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Clinical characteristics and factors associated with severe disease in hospitalized infants with human metapneumovirus pneumonia and respiratory bacterial co-detection: a single-center retrospective study

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Abstract

Background

Human metapneumovirus (hMPV) is an important cause of lower respiratory tract infection in infants, but data on infants with respiratory bacterial co-detection are limited. We aimed to describe the clinical and microbiological characteristics of this population and to explore factors associated with severe disease.

Methods

We conducted a single-center retrospective study of infants aged 12 months or younger who were hospitalized at Henan Children's Hospital between October 2024 and March 2025 with hMPV pneumonia and clinically adjudicated respiratory bacterial co-detection. Demographic, clinical, laboratory, imaging, treatment, and 6-month follow-up data were extracted from medical records. Severe disease was classified according to the pediatric community-acquired pneumonia guideline and the discharge diagnosis. Group comparisons used chi-square or Fisher's exact tests and the Mann–Whitney U test. Exploratory logistic regression was performed; the primary model excluded lethargy because it overlapped with severity criteria, and a secondary warning-sign model included lethargy.

Results

Among 309 infants, 190 (61.5%) were male and 42 (13.6%) were classified as severe cases. Streptococcus pneumoniae was the most frequently co-detected bacterium. Among 143 infants who underwent chest CT, multilobar pneumonia (90.9%) and ground-glass opacity (56.6%) were the most common findings. In the primary exploratory model, artificial feeding (OR 2.60, 95% CI 1.27–5.34), underlying diseases (OR 2.43, 95% CI 1.14–5.21), and lower albumin levels (OR 0.85 per 1 g/L increase, 95% CI 0.78–0.94) were associated with severe disease. In the secondary model, lethargy was strongly associated with severe presentation (OR 5.02, 95% CI 2.38–10.62) and should be interpreted as a warning sign rather than an independent causal factor.

Conclusions

Underlying diseases, artificial feeding, and lower albumin levels may help identify infants with hMPV pneumonia and respiratory bacterial co-detection who require closer monitoring. Lethargy should be regarded as an early warning sign. These association-based findings require confirmation in multicenter prospective studies with standardized pathogen quantification and adjudication.

Background

Lower respiratory tract infections are a leading cause of morbidity and mortality in infants and children worldwide [1–3]. Viral pneumonia accounts for a substantial proportion of these cases. Human metapneumovirus (hMPV), first identified in 2001, is an important respiratory pathogen with clinical manifestations that overlap with those of respiratory syncytial virus (RSV) [4]. hMPV can infect individuals of all ages, but infants, young children, older adults, and immunocompromised individuals are particularly vulnerable. Globally, hMPV is considered one of the major viral causes of bronchiolitis and pneumonia in children under 5 years of age [5, 6]. In 2018, hMPV-associated acute lower respiratory infection caused a substantial burden among children under 5 years of age worldwide, including severe cases requiring hospitalization and deaths [7].

Previous studies on hMPV have mainly focused on epidemiological characteristics and general clinical features. However, data on hMPV pneumonia in infants, especially cases with bacterial co-detection or suspected bacterial coinfection, remain limited. Viral infection may impair the respiratory mucosal barrier and disrupt host immune responses, creating conditions that facilitate bacterial overgrowth or invasion and may aggravate pulmonary inflammation [8–10]. Nevertheless, detection of bacterial DNA in respiratory specimens does not by itself confirm invasive bacterial infection, especially for organisms that may colonize the upper airway, and therefore requires clinical adjudication.

To address this gap, the present study focused on infants aged 12 months or younger with hMPV pneumonia and clinically adjudicated respiratory bacterial DNA co-detection after exclusion of cases considered to represent airway colonization. We systematically summarized their clinical characteristics, bacterial co-detection profile, imaging findings, treatment, short-term follow-up outcomes, and severity-associated clinical and laboratory features. The study aimed to provide descriptive evidence for early recognition and risk stratification of high-risk infants in clinical practice while avoiding interpretation of bacterial DNA positivity alone as evidence of concomitant bacterial pneumonia.

Methods

Study design, setting, and participants

This single-center retrospective observational study included infants aged 12 months or younger who were hospitalized at Henan Children's Hospital (Zhengzhou Children's Hospital), Zhengzhou, China, from October 2024 to March 2025 with hMPV pneumonia and respiratory bacterial co-detection. Inclusion criteria were: (1) age ≤ 12 months at admission; (2) pneumonia diagnosed according to the Chinese pediatric community-acquired pneumonia guideline [11]; (3) hMPV confirmed by nucleic acid testing of a respiratory specimen; and (4) at least one bacterial pathogen detected in a respiratory specimen and judged clinically compatible with concomitant bacterial pneumonia rather than simple airway colonization. Exclusion criteria were: (1) nosocomial infection; (2) incomplete records; (3) clinically relevant co-detection of another respiratory virus; (4) clinically relevant co-detection of Mycoplasma pneumoniae, Chlamydia spp., fungi, or Mycobacterium tuberculosis; and (5) bacterial detection adjudicated as airway colonization. Severe disease was classified using the pediatric community-

acquired pneumonia guideline and the discharge diagnosis. The assessment considered respiratory distress, hypoxemia, systemic toxicity or altered mental status, severe complications, and the need for intensive supportive care. Infants who did not meet the severe-disease criteria were classified as non-severe. The study was approved by the Ethics Committee of Henan Children's Hospital (2025-IITGC-011-001), which waived the requirement for informed consent because of the retrospective observational design.

