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PNEUMONIA AMONG CHILDREN WITH CONGENITAL HEART DISEASE: PATTERNS BY SHUNT TYPE IN A TERTIARY HOSPITAL IN INDONESIA

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ABSTRACT
Congenital Heart Disease (CHD) in children is frequently associated with lower respiratory tract infections, particularly pneumonia. Pneumonia risk in CHD is influenced by shunt type, defect size, nutritional status, yet local data regarding these associations remains limited. To determine the incidence of pneumonia in children with CHD and to analyze its association with shunt type and defect size. This retrospective cross-sectional study consecutively extracted demographic and clinical data—including CHD shunt type and defect size, nutritional status, and pneumonia diagnosis—from 134 echocardiography-confirmed medical records of hospitalized and outpatient pediatric CHD treated at Adam Malik General Hospital, Medan, from January 2022 to December 2024. Data associations were analyzed using Chi-square or Fisher's exact tests, and prevalence ratios (PR) were calculated. Pneumonia occurred in 32.8% (44/134) of children with CHD. A higher proportion of pneumonia was observed in acyanotic CHD compared with cyanotic CHD (40.3% vs. 25.4%; PR 1.57; p = 0.066). Among acyanotic CHD, pneumonia was more frequent in children with large defects than in those with moderate to small defects (47.0% vs. 38.0%; PR 1.24; p = 0.511). Pneumonia is a frequent complication in children with CHD. Acyanotic CHD and larger defect size show a tendency toward increased pneumonia risk, although no statistically significant associations were identified.

Keywords: children; congenital heart disease; defect size; left-to-right shunt; pneumonia

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INTRODUCTION

Congenital heart disease (CHD) is one of the most prevalent congenital disorders in childhood and remains a major contributor to pediatric morbidity worldwide (Bai et al., 2024; Salari et al., 2024). CHD is a structural abnormality of the heart and/or great vessels that is present at birth (Bai et al., 2024). Globally, congenital birth defects are reported by the World Health Organization to occur in approximately 6% of all births worldwide, while congenital heart defects affect an estimated 2.78 per 1,000 live births among infants (Congenital Disorders, n.d.; Salari et al., 2024). Although advances in diagnosis and management have significantly improved survival, children with CHD continue to experience a high burden of non-cardiac complications that influence clinical outcomes and healthcare utilization (Su et al., 2022; Ye et al., 2025). Among these, pneumonia represents one of the most frequent and clinically relevant complications, often leading to prolonged hospitalization, recurrent admissions, and increased mortality risk (Nyang et al., 2025). In resource-limited settings, where pneumonia remains a leading cause of childhood death, the coexistence of CHD may further amplify disease severity (Nyang et al., 2025; Yasmine et al., 2022). Despite this, pneumonia in children with CHD is frequently regarded as an accompanying condition rather than a complication directly related to underlying cardiac physiology.

From a pathophysiological perspective, the predisposition of children with CHD to pneumonia is closely linked to altered cardiopulmonary hemodynamics (Jat et al., 2022). In acyanotic CHD with

left-to-right shunts—such as ventricular septal defect (VSD), atrioventricular septal defect (AVSD), and patent ductus arteriosus (PDA)—chronic pulmonary overcirculation results in increased pulmonary blood volume, interstitial edema, and airway mucosal congestion (Esmail et al., 2024; Jat et al., 2022). These changes impair mucociliary clearance and local pulmonary defense mechanisms, facilitating lower respiratory tract infection (Jat et al., 2022). In contrast, cyanotic CHD is characterized by chronic hypoxemia, which has been associated with impaired immune responses, altered inflammatory regulation, and reduced ciliary function (Esmail et al., 2024; Jat et al., 2022). While both physiological patterns plausibly increase susceptibility to pneumonia, existing literature often relies on broad cyanotic–acyanotic classifications without sufficient consideration of shunt magnitude.

Previous studies (Esmail et al., 2024; Jat et al., 2022) consistently report a high prevalence of pneumonia among children with CHD, particularly in those with left-to-right shunt lesions. A prospective cohort study in Egypt identified atrial septal defect (ASD) as the predominant lesion among children with congenital heart disease and pneumonia (36%), followed by AVSD (20%) (Esmail et al., 2024). Conversely, a cross-sectional study in India reported CHD in 12.5% of pediatric pneumonia cases, with VSD being the most prevalent (8.8%) (Jat et al., 2022). Several investigations suggest that a larger defect size may confer a higher risk of pneumonia (Murni et al., 2023; Sulthoni et al., 2023; Talukder et al., 2023), likely due to more pronounced pulmonary overcirculation and earlier onset of congestive heart failure.

