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Determinants of prolonged hospitalization in childhood pneumonia: A five-year retrospective study from rural South Africa

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Abstract: This study aimed to describe five-year trends and seasonal patterns in childhood pneumonia and identify determinants of prolonged hospitalization at a rural tertiary hospital in the Eastern Cape, South Africa. This retrospective cross-sectional study reviewed admissions of children aged 0–14 years from January 2020 to December 2024. Of 9,099 pediatric admissions, 951 were pneumonia-related, and 190 records were randomly selected for detailed analysis. Prolonged hospitalization was defined as a stay exceeding five days. Negative binomial regression with robust standard errors was used to estimate unadjusted and adjusted incidence rate ratios. Pneumonia accounted for 10.4% of admissions, and mortality was 0.7%. Among the sampled children, 51.1% experienced prolonged hospitalization. Significant predictors included male sex, infancy, non-viral pneumonia, incomplete vaccination status, and lack of breastfeeding. Admission during spring, bronchiolitis, and prior use of herbal medications were associated with shorter hospital stays. Prolonged hospitalization reflects interacting demographic, clinical, and preventive health factors, with infants and children who were incompletely vaccinated, not breastfed, or diagnosed with non-viral pneumonia at greatest risk. Strengthening immunization coverage, promoting breastfeeding, and implementing early risk stratification, alongside seasonal preparedness, may reduce hospital stays and improve resource utilization in rural pediatric healthcare settings.

Keywords: *Childhood pneumonia, Pediatric respiratory infections, Prolonged hospitalization, Risk factors, Rural Health, South Africa.*

1. Introduction

Pneumonia remains a significant global health burden, characterized by acute inflammation of the lung parenchyma due to infectious agents including bacteria, viruses, or fungi [1, 2]. Transmission typically occurs via inhalation of nasopharyngeal flora, aerosolized respiratory droplets, or hematogenous spread, particularly in neonates [3]. The infection leads to alveolar consolidation with pus and fluid, impairing gas exchange and resulting in respiratory distress and hypoxemia [3]. Despite being preventable and treatable, pneumonia continues to account for substantial morbidity and mortality, particularly in low-resource settings. It is often termed the "forgotten child killer" due to its persistent neglect in global health agendas [4]. Although some progress has been made, the decline in pneumonia-related mortality lags that of other infectious diseases, with recent estimates indicating a 55% reduction, deemed the slowest decline among childhood infections [5-7]. Global data highlight that pneumonia accounts for a high proportion of hospital admissions and mortality, especially in children under five, with incidence rates near 1400 per 100,000 globally [4, 5]. The burden is disproportionately concentrated in Southeast Asia and Sub-Saharan Africa, with reported rates of up to 2,500 per 100,000 in some regions [4]. In East Africa alone, pooled prevalence reaches 34% [2], while studies across Ethiopia, Nigeria, Uganda, South Sudan, and South Africa report substantial regional heterogeneity [8-12]. The 2019

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Global Burden of Disease report indicated that lower respiratory infections, primarily pneumonia, were the fourth leading cause of death worldwide, responsible for 2.5 million deaths, with children disproportionately affected [5]. In South Africa alone, 4,323 child deaths were attributed to pneumonia in 2019 [5]. Encouragingly, trend analyses indicate declining mortality, attributed to conjugate vaccination (PCV, Hib), expanded healthcare access, and HIV prevention strategies [12, 13]. However, these declines remain insufficient to meet SDG 3.2, which aims to end preventable child deaths by 2030 [14]. Recent studies emphasize emerging challenges, including viral pneumonia (notably RSV), coinfections, antibiotic resistance, and TB-related pneumonia, particularly in Sub-Saharan Africa, where vaccine coverage remains suboptimal [15, 16]. Environmental and socioeconomic determinants such as undernutrition, indoor air pollution, and delayed healthcare-seeking behavior further compound pneumonia risk and outcomes [7, 17]. In South Africa, regional disparities and shifting pathogen profiles have been observed [18, 19]. Factors such as malnutrition, delayed referral, hypoglycemia, lack of exclusive breastfeeding, and inadequate antibiotic initiation are consistently associated with worse outcomes [20-22]. Rural provinces such as the Eastern Cape continue to face structural healthcare challenges, including delayed referral pathways, resource constraints, and evolving pathogen profiles. These factors contribute not only to disease incidence but also to adverse clinical outcomes, including prolonged hospitalization. Despite national progress in reducing pneumonia-related mortality, there remains a lack of data from rural and underserved regions of South Africa, particularly the Eastern Cape, where vaccination gaps, healthcare delays, and changing pathogen profiles persist. A clearer understanding of local epidemiological trends and predictors of hospitalization outcomes is crucial for tailoring interventions. Recent evidence indicates that childhood pneumonia outcomes are influenced by a combination of clinical severity, comorbidities, vaccination status, nutritional and feeding practices, healthcare access, and environmental conditions. The 2024 WHO guideline emphasises updated, age-inclusive approaches to pneumonia assessment and management in children up to 10 years old [23]. Recent African studies have further identified hypoxaemia, comorbidities, incomplete vaccination, rural residence, previous respiratory infections, and delayed healthcare access as important determinants of prolonged recovery or hospitalization. In South Africa, climatic variability, particularly changes in temperature and rainfall, has also been associated with seasonal patterns of acute respiratory disease. Nevertheless, evidence concerning these determinants among hospitalized children in rural South African settings remains limited, particularly in the Eastern Cape. This study therefore aimed to describe five-year trends in pediatric pneumonia admissions, examine seasonal patterns, and identify determinants of prolonged hospitalization among children admitted to a rural tertiary hospital in the Eastern Cape, South Africa. By integrating demographic, clinical, and contextual variables, this study provides novel insights to inform risk stratification, optimize clinical management, and support targeted public health interventions in resource-limited settings.