Specimen collection and microbiological testing

Deep sputum, blood, and nasopharyngeal swab specimens were collected by trained staff using aseptic procedures within 24 h of admission and were tested in the institutional clinical laboratory. hMPV and bacterial targets were identified from routine nucleic-acid reports, and culture results were recorded when available. Pathogen-load information was extracted when reported. No additional microbiological testing was performed for this study.

Clinical adjudication of bacterial infection versus airway colonization

Bacterial colonization and possible concomitant bacterial pneumonia were differentiated by integrating clinical deterioration, inflammatory markers, chest imaging, reported pathogen load, culture results when available, and the treating team’s documented response assessment. Detection of low-load oropharyngeal commensal organisms without compatible clinical, inflammatory, or imaging evidence was classified as colonization and excluded. Because this retrospective adjudication did not use universal culture confirmation or a prospectively validated algorithm, the retained cohort is described as having clinically adjudicated bacterial co-detection rather than microbiologically proven bacterial pneumonia.

Data collection and definitions

Clinical data were extracted from the electronic inpatient record, including demographics, admission and discharge dates, symptoms, prematurity, feeding method, delivery mode, underlying diseases, laboratory tests within 24 h, chest imaging, treatments, ventilatory support, length of stay, and follow-up outcomes. Poor appetite was defined as a ≥ 50% reduction in daily food or milk intake from the pre-illness level for > 48 h. Underlying disease was coded when a chronic, congenital, genetic, metabolic, neurologic, cardiopulmonary, hematologic, or oncologic condition was documented. Wheezing was defined as a history of wheezing or wheezing during the current illness; this combined definition was used consistently in Fig. 2 and Table 3. Lethargy was based on admission documentation of poor mental status. Recurrent wheezing was defined as at least two parent-reported wheezing episodes after discharge or physician-diagnosed wheezing requiring medical care during the 6-month follow-up period.

Statistical analysis

SPSS version 27.0 was used for statistical analysis. Continuous variables were assessed descriptively and are presented as median (Q1, Q3); categorical variables are presented as n (%). Between-group comparisons used the Mann–Whitney U test for continuous variables and the chi-square or Fisher's exact test for categorical variables, as appropriate. No imputation was performed; available-case analysis was used. IL-6 was unavailable for 24 infants (3 severe and 21 non-severe), whereas variables included in the regression models were complete. Given 42 severe outcomes, the exploratory primary logistic regression model was restricted to three clinically selected variables: artificial feeding, underlying diseases, and albumin. A secondary warning-sign model added lethargy, which overlaps with severity classification and was therefore not treated as a causal predictor. Odds ratios (ORs) and 95% confidence intervals (CIs) were reported; the OR for albumin represents a 1 g/L increase. No adjustment was made for multiple comparisons. All results were interpreted as associations, and two-sided $P < 0.05$ was considered statistically significant.

Results

Underlying disease conditions

Among the 309 included infants, 190 were male and 119 were female, and 42 were classified as severe cases. Fifty-four infants had at least one recorded underlying disease. The conditions included hematologic disorders, congenital heart disease, airway abnormalities, prematurity-related chronic lung disease, neurodevelopmental disorders, gastrointestinal disorders, tumors, and genetic or metabolic diseases (Supplementary Table S1).

Seasonal and age distribution

The number of enrolled infants increased from October, peaked in December, and then gradually decreased. Because the denominator of all tested or hospitalized infants by month was unavailable, this result represents the monthly distribution of enrolled cases rather than a monthly detection rate. Therefore, the seasonal pattern was interpreted descriptively (Fig. 1a). The age distribution of enrolled cases is shown in Fig. 1b.

Clinical manifestations and laboratory results

Of the 309 infants, 54 (17.5%) had complications and 38 (12.3%) were born prematurely. The most frequently recorded clinical features were cough (303/309, 98.1%), wheezing history or wheezing during the current illness (178/309, 57.6%), fever (159/309, 51.5%), poor appetite (147/309, 47.6%), rhinorrhea (144/309, 46.6%), nasal congestion (114/309, 36.9%), and vomiting (54/309, 17.5%) (Fig. 2). Laboratory testing showed WBC > 15×10^9/L in 28 infants (9.1%), NEUT% >50% in 67 (21.7%), CRP > 20 mg/L in 23 (7.4%), PCT > 0.5 ng/mL in 18 (5.8%), ALT > 70 U/L in 8 (2.6%), AST > 80 U/L in 12 (3.9%), LDH > 250 U/L in 271 (87.7%), TP < 55 g/L in 26 (8.4%), ALB < 39 g/L in 34 (11.0%), CK > 310 U/L in 9 (2.9%), and CK-MB ≥ 48 U/L in 15 (4.9%). Among the 285 infants with available IL-6 results, 89 (31.2%) had IL-6 > 20 pg/mL.

