ORIGINAL ARTICLE

Frequency of Pneumonia and Associated Breastfeeding Status in Infants Presenting with Suspected Pneumonia in an Outpatient Setting: A Cross-Sectional Study

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Abstract

Background: Pneumonia remains a major cause of infant mortality worldwide, including Pakistan, yet data on radiologically confirmed pneumonia in young infants remain limited.

Objective: To determine the frequency of pneumonia and breastfeeding status among infants aged less than 6 months presenting with clinically suspected pneumonia in an outpatient setting.

Methods: This cross-sectional study was conducted in the pediatric outpatient department at Patel Hospital, Karachi, from June 2022 to December 2022. Infants (n=162) aged 1-6 months of either gender, presenting with clinical suspicion of pneumonia, were included. Pneumonia was classified as positive based on signs and symptoms (difficulty breathing, tachypnoea, and hypoxemia) and radiologically confirmed by consolidation or patchy opacities. Data were analyzed using SPSS version 24.

Results: The frequency of radiologically confirmed pneumonia was 33.3%. Frequency of pneumonia among exclusively breast-fed and non-exclusively breast-fed infants was 33.3% and 66.7% respectively. Independent predictors were lack of antenatal breastfeeding counselling [aOR=3.01, 95% CI: 1.45-6.25, p=0.003], preterm birth [<36+6 weeks; aOR=2.89, 95% CI: 1.42-5.88, p=0.003], and maternal education below intermediate [aOR=2.34, 95% CI: 1.15-4.76, p=0.019]. Non-exclusive breastfeeding was not independently associated with pneumonia [aOR=1.36, 95% CI: 0.62-2.98, p=0.445] but increased risk sixfold in preterm infants and threefold when counseling was absent.

Conclusion: Radiologically confirmed pneumonia occurred in 33.3% of suspected pneumonia cases among infants. Lack of antenatal breastfeeding counseling, preterm birth, and low maternal education independently predicted pneumonia. Non-exclusive breastfeeding increased risk with lack of antenatal breastfeeding counseling and in infants born preterm. Strengthening antenatal counseling and promoting exclusive breastfeeding at the primary care level may help reduce the burden of pneumonia in this highly vulnerable age group.

Keywords: *Pneumonia, breastfeeding, infants, preventable, signs.*

INTRODUCTION

Pneumonia remains one of the most significant causes of morbidity and mortality among children under five, particularly in low- and middle-income countries. Despite global efforts to control childhood illnesses, pneumonia accounts for a substantial proportion of under-five deaths worldwide [1]. The condition is frequently exacerbated by malnutrition, incomplete immunization, and poor access to healthcare services. In recent years, a growing body of research has emphasized the role of preventive strategies, including breastfeeding, in reducing the incidence and severity of respiratory infections in early childhood [2, 3].

Breastfeeding, particularly when exclusive during the first six months of life, offers unmatched immunological and nutritional benefits to infants [4]. Breast milk contains a complex array of bioactive components, including antibodies, lactoferrin, and immune cells, that support neonatal immune development and protect against both upper and lower respiratory tract infections [5-7]. Epidemiological studies have demonstrated a significant reduction in the incidence of pneumonia among exclusively breastfed infants compared with those who are not, with some data indicating a twofold or greater reduction in risk [8]. These protective effects are most pronounced during the first six months but may extend well into the second year of life [9].

Despite this strong evidence, global adherence to exclusive breastfeeding practices remains suboptimal. According to the United Nations Children's Fund (UNICEF), only 48% of infants up to six months of age are exclusively breastfed in Pakistan [9]. Cultural practices, low maternal education, and inadequate postnatal support contribute to early cessation of breastfeeding and increased reliance on formula or

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Received: February 12, 2026; Revised: August 13, 2026; Accepted: September 08, 2026
DOI: https://doi.org/10.37184/lnjpc.2707-3521.8.85

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prelacteal feeds, both of which have been associated with a heightened risk of infections, including pneumonia [10, 11]. Interventions aimed at promoting and sustaining exclusive breastfeeding have shown potential not only for improving child survival rates but also for reducing healthcare costs and antibiotic use [12].