In Indonesia, a case–control study conducted at Dr. Soetomo General Hospital, Surabaya, involving 96 children with left-to-right shunt CHD and pneumonia, found ASD to be the most prevalent lesion (44.8%), followed by VSD (20.8%) (Sulthoni et al., 2023). The study further demonstrated that mortality risk in children with left-to-right shunt CHD complicated by pneumonia was significantly associated with defect size, oxygen desaturation, first-line antibiotic modification, and the presence of pulmonary hypertension. Similarly, a retrospective study at Hasan Sadikin General Hospital, Bandung, reported recurrent pneumonia in 232 of 1,258 children with congenital heart disease (18.4%), with left-to-right shunt lesions accounting for the vast majority of cases (91.8%) (Rahayuningsih et al., 2021). VSD was the most common lesion, followed by PDA, both of which were identified as significant risk factors for recurrent pneumonia ($p = 0.001$ for each); the odds of recurrent pneumonia were 1.55-fold higher in patients with VSD compared with atrial septal defect, whereas PDA was associated with a lower risk than ASD (odds ratio 0.652).

However, where both CHD and childhood pneumonia remain highly prevalent in Indonesia, data examining their interaction remain scarce, particularly outside major centers in Java. Most available evidence focuses on clinical outcomes rather than on mechanistic factors such as shunt type and defect size. This gap limits the development of targeted preventive strategies and hampers early identification of high-risk patients. Therefore, this study aimed to determine the incidence of pneumonia among children with CHD treated at a tertiary referral hospital in Indonesia and to examine the association between CHD shunt type, defect size, and pneumonia occurrence.

METHOD

Study Design and Setting

This retrospective cross-sectional study was conducted at the Department of Child Health, Adam Malik General Hospital, a national tertiary referral center in Medan, North Sumatra, Indonesia. The study evaluated medical records of children aged 3 months to 18 years diagnosed with congenital heart disease (CHD) who were hospitalized or attended outpatient care from January 1, 2022, to December 31, 2024. The study design was chosen to assess the prevalence of pneumonia and its association with CHD characteristics, with a main focus on shunt type and defect size.

Study Population and Eligibility Criteria

Eligible participants were children with a confirmed diagnosis of CHD based on transthoracic echocardiography performed by pediatric cardiologists. Inclusion criteria comprised the availability of complete clinical, echocardiographic, and radiological data, including documentation of pneumonia status during the study period. Patients were excluded if medical records were incomplete, if pneumonia occurred before CHD diagnosis, or if children had conditions that could independently predispose them to recurrent pulmonary infections, such as tuberculosis, chronic lung disease unrelated to infection, other congenital disorders, Eisenmenger syndrome, or previous definitive corrective cardiac surgery. From an initial pool of 201 medical records, 134 patients met the eligibility criteria and were included in the final analysis.

Variable Definitions and Data Collection

Congenital heart disease was classified according to shunt physiology into acyanotic and cyanotic CHD based on clinical findings and echocardiographic assessment. Acyanotic CHD predominantly represented left-to-right shunt lesions, while cyanotic CHD included lesions associated with right-to-left shunting or complex mixing physiology. In patients with acyanotic CHD, defect size was further categorized as small (< 3mm), moderate (3-6 mm), or large (> 6mm) using standard echocardiographic criteria routinely applied in pediatric cardiology practice.

Pneumonia was defined as a documented clinical diagnosis supported by compatible symptoms (such as fever, cough, tachypnea, or respiratory distress), physical examination findings, and radiological evidence on chest imaging, as recorded by the treating pediatrician. Demographic variables (age and sex) and nutritional status were extracted from the medical records and considered as potential confounders due to their known influence on susceptibility to infection. Nutritional evaluation was based on the World Health Organization (WHO) growth standards.

Statistical Analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS). Categorical variables were summarized as frequencies and percentages. The association between CHD shunt type, defect size, and the occurrence of pneumonia was evaluated using the Chi-square test. Effect size was expressed as prevalence ratio (PR) with corresponding 95% confidence intervals (CI) to quantify the strength of association. Statistical significance was defined as p-value < 0.05. All analyses were performed in accordance with established epidemiological reporting standards for observational studies.