Imaging features

Among the 143 infants who underwent complete chest CT examination, the most common findings were multilobar pneumonia (130/143, 90.9%), ground-glass opacity (81/143, 56.6%), airway narrowing of varying degrees (40/143, 28.0%), and pulmonary consolidation (24/143, 16.8%) (Fig. 3). These imaging findings refer to the CT-scanned subgroup rather than the entire cohort, and no inference was made regarding the prevalence of these CT abnormalities in all included infants. Airway narrowing mainly involved the right middle-lobe bronchus and the left main bronchus. Pulmonary consolidation included multilobar consolidation, right upper-lobe consolidation, left lower-lobe consolidation, pulmonary atelectasis, right lower-lobe consolidation, and right middle-lobe consolidation.

Bacterial co-detection profile

Among the 309 infants, Streptococcus pneumoniae (SP) was the most frequently co-detected bacterium, with 152 detections (49.2%), followed by Haemophilus influenzae (HI) in 119 cases (38.5%), Staphylococcus aureus (SA) in 61 cases (19.7%), Moraxella catarrhalis in 32 cases (10.4%), Escherichia coli in 29 cases (9.4%), Acinetobacter baumannii in 11 cases (3.6%), Klebsiella pneumoniae in 10 cases (3.2%), Pseudomonas aeruginosa in 8 cases (2.6%), Klebsiella oxytoca in 3 cases (1.0%), Enterobacter hormaechei in 2 cases (0.6%), and several other bacteria in 1 case each (0.3%). A single bacterial species was co-detected in 209 infants (67.6%) (Table 1), whereas two or more bacterial species were co-detected in 100 infants (32.4%), including 77 double detections (24.9%) and 23 detections of three or more bacterial species (7.5%) (Table 2). These findings describe the bacterial DNA profile of cases retained after clinical adjudication and exclusion of cases considered to represent airway colonization.

Table 1
Single bacterial co-detections

Pathogen type	Cases (n)	Detection rate (%)	Proportion (%)
SP	72	23.3	34.4
HI	53	17.2	25.4
SA	25	8.1	11.9
E. coli	21	6.8	10.0
M. catarrhalis	16	5.2	7.7
K. pneumoniae	5	1.6	2.4
A. baumannii	4	1.3	1.9
K. oxytoca	3	1.0	1.4
P. aeruginosa	3	1.0	1.4
E. hormaechei	2	0.6	1.0
S. pyogenes	1	0.3	0.5
R. ornithinolytica	1	0.3	0.5
A. pittii	1	0.3	0.5
S. marcescens	1	0.3	0.5
E. asburiae	1	0.3	0.5
Total	209	67.6	100

Note: Detection rate was calculated using the entire cohort as the denominator (n = 309). Proportion was calculated using infants with single bacterial co-detection as the denominator (n = 209). SP, Streptococcus pneumoniae; SA, Staphylococcus aureus; HI, Haemophilus influenzae; E. coli, Escherichia coli; M. catarrhalis, Moraxella catarrhalis; K. pneumoniae, Klebsiella pneumoniae; A. baumannii, Acinetobacter baumannii; K. oxytoca, Klebsiella oxytoca; P. aeruginosa, Pseudomonas aeruginosa; E. hormaechei, Enterobacter hormaechei; S. pyogenes, Streptococcus pyogenes; R. ornithinolytica, Raoultella ornithinolytica; A. pittii, Acinetobacter pittii; S. marcescens, Serratia marcescens; E. asburiae, Enterobacter asburiae.

Table 2
Multiple bacterial co-detections

Pathogen type	Cases (n)	Detection rate (%)	Proportion (%)
SP + HI	34	11.0	34
SP + SA	14	4.5	14
SP + M. catarrhalis	4	1.3	4
SP + K. pneumoniae	3	1.0	3
SP + E. coli	2	0.6	2
E. coli + A. baumannii	2	0.6	2
HI + SA	7	2.3	7
HI + E. coli	4	1.3	4
HI + P. aeruginosa	2	0.6	2
M. catarrhalis + SA	3	1.0	3
P. aeruginosa + A. baumannii	2	0.6	2
SP + HI +SA	10	3.2	10
SP + HI + M. catarrhalis	8	2.6	8
SP + K. pneumoniae + A. baumannii	2	0.6	2
SP + SA+M. catarrhalis	1	0.3	1
SP + SA+A. baumannii	1	0.3	1
SP + HI +P. aeruginosa + K. oxytoca	1	0.3	1
Total	100	32.4	100

Note: Detection rate was calculated using the entire cohort as the denominator (n = 309). Proportion was calculated using infants with multiple bacterial co-detection as the denominator (n = 100).

Comparison of clinical characteristics and laboratory findings between severe and non-severe cases

In univariable comparisons, the severe group had higher proportions of artificial feeding, underlying diseases, preterm birth, lethargy, and wheezing and a longer hospital stay than the non-severe group (all $P < 0.05$). Age and sex did not differ significantly between groups. Delivery mode, complications, poor appetite, vomiting, nasal congestion, and rhinorrhea were not significantly different (Table 3). WBC, PCT, ALT, IL-6, and GLB were higher in the severe group, whereas ALB and CK were lower (all $P < 0.05$). NEUT%, CRP, AST, LDH, TP, and CK-MB did not differ significantly (Table 4).

