Section: Paediatrics

Original Research Article

CLINICAL, ENVIRONMENTAL AND LABORATORY FACTORS ASSOCIATED WITH READMISSION IN CHILDREN UNDER 2 YEARS OF AGE WITH ACUTE BRONCHIOLITIS AND WHEEZE-ASSOCIATED LOWER RESPIRATORY TRACT INFECTION IN THE POST-COVID PERIOD

Barsha Agarwal[1], Debadatta Mukhopadhyay[2], Trijit Das[1]

[1]Post Graduate Resident, Department of Paediatrics, Dr B C Roy Post Graduate Institute of Paediatric Sciences Kolkata, West Bengal, India
[2]Associate Professor, department of paediatrics Dr B C Roy Post Graduate Institute of Paediatric Sciences Kolkata, West Bengal, India

Received *: 05/10/2026*
Received in revised form *: 03/11/2026*
Accepted *: 16/11/2026*

Corresponding Author:
Dr. Barsha Agarwal,
Post Graduate Resident, Department of Paediatrics, Dr B C Roy Post Graduate Institute of Paediatric Sciences Kolkata, West Bengal, India.
Email: agarwalbarsha026@gmail.com

DOI: 10.70034/ijmedph.2026.4.401

Source of Support: Nil,
Conflict of Interest: None declared

Int J Med Pub Health
2026; 16 (4); 2661-2670

ABSTRACT

Background: Acute bronchiolitis and wheeze-associated lower respiratory tract infection (WALRI) are leading causes of hospitalisation in early childhood. Environmental exposure, particularly ambient air pollution, and host factors such as prematurity and nutritional status may influence severity and readmission. The objective is to evaluate clinical, environmental and laboratory factors associated with readmission among children aged 1 month to 2 years admitted with acute bronchiolitis and WALRI in the post-COVID period.

Materials and Methods: This hospital-based, cross-sectional, descriptive observational study was conducted in the Department of Paediatrics, Dr. B. C. Roy Post Graduate Institute of Paediatric Sciences, Kolkata, among 384 children aged 1 month to 2 years with a past history of acute bronchiolitis or WALRI, recruited consecutively. Demographic, clinical, environmental (AQI category), laboratory, respiratory viral panel and radiological data were recorded using a predesigned proforma. Data were analysed using SPSS version 27.0, with $p \leq 0.05$ considered significant.

Results: Mean age was 12.80±6.09 months, with male predominance (57.3%). Prematurity was the commonest risk factor (28.1%), followed by congenital heart disease (15.6%) and chronic lung disease (12.5%). Poor AQI category accounted for 36.5% of children. Respiratory viral panel was negative in 58.9%; RSV positivity was 13.0%. Mean hospital stay was 8.98±4.44 days and mean admissions 2.31±1.17. AQI category was significantly associated with readmission frequency ($p<0.001$), with frequent readmissions highest in the poor AQI group (72.9%). BMI category was significantly associated with readmission ($p=0.006$), underweight children showing the highest proportion (58.0%). Prematurity and abnormal chest X-ray findings were significantly associated with advanced respiratory support ($p<0.001$). Viral panel positivity was associated with longer hospital stay (10.6±4.8 vs 7.8±3.9 days; $p<0.001$). Inflammatory and cardiac biomarkers increased significantly with worsening AQI, while albumin declined ($p<0.001$).

Conclusion: Prematurity, abnormal radiology, viral positivity, poor ambient air quality and underweight status were significantly associated with disease severity and readmission, highlighting the need for integrated environmental, nutritional and clinical assessment in young children with acute respiratory illness.

Keywords: Acute bronchiolitis; WALRI; Readmission; Air Quality Index; Respiratory viral panel; Prematurity.

INTRODUCTION

Acute respiratory illnesses remain among the leading causes of morbidity and hospitalisation in early childhood, particularly among infants and young children. Anatomical and immunological immaturity during this period predisposes children to respiratory infections and rapid clinical deterioration. Lower respiratory tract infections (LRTIs) continue to contribute substantially to childhood disease burden, accounting for a considerable proportion of hospital admissions and mortality among children below five years of age.[1] Children are particularly vulnerable to severe respiratory illnesses because of their developing respiratory systems and relatively limited physiological reserves.

Environmental exposure, particularly ambient air pollution, has emerged as an important contributor to respiratory morbidity among children. Children are considered especially susceptible to air pollution because they inhale a greater volume of air per kilogram of body weight, while their lungs and respiratory systems are still undergoing development. Exposure to ambient pollutants has been associated with increased respiratory infections, exacerbation of airway diseases and impaired pulmonary development.[2] Recognising the health implications of air pollution, the World Health Organization (WHO) revised its global air quality recommendations in 2021, emphasising the importance of reducing pollutant exposure to prevent adverse health outcomes.[3] Ambient outdoor air pollution continues to be recognised as a significant environmental health risk, with important implications for respiratory health, particularly in vulnerable populations such as infants and young children.[4]

Viral infections constitute another major determinant of acute lower respiratory infections during early childhood. Among respiratory pathogens, respiratory syncytial virus (RSV) is recognised as a leading cause of acute lower respiratory infection and hospitalisation in infants worldwide.[5] Global disease burden estimates for 2019 demonstrated a substantial number of RSV-associated hospitalisations and deaths among children younger than five years, highlighting its considerable contribution to childhood respiratory morbidity and mortality.[6] Respiratory viral panel (RVP) testing has increasingly become an important diagnostic tool in hospital settings, assisting in the identification of respiratory pathogens and supporting infection control practices.