2. Materials and Methods

2.1. Study Design and Study Setting

A retrospective, facility-based cross-sectional study was conducted using medical records of children admitted with clinical pneumonia at Nelson Mandela Central Hospital (NMCH), Mthatha, South Africa, between January 2020 and December 2024. This design was selected to evaluate trends in morbidity and mortality and to identify predictors of clinical outcomes across five years. Data were extracted from ward registers and individual case files of the neonatal and pediatric wards. NMCH is a tertiary referral hospital located in the King Sabata Dalindyebo Local Municipality within the OR Tambo District of the Eastern Cape Province. The hospital serves as a regional centre for both public and private healthcare referrals and provides specialised paediatric care, including the management of childhood pneumonia.

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2.2. Study Population and Sampling

2.2.1. Target Population

The population consisted of children aged 0–14 years admitted with a clinical diagnosis of pneumonia, as recorded in hospital files. The age range of 0–14 years was selected because it aligns with the pediatric admission definition used at Nelson Mandela Central Hospital and with the World Health Organization (WHO) and South African pediatric pneumonia case definitions [23, 24]. Including older children also enabled a comprehensive assessment of pneumonia burden across the full pediatric spectrum, rather than restricting the analysis to under-five children. Recurrent admissions for the same case within a short interval were treated as a single episode.

Inclusion Criteria: Age: 0–14 years; clinical diagnosis of pneumonia (irrespective of etiology); residency within OR Tambo District; participants admitted between January 2020 and December 2024.

Exclusion Criteria: children older than 14 years of age, children with incomplete or missing medical records, those admitted primarily for conditions other than pneumonia (e.g., congenital heart disease or primary asthma), and readmissions for the same pneumonia episode within a short interval were excluded.

2.3. Sample Size Estimation

Epidemiological Data Analysis Program (EPIDAT) version 3.1 was used to calculate the sample size based on a pneumonia prevalence of 11.6% among South African children [25]. At a 95% confidence level and an absolute precision of 5%, using the built-in formula Z2*p*(1-p)/e2, a sample size of 158 was estimated:

Z, for a confidence level (α) of 95% = 1.96
p, the proportion (expressed as a decimal) = 11.6 (0.116)
e the margin of error = 5% = 0.05
= (1.96)2(0.116) (1-0.116)/ (0.05)2
=157.6 ~158
An additional 20% (32 files) was added to compensate for incomplete data, bringing the final sample size to 190 medical records.

2.3.1. Sampling Technique

A simple random sampling method was used. Eligible files were assigned numeric codes and tabulated in Microsoft Excel. These codes were randomized in EPIDAT and cross-referenced with Excel to select 190 files. Files that did not meet the inclusion criteria were replaced with the next randomly generated number. Of the 951 pneumonia admissions during the study period, 190 were randomly selected for detailed demographic, clinical, and pathological analysis. All subsequent analyses of severity, comorbidities, vaccination status, and risk factors for prolonged hospitalization were restricted to this sampled dataset (n = 190).

2.4. Data Collection and Measurement

2.4.1. Data Collection Procedure

Following ethical clearance (Ref 231/2024), data extraction was conducted within the file storage unit. Records were retrieved from nursing logs and coded. Files meeting the inclusion criteria were reviewed using a structured data collection worksheet. Data from each file were extracted in under 20 minutes and refiled securely after review. Comorbidities were limited to those recognized as important modifiers of pneumonia outcomes in children and documented in pediatric admission records. All variables were extracted and analyzed only for the sampled cohort (n = 190), ensuring consistency across descriptive and inferential analyses.