Table 3
Clinical characteristics by disease severity

Characteristic	Severe group (n = 42)	Non-severe group (n = 267)	χ^2/Z	P
Artificial feeding [n (%)]	18 (42.9)	53 (19.9)	10.85	0.001
Underlying diseases [n (%)]	15 (35.7)	39 (14.6)	11.21	< 0.001
Vaginal delivery [n (%)]	13 (31.0)	113 (42.3)	1.94	0.163
Complications [n (%)]	11 (26.2)	43 (16.1)	2.56	0.110
Preterm birth [n (%)]	10 (23.8)	28 (10.5)	5.97	0.015
Length of hospitalization (days)	9.0 (7.75, 12.25)	6.0 (5.0, 8.0)	−6.94	< 0.001
Poor appetite [n (%)]	24 (57.1)	123 (46.1)	1.78	0.182
Lethargy/poor mental status [n (%)]	28 (66.7)	82 (30.7)	20.46	< 0.001
Vomiting [n (%)]	7 (16.7)	47 (17.6)	0.02	0.882
Nasal congestion [n (%)]	14 (33.3)	100 (37.5)	0.26	0.607
Rhinorrhea [n (%)]	15 (35.7)	129 (48.3)	2.32	0.128
Wheezing history/current illness [n (%)]	36 (85.7)	142 (53.2)	15.73	< 0.001

Note: Continuous variables are presented as median (Q1, Q3), and categorical variables are presented as n (%).

Table 4
Laboratory findings by disease severity

Laboratory test	Severe group	Non-severe group	Z	P
WBC (×10^9/L)	11.36 (7.78, 13.00)	8.60 (6.64, 11.66)	−2.22	0.026
NEUT (%)	37.55 (24.15, 50.80)	34.50 (22.75, 46.45)	−1.42	0.155
CRP (mg/L)	2.38 (0.50, 9.59)	1.60 (0.50, 5.53)	−0.80	0.424
PCT (ng/mL)	0.10 (0.05, 0.26)	0.07 (0.04, 0.10)	−2.89	0.004
ALT (U/L)	30.20 (19.55, 39.48)	24.00 (18.90, 31.10)	−1.97	0.049
AST (U/L)	40.00 (33.62, 58.10)	40.30 (34.85, 48.00)	−0.41	0.684
LDH (U/L)	316.40 (285.50, 365.25)	306.50 (274.50, 348.50)	−1.04	0.300
TP (g/L)	62.70 (57.83, 66.07)	62.90 (58.60, 65.55)	−0.17	0.866
ALB (g/L)	41.60 (38.12, 44.22)	43.70 (41.90, 45.45)	−3.60	< 0.001
GLB (g/L)	20.20 (18.25, 23.03)	18.90 (16.75, 21.40)	−2.34	0.019
CK (U/L)	68.75 (40.23, 117.83)	96.00 (70.60, 138.75)	−3.13	0.002
CK-MB (U/L)	23.15 (16.23, 28.95)	24.20 (20.20, 30.20)	−1.11	0.269
IL-6 (pg/mL)	21.30 (10.87, 33.02) (n = 39)	9.28 (4.33, 20.10) (n = 246)	−3.30	< 0.001

Note: Values are median (Q1, Q3). IL-6 was available for 39 severe and 246 non-severe infants; all other laboratory tests were available for all 309 infants.

Exploratory multivariable analyses

In the primary model excluding lethargy, artificial feeding (OR 2.60, 95% CI 1.27–5.34), underlying diseases (OR 2.43, 95% CI 1.14–5.21), and higher ALB (OR 0.85 per 1 g/L increase, 95% CI 0.78–0.94) were associated with severe disease. In the secondary warning-sign model, lethargy was associated with severe presentation (OR 5.02, 95% CI 2.38–10.62); artificial feeding, underlying diseases, and ALB remained associated with the outcome. Because lethargy overlaps with the severe-disease definition, the primary model is emphasized and the secondary model should be interpreted clinically rather than causally (Table 5).

Table 5
Exploratory logistic regression models for severe disease

Model	Factor	β	Wald χ^2	P	OR	95% CI
Primary	Artificial feeding	0.955	6.76	0.009	2.60	1.27–5.34
	Underlying disease	0.889	5.23	0.022	2.43	1.14–5.21
	Albumin (per 1 g/L)	−0.157	11.69	< 0.001	0.85	0.78–0.94
Secondary	Lethargy	1.614	17.84	< 0.001	5.02	2.38–10.62
	Artificial feeding	0.926	5.80	0.016	2.53	1.19–5.37
	Underlying disease	1.063	6.53	0.011	2.89	1.28–6.54
	Albumin (per 1 g/L)	−0.160	10.72	0.001	0.85	0.77–0.94

Note: Model 1 was the primary model and excluded lethargy because altered mental status may contribute to severe-disease classification. Model 2 added lethargy as a secondary warning-sign analysis. ALB, albumin; OR, odds ratio; CI, confidence interval.