The clinical course of respiratory infections in young children varies considerably, ranging from mild respiratory symptoms to severe respiratory distress requiring hospitalisation, intensive care and ventilatory support. Although many children recover following supportive treatment, a proportion experience recurrent respiratory symptoms and repeated hospital admissions. The World Health Organization's Integrated Management of Childhood Illness (IMCI) guidelines emphasise the importance of assessing nutritional status and environmental factors while managing childhood illnesses, highlighting the need for a comprehensive approach to paediatric healthcare.[7]

The global burden of acute lower respiratory infections remains substantial, particularly among children younger than five years. Recent systematic analyses of disease burden and associated risk factors have reinforced the continuing importance of childhood lower respiratory infections as a major public health concern.[8] Similarly, estimates from the Institute for Health Metrics and Evaluation have highlighted the considerable contribution of lower respiratory infections to the global burden of disease.[9] These findings emphasise the importance of identifying clinical and environmental determinants that may influence disease severity, recurrence and healthcare utilisation in young children.

The Air Quality Index (AQI) provides a practical framework for assessing and communicating ambient air pollution levels. It facilitates categorisation of air quality into different levels, allowing environmental exposure to be evaluated in relation to clinical outcomes. The WHO Global Air Quality Guidelines further highlight the health implications of exposure to air pollutants and emphasise that even pollutant concentrations previously considered acceptable may carry health risks.[10] Understanding the relationship between ambient air quality and respiratory illness is particularly important in young children, given their increased biological susceptibility to environmental pollutants.

Apart from environmental and viral factors, underlying host characteristics may also influence the severity and recurrence of respiratory illnesses. Prematurity, congenital heart disease, chronic lung disease and nutritional status may contribute to increased vulnerability among children presenting with acute respiratory infections. Repeated hospitalisation may reflect persistent airway inflammation, incomplete recovery from the initial illness, underlying comorbidities and continued exposure to environmental triggers. Readmission therefore represents an important clinical outcome, contributing to increased healthcare utilisation and caregiver burden.

Radiological evaluation, particularly chest X-ray (CXR), is frequently undertaken in hospitalised children presenting with respiratory distress. The identification of pulmonary infiltrates, consolidation, hyperinflation and other radiological abnormalities may provide additional clinical information regarding the underlying respiratory pathology. Similarly, inflammatory markers such as C-reactive protein (CRP), ferritin, interleukin-6 (IL-6) and procalcitonin, along with cardiac biomarkers, may provide additional information regarding the inflammatory response and physiological stress associated with severe respiratory illness.

In this context, the present study was undertaken to evaluate factors associated with readmission among children aged 1 month to 2 years admitted with acute bronchiolitis and wheeze-associated lower respiratory tract infection (WALRI) during the post-COVID period. Particular emphasis was placed on the relationship between ambient Air Quality Index categories, clinical severity, requirement for ventilatory support, duration of hospital stay, inflammatory and cardiac biomarkers, respiratory viral panel results and radiological findings. Through an integrated assessment of demographic, clinical, environmental, laboratory and radiological parameters, the study aimed to identify factors associated with recurrent hospital admissions and explore their relevance in the clinical assessment and management of young children with acute respiratory illnesses.

MATERIALS AND METHODS

This hospital-based, cross-sectional, descriptive observational study was conducted in the Department of Paediatrics, Dr. B. C. Roy Post Graduate Institute of Paediatric Sciences, Kolkata, West Bengal. The study was carried out among children admitted to the Paediatric General Wards, Respiratory Care Unit (RCU), High Dependency Unit (HDU) and Paediatric Intensive Care Unit (PICU). The study population comprised children aged 1 month to 2 years with a past history of acute bronchiolitis or wheeze-associated lower respiratory tract infection (WALRI), who were admitted to the respective hospital units during the study period.

A total of 384 children were included in the study. The sample size was calculated using the standard formula for estimating a proportion, considering a 95% confidence interval, an anticipated prevalence of paediatric readmission following hospitalisation for lower respiratory tract infection of 48.2%, and an allowable error of 5%. The calculated sample size was 384. Eligible participants fulfilling the inclusion criteria were recruited consecutively until the required sample size was achieved. As this was an observational cross-sectional study, no separate control group was required.

Demographic and clinical variables recorded included age, sex, birth history, prematurity, low birth weight and history of birth asphyxia. Relevant clinical risk factors such as household crowding, parental smoking exposure, type of cooking fuel used and geographical area of residence were documented. Information regarding previous episodes of acute bronchiolitis or WALRI, associated medical conditions including congenital heart disease, syndromic conditions and chronic illnesses, family history of asthma or atopy, and immunisation status was also collected. The ambient Air Quality Index (AQI) corresponding to the residential area of each child during the relevant period was recorded and categorised as satisfactory, moderate or poor based on available area-specific AQI data.

Data were collected using a predesigned structured proforma (case record form). Relevant information was obtained from clinical history sheets, bed head tickets, examination records, laboratory investigation reports, radiological reports, intensive care monitoring charts and discharge summaries. A detailed history was recorded, including presenting complaints such as cough, fever, increased work of breathing, fast breathing and feeding difficulty. Previous hospital admissions, associated comorbidities, environmental exposures, birth history and immunisation details were also documented, along with the number and frequency of readmissions.

All children underwent general and systemic clinical examination. Vital parameters, including temperature, respiratory rate, pulse rate and peripheral oxygen saturation (SpO_2), were recorded. Respiratory assessment included evaluation of breathing pattern, nasal flaring, chest retractions and grunting, along with auscultation for wheeze, crepitations and air entry. Anthropometric measurements included body weight, length or height, mid-upper arm circumference (MUAC), head circumference and chest circumference. Nutritional status was assessed wherever applicable.