2.4.2. Data Collection Instrument

The instrument was a structured, self-designed worksheet, validated by departmental reviewers and supervisors. It captured demographic data: age, sex, weight, immunization status, and place of stay. Place

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of stay was defined according to the child's residential setting as recorded in hospital files. Clinical data (child): presenting symptoms, date of onset, diagnostic modality, comorbidities (e.g., HIV, asthma, diarrhea), vitamin A supplementation, breastfeeding status, timing of complementary feeding, and treatment regimen. Pathogenic sources were confirmed from detailed bacteriological culture reports and were documented in the discharge summary. Bronchiolitis was diagnosed clinically based on a viral prodrome followed by persistent cough, tachypnoea or chest recession, and wheeze and/or crackles on auscultation in infants or young children, with pulse oximetry used to assess severity. Laboratory tests and chest radiography were reserved for atypical or severe cases, or when alternative diagnoses were considered [26]. Outcome variables: discharge status (alive or deceased) and length of hospitalization (lengths of stay longer than 5 days were considered prolonged).

2.4.3. Validity and Reliability

Face validity was verified by academic supervisors for content appropriateness and clarity. Content validity was assessed by departmental reviewers to ensure comprehensiveness. Reliability was ensured through the uniform use of the structured worksheet and cross-checking of extracted data for internal consistency and accuracy.

2.4.4. Confounding Variables

Potential confounders and HIV status were considered based on the literature. Although no mortality was observed in the study, Poisson regression was used to adjust for possible predictors of prolonged hospital stay. Stratification was not necessary in this instance.

2.4.5. Pilot Study

A pilot test was conducted on 10 records that were later excluded from the main study. This informed tool refinement and ensured alignment with the study objectives.

2.5. Statistical Analysis

All analyses were conducted using IBM SPSS Statistics version 29 and Stata version 19. Descriptive statistics were used to summarize categorical variables (frequencies and percentages) and continuous variables (medians and interquartile ranges) because the variables were non-normally distributed. Morbidity and mortality trends were stratified by year, month, and season. Wilson score confidence intervals were calculated for the proportions of pneumonia cases and hospital admissions, whereas exact Clopper-Pearson confidence intervals were used for the proportions of pneumonia-related deaths. The outcome variable was admission duration, measured as length of hospital stay in days. Negative binomial regression, an established approach for modelling hospital length of stay [27-30] was used to identify factors associated with admission duration. The assumption of independence of observations was satisfied, as each child contributed a single observation and there were no repeated admissions for the same pneumonia episode. Because breastfeeding status and current diet were strongly correlated (Cramer's V = 0.937, $p < 0.001$), only breastfeeding status was retained in the final multivariable model to avoid redundancy and potential multicollinearity. Initial Poisson regression demonstrated substantial overdispersion (Pearson $\chi^2/df = 10.6$; Deviance/df = 8.8), poor model convergence, and inadequate fit (AIC = 2275.9; BIC = 2318.1) (Supplementary Table S1). Consequently, negative binomial regression with a log link and robust standard errors was used for all inferential analyses. Exponentiated coefficients were reported as incidence rate ratios (IRRs) with 95% confidence intervals, and statistical significance was defined as $p < 0.05$. Variables significant in univariable analyses were entered into the multivariable model. The final model demonstrated good fit (AIC = 1196.1, BIC = 1238.3, Pearson $\chi^2/df = 0.82$). Sensitivity analysis excluding the participant with the longest length of stay (300 days) yielded similar results, indicating that the findings were robust and not driven by a single extreme observation.

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3. Results

Over the five-year study period, a total of 9,099 pediatric admissions were recorded at Nelson Mandela Central Hospital, of which 951 (10.4%) were due to pneumonia. Pneumonia-related mortality remained low, with only seven in-hospital deaths (0.7%), including four (4; 57.1%) females and three (3; 42.9%) males, at a median age of 3 months (interquartile range: 1–9 months).

3.1. Five-Year Mortality Trend for Childhood Clinical Pneumonia

A trend in mortality related to childhood clinical pneumonia was observed, with the highest proportion (42.9%, n = 3) in 2021 and 2022 and the lowest (14.3%, n = 1) in 2024. There were no deaths in 2020 and 2023. In terms of monthly pneumonia-related deaths, the highest rate was in May and June (28.6%, n = 2), followed by March, April, and December (14.3%, n = 1) (Table 1). The monthly occurrence translates into a higher proportional incidence in autumn (30.7%, n = 292) and spring (27.7%, n = 263) than in winter (21.0%, n = 200) and summer (20.6%, n = 196) (Table 1).