Treatment and follow-up

All 309 infants received antimicrobial therapy according to local clinical practice. The study was therefore not designed to evaluate antibiotic effectiveness or compare antimicrobial strategies. Forty infants received systemic glucocorticoids, 26 received human immunoglobulin, and 5 received ventilatory assistance. At 6-month telephone follow-up, 31 infants were lost to follow-up and 278 were assessed. Recurrent wheezing was reported in 92/278 infants (33.1%). All five ventilated infants had recurrent wheezing, but this descriptive observation is based on a very small subgroup and should not be interpreted as evidence of a causal effect.

Discussion

This retrospective study described infants aged 12 months or younger with hMPV pneumonia and clinically adjudicated respiratory bacterial co-detection. The enrolled cases peaked in December; S. pneumoniae, H. influenzae, and S. aureus were the most frequently reported bacteria in the current coding; multilobar pneumonia and ground-glass opacity were the predominant CT findings among scanned infants; and artificial feeding, underlying diseases, and lower ALB were associated with severe disease in the primary exploratory model. Lethargy was strongly associated with severe presentation in the secondary model but is best regarded as a warning sign because it overlaps with severity classification.

The seasonal distribution in this study showed that the number of enrolled cases peaked in December. This pattern may be related to climate, temperature, humidity, and indoor crowding during winter [12].

Because the present study did not include the total number of tested or hospitalized children in each month as a denominator, the result should be interpreted as a distribution of enrolled cases rather than a monthly detection rate. The clinical manifestations were dominated by cough, wheezing, and fever, which is consistent with the clinical overlap between hMPV and RSV infection reported in previous studies [13–15].

Among infants who underwent complete chest CT examination, multilobar pneumonia and ground-glass opacity were the major imaging features. Airway narrowing was also observed in a subset of patients. The predominance of airway involvement may be related to infant airway anatomy, airway wall edema, mucus plugging, and inflammatory exudation during viral-bacterial interaction. However, because only 143 of 309 infants underwent chest CT and CT examination was performed according to clinical judgment, the imaging findings may over-represent infants with more severe, persistent, or atypical manifestations. These CT results should therefore be interpreted as findings among scanned infants rather than the entire cohort.

S. pneumoniae was the most frequently reported co-detected bacterium, followed by H. influenzae and S. aureus. Viral respiratory infection may impair epithelial barriers and host responses and thereby facilitate bacterial adherence and proliferation [16–21]. However, nucleic-acid detection in respiratory specimens cannot by itself distinguish colonization from lower respiratory infection, particularly for common nasopharyngeal colonizers. Although the study used clinical adjudication, it was retrospective and lacked universal culture confirmation and standardized quantitative thresholds. The pathogen spectrum should therefore be interpreted as a clinically adjudicated co-detection profile, and the final counts require reconciliation with the source-data coding before submission.

Artificial feeding, underlying diseases, and preterm birth were more common in the severe group in univariable analysis. Breast milk contains immunologically active components, including antibodies, immune cells, and enzymes, which may reduce susceptibility to severe respiratory infection [22]. However, feeding method may also reflect age, nutritional status, passive immunity, caregiving patterns, and other unmeasured factors; therefore, the association between artificial feeding and severe disease should not be interpreted as causal. Infants with underlying diseases or prematurity may have immature immune responses, reduced cardiopulmonary reserve, or impaired airway clearance, making them more likely to develop severe pneumonia [23–26].

The severe group had higher WBC, PCT, ALT, IL-6, and GLB levels and lower ALB and CK levels. Higher WBC, PCT, and IL-6 levels may reflect stronger systemic inflammatory activation. Lower ALB may be related to inflammation, increased vascular permeability, nutritional depletion, and reduced hepatic synthesis during severe infection. Because the absolute difference in ALB between groups was modest, ALB should be interpreted as a supportive severity marker rather than a standalone decision-making threshold. The lower CK level observed in the severe group was unexpected and should be interpreted cautiously because it may be influenced by age, nutritional status, timing of blood sampling, disease course, and unmeasured confounding. Further studies are needed to clarify this finding.

The primary multivariable model excluded lethargy to reduce incorporation bias and identified artificial feeding, underlying diseases, and lower ALB as features associated with severe disease. A secondary model that included lethargy yielded a strong association, supporting its value as a bedside warning sign but not as an independent causal determinant. These findings are exploratory and should not be converted into a clinical prediction rule without external validation, assessment of calibration and discrimination, and prospective confirmation.

During 6-month follow-up, recurrent wheezing occurred in 33.1% of followed infants. This finding is consistent with the known association between severe viral lower respiratory tract infection and later wheezing [27]. Nevertheless, the present study lacked a comparison group of infants with hMPV infection without bacterial co-detection, and therefore it cannot determine whether bacterial co-detection contributed to later wheezing. The observation that all five ventilated infants developed recurrent wheezing is clinically noteworthy but limited by the very small sample size and should not be used as a primary inference.