The requirement and type of respiratory support were documented for each participant. Respiratory support modalities were categorised according to the level of support received, including humidified oxygen or face mask, humidified heated high-flow nasal cannula, non-invasive ventilation and invasive ventilation. The duration of respiratory support, total number of ventilation days and intensive care unit stay were recorded. Other hospital course parameters included total duration of hospitalisation and antibiotic administration, including duration of therapy.

Laboratory investigations were performed according to institutional clinical protocols and study requirements. These included complete blood count, serum albumin, inflammatory markers and respiratory viral panel (RVP) testing. Arterial blood gas analysis was performed whenever clinically indicated. Additional inflammatory and cardiac biomarkers were documented where available. Imaging evaluation included chest X-ray (CXR), while high-resolution computed tomography (HRCT) of the thorax and echocardiography were performed when clinically indicated. The relevant radiological and echocardiographic findings were recorded for subsequent analysis.

The primary outcome was the frequency of hospital readmission among children aged 1 month to 2 years with a previous history of acute bronchiolitis or WALRI. Readmission was defined as any subsequent hospital admission following discharge for acute bronchiolitis or WALRI, as recorded during the study period. Secondary outcomes included the association of AQI categories with inflammatory markers, cardiac biomarkers, requirement for oxygen or ventilatory support, duration of hospitalisation and

intensive care stay. The association between respiratory viral panel positivity and chest X-ray findings was also evaluated. Clinical determinants of disease severity, including escalation of respiratory support and prolonged hospitalisation, were assessed. All collected data were entered into Microsoft Excel and analysed using Statistical Package for the Social Sciences (SPSS), version 27.0. Categorical variables were expressed as frequencies and percentages, while continuous variables were presented as mean ± standard deviation or median with interquartile range (IQR), depending on the distribution of data. Associations between categorical variables were assessed using the Chi-square test or Fisher's exact test, as appropriate. Comparisons of continuous variables between groups were performed using Student's independent t-test or analysis of variance (ANOVA), with appropriate non-parametric alternatives wherever required. A p-value of ≤0.05 was considered statistically significant.

Written approval from the Institutional Ethics Committee was obtained before commencement of the study. Written informed consent was obtained from the parents or attending guardians of all participating children before inclusion. Participation was voluntary, and confidentiality of patient information was maintained throughout the study.

RESULTS

A total of 384 children aged 1 month to 2 years, admitted with acute bronchiolitis and wheeze-associated lower respiratory tract infection (WALRI), were included in the study. The demographic characteristics, clinical risk factors, laboratory parameters, radiological findings, respiratory support requirements, ambient air quality exposure and readmission patterns were analysed.

Categorical variables were expressed as frequencies and percentages, whereas continuous variables were presented as mean ± standard deviation (SD) or median with interquartile range (IQR), as appropriate. Associations between categorical variables were assessed using the Chi-square test. Student's independent t-test was used for comparison of continuous variables between two groups, while one-way analysis of variance (ANOVA) was used for comparisons across three AQI categories. A p-value of ≤0.05 was considered statistically significant.

Table 1: Sociodemographic and anthropometric characteristics of the study population (n = 384)

Characteristics	Values
Age (months)	
Mean ± SD	12.80 ± 6.09
Median (IQR)	13.0 (10.3)
Minimum–Maximum	1–24
Gender distribution	
Male, n (%)	220 (57.3)
Female, n (%)	164 (42.7)
Anthropometric parameters	
Weight (kg), Mean ± SD	7.78 ± 1.68
Height (cm), Mean ± SD	68.40 ± 7.36
MUAC (cm), Mean ± SD	12.60 ± 1.41
Head circumference (cm), Mean ± SD	43.40 ± 3.54
Chest circumference (cm), Mean ± SD	44.40 ± 3.54

MUAC: Mid-upper arm circumference; SD: Standard deviation; IQR: Interquartile range.

The mean age of the study population was 12.80 ± 6.09 months, with participants ranging from 1 to 24 months. Male children constituted 57.3% of the study population, demonstrating a male predominance. The mean weight and height were 7.78 ± 1.68 kg and 68.40 ± 7.36 cm, respectively. The mean MUAC, head circumference and chest circumference were 12.60 ± 1.41 cm, 43.40 ± 3.54 cm and 44.40 ± 3.54 cm, respectively.

Table 2: Distribution of clinical risk factors, environmental exposure and respiratory viral panel findings (n = 384)

Parameters	Frequency (n)	Percentage (%)
Prematurity	108	28.1
Congenital heart disease	60	15.6
Chronic lung disease	48	12.5
Crowding	8	2.1
Parental asthma	8	2.1
Smoking exposure	8	2.1
Extreme prematurity	6	1.6
Atopic dermatitis	4	1.0
Immunodeficiency	2	0.5
Wood stove exposure	2	0.5
No identifiable risk factor	130	33.9
Ambient Air Quality Index category		
Poor	140	36.5
Moderate	128	33.3
Satisfactory	116	30.2

Respiratory viral panel findings		
Negative	226	58.9
Respiratory syncytial virus positive	50	13.0
Rhinovirus positive	16	4.2
Other viral positives	92	24.0
Total	384	100.0

Prematurity was the most frequently identified risk factor, accounting for 28.1% of the study population, followed by congenital heart disease (15.6%) and chronic lung disease (12.5%). No identifiable risk factor was documented in 33.9% of children.

Regarding environmental exposure, 36.5% of children belonged to the poor AQI category, while 33.3% and 30.2% belonged to the moderate and satisfactory categories, respectively.

