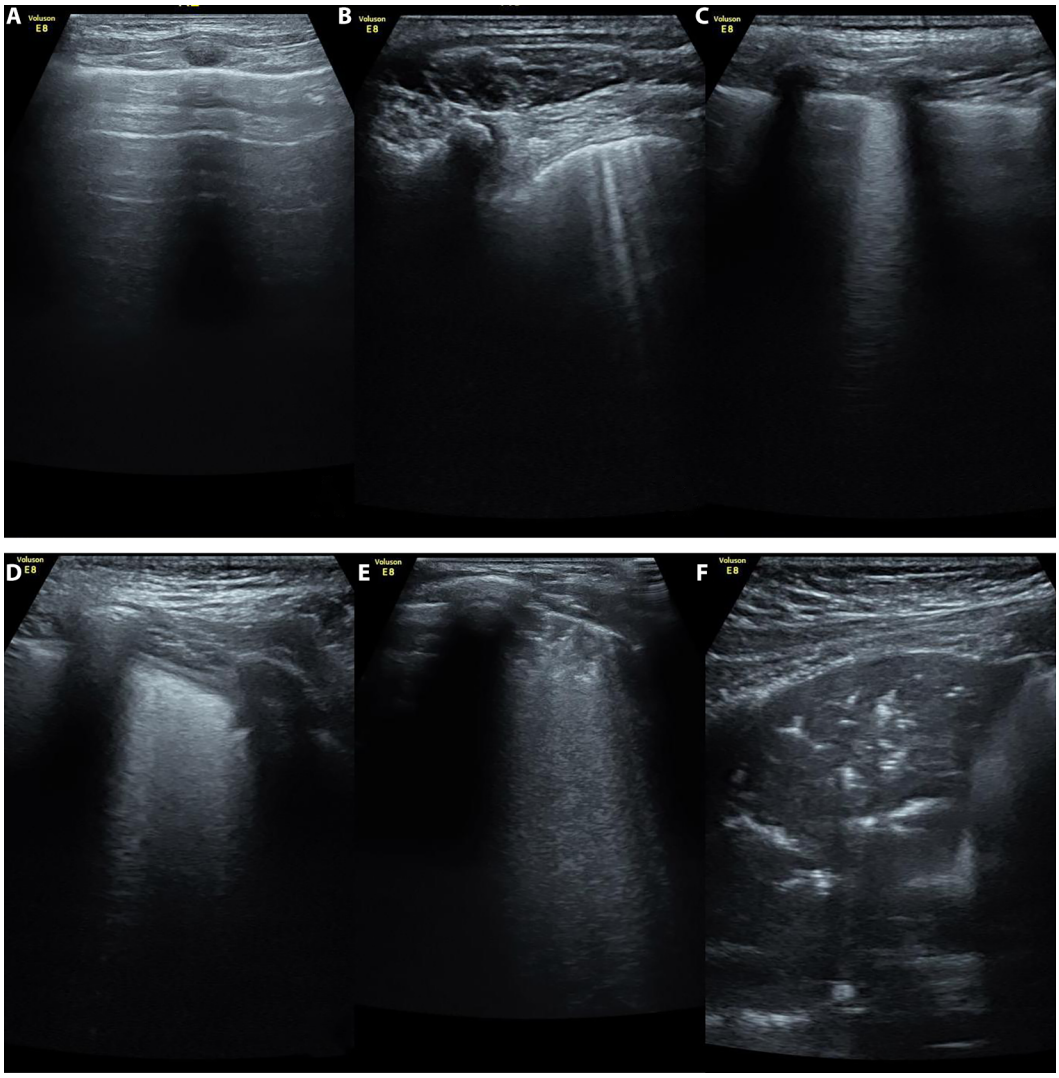

Figure 2. The scoring criteria for the modified lung ultrasound images. A)A-line is dominant, <3 non-confluent B-lines(0 point);B)multiple non-confluent B-lines(1 point); C) dense, partially confluent B-lines(2 points); D)completely confluent B-lines(3 points); E)abnormal pleural line with a small range (depth <1 cm) of subpleural lung consolidation(4 points); F)abnormal pleural line with large-area (depth >1 cm) lung consolidation (5 points).

with bacterial pneumonia, and 63 with viral pneumonia. Lung ultrasound signs of A-line, B-line, extensive lung solid lesions, small lung solid lesions, and pleural effusion were recorded for each child. A total of at least 14 static ultrasound images from the 14 lung zones were collected, and the MLUS score was documented for each patient. Clinical baseline data, including age, gender, clinical symptoms, disease severity, laboratory findings, and pathogenetic findings, were recorded and analyzed. The clinical baseline characteristics and ultrasound indices are presented in Table 1.In the bacterial pneumonia group: *Streptococcus pneumoniae* 15 cases, *Haemophilus influenzae* 12 cases, *Moraxella catarrhalis* 4 cases, *Staphylococcus aureus* 3 cases, Gram-negative bacteria 3 cases, *Pseudomonas aeruginosa* 2 cases, and mixed bacterial infection 10 cases. In the viral pneumonia group: respiratory syncytial virus 18 cases, influenza A virus 8 cases, parainfluenza virus 6 cases, adenovirus 6 cases, COVID-19 virus 4 cases, rhinovirus 5 cases, bocavirus 2 cases, cytomegalovirus 2 cases, and mixed viral infection 12 cases.