Table 1.
Five-year distribution of pediatric pneumonia admissions, pneumonia-related deaths, seasonality, and total hospital admissions at Nelson Mandela Central Hospital, Eastern Cape, South Africa (2020–2024).

Variables of interest	Pneumonia cases, N=951; n (%; 95% CI)	Deaths, n=7; n (%; 95% CI)	Total Admissions, n=9099; n (%; 95% CI)
Year			
2020	184 (19.3; 17.0-22.0)	0 (0.0; 0.0-41.0)	1311 (14.4; 13.7-15.1)
2021	165 (17.4; 15.1-19.9)	3 (42.9; 9.9-81.6)	1117 (12.3; 11.6-13.0)
2022	196 (20.6; 18.2-23.3)	3 (42.9; 9.9-81.6)	1536 (16.9; 16.1-17.7)
2023	183 (19.2; 16.9-21.9)	0 (0.0; 0.0-41.0)	1565 (17.2; 16.4-18.0)
2024	223 (23.4; 20.9-26.2)	1 (14.3; 0.4-57.9)	3570 (39.2; 38.2-40.2)
Month			
January	62 (6.5; 5.1-8.3)	0 (0.0; 0.0-41.0)	802 (8.8; 8.2-9.4)
February	41 (4.3; 3.2-5.8)	0 (0.0; 0.0-41.0)	614 (6.7; 6.3-7.3)
March	81 (8.5; 6.9-10.5)	1 (14.3; 0.4-57.9)	821 (9.0; 8.5-9.6)
April	102 (10.7; 8.9-12.9)	1 (14.3; 0.4-57.9)	832 (9.1; 8.6-9.8)
May	109 (11.5; 9.6-13.6)	2 (28.6; 3.7-71.0)	837 (9.2; 8.6-9.8)
June	86 (9.0; 7.4-11.0)	2 (28.6; 3.7-71.0)	721 (7.9; 7.4-8.5)
July	67 (7.0; 5.6-8.9)	0 (0.0; 0.0-41.0)	662 (7.3; 6.8-7.8)
August	47 (4.9; 3.7-6.5)	0 (0.0; 0.0-41.0)	740 (8.1; 7.6-8.7)
September	47 (4.9; 3.7-6.5)	0 (0.0; 0.0-41.0)	757 (8.3; 7.8-8.9)
October	105 (11.0; 9.2-13.2)	0 (0.0; 0.0-41.0)	835 (9.2; 8.6-9.8)
November	111 (11.7; 9.8-13.9)	0 (0.0; 0.0-41.0)	819 (9.0; 8.4-9.6)
December	93 (9.8; 8.1-11.8)	1 (14.3; 0.4-57.9)	659 (7.2; 6.7-7.8)
Season			
Autumn	292 (30.7; 27.9-33.7)	4 (57.1; 18.4-90.1)	2490 (27.4; 26.5-28.3)
Winter	200 (21.0; 18.6-23.7)	2 (28.6; 3.7-71.0)	2123 (23.3; 22.5-24.2)
Summer	196 (20.6; 18.2-23.3)	1 (14.3; 0.4-57.9)	2075 (22.8; 22.0-23.7)
Spring	263 (27.7; 24.9-30.6)	0 (0.0; 0.0-41.0)	2411 (26.5; 25.6-27.4)

Note: Wilson score 95% CIs were used for pneumonia cases and total admissions; exact Clopper-Pearson binomial 95% CIs were used for death proportions, with one-sided exact binomial CIs for cells with zero deaths.

3.2. Demographic, Clinical, and Pathological Profile of Children with Clinical Pneumonia Based on the Sampled Dataset (n = 190).

Of the 951 pneumonia admissions, 190 were randomly selected for detailed analysis of demographic, clinical, and pathological profiles, as presented in Table 2. Pneumonia was more frequent among infants (63.2%, n = 120) and males (51.6%, n = 98). Diagnosis was established by chest radiography in almost all cases (95.8%), and bacteriologic culture reports confirmed viral pneumonia as the most common form (91.6%, n = 174). A detailed assessment of presenting symptoms and radiographic reports classified 168 (88.4%) as mild and only 22 (11.6%) as severe. Pneumonia occurred concomitantly with bronchiolitis (10%,

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n = 19), hypoxia (3.2%, n = 6), and other respiratory infections (4.2%, n = 8). These characteristics and others are detailed in Table 2.