Respiratory viral panel testing was negative in 58.9% of children. Among the positive cases, respiratory syncytial virus accounted for 13.0%, rhinovirus for 4.2%, and other viral pathogens for 24.0% of the total study population.

Table 3: Distribution of hospital course, respiratory support requirements and radiological findings (n = 384)

A. Hospital course parameters		
Parameters	**Mean ± SD**	**Median (IQR)**
Duration of oxygen support (days)	4.83 ± 2.66	5 (3)
Number of hospital admissions	2.31 ± 1.17	2 (2)
Interval between admissions (months)	2.91 ± 2.65	2.5 (5)
Total hospital stay (days)	8.98 ± 4.44	8 (6)
B. Type of respiratory support required		
Respiratory support	**Frequency (n)**	**Percentage (%)**
Continuous positive airway pressure (CPAP)	102	26.6
Humidified heated high-flow nasal cannula (HHHFNC)	96	25.0
Non-invasive ventilation (NIV)	96	25.0
Room air	30	7.8
Others*	60	15.6
Total	384	100.0
Others included invasive ventilation and nasal cannula.		
C. Chest radiograph findings		
Chest X-ray findings	**Frequency (n)**	**Percentage (%)**
Bilateral infiltrates	116	30.2
Unilateral consolidation	110	28.6
Normal chest X-ray	114	29.7
Hyperinflation	16	4.2
Peribronchial thickening/perihilar prominence	16	4.2
Bilateral/extensive consolidation	12	3.1
Total	384	100.0

The mean duration of hospital stay was 8.98 ± 4.44 days, with a mean oxygen support duration of 4.83 ± 2.66 days. The average number of hospital admissions was 2.31 ± 1.17.

Regarding respiratory support, CPAP was the most frequently documented modality (26.6%), followed by HHHFNC and NIV (25.0% each). Only 7.8% of children were maintained on room air.

Chest radiography revealed bilateral infiltrates in 30.2% of children and unilateral consolidation in 28.6%. Normal chest radiographs were observed in 29.7% of the participants, indicating that radiological abnormalities were present in approximately 70% of the study population.

Table 4. Association between readmission status, BMI category and ambient Air Quality Index (n = 384)

A. Association between AQI category and frequency of hospital readmissions			
AQI category	**≥2 admissions, n (%)**	**Single admission, n (%)**	**Total, n (%)**
Poor	102 (72.9)	38 (27.1)	140 (100.0)
Moderate	66 (51.6)	62 (48.4)	128 (100.0)
Satisfactory	40 (34.5)	76 (65.5)	116 (100.0)
Total	208 (54.2)	176 (45.8)	384 (100.0)
Chi-square test: $\chi^2 = 39.84$; df = 2; $p < 0.001$.			
B. Association between BMI category and readmission			
BMI category	**No readmission, n (%)**	**≥1 readmission, n (%)**	**Total, n (%)**
Underweight	42 (42.0)	58 (58.0)	100 (100.0)
Normal BMI	108 (64.3)	60 (35.7)	168 (100.0)
Overweight	52 (61.9)	32 (38.1)	84 (100.0)
Obese	18 (56.3)	14 (43.7)	32 (100.0)
Total	220 (57.3)	164 (42.7)	384 (100.0)
Chi-square test: $\chi^2 = 12.48$; df = 3; $p = 0.006$.			

A statistically significant association was observed between AQI category and frequency of hospital readmissions ($p < 0.001$). The proportion of children with frequent readmissions was highest in the poor AQI category (72.9%), followed by the moderate (51.6%) and satisfactory (34.5%) categories.

BMI category was also significantly associated with readmission status ($p = 0.006$). Underweight children demonstrated the highest proportion of readmissions (58.0%), compared with children with normal BMI (35.7%). These findings suggest that poor ambient air quality and nutritional status were important factors associated with repeated hospital admissions in the study population.

Table 5: Association of clinical, radiological, virological and biochemical parameters with disease severity and environmental exposure (n = 384)