Ethical Considerations

The study protocol was reviewed and approved by the Health Research Ethics Committee of the Faculty of Medicine, Universitas Sumatera Utara (No.467/UN5.2.1.1.11/KRK/2024). As this study involved a retrospective review of anonymized medical records, informed consent was waived. Patient confidentiality was strictly maintained throughout the data collection and analysis process.

RESULT

This study provides a three-year overview of the burden of pneumonia among children with congenital heart disease (CHD) treated at a tertiary referral hospital in Medan, North Sumatra, Indonesia. A total of 201 paediatric medical records with congenital heart disease were screened; 65 records (32.3%) were excluded due to incomplete echocardiographic, laboratory, or radiological data, and 2 patients (1.0%) were excluded for Eisenmenger syndrome. After exclusions, 134 patients (66.7%) fulfilled the inclusion criteria and were eligible for analysis. The final sample was evenly stratified into 67 cyanotic and 67 acyanotic CHD patients to enable balanced comparative analysis.

The study included 134 children with congenital heart disease, with a male predominance (59.7%). Most patients were aged 1–4 years (45.5%), followed by those older than 5 years (34.3%). Malnutrition was highly prevalent, with 75.4% of children classified as severely malnourished (31.4%) or undernourished (44.0%), while only 19.4% had a normal nutritional status. Nutritional problems were commonly observed among children with CHD who developed pneumonia, regardless of shunt type.

Table 1.
Demographic and clinical characteristics of the study population (n = 134)

Characteristic	f (%)
Sex	
Male	80 (59.7)
Female	54 (40.3)
Age group	
< 1 year	27 (20.2)
1-4 years	61 (45.5)
>5 years	46 (34.3)
Nutritional status	
Severely malnourished	42 (31.4)
Undernourished	59 (44.0)
Normal	26 (19.4)
Overweight	6 (4.5)
Obese	1 (0.7)
Shunt type of CHD	
Acyanotic	67 (50)
Cyanotic	67 (50)
CHD diagnosis	
Tetralogy of Fallot (TOF)	56 (41.8)
Transposition of the Great Arteries (TGA)	11 (8.2)
Ventricular septal defect (VSD)	48 (35.8)
Atrial septal defect (ASD)	14 (10.5)
Patent ductus arteriosus (PDA)	5 (3.7)
Defect size in acyanotic CHD	
Large (> 6 mm)	17 (25.3)
Moderate (3-6 mm)	44 (65.7)
Small (< 3 mm)	6 (9.0)

n, total number of subjects; CHD, Congenital heart disease; mm, millimeter

Acyanotic and cyanotic congenital heart disease were equally represented. Tetralogy of Fallot was the most frequent CHD diagnosis (41.8%), followed by ventricular septal defect (35.8%). Among children with acyanotic defects, moderate defect size predominated (65.7%), whereas large defects were observed in one-quarter of cases. Overall, pneumonia was identified in 44 of the 134 children with CHD, corresponding to an incidence of 32.8%. Pneumonia occurred in both inpatient and outpatient settings and was documented based on compatible clinical findings supported by radiological evidence. This finding indicates that nearly one-third of children with CHD in this tertiary referral population experienced pneumonia during the study period.

Table 2.
Incidence of pneumonia in children with congenital heart disease

Variable	n, %
Pneumonia	
Yes	44 (32.8%)
No	90 (67.2%)

n, total number of subjects

In this study, pneumonia was more frequently observed in children with acyanotic CHD compared with those with cyanotic CHD. Children with acyanotic congenital heart disease demonstrated a higher proportion of pneumonia compared with those with cyanotic lesions (40.3% vs 25.4%). In contrast, the majority of children with cyanotic CHD did not develop pneumonia during the study period (74.6%). Although the difference did not reach statistical significance (p = 0.066), acyanotic

CHD was associated with a 1.57-fold higher prevalence of pneumonia. This trend suggests a clinically relevant association between left-to-right shunt physiology and increased susceptibility to lower respiratory tract infections.