Table 2.
Demographic, Clinical, and Pathological profile of children with clinical pneumonia based on the sampled dataset (n = 190).

Variables of interest	Frequency (n) N=190	Percent (%)
Age group		
Infants	120	63.2
Toddlers	33	17.4
Neonates	23	12.1
Preschoolers	8	4.2
Middle childhood	6	3.2
Sex		
Male	98	51.6
Female	92	48.4
Weight | Median |IQR	6	4.1-9.9
Childhood vaccination status		
Up to date	121	63.7
Incomplete	22	11.6
No vaccination card	45	23.7
None taken to date	2	1.1
Use of herbal medication	7	3.7
Other morbidities	51	26.8
HIV exposed	64	33.7
HIV positive, n=64	7	10.9
Previous hospitalisation	10	5.3
Breastfeeding status		
Exclusive breastfed	44	23.2
Formula	49	25.8
Unspecified	97	51.1
Presenting symptoms		
Cough	158	83.2
Difficulty breathing	127	66.8
Shortness of breath	113	59.5
High fever	112	58.9
Vomiting	67	35.3
Diarrhoea	34	17.9
Loss of appetite	23	12.1
Fast Breathing	20	10.5
Nasal congestion	16	8.4
Irritability	13	6.8
Night Sweat	5	2.6
Seizures	4	2.1
Weight loss	3	1.6
Chest X-ray performed	182	95.8
Wheezes on CXR	12	6.3
Type of pneumonia		
Viral	174	91.6
Bacterial	13	6.8
Polymicrobial	2	1.1
Fungal	1	0.5
Severity		
Mild	168	88.4
Severe	22	11.6
Bronchiolitis	19	10.0

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Hypoxia	6	3.2
Other Respiratory tract infections	8	4.2
Named Other Respiratory tract infections, n=8		
Pulmonary tuberculosis	7	87.5
Lung disease	1	12.5
Treatment administered		
Antibiotics	153	80.5
Oxygen therapy	42	22.1
Corticosteroids	33	17.4
Bronchodilators	23	12.1
Antifungal	18	9.5
Supplementations	12	6.3
Other treatments	5	2.6
Antiviral	3	1.6

3.3. Factors associated with Length of Hospital Stay

The median hospital stay was 5 days (IQR = 4-8), and more than half (51.1%, n = 97) had prolonged stays. Factors independently associated with prolonged hospital stay were male sex [adjusted incidence rate ratio (aIRR) = 1.4, 95% confidence interval (CI): 1.1-1.7], age ≤1 year (aIRR = 1.6, 95% CI: 1.3-2.1), non-viral pneumonia (aIRR = 2.6, 95% CI: 1.5-4.5), incomplete vaccination status (aIRR = 2.8, 95% CI: 1.4-5.6), and not being breastfed (aIRR = 1.4, 95% CI: 1.1-1.8). Admission during spring (aIRR = 0.6, 95% CI: 0.3-0.9), bronchiolitis (aIRR = 0.7, 95% CI: 0.5-1.0), and prior use of herbal medication (aIRR = 0.6, 95% CI: 0.3-1.0) were independently associated with shorter hospital stays (Table 3).

Table 3.
Unadjusted and adjusted incidence rate ratios for factors associated with length of hospital stay among 190 children admitted with pneumonia at a referral hospital in rural Eastern Cape, South Africa.

Parameter /Variable	Unadjusted incidence rate ratio (95% Confidence Interval)	Adjusted incidence rate ratio (95% Confidence Interval)	*p*-value
Intercept	-	3.0 (1.8-4.9)	<0.001
Season			0.012
Winter	0.4 (0.1-0.9) *	0.8 (0.5-1.4)	0.512
Autumn	0.6 (0.2-2.1)	0.9 (0.5-1.4)	0.612
Spring	0.3 (0.1-0.9) *	0.6 (0.3-0.9)	0.029
Summer (Ref.)	1.0	1.0	-
Sex			
Male	2.3 (1.2-4.1) *	1.4 (1.1-1.7)	0.002
Female (Ref.)	1.0	1.0	-
Age group			
≤1 year	2.3 (1.3-3.8) *	1.6 (1.3-2.1)	<0.001
>1 year (Ref.)	1.0	1.0	-
Type of pneumonia			
Non-viral	4.2 (1.5-11.9) *	2.6 (1.5-4.5)	<0.001
Viral (Ref.)	1.0	1.0	-
Severity			
Severe	1.9 (0.9-4.1)	-	-
Mild (Ref.)	1.0	-	-
Bronchiolitis			
Yes	0.4 (0.2-0.7) *	0.7 (0.5-1.0)	0.041
No (Ref.)	1.0	1.0	-
Hypoxia			
Yes	2.5 (1.0-6.2)	-	-
No (Ref.)	1.0	-	-
Received oxygen therapy			
Yes	1.2 (0.6-2.4)	-	-