A. Association between prematurity and requirement of advanced respiratory support			
Prematurity	**Advanced support required, n (%)**	**No advanced support, n (%)**	**Total**
Present	68 (75.6)	22 (24.4)	90
Absent	136 (46.3)	158 (53.7)	294
Total	204 (53.1)	180 (46.9)	384
$\chi^2 = 22.18$; df = 1; $p < 0.001$.			
B. Association between chest X-ray findings and requirement of advanced respiratory support			
Chest X-ray findings	**Advanced support required, n (%)**	**No advanced support, n (%)**	**Total**
Abnormal chest X-ray	176 (67.4)	85 (32.6)	261
Normal chest X-ray	28 (24.6)	86 (75.4)	114
Total	204 (53.1)	180 (46.9)	384
$\chi^2 = 48.96$; df = 1; $p < 0.001$.			
C. Comparison of hospital stay according to respiratory viral panel positivity			
Respiratory viral panel status	**Mean hospital stay (days) ± SD**	**Number of children**	
Positive	10.6 ± 4.8	158	
Negative	7.8 ± 3.9	226	
Total	8.98 ± 4.44	384	
Independent Student's t-test: t = 6.31; df = 382; $p < 0.001$.			
D. Association between AQI category and cardiac biomarkers			
Cardiac biomarker	**Satisfactory AQI (n = 116), Mean ± SD**	**Moderate AQI (n = 128), Mean ± SD**	**Poor AQI (n = 140), Mean ± SD**
LDH (U/L)	417.12 ± 89.47	550.61 ± 114.52	697.29 ± 210.05
NT-proBNP (pg/mL)	433.79 ± 216.32	973.44 ± 593.89	1938.50 ± 1263.24
hs-Troponin-I (ng/mL)	0.55 ± 1.13	1.63 ± 3.49	4.82 ± 7.33
One-way ANOVA: LDH, F = 100.63; NT-proBNP, F = 111.38; hs-Troponin-I, F = 33.62. For all comparisons, df = (2, 381), $p < 0.001$.			
E. Association between AQI category and inflammatory markers			
Inflammatory marker	**Satisfactory AQI (n = 116), Mean ± SD**	**Moderate AQI (n = 128), Mean ± SD**	**Poor AQI (n = 140), Mean ± SD**
CRP (mg/L)	20.06 ± 8.76	36.01 ± 12.61	54.52 ± 24.92
Ferritin (ng/mL)	357.10 ± 166.80	542.00 ± 302.63	845.99 ± 507.18
IL-6 (pg/mL)	5.52 ± 3.00	10.00 ± 5.53	21.61 ± 14.72
Procalcitonin (ng/mL)	0.59 ± 0.35	1.25 ± 0.48	2.38 ± 0.97
Albumin (g/dL)	3.50 ± 0.40	3.16 ± 0.31	2.76 ± 0.53
One-way ANOVA: CRP, F = 121.03; ferritin, F = 65.99; procalcitonin F = 232.45; IL-6, F = 108.83 and albumin: F = 77.42. The reported degrees of freedom were (2, 381), with $p < 0.001$.			
F. Association between respiratory viral panel results and chest X-ray findings			
Chest X-ray findings	**RVP negative, n (%)**	**RVP positive, n (%)**	**Total, n (%)**
Normal	114 (50.4)	0 (0.0)	114 (29.7)
Bilateral infiltrates	96 (42.5)	20 (12.7)	116 (30.2)
Consolidation	0 (0.0)	110 (69.6)	110 (28.6)
Hyperinflation	16 (7.1)	0 (0.0)	16 (4.2)
Peribronchial thickening/perihilar prominence	0 (0.0)	16 (10.1)	16 (4.2)
Extensive/bilateral consolidation	0 (0.0)	12 (7.6)	12 (3.1)
Total	226 (100.0)	158 (100.0)	384 (100.0)
Chi-square test: $\chi^2 = 315.65$; df = 5; $p < 0.001$.			

Prematurity was significantly associated with the requirement for advanced respiratory support ($p < 0.001$). Among children with a history of prematurity, 75.6% required advanced respiratory support compared with 46.3% of those without prematurity.

Similarly, abnormal chest X-ray findings were significantly associated with increased respiratory support requirements ($p < 0.001$). Advanced respiratory support was required in 67.4% of children with abnormal chest radiographs compared with 24.6% of those with normal radiographs.

Respiratory viral panel positivity was associated with a significantly longer hospital stay. Children with positive viral panel results had a mean hospital stay of 10.6 ± 4.8 days compared with 7.8 ± 3.9 days among those with negative results ($p < 0.001$).

A significant increasing trend in cardiac biomarkers was observed with worsening AQI category. Mean LDH increased from 417.12 U/L in the satisfactory

AQI category to 697.29 U/L in the poor AQI category. Similarly, NT-proBNP and hs-Troponin-I demonstrated progressive elevation with worsening air quality ($p < 0.001$).

Inflammatory markers, including CRP, ferritin, IL-6 and procalcitonin, also demonstrated increasing mean values across worsening AQI categories. Conversely, serum albumin showed a declining trend, from 3.50 ± 0.40 g/dL in the satisfactory category to 2.76 ± 0.53 g/dL in the poor AQI category.

A statistically significant association was also observed between respiratory viral panel results and chest X-ray findings ($\chi^2 = 315.65$, $p < 0.001$). Viral-positive children predominantly demonstrated consolidation and other abnormal radiological patterns.

DISCUSSION

The present study evaluated children aged 1 month to 2 years with a past history of acute bronchiolitis or wheeze-associated lower respiratory tract infection (WALRI) who required hospitalisation. The study explored their demographic and clinical profiles, underlying risk factors, laboratory and radiological findings, environmental exposure and factors associated with disease severity and readmission. A total of 384 children were included. The mean age of the study population was 12.8 ± 6.09 months, with a male predominance (57.3%). Overall, the findings indicate that disease severity in this population was influenced by baseline host vulnerability, environmental exposure, radiological abnormalities, respiratory viral positivity and inflammatory as well as cardiac biomarker responses.

In the present study, prematurity emerged as an important background risk factor, reported in 23.4% of children in the discussion summary. This observation is consistent with the findings of Mecklin et al., who demonstrated that low age, low birth weight and congenital heart disease were significant risk factors for intensive care requirement among infants with bronchiolitis.[11] Their findings highlight the importance of underlying host vulnerability in determining the clinical course of bronchiolitis.

In our study, prematurity was significantly associated with the requirement for advanced respiratory support, including bilevel positive airway pressure (BiPAP), non-invasive ventilation (NIV) and invasive ventilation. Among premature children, 75.6% required advanced respiratory support compared with 46.3% of children without prematurity ($\chi^2 = 22.18$, $df = 1$, $p < 0.001$). This finding reinforces the importance of prematurity as a clinical marker for severe respiratory illness and the need for timely escalation of respiratory support.

Congenital heart disease was also an important associated comorbidity, reported in 15.6% of the study population. Children with underlying cardiac abnormalities may have reduced cardiopulmonary reserve and increased susceptibility to severe respiratory infections. Mohammed et al. evaluated palivizumab prophylaxis in children younger than 2 years with congenital heart disease and highlighted the importance of targeted prevention against severe RSV-associated illness in this vulnerable population.[12] Although their study primarily focused on prophylaxis, it supports the clinical relevance of identifying children with underlying cardiac conditions. In our study, echocardiographic evaluation revealed reduced left ventricular ejection fraction or left ventricular dysfunction in 25.6% of children and pulmonary arterial hypertension in 5.7%, suggesting that cardiopulmonary abnormalities were not uncommon among hospitalised children.