Table 3.
Association Between CHD Shunt Type and Defect Size in Relation to Pneumonia Occurrence

Variable	Pneumonia		p value	PR
	Yes (f, %)	No (f, %)		
Shunt type				
Acyanotic	27 (40.3%)	40 (59.7%)	0.066	1.57
Cyanotic	17 (25.4%)	50 (74.6%)		
Defect size in acyanotic CHD				
Large	8 (47.0%)	9 (53.0%)	0.511	1.24
Moderate to small	19 (38.0%)	31 (62.0%)		

n, total number of subjects; CHD, Congenital heart disease; PR, prevalence ratio

Further analysis within the acyanotic CHD group, children with large congenital heart defects exhibited a higher proportion of pneumonia compared with those with moderate-to-small defects (47.0% vs. 38.0%). However, this difference did not reach statistical significance ($p = 0.511$), with a prevalence ratio of 1.24. Children with large cardiac defects had a 1.24-fold higher risk of developing pneumonia compared with those with moderate-to-small defects. Despite the lack of a statistically significant association, the observed trend suggests that a greater haemodynamic burden associated with larger defects may increase vulnerability to lower respiratory tract infections.

DISCUSSION

This study provides an integrated description of pneumonia burden and its clinical association among children with congenital heart disease (CHD) treated at a tertiary referral hospital in Indonesia. We observed that pneumonia occurred in 32.8% of children with CHD during the study period, confirming that lower respiratory tract infection remains a frequent and clinically important complication in this population. Although the study design does not allow causal inference or comparison with children without CHD, the finding that nearly one-third of patients with CHD developed pneumonia highlights the magnitude of respiratory morbidity associated with paediatric structural heart disease. This proportion is broadly consistent with reports from low- and middle-income countries, where delayed diagnosis, limited access to early corrective interventions, and a high prevalence of malnutrition amplify the vulnerability of children with CHD to infectious complications (Jat et al., 2022; Rabbani & Rajani, 2025).

The predominance of male patients (59.7%) observed in this cohort aligns with established epidemiological patterns in both CHD and paediatric pneumonia. Sex-based biological differences have long been recognised as contributors to differential susceptibility to infection. Oestrogen exerts immunomodulatory effects that enhance both innate and adaptive immune responses, whereas testosterone has been associated with relatively immunosuppressive properties, potentially leading to less efficient pathogen clearance in males. In addition, male infants and young children typically have smaller airway diameters relative to lung volume, predisposing them to more pronounced airflow limitation in the presence of mucosal oedema and inflammation. Genetic factors may further contribute, as several genes involved in immune regulation and cardiovascular development are located on the X chromosome, leaving males with reduced genetic redundancy. In the context of CHD, where cardiopulmonary reserve is already compromised, these sex-related vulnerabilities may partially explain the higher proportion of males observed among children experiencing pneumonia (Jat et al., 2022; Rabbani & Rajani, 2025).

Age distribution in this study underscores early childhood as a critical period of susceptibility. The largest proportion of pneumonia cases occurred in children aged 1–4 years (45.5%), while infants younger than one year accounted for 20.1%. Although infants represented a smaller proportion than

toddlers, they remain a clinically high-risk group because of immature immune function, reduced pulmonary reserve, and limited physiological capacity to compensate for cardiopulmonary stress (Nyang et al., 2025; Rabbani & Rajani, 2025). The higher proportion observed among children aged 1–4 years may reflect increased exposure to respiratory pathogens in the community, nutritional challenges during the transition from exclusive breastfeeding, and delayed recognition or intervention for underlying cardiac lesions. Previous studies have consistently demonstrated that infancy and early childhood are associated with higher rates of severe pneumonia, hospitalization, and adverse outcomes, particularly when CHD is present (Jat et al., 2022; Nyang et al., 2025; Rabbani & Rajani, 2025). Clinically, these findings emphasize that vigilance should extend beyond infancy to encompass the entire early childhood period in children with CHD.

Nutritional status emerged as one of the most striking characteristics of the study population. A substantial majority of children were classified as undernourished (44.0%) or severely malnourished (31.3%), reflecting the chronic metabolic and feeding challenges inherent to CHD. Malnutrition in children with CHD is multifactorial, resulting from increased energy expenditure due to elevated cardiac workload, reduced oral intake secondary to fatigue or dyspnoea, gastrointestinal congestion impairing nutrient absorption, and the adverse metabolic effects of chronic hypoxaemia. Importantly, malnutrition is a well-established determinant of immune dysfunction, impairing both cellular and humoral immunity, and reducing the body's ability to mount effective responses to respiratory pathogens. The high prevalence of malnutrition in this study likely contributed substantially to the observed pneumonia burden and may have acted as a key effect modifier in the relationship between CHD characteristics and infection risk (Djer et al., 2020; Murni et al., 2023). These findings reinforce the need to view nutritional optimisation as a core component of pneumonia prevention and overall management in children with CHD.