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No (Ref.)	1.0	-	-
Other respiratory tract infections			
Yes	2.1 (0.6-7.1)	-	-
No (Ref.)	1.0	-	-
Childhood vaccination status			0.010
No card/none taken	0.7 (0.5-1.0)	1.0 (0.8-1.3)	0.951
Incomplete	4.2 (1.5-11.9) *	2.8 (1.4-5.6)	0.003
Up to date (Ref.)	1.0		
Use of herbal medication			
Yes	0.5 (0.3-0.9) *	0.6 (0.3-1.0)	0.036
No (Ref.)	1.0	1.0	-
Vomiting			
Yes	1.3 (0.5-3.0)	-	-
No (Ref.)	1.0	-	-
Diarrhoea			
Yes	1.8 (0.6-5.4)	-	-
No (Ref.)	1.0	-	-
Other morbidities			
Yes	0.8 (0.4-1.3)	-	-
No (Ref.)	1.0	-	-
HIV exposure			
Unknown	0.7 (0.4-1.3)	-	-
No	1.3 (0.7-2.7)	-	-
Yes (Ref.)	1.0		
Breastfeeding status			<0.001
Unspecified	2.6 (1.4-4.7) *	1.9 (1.5-2.6)	<0.001
Not breastfed	1.2 (0.9-1.6)	1.4 (1.1-1.8)	0.018
Breastfed (Ref.)	1.0	1.0	-
Antibiotics			
Yes	0.9 (0.4-1.9)	-	-
No (Ref.)	1.0	-	-
Weight (kg)	1.0 (0.9-1.0)	-	-

Note: The reference category for each categorical variable was assigned an Incidence Rate Ratio (IRR) of 1.0.

4. Discussion

This study provides a comprehensive five-year assessment of childhood pneumonia in a rural tertiary hospital in the Eastern Cape, South Africa, highlighting important epidemiological trends, seasonal variation, and determinants of prolonged hospitalization. The findings reveal a rising burden of pneumonia admissions over time, a predominance of viral etiologies, and several clinically and contextually relevant predictors of extended hospital stay [15, 31, 32]. The observed trend in pneumonia admissions, with peaks in 2020 and 2024, suggests a re-emerging burden following earlier declines. This pattern may reflect post-pandemic shifts in healthcare utilization, disruptions in routine immunization, and increased circulation of respiratory viruses, as reported in similar settings [33]. The predominance of viral pneumonia (91.6%) in this cohort aligns with growing global evidence indicating a transition in pediatric pneumonia etiology toward viral pathogens, particularly respiratory syncytial virus (RSV), following widespread pneumococcal and Haemophilus influenzae type b (Hib) vaccination. This epidemiological shift underscores the need to strengthen viral surveillance systems and reconsider empirical treatment strategies in resource-limited settings [34].

Seasonality analysis demonstrated that autumn and winter were significantly associated with increased admissions, consistent with known seasonal dynamics of respiratory infections [35-37]. The marked autumn predominance observed in this study is particularly notable and may reflect localized climatic and behavioral patterns unique to the Eastern Cape [38, 39]. Infants constituted most cases and were significantly more likely to experience prolonged hospitalization. This aligns with existing literature demonstrating that immature immune function, reduced airway caliber, and limited pulmonary reserve

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increase susceptibility to severe disease in this age group [40-42]. The low but notable mortality rate (0.7%), concentrated among infants aged 1–9 months, further reinforces early infancy as a critical risk window requiring targeted preventive and clinical interventions [43, 44].