One of the important observations of the present study was the association between ambient air quality, represented by Air Quality Index (AQI) categories, and clinical severity. Children belonging to the poor AQI category demonstrated higher inflammatory and cardiac biomarker levels and greater requirements for respiratory support.

The association between AQI category and ventilatory support requirement was statistically significant ($\chi^2 = 715.59$, $df = 12$, $p < 0.001$). This finding indicates a strong relationship between residential ambient air quality category and the level of respiratory support required during hospitalisation.

The inflammatory markers also demonstrated significant differences across AQI categories. Mean C-reactive protein (CRP) increased progressively with worsening air quality ($F = 121.03$, $df = 2,381$, $p < 0.001$). Similar statistically significant differences were observed for ferritin ($F = 65.99$, $p < 0.001$), interleukin-6 (IL-6) ($F = 108.83$, $p < 0.001$) and procalcitonin ($F = 232.45$, $p < 0.001$). In contrast, serum albumin demonstrated a declining trend with worsening AQI category ($F = 77.42$, $p < 0.001$).

These findings suggest that children belonging to poorer air quality categories experienced a greater inflammatory response during hospitalisation. The observed pattern provides additional clinical evidence supporting the possible relationship between environmental exposure and systemic inflammatory burden in children with acute respiratory illness.[13]

Respiratory viral panel testing was negative in 58.9% of children, while respiratory syncytial virus positivity was identified in 13% of the study population. Despite the relatively high proportion of negative results, viral positivity demonstrated a significant association with the duration of hospitalisation.

Children with positive respiratory viral panel results had a mean hospital stay of 10.6 ± 4.8 days compared with 7.8 ± 3.9 days among children with negative results ($t = 6.31$, $df = 382$, $p < 0.001$).

This observation is comparable to the findings of Naja et al., who reported that RSV-associated bronchiolitis was associated with a significantly longer hospital stay than non-RSV bronchiolitis ($p = 0.007$).[14] Their study also demonstrated associations between smoking exposure, intensive care

admission, oxygen requirement and prolonged hospitalisation. These findings support the importance of considering both viral aetiology and environmental exposure when evaluating the clinical course of bronchiolitis.

Chest X-ray findings demonstrated an important association with respiratory support requirements in the present study. Among children with abnormal chest radiographs, 67.4% required advanced respiratory support compared with 24.6% of children with normal chest radiographs. This association was statistically significant ($\chi^2 = 48.96$, df = 1, $p < 0.001$). These findings are comparable to those reported by Gonçalves et al., who evaluated the prognostic relevance of chest radiographic patterns in newborns with RSV disease. Their study demonstrated that consolidation patterns were associated with more severe disease, increased respiratory support requirements and a greater likelihood of invasive mechanical ventilation.[13] Thus, radiological abnormalities may provide useful additional information regarding disease severity and the possible need for escalation of respiratory support.

In our study, a strong association was also observed between respiratory viral panel status and chest X-ray findings ($\chi^2 = 315.65$, df = 5, $p < 0.001$). Viral-positive children predominantly demonstrated consolidation and peribronchial changes. These findings indicate that combined interpretation of virological and radiological investigations may provide better clinical understanding than either parameter considered independently.

The present study demonstrated elevated inflammatory marker levels among hospitalised children, with mean CRP of 36.7 ± 23.0 mg/L, ferritin of 580 ± 411 ng/mL, IL-6 of 12.5 ± 11.7 pg/mL and procalcitonin of 1.40 ± 1.03 ng/mL. These findings suggest a considerable inflammatory response among children requiring hospitalisation for acute bronchiolitis and WALRI.

The observations are consistent with the study by Costa et al., who evaluated the relationship between CRP and disease severity in children with bronchiolitis. They reported significant associations between elevated CRP levels and intensive care admission ($p = 0.008$), prolonged hospital stay ($p = 0.025$) and oxygen requirement ($p = 0.022$).[15] The similarity in findings supports the potential utility of inflammatory markers, particularly CRP, as supplementary indicators of disease severity and clinical progression.

However, inflammatory markers should be interpreted alongside clinical findings and other investigations rather than being considered independent indicators of disease severity.

An important consideration in the management of bronchiolitis is the interpretation of haematological parameters when evaluating the possibility of concurrent bacterial infection. In the present study, total leukocyte count demonstrated considerable variability, with a mean value of 14,635 ± 10,077/mm³.

Purcell and Fergie investigated the usefulness of abnormal white blood cell counts in predicting concurrent serious bacterial infection among infants and young children hospitalised with RSV-associated lower respiratory tract infection. They reported that abnormal leukocyte counts had limited predictive value for identifying bacterial coinfection.[16]

This observation highlights the importance of avoiding excessive reliance on isolated leukocyte count abnormalities when making clinical decisions. In children with suspected viral respiratory infections, the overall clinical condition, disease progression and supporting investigations should guide the assessment of possible bacterial coinfection and the need for antimicrobial therapy.

Severe respiratory outcomes in children are influenced not only by the infecting pathogen but also by underlying host characteristics and associated medical conditions.