Table 1. A list of clinical baseline status and ultrasound indicators.

Indicator	n(%)/M(IQR)
Age(years)	4.46(1.8,6)
Gender	
Male	102(54.84)
Female	84(45.16)
Fever	
No	57(30.65)
Yes	129(69.35)
Cough and sputum	
No	6(3.23)
Yes	180(96.77)
Wheeze	
No	132(70.97)
Yes	54(29.03)
White blood cell counts	
Normal	94(50.54)
Abnormal	92(49.46)
C-reactive protein	
Normal	76(40.86)
Abnormal	110(59.14)
Large-area lung consolidation	
No	106(56.99)
Yes	80(43.01)
Small-area lung consolidation	
No	114(61.62)
Yes	71(38.38)
Pleural effusion	
No	155(83.33)
Yes	31(16.67)
MLUS(score)	11(5,18)
Severity of illness	
Mild	146(78.49)
Severe	40(21.51)
Pathogen	
Bacteria	49(26.34)
Virus	63(33.87)
Mycoplasma pneumoniae	74(39.78)

Comparison of indicators for bacterial, viral and mycoplasma pneumonia

Significant differences were observed among the three groups in terms of age, fever, cough and sputum production, shortness of breath, extensive lung solid changes, small lung solid changes, and MLUS ($P< 0.05$, Table 2, Figure 3). Further two-by-two comparisons showed that cough and sputum, along with small lung solid lesions, were significantly more common in the mycoplasma pneumonia group than in the bacterial pneumonia group ($P< 0.05$). Additionally, the mycoplasma pneumonia group has a higher median age of 6 (4.58,8) years, greater than the bacterial pneumonia group (3 [1.1,4.83] years) and the viral pneumonia group (3.41 [1.16,4.75] years). The mycoplasma pneumonia group also exhibited more febrile symptoms and extensive pulmonary solid changes, but fewer asthmatic symptoms compared to the other two groups. Furthermore, the MLUS for the mycoplasma pneumonia group were higher than those for the bacterial and viral pneumonia groups, with a statistically significant difference ($P < 0.05$).For the differentiation of *Mycoplasma pneumoniae* pneumonia from bacterial and viral pneumonia, the presence of extensive lung consolidation demonstrated a sensitivity of 70.27% (52/74), a specificity of 75.00% (84/112), and an overall accuracy of 73.12% (136/186).

Discussion

MLUS and extensive pulmonary solid lesions in patients with Mycoplasma pneumonia differ from those of bacterial and viral pneumonia

In this study, we found that the MLUS of the mycoplasma pneumonia group were higher than those of the viral and bacterial pneumonia groups. Additionally, a greater proportion of patients with mycoplasma pneumonia had signs of extensive pulmonary solid lesions. Based on relevant pediatric lung ultrasound studies and our findings, ultrasonic abnormalities in Mycoplasma pneumonia predominantly show a multifocal and segmental distribution, with the lower lobes and dorsal

Table 2. Comparison of indicators between pneumonia groups with different pathogens.

	Bacterial pneumonia group (n=49)	Viral pneumonia group (n=63)	Mycoplasma pneumonia group(n=74)	X^2/H	*P*
Age (years)	3(1.1,4.83)	3.41(1.16,4.75)	6(4.58,8)*#	38.07	<0.01
Gender (%)				1.18	0.55
Male	30(61.22)	34(53.97)	38(51.35)		
Female	19(38.78)	29(46.03)	36(48.65)		
Fever (%)				14.99	<0.01
No	22(44.9)	24(38.10)	11(14.86)*#		
Yes	27(55.1)	39(61.90)	63(85.14)*#		
Cough and sputum (%)				7.56	0.02
No	4(8.16)	2(3.17)	0(0)*		
Yes	45(91.84)	61(96.83)	74(100)*		
Wheeze (%)				29.96	<0.01
No	29(59.18)	34(53.97)	69(93.24)*#		
Yes	20(40.82)	29(46.03)	5(6.76)*#		
White blood cell counts (%)				5.11	0.07
Normal	19(38.78)	31(49.21)	44(59.46)		
Abnormal	30(61.22)	32(50.79)	30(40.54)		
C-reactive protein (%)				2.26	0.32
Normal	24(48.98)	22(34.92)	30(40.54)		
Abnormal	25(51.02)	41(65.08)	44(59.46)		
Large-area lung consolidation (%)				39.33	<0.01
No	33(67.35)	51(80.95)	22(29.73)*#		
Yes	16(32.65)	12(19.05)	52(70.27)*#		
Small-area lung consolidation (%)				11.35	<0.01
No	38(77.55)	41(65.08)	35(47.95)*		
Yes	11(22.45)	22(34.92)	38(52.05)*		
Pleural effusion (%)				5.63	0.06
No	42(85.71)	57(90.48)	56(75.68)		
Yes	7(14.29)	6(9.52)	18(24.32)		
Severity of illness (%)				3.31	0.19
Mild	37(75.51)	46(73.02)	63(85.14)		
Severe	12(24.49)	17(26.98)	11(14.86)		
MLUS points	9(5,16)	8(5,15)	15(10,22)*#	17.33	<0.01