Limitations

This study has several limitations. First, it was a single-center retrospective study and is susceptible to selection and information bias. Second, the currently uploaded source dataset contains records that require confirmation against the stated age, study-period, and pathogen exclusion criteria; the final cohort and all derived results must be locked after this audit. Third, colonization versus concomitant bacterial pneumonia was determined retrospectively without universal culture confirmation, standardized quantitative thresholds, or a prospectively validated adjudication algorithm. Fourth, CT was performed in only 143 infants according to clinical judgment, creating imaging-selection bias. Fifth, 24 infants lacked IL-6 results, and available-case analysis was used. Sixth, multiple univariable comparisons were performed without multiplicity adjustment, and the regression models were exploratory and not externally validated. Seventh, all infants received antimicrobial therapy, precluding assessment of antibiotic effectiveness. Eighth, follow-up lacked an hMPV-only comparison group and had 10.0% loss to follow-up; therefore, bacterial co-detection cannot be considered a cause of recurrent wheezing. Future multicenter prospective studies should use standardized pathogen quantification, culture confirmation when feasible, predefined adjudication, and longer follow-up.

Conclusions

Among infants hospitalized with hMPV pneumonia and clinically adjudicated respiratory bacterial co-detection, S. pneumoniae was the most frequently reported bacterium in the current coding, and multilobar pneumonia and ground-glass opacity were common among those who underwent CT. Artificial feeding, underlying diseases, and lower albumin levels were associated with severe disease in an exploratory model, whereas lethargy should be regarded as an early warning sign. These findings are association-based and require confirmation after final data reconciliation and in prospective multicenter cohorts.

Abbreviations

A. baumannii Acinetobacter baumannii

A. pittii Acinetobacter pittii

ALB albumin

ALT alanine aminotransferase

ARDS acute respiratory distress syndrome

AST aspartate aminotransferase

CAP community-acquired pneumonia

CK creatine kinase

CK-MB creatine kinase isoenzyme

CRP C-reactive protein

E. asburiae Enterobacter asburiae

E. coli Escherichia coli

E. hormaechei Enterobacter hormaechei

GLB globulin

HI Haemophilus influenzae

hMPV human metapneumovirus

IL-6 interleukin 6

K. oxytoca Klebsiella oxytoca

K. pneumoniae Klebsiella pneumoniae

LDH lactate dehydrogenase

M. catarrhalis Moraxella catarrhalis

NEUT neutrophil

P. aeruginosa Pseudomonas aeruginosa

PCT procalcitonin

R. ornithinolytica Raoultella ornithinolytica

RSV respiratory syncytial virus

S. marcescens Serratia marcescens

S. pyogenes Streptococcus pyogenes

SA Staphylococcus aureus

SP Streptococcus pneumoniae

TP total protein

WBC white blood cell

Declarations

Ethics approval and consent to participate

The study was approved by the Ethics Committee of Henan Children's Hospital (Ethics Approval No. 2025-IITGC-011-001). The requirement for informed consent was waived owing to the retrospective observational nature of the study. The decision not to require informed consent was upheld by the Ethics Committee of Henan Children's Hospital. All methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication

Not applicable.

Availability of data and materials

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

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Y.G., Y.L., S.Z., and W.L. acquired the data. Y.G., S.Z., and W.L. analysed and interpreted the data. Y.G. and Y.L. drafted the manuscript. Y.G., Y.L., and X.S. critically revised the manuscript for important intellectual content. All authors read and approved the final manuscript.