Lee et al. evaluated risk factors associated with mortality in children with severe RSV infection and reported that Down syndrome was an independent risk factor for mortality (OR = 7.20; 95% CI: 1.13–45.76; $p = 0.036$). Nosocomial RSV infection was also independently associated with mortality (OR = 4.46; 95% CI: 1.09–18.27; $p = 0.038$).[17]

Ram and Chinen reviewed the association between infections and immune dysfunction in children with Down syndrome. They described abnormalities involving T-cell function, humoral immunity and neutrophil/monocyte responses, along with structural abnormalities such as congenital heart disease and airway anomalies, contributing to increased susceptibility to infections and more severe clinical presentations.[18]

Although mortality was not evaluated as an outcome in our study, these observations emphasise the importance of recognising syndromic children and those with underlying comorbidities as potentially vulnerable groups requiring careful clinical monitoring, appropriate respiratory support and planned follow-up after discharge.

Coinfection with multiple respiratory viruses may further influence disease severity among hospitalised children. Richard et al. evaluated the impact of dual viral infections among infants admitted to a paediatric intensive care unit with severe bronchiolitis. Their findings demonstrated that dual viral infections were significantly associated with severe disease, with multivariable analysis showing a 2.7-fold increase in the odds of intensive care admission (95% CI: 1.2–6.2).[19]

Although the present study did not separately evaluate dual viral detection patterns as an independent outcome, the significant association between respiratory viral panel positivity, radiological abnormalities and prolonged hospitalisation supports the relevance of viral aetiology in determining the clinical course of respiratory illness.

The requirement for advanced respiratory support represents an important indicator of disease severity

in children with bronchiolitis and WALRI. In the present study, prematurity and abnormal chest X-ray findings were both significantly associated with the requirement for advanced respiratory support.

Sala et al. evaluated 734 admissions for bronchiolitis and reported that 22% of children required intensive care admission, while 10% required intubation. Children requiring intensive care were younger than those who did not require intensive care (median age 69 days versus 110 days, $p < 0.001$). Prematurity was also associated with an increased risk of intensive care admission (OR = 1.7; 95% CI: 1.1–2.4; $p = 0.01$).[20]

Similarly, López Guinea et al. studied 284 children with severe bronchiolitis and reported RSV positivity in 74% of cases. At least one underlying risk factor was present in 68% of children, while mechanical ventilation was required in 24% (64/284). Mortality was reported in 1.8% of cases and was associated with chronic illness ($p < 0.001$).[21]

Although these studies involved different patient populations, their findings are consistent with our observations that underlying vulnerability, particularly prematurity and associated comorbidities, contributes to severe respiratory illness and the need for escalation of respiratory support.

An important contribution of the present study was the evaluation of cardiac biomarkers in relation to ambient AQI categories. Mean lactate dehydrogenase (LDH), N-terminal pro-B-type natriuretic peptide (NT-PROBNP) and high-sensitivity troponin-I (HS-Troponin-I) demonstrated progressive increases with worsening air quality.

Mean LDH increased from 417.12 ± 89.47 U/L in the satisfactory AQI category to 697.29 ± 210.05 U/L in the poor AQI category. Similarly, NT-proBNP increased from 433.79 ± 216.32 pg/mL to 1938.50 ± 1263.24 pg/mL, while HS-Troponin-I increased from 0.55 ± 1.13 ng/mL to 4.82 ± 7.33 ng/mL.

All three cardiac biomarkers demonstrated statistically significant differences across AQI categories ($p < 0.001$). These observations suggest an association between poorer ambient air quality and increased biochemical evidence of systemic and cardiopulmonary stress among hospitalised children.

The echocardiographic findings further demonstrated reduced left ventricular function in a proportion of the study population, supporting the importance of evaluating cardiovascular involvement in children presenting with severe respiratory illness. The combined assessment of cardiac biomarkers and echocardiographic parameters may therefore provide additional information regarding the physiological impact of severe respiratory disease.

The association between ambient air quality and hospital readmission was one of the principal findings of the present study. Children belonging to the poor AQI category demonstrated the highest frequency of repeated hospital admissions.

Frequent readmission, defined as two or more admissions, was observed in 72.9% of children belonging to the poor AQI category, compared with 51.6% in the moderate AQI category and 34.5% in the satisfactory AQI category. This association was statistically significant ($\chi^2 = 39.84$, $df = 2$, $p < 0.001$). These findings suggest that children residing in areas with poorer ambient air quality may experience a greater burden of recurrent respiratory illness requiring hospitalisation. Continued environmental exposure following discharge may potentially contribute to recurrent respiratory symptoms and subsequent hospital visits.

The findings of the present study are clinically relevant in the context of the increasing recognition of environmental determinants of childhood respiratory morbidity. They also highlight the importance of considering residential environmental exposure during clinical assessment and discharge counselling.

Nutritional status was another important parameter evaluated in relation to hospital readmission. In the present study, BMI category demonstrated a statistically significant association with readmission status ($\chi^2 = 12.48$, $df = 3$, $p = 0.006$).

The proportion of children with at least one readmission was highest among underweight children (58.0%), compared with 35.7% among children with normal BMI, 38.1% among overweight children and 43.7% among obese children.

This finding suggests that nutritional status may influence the pattern of recurrent hospitalisation among children with bronchiolitis and WALRI. Underweight children may represent a particularly vulnerable group requiring careful nutritional assessment, appropriate feeding advice and closer follow-up after discharge.