The study identified several independent predictors of prolonged hospital stay, including male sex, infancy, non-viral pneumonia, incomplete vaccination status, and lack of breastfeeding. The strong association between incomplete vaccination status (aIRR = 2.8) highlights the important role of childhood immunization in mitigating disease severity and reducing hospitalization burden among children with pneumonia. This finding is consistent with reports that unvaccinated or partially vaccinated children experience longer hospital stays and more severe pneumonia-related complications, reflecting a more complicated clinical course and increased healthcare utilization [11, 45, 46]. Similarly, children who were not breastfed had an increased risk of prolonged hospitalization, highlighting the protective role of breastfeeding against severe childhood infections [47-49]. This finding is biologically plausible given the immunological benefits of breast milk, including passive antibody transfer and enhanced mucosal immunity. Male sex was associated with longer hospital stay, which may reflect sex-related differences in susceptibility to respiratory infections and immune responses [50, 51]. Furthermore, non-viral pneumonia was associated with prolonged hospitalization, likely reflecting the greater severity and treatment complexity of bacterial respiratory infections [52]. Conversely, admission in spring, bronchiolitis, and prior use of herbal medication were associated with shorter hospital stays. Overall, this study reinforces the importance of context-specific epidemiological surveillance in understanding evolving disease patterns and informing targeted interventions. Strategies such as early risk stratification, improved vaccination coverage, and seasonal preparedness planning are critical to reducing the burden of hospitalizations and improving outcomes among children in rural and underserved populations.

5. Conclusion

Pneumonia admissions followed a trend over the five years, with peaks during autumn and winter, underscoring the influence of climatic and environmental factors on disease transmission. In-hospital mortality was low, but morbidity remained substantial, particularly among infants, who constituted the most affected and vulnerable group. Several key predictors of prolonged hospitalization were identified, including male sex, infancy, non-viral pneumonia, incomplete vaccination status, and lack of breastfeeding. These findings highlight the need for early clinical risk stratification, targeted management of high-risk groups, and strengthened seasonal preparedness strategies to reduce hospitalization duration and alleviate pressure on healthcare systems. Enhancing preventive interventions, particularly immunization coverage, breastfeeding promotion, and timely care-seeking, remains essential to mitigating the burden of childhood pneumonia in underserved settings. Overall, this study provides important context-specific evidence to inform clinical practice and public health planning, emphasizing the urgency of integrated and locally adapted strategies to reduce pneumonia-related morbidity among children in rural South Africa.

5.1. Strengths and Limitations of the Study

This study has several important strengths. First, it provides rare, context-specific epidemiological evidence on childhood pneumonia from a rural and underserved region of South Africa, where data remain limited. The five-year study period enabled robust assessment of temporal trends and seasonal patterns, offering valuable insights into the dynamic nature of pneumonia burden in this setting. Second, the study integrates a broad range of demographic, clinical, and contextual variables, including feeding practices and comorbid conditions, allowing for a more comprehensive evaluation of factors associated with prolonged hospitalization than is typically reported. Third, the inclusion of children aged 0–14 years extends beyond the conventional focus on the under-five population, capturing the full pediatric spectrum and improving the generalizability of findings across similar healthcare contexts.

Methodologically, the use of negative binomial regression with robust standard errors strengthened the validity of the findings by appropriately modelling length-of-stay outcomes and accounting for

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substantial overdispersion observed in the data. The random sampling approach from a well-defined hospital population further enhances internal validity.

However, several limitations should be considered. The retrospective design inherently limits causal inference and is subject to missing or incomplete data, particularly for variables such as feeding history and prior care-seeking behavior. The reliance on routinely collected hospital records may also introduce misclassification bias, especially in the diagnosis of pneumonia etiology, where laboratory confirmation was limited. Additionally, the study was conducted at a single tertiary referral hospital, which may limit external generalizability to primary care or community settings.

The relatively small analytical sample (n = 190), although statistically adequate, may reduce power for detecting weaker associations and limit subgroup analyses. Furthermore, potentially important determinants such as socioeconomic status, environmental exposures (e.g., indoor air pollution), and caregiver factors were not systematically captured. Finally, treatment-related variables, including timing and appropriateness of antibiotic therapy, could not be comprehensively assessed, which may have influenced the duration of hospitalization.

Despite these limitations, the study provides important and timely insights into the determinants of prolonged hospitalization in childhood pneumonia within a resource-limited rural context.

5.2. Future Research

Future research should prioritize prospective, multicenter studies incorporating standardized clinical and laboratory diagnostics to validate these findings and better elucidate causal pathways underlying prolonged hospitalization in childhood pneumonia. Longitudinal cohort designs would be particularly valuable in capturing disease progression, treatment responses, and post-discharge outcomes.

There is also a need to integrate broader contextual determinants, including socioeconomic status, environmental exposures (such as indoor air pollution and household crowding), nutritional status, and caregiver health-seeking behavior. These factors are likely to play a critical role in shaping both disease severity and healthcare utilization but remain underexplored in rural African settings.