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Authors' information

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Figures

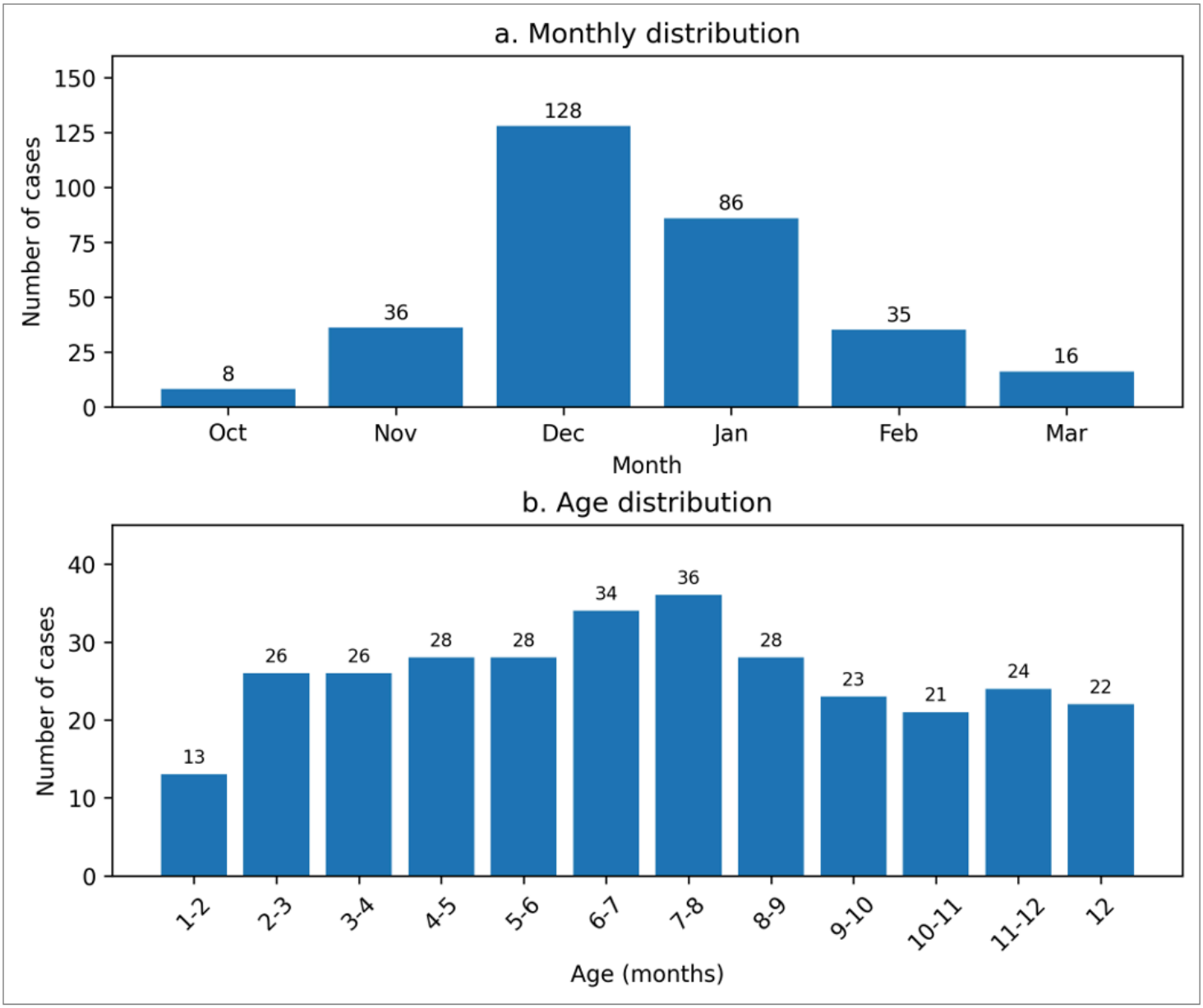

Figure 1

Monthly distribution (a) and age distribution (b) of infants with hMPV pneumonia and bacterial co-detection.