:P<0.05 compared with bacterial pneumonia group; #:#P<0.05 compared with viral pneumonia group.

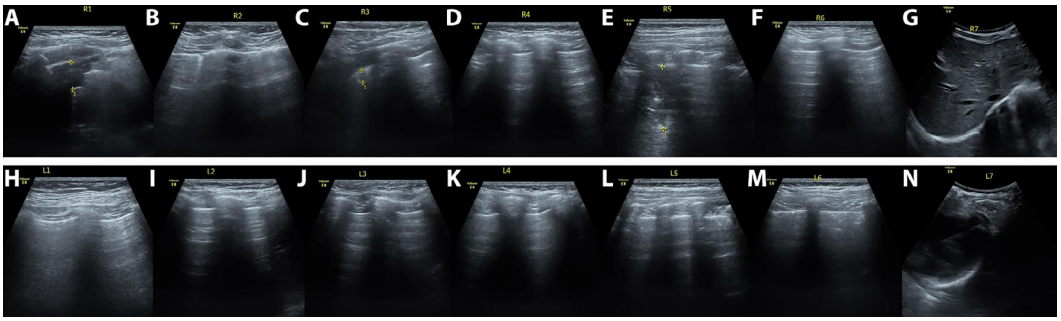

Figure 3. Fourteen-zone ultrasound images of the lungs of a 6-year-old male child with mycoplasma pneumonia. A: pleural line abnormalities with extensive (>1 cm depth) pulmonary solid lesions in the right upper anterior region; B: scattered, non-confluent B-lines are seen in the right anterior-inferior region; C: pleural line abnormalities with small (<1 cm depth) subpleural pulmonary solid lesions in the right supra-axillary region; D: A line predominance with sporadic (<3) B-lines in the right infra-axillary region; E: right posterior upper zone see pleural line abnormalities with extensive (>1 cm depth) pulmonary solid lesions; F: right posterior inferior zone see predominantly A-lines, see scattered (<3) B lines; G: right lung base zone see scattered, non-confluent B-lines; H: left anterior upper zone showing scattered, non-confluent B-lines; I: left anterior inferior zone showing predominantly A-lines with scattered (<3) B-lines; J: left axillary upper zone showing predominantly A-lines with scattered (<3) B-lines; K: left axillary region showing predominantly A-lines with sporadic (<3) B-lines; L:left posterior superior region showing predominantly A-lines with sporadic (<3) B-lines; M: left posterior inferior region showing predominantly A-lines with sporadic (<3) B-lines; N: left lung base region showing predominantly A-lines with sporadic (<3) B-lines. The combined MLUS for this patient was 17.

regions of both lungs more commonly involved (10,11). Although no relevant reports on using MLUS to distinguish mycoplasma pneumonia from other types of pneumonia have been published previous reports (12) have shown that children with mycoplasma pneumonia have more pulmonary solid lesions than those with other types of pneumonia. This can be attributed to the high affinity of *Mycoplasma pneumoniae* for human respiratory epithelial cells, where its P1 protein binds to sialylated glycoproteins, allowing the bacteria to adhere and slide along the epithelium. This adherence can cause direct damage to host respiratory epithelium, resulting in more lung solid lesions in these patients (13,14). Severe pneumonia in children is often characterized by *Mycoplasma pneumoniae* infection. Children with severe pneumonia have difficulty coughing and increased airway secretions, causing airway obstruction and, in severe cases, sputum embolism, bronchial blockage, which can lead to respiratory failure, carbon dioxide retention, pulmonary atelectasis, and other complications. In children, the elastic tissue of the lungs is less developed, with high number of blood vessels, high blood content, low air content, vigorously growing interstitium , and low number of alveoli, making them susceptible to mucus plugging and pulmonary changes. This renders patients with severe pneumonia more prone to pulmonary consolidation.Previous studies have confirmed that lung ultrasound scores are positively correlated with disease severity; higher scores indicate more extensive pulmonary involvement and more impaired ventilation (15,16).The higher mLUS score and more extensive consolidation in children with Mycoplasma pneumoniae pneumonia are attributable to expanded affected lung fields secondary to multifocal and segmental inflammation, rather than global pulmonary hypoventilation, which may provide useful information for ultrasound-based differential diagnosis and disease severity assessment.