Given the observed predominance of viral pneumonia, future investigations should strengthen pathogen-specific surveillance, including molecular diagnostics for respiratory viruses, to better inform antimicrobial stewardship and treatment guidelines. Additionally, research examining the interaction between tuberculosis, HIV exposure, and pneumonia outcomes is essential in high-burden settings such as South Africa. Implementation research is urgently needed to evaluate the effectiveness of integrated child health interventions, including vaccination coverage optimization, breastfeeding promotion, caregiver education, and early referral systems. Evaluating seasonal preparedness strategies such as resource allocation and surge capacity planning could further reduce healthcare system strain during peak periods. Finally, studies assessing the impact of treatment quality, including the timeliness and appropriateness of antibiotic and supportive therapies, on length of hospital stay and clinical outcomes would provide actionable evidence to improve pediatric pneumonia management in resource-constrained environments.

Abbreviations:

The following abbreviations are used in this manuscript:

UNICEF	United Nations Children's Fund
GBD	Global Burden of Disease
RSV	Respiratory syncytial virus
WHO	World Health Organization
NMCH	Nelson Mandela Central Hospitals
TB	Tuberculosis

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Institutional Review Board Statement:

The study involved the review of medical records of pediatric patients and was conducted in accordance with ethical principles for research involving human participants. Ethical approval was obtained from the relevant Institutional Review Board/Ethics Committee (Reference No. 231/2024) before data collection commenced.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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Supplementary Table S1.
Univariable and multivariable Poisson regression analysis of factors associated with length of hospital stay.

Parameter/Variable	Crude Rate Ratio (95% Confidence Interval)	Adjusted Rate Ratio (95% Confidence Interval)	p-value
Intercept		1.6 (0.8-3.0)	0.155
Season			0.002
Winter	0.4 (0.1-0.9) *	0.7 (0.4-1.3)	0.260
Autumn	0.6 (0.2-2.1)	0.8 (0.4-1.6)	0.508
Spring	0.3 (0.1-0.9) *	0.4 (0.2-0.8)	0.004
Summer	1.0	1.0	
Sex			
Male	2.3 (1.2-4.1) *	1.9 (1.3-2.6)	<0.001
Female	1.0	1.0	
Age group			

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<1 year	2.3 (1.3-3.8) *	2.2 (1.5-3.2)	<0.001
≥1 year	1.0	1.0	
Type of pneumonia			
Non-viral	4.2 (1.5-11.9) *	3.1 (1.8-5.2)	<0.001
Viral	1.0	1.0	
Severity			
Severe	1.9 (0.9-4.1)	–	-
Mild	1.0	–	
Bronchiolitis			
Yes	0.4 (0.2-0.7) *	0.4 (0.2-0.9)	0.031
No	1.0	1.0	
Hypoxia			
Yes	2.5 (1.0-6.2)	–	-
No	1.0	–	
Received oxygen therapy			
Yes	1.2 (0.6-2.4)	–	-
No	1.0	–	
Other respiratory tract infections			
Yes	2.1 (0.6-7.1)	–	-
No	1.0	–	
Childhood vaccination status			<0.001
No card/none taken	0.7 (0.5-1.0)	1.0 (0.7-1.5)	0.983
Incomplete	4.2 (1.5-11.9) *	4.7 (2.1-10.3)	<0.001
Up to date	1.0	1.0	
Use of herbal medication			
Yes	0.5 (0.3-0.9) *	0.3 (0.1-0.7)	0.009
No	1.0	1.0	
Vomiting			
Yes	1.3 (0.5-3.0)	–	-
No	1.0	–	
Diarrhoea			
Yes	1.8 (0.6-5.4)	–	0.311
No	1.0	–	
Other morbidities			
Yes	0.8 (0.4-1.3)	–	-
No	1.0	–	
HIV exposure			
Unknown	0.7 (0.4-1.3)	–	-
No	1.3 (0.7-2.7)	–	-
Yes	1.0	–	
Breastfeeding status			<0.001
Unspecified	2.6 (1.4-4.7) *	3.0 (1.8-4.8)	<0.001
Not breastfed	1.2 (0.9-1.6)	1.7 (1.0-2.7)	0.032
Breastfed	1.0	1.0	
Antibiotics			
Yes	0.9 (0.4-1.9)	–	-
No	1.0	–	
Weight (kg)	1.0 (0.9-1.0)	–	-

Note: * Significant univariable. Variables not included in the multivariable model are shown with adjusted estimates and *p*-values omitted (–). The reference category for each categorical variable was assigned a Rate Ratio of 1.0. The multivariable Poisson model demonstrated substantial overdispersion (Pearson χ^2/df = 10.6; Deviance/df = 8.8), poor convergence, and inferior fit (AIC = 2275.9; BIC = 2318.1).

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