The rationale for the present study stems from the need to generate localized data on the relationship between breastfeeding practices and pneumonia incidence among infants. Given the significant impact of pneumonia on infant health and the well-documented benefits of breastfeeding, this research aims to determine the frequency of pneumonia among infants aged 1-6 months presenting with clinically suspected pneumonia, in relation to their breastfeeding status. The findings will provide evidence to inform targeted public health strategies and reinforce the promotion of exclusive breastfeeding as a critical intervention in pneumonia prevention and child health promotion [13].

METHODOLOGY

This cross-sectional study was conducted in the Department of Pediatrics at Patel Hospital, Karachi, Pakistan, over a period of six months, from June 2022 to December 2022. The study was conducted after obtaining approval from the Ethics Committee of Patel Hospital (Approval No. PH/IRB/2022/2004). Inclusion criteria were infants aged 1-6 months of either gender, exclusively or non-exclusively breastfed (as defined in the operational definitions), visiting pediatric outpatient with clinically suspected pneumonia. Exclusion criteria were infants with chronic illness such as congenital heart disease, congenital chromosomal anomalies, surgical problems, or chronic renal disease confirmed based on medical records and history, and infants born to mothers positive for HIV, hepatitis B, or hepatitis C.

The Epi Info sample size calculator was used to estimate the sample size, using a 95% confidence interval, a 4% margin of error, and a reported pneumonia prevalence of 7.3% among exclusively breastfed infants [10]. The estimated sample size was 162. Non-probability consecutive sampling was used to collect data.

All infants who met the inclusion criteria and presented to the outpatient paediatric department during the study period were enrolled. Written informed consent was obtained from the parents of all eligible infants. Pneumonia was labeled as positive based on signs and symptoms, including difficulty breathing (nasal flaring, abdominal breathing, or intercostal retractions), tachypnea (per the operational definition), and hypoxemia (arterial oxygen saturation [SpO2] below 90%). It was subsequently confirmed by radiological evidence of consolidation or patchy opacities. Radiologists were blinded to clinical severity and feeding history to reduce confirmation bias.

Data on age, gender, residence, maternal educational and occupational status, socioeconomic status, breastfeeding counseling during antenatal visits, breastfeeding status, and smoking within the family (defined as a household in which a parent smokes cigarettes daily) were recorded on a proforma attached as an annexure. Breastfeeding status was determined through a structured interview with the mother or caregiver, using a pre-tested proforma based on the World Health Organization (WHO) Infant and Young Child Feeding (IYCF) indicators, 2021 [14], and documented on a data sheet. Clinical records for each study participant were entered and maintained by the principal investigator and co-investigators.

Breastfeeding-related variables recorded in this study were breastfeeding status (exclusive or non-exclusive) and breastfeeding counseling received during antenatal visits. Exclusive breastfeeding was defined as an infant receiving only maternal milk either directly from the breast or expressed with no other liquid or solid intake, except for drops or syrups of medicine, within the first six months of age. Infants who received foods or fluids in addition to breast milk within the first six months of age were classified as non-exclusively breastfed.

SPSS version 24 was used for statistical analysis. Mean and standard deviation were calculated for quantitative variables, such as infant age. Frequencies and percentages were calculated for qualitative variables like gender, parity, residence, maternal educational status, maternal occupational status, socioeconomic status, type of delivery, breastfeeding counseling during antenatal visits, smokers in the household, breastfeeding status, and pneumonia. Comparisons were performed to assess the association between pneumonia and breastfeeding status. Associations between categorical variables and pneumonia were assessed using univariate logistic regression analysis to estimate crude odds ratios with 95% confidence intervals. To identify independent associated factors of confirmed pneumonia, multivariable logistic regression was applied. A parsimonious model was constructed to address overfitting due to a limited number of events per variable. The Hosmer-Lemeshow test was used to assess model calibration. A p-value <0.05 was considered statistically significant.

RESULTS

Combined demographics of infants and mothers are shown in Table **1**. Of the 162 infants, the mean age was 3.2 ± 1.4 months. Table **1** depicts gender distribution, residence, mode of delivery, gestational age, gravida, maternal education and occupation, socioeconomic status, breastfeeding counseling during antenatal visits, smokers in family, and breastfeeding type. There were 54 (33.3%) infants who had confirmed pneumonia.