Mycoplasma pneumonia is distinguished from bacterial and viral pneumonia by age of onset, fever, and shortness of breath

Our study found that the median age in the mycoplasma pneumonia group was significantly greater than that in the bacterial and viral pneumonia groups. The mycoplasma pneumonia group also showed more febrile symptoms, which aligns with previous studies

(12). Another study (17) pointed out that the incidence of fever was higher in older than younger patients with mycoplasma pneumonia, which may be due to the fact that children's immunity improves with age, and the immune response of older children is stimulated more strongly. Therefore, in our clinical practice, we tend to favor *Mycoplasma pneumoniae* infections in older children with pneumonia and fever.

Interestingly, in the present study, the mycoplasma pneumonia group showed fewer asthma symptoms compared to the other groups. This finding contradicts some previous reports(18) that suggest *Mycoplasma pneumoniae* infection can cause airway hyperresponsiveness and increase airway secretions, which exacerbate asthma symptoms. We hypothesized that this could be due to the younger age of children in the viral and bacterial pneumonia groups. Younger children have relatively narrow airways, making them more susceptible to airway hyperresponsiveness, hypersecretion, and wheezing. Furthermore, studies have shown(19) that common respiratory viruses and bacterial overgrowth are associated with acute episodes of wheezing and asthma, which may explain the higher incidence of asthma symptoms in the bacterial and viral groups.

In summary, *Mycoplasma pneumoniae* infection can be suggested in older children with higher MLUS, febrile symptoms, and less shortness of breath compared to those with bacterial or viral pneumonia.

Cough, sputum and small pulmonary solid lesions in patients with mycoplasma pneumonia are distinct from bacterial pneumonia

Notably, our results also showed that coughing and sputum production, along with small solid pulmonary lesions were more common in the mycoplasma pneumoniae group than in the bacterial pneumonia group. This is likely due to the tendency of *Mycoplasma pneumoniae* to invade the respiratory epithelium, causing tracheobronchitis and promoting coughing and sputum production (20). Interestingly, although other studies (21) have suggested that bacterial pneumonia typically causes more solid lung changes than mycoplasma pneumonia, the results of this study show that small-scale solid lung changes are more commonly observed in mycoplasma pneumonia. This difference may be because bacterial pneumonia often results in more extensive lung damage, with larger, more diffuse solid lesions due to bacterial invasion of the alveolar walls and subsequent pulmonary edema. The present study, however, distinguished between large and small solid pulmonary lesions using a depth of 10 mm as the boundary, providing a more detailed analysis of the lung changes associated with the pathogen.

This study has some limitations, as deep lung lesions may not always be visible on ultrasound due to gas interference, and superficial lung conditions do not reflect the overall picture of lung disease. Additionally, the acquisition and interpretation of lung ultrasound images depend on the control and skill of the operator, which makes the scoring results somewhat subjective.In addition, the 5-point modified lung ultrasound score used in this study has not been externally validated. Its accuracy, sensitivity, and specificity need to be further verified in larger-sample and multicenter studies. In future research, more refined scoring systems such as the 7-point scale may be incorporated to optimize the quantitative evaluation of aeration loss and lung consolidation in children with pneumonia.

Conclusion

Patients with pneumonia who present with high MLUS, extensive solid lung lesions, older age, febrile symptoms, and less shortness of breath are more likely to have *Mycoplasma pneumoniae* infection. However, in clinical practice, pulmonary ultrasound findings alone are insufficient to accurately distinguish Mycoplasma, bacterial, and viral infections. The MLUS scoring system is simple and radiation-free. Although it cannot replace etiological testing, it represents a useful adjunctive tool that, when combined with clinical information, provides supportive evidence for early and rational clinical diagnosis and treatment.

List of abbreviations:

COVID-19: Coronavirus disease 2019
LUS: Lung Ultrasound Score
MLUS: Modified lung ultrasound score
PCR: Polymerase chain reaction

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Ethics Approval and Consent to Participate: This study was approved by the QuanZhou Maternal and Children's Hospital Ethics Committee (Ethics Review No. 102 of 2023). Written informed consent was provided by the parents or legal guardians of the children.

Consent for Publication: Informed consent was obtained from all subjects involved in this study.

Competing Interests: The authors have no conflicts of interest to declare.

Declaration on the Use of AI: None.

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