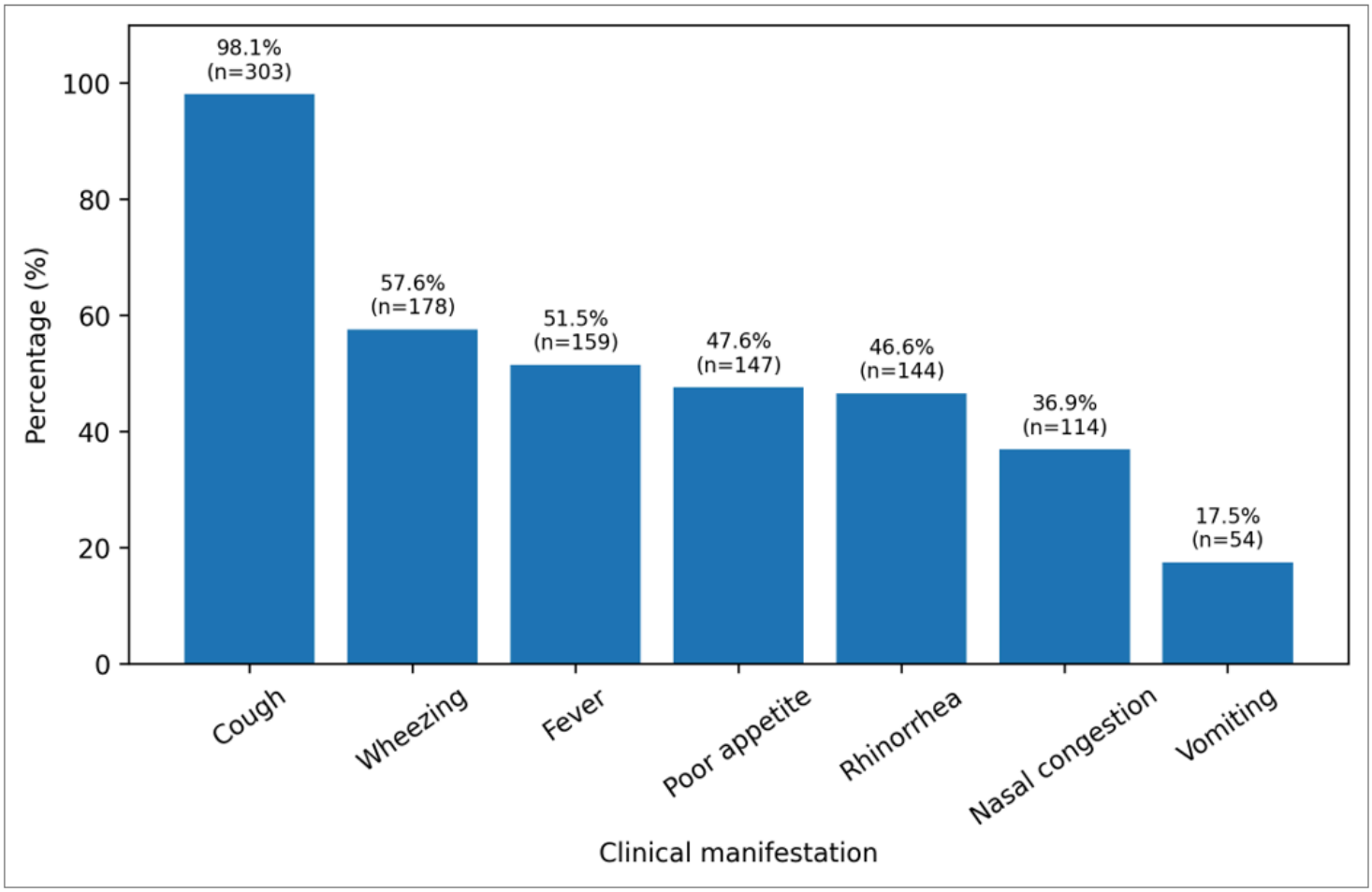

Figure 2

Clinical features recorded in the cohort. Wheezing includes a history of wheezing or wheezing during the current illness.

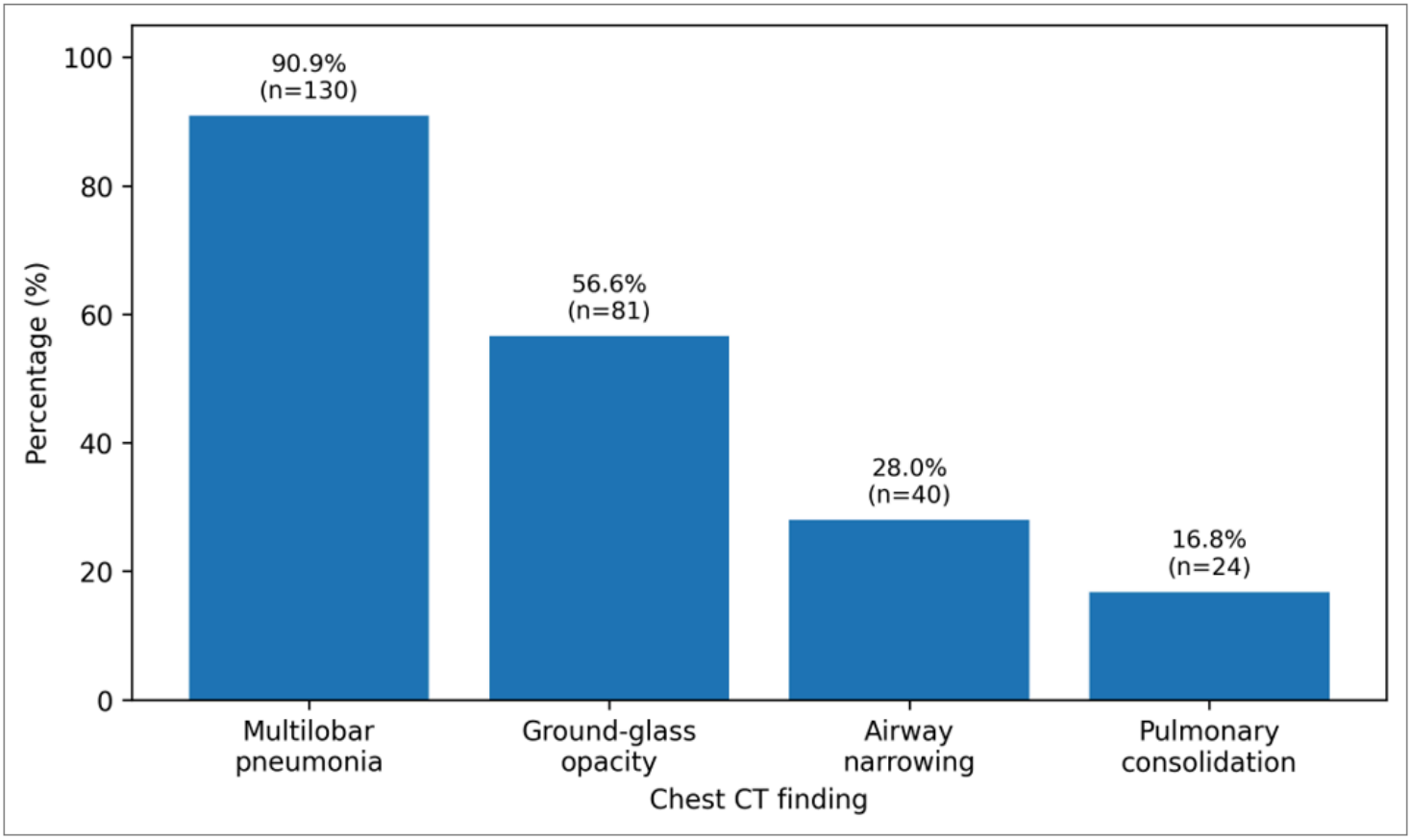

Figure 3

Chest CT findings among the 143 infants who underwent complete CT examination.

Supplementary Files

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- SupplementaryTableS1.docx