CONCLUSION

The present study involving 384 children aged 1 month to 2 years with a history of acute bronchiolitis or wheeze-associated lower respiratory tract infection demonstrated that disease severity and recurrent hospitalisation were associated with multiple host-related and environmental factors. Prematurity was significantly associated with the requirement for advanced respiratory support ($p < 0.001$), while abnormal chest X-ray findings were also significantly associated with greater respiratory support requirements ($p < 0.001$). Respiratory viral panel positivity was associated with prolonged hospital stay ($p < 0.001$). An important finding was the significant association between worsening ambient Air Quality Index categories, increased inflammatory and cardiac biomarker levels, greater ventilatory support requirements and frequent hospital readmissions ($p < 0.001$). Underweight children also demonstrated a higher proportion of readmissions. These findings highlight the importance of considering environmental exposure alongside clinical and biochemical parameters when evaluating respiratory illness in young children.

Based on the findings of the present study, early identification and closer monitoring should be prioritised in children with prematurity, congenital heart disease and other underlying comorbidities. AQI assessment may be considered during clinical evaluation to identify children potentially exposed to poor ambient air quality. Caregivers should be counselled regarding avoidance of smoke exposure and unnecessary outdoor exposure during periods of poor air quality. Nutritional assessment and appropriate feeding counselling should be incorporated into routine clinical management, particularly for underweight children. Inflammatory and cardiac biomarkers may be considered supportive indicators of disease severity in clinically indicated cases, alongside comprehensive clinical assessment. Structured follow-up, caregiver education regarding respiratory warning signs and appropriate discharge counselling should be emphasised to minimise recurrent hospitalisation. Further prospective, multicentric studies incorporating individual-level assessment of ambient and indoor air pollution exposure, detailed evaluation of respiratory viral infections and long-term follow-up are recommended to establish the relationship between environmental factors, disease severity and subsequent respiratory outcomes.

REFERENCES

1. Kang L, Zhang Y, Zhou M, et al. An analysis for the Global Burden of Disease Study 2019. Respirology. 2023;28(2):120-132.
2. Aithal SS, Aithal P. Air quality and respiratory health in children. Clin Exp Pediatr. 2023;66(6):266-276.
3. World Health Organization. New WHO Global Air Quality Guidelines aim to save millions of lives from air pollution. Geneva: World Health Organization; 2021.
4. World Health Organization. Ambient (outdoor) air pollution. Geneva: World Health Organization; 2024.
5. World Health Organization. Respiratory syncytial virus (RSV). Geneva: World Health Organization; 2024.
6. Li Y, Wang X, Blau DM, et al. Global, regional, and national disease burden estimates of acute lower respiratory infections due to respiratory syncytial virus in young children in 2019: a systematic analysis. Lancet. 2022;399(10340):2047-2064.
7. World Health Organization. IMCI Chart Booklet: Integrated Management of Childhood Illness. Geneva: World Health Organization; 2014.
8. Wang X, Li Y, O'Brien KL, et al. Global disease burden of and risk factors for acute lower respiratory infections in children younger than 5 years, 1990–2019: a systematic analysis. Lancet. 2024;403:1423-1434.
9. Institute for Health Metrics and Evaluation (IHME). Lower Respiratory Infections. Seattle: Institute for Health Metrics and Evaluation; 2020.
10. World Health Organization. WHO Global Air Quality Guidelines: Questions and Answers. Geneva: World Health Organization; 2021.
11. Mecklin M, Heikkilä P, Korppi M. Low age, low birthweight and congenital heart disease are risk factors for intensive care in infants with bronchiolitis. Acta Paediatr. 2017;106(12):2004-2010.
12. Mohammed MHA, Agouba R, El Obaidy I, Alhabshan F, Abu-Sulaiman R. Palivizumab prophylaxis against respiratory syncytial virus infection in patients younger than 2 years of age with congenital heart disease. Ann Saudi Med. 2021;41(1):31-35.
13. Gonçalves A, Rocha G, Guimarães H, Fernandes PC, Proença E, Oliveira D, et al. Value of chest radiographic pattern in RSV disease of the newborn: a multicenter retrospective cohort study. Crit Care Res Pract. 2012;2012:861867.
14. Naja Z, Fayad D, Khafaja S, Chamseddine S, Dbaibo G, Hanna-Wakim R. Bronchiolitis admissions in a Lebanese tertiary medical center: a 10 years' experience. Front Pediatr. 2019;7:189.
15. Costa S, Rocha R, Tavares M, Bonito-Vítor A, Guedes-Vaz L, João HS. C reactive protein and disease severity in bronchiolitis. Rev Port Pneumol. 2009;15(1):55-65.
16. Purcell K, Fergie J. Lack of usefulness of an abnormal white blood cell count for predicting a concurrent serious bacterial infection in infants and young children hospitalized with respiratory syncytial virus lower respiratory tract infection. Pediatr Infect Dis J. 2007;26(4):311-315.
17. Lee YI, Peng CC, Chiu NC, Huang DTN, Huang FY, Chi H. Risk factors associated with death in patients with severe respiratory syncytial virus infection. J Microbiol Immunol Infect. 2016;49(5):737-742.
18. Ram G, Chinen J. Infections and immunodeficiency in Down syndrome. Clin Exp Immunol. 2011;164(1):9-16.
19. Richard N, Komurian-Pradel F, Javouhey E, Perret M, Rajoharison A, Bagnaud A, et al. The impact of dual viral infection in infants admitted to a pediatric intensive care unit associated with severe bronchiolitis. Pediatr Infect Dis J. 2008;27(3):213-217.
20. Sala KA, Moore A, Desai S, Welch K, Bhandari S, Carroll CL. Factors associated with disease severity in children with bronchiolitis. J Asthma. 2015;52(3):268-272.
21. López Guinea A, Casado Flores J, Martín Sobrino MA, Espínola Docio B, de la Calle Cabrera T, Serrano A, et al. Severe bronchiolitis. Epidemiology and clinical course of 284 patients. An Pediatr (Barc). 2007;67(2):116-122.