Tetralogy of Fallot (41.8%) and ventricular septal defect (35.8%) were the most frequently encountered diagnoses. The predominance of Tetralogy of Fallot likely reflects the role of the study centre as a referral hospital for complex and severe cardiac lesions. While cyanotic CHD is characterized by chronic hypoxaemia, the burden of pneumonia was proportionally higher among children with acyanotic CHD. This observation supports the concept that pulmonary overcirculation, rather than hypoxaemia alone, plays a central role in predisposing children with CHD to respiratory infections. In acyanotic lesions with left-to-right shunts, persistent increases in pulmonary blood flow lead to chronic pulmonary congestion, interstitial oedema, and impaired mucociliary clearance. These changes facilitate bacterial colonisation and recurrent lower respiratory tract infections, even in the absence of cyanosis (Djer et al., 2020; Yasmine et al., 2022). The distribution of CHD types in this study therefore, provides important context for interpreting the observed patterns of pneumonia.

Children with acyanotic CHD demonstrated a higher proportion of pneumonia (40.3%) compared with those with cyanotic CHD (25.4%). Although this difference did not reach statistical significance ($p = 0.066$), the estimated prevalence ratio (PR = 1.57) suggests a clinically meaningful trend toward increased risk. The absence of statistical significance should be interpreted cautiously, as it may reflect a limited sample size rather than a true lack of association. Importantly, both the magnitude and direction of the effect estimate are consistent with previous studies reporting a higher frequency of pneumonia among children with left-to-right shunt lesions, such as VSD, ASD, or PDA (Djer et al., 2020; Park & Salamat, 2020; Rabbani & Rajani, 2025). From a clinical perspective, this finding reinforces the importance of proactive respiratory surveillance and early management of pulmonary overcirculation in children with acyanotic CHD, even when statistical thresholds are not met.

A similar pattern was observed when pneumonia incidence was analysed according to defect size. Children with large defects experienced pneumonia in 47% of cases, compared with 38% among

those with moderate-to-small defects, yielding a non-significant difference (p = 0.511; PR = 1.24). Large defects are typically associated with substantial left-to-right shunts, resulting in excessive pulmonary blood flow, elevated pulmonary venous pressure, and chronic airway oedema. Over time, these haemodynamic disturbances impair mucociliary clearance and disrupt local immune defences within the respiratory tract. Although statistical significance was not achieved, the observed trend aligns with established pathophysiological principles and with prior evidence linking larger defect size to increased respiratory morbidity, recurrent hospitalization, and failure to thrive (Djer et al., 2020; Park & Salamat, 2020; Yasmine et al., 2022).

The findings of this study should be interpreted in light of several limitations. The retrospective cross-sectional design precludes causal inference and limits the ability to assess temporal relationships between CHD characteristics and pneumonia occurrences. The absence of a control group of children without CHD prevents estimation of relative risk compared with the general paediatric population. Additionally, potential confounders such as immunisation status, socioeconomic factors, environmental exposures, and timing of cardiac intervention could not be fully controlled. Nevertheless, the study provides valuable descriptive data on pneumonia burden and reflects real-world clinical conditions in a tertiary referral setting in a low- to middle-income country.

Despite these limitations, the study has important clinical implications. The observation that approximately one in three children with CHD developed pneumonia underscores the need for integrated management strategies. Male sex, early childhood age, malnutrition, left-to-right shunts, and larger defect size appear to cluster in children at higher risk for pneumonia, even when statistical significance is not consistently demonstrated. These findings support a holistic approach to care that incorporates early nutritional intervention, vigilant respiratory monitoring, timely management of pulmonary overcirculation, and consideration of early referral for definitive cardiac repair when feasible. Future studies employing prospective or comparative designs are needed to clarify causal pathways and quantify risk more precisely. Until such data are available, clinicians should remain vigilant to the substantial respiratory morbidity faced by children with CHD and prioritize preventive and supportive strategies tailored to this vulnerable population.

CONCLUSION

Pneumonia is a frequent complication in children with CHD. Children with acyanotic CHD have a higher risk of pneumonia than those with cyanotic CHD, likely due to the hemodynamic impact of left-to-right shunts. Larger defect size showed a tendency toward increased risk but was not statistically significant. Pulmonary overcirculation and malnutrition appear to play key roles in increasing susceptibility to pneumonia in this population.

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