Table 1: Characteristics of study participants (n=162).

Variables	Frequency, n (%)
Age	
1 to <3 months	71 (43.8)
3 to 6 months	91 (56.2)

Variables	Frequency, n (%)
Gender	
Male	107 (66.0)
Female	55 (34.0)
Residence	
Rural	21 (13.0)
Urban	141 (87.0)
Parity	
Primigravida	64 (39.5)
Multigravida	98 (60.5)
Mode of Delivery	
Vaginal delivery	86 (53.1)
Caesarean section	76 (46.9)
Gestational Age	
Preterm	52 (32.1)
Term	110 (67.9)
Maternal Education	
Illiterate	28 (17.3)
Less than Matric	35 (21.6)
Intermediate or more	99 (61.1)
Maternal Occupation	
Housewife	141 (87.0)
Working	21 (13.0)
Socioeconomic Status	
Lower	41 (25.3)
Middle	83 (51.2)
Upper Middle	28 (17.3)
Higher	10 (6.2)
Antenatal Breastfeeding Counseling	
Yes	59 (36.4)
No	103 (63.6)
Breastfeeding Status	
Exclusive	69 (42.6)
Non-Exclusive	93 (57.4)
Smoker in Family	
Yes	15 (9.3)
No	147 (90.7)
Pneumonia Status	
Confirmed Pneumonia	54 (33.3)
No Pneumonia	108 (66.7)

Univariate analysis of factors associated with confirmed pneumonia is presented in Table **2**. Preterm infants had 2.58 times higher odds of pneumonia compared to term infants (OR=2.58, 95% CI: 1.29-5.17, p=0.006). Infants whose mothers did not receive breastfeeding counseling during antenatal care had 2.70 times higher odds of pneumonia (OR=2.70, 95% CI: 1.27-5.72, p=0.008). Lower maternal education (illiterate or less than Matric) was associated with 2.25 times higher odds of pneumonia (OR=2.25, 95% CI: 1.15-4.39, p=0.016). Lower socioeconomic status was also significantly associated with pneumonia (OR=2.12, 95% CI: 1.02-4.39, p=0.041). Non-exclusive breastfeeding showed a trend toward increased odds of pneumonia but did not reach statistical significance (OR=1.79, 95% CI: 0.91-3.52, p=0.090). Gender, residence, mode of delivery, parity, and presence of smokers in the family were not significantly associated with pneumonia on univariable analysis.

Table 2: Univariable logistic regression analysis of risk factors for pneumonia (n=162).

Variables	Pneumonia n (%)	No Pneumonia n (%)	Crude Odds Ratio (95% CI)	p-value
Gestational Age				
Preterm	25 (46.3)	27 (25.0)	2.58 (1.29-5.17)	*0.006
Term	29 (53.7)	81 (75.0)	Ref	—
Antenatal Breastfeeding Counseling				
No	42 (77.8)	61 (56.5)	2.70 (1.27-5.72)	*0.008
Yes	12 (22.2)	47 (43.5)	Ref	—
Maternal Education				
Illiterate + up till Matric	28 (51.9)	35 (32.4)	2.25 (1.15-4.39)	*0.016
Intermediate or more	26 (48.1)	73 (67.6)	Ref	—
Socioeconomic Status				
Lower	19 (35.2)	22 (20.4)	2.12 (1.02-4.39)	*0.041
Middle + Upper	35 (64.8)	86 (79.6)	Ref	—
Breastfeeding Status				
Non-exclusive	36 (66.7)	57 (52.8)	1.79 (0.91-3.52)	0.090
Exclusive	18 (33.3)	51 (47.2)	Ref	—
Sex				
Male	40 (74.1)	67 (62.0)	1.75 (0.85-3.59)	0.127
Female	14 (25.9)	41 (38.0)	Ref	—
Residence				
Rural	10 (18.5)	11 (10.2)	2.00 (0.79-5.07)	0.136
Urban	44 (81.5)	97 (89.8)	Ref	—
Mode of Delivery				
Caesarean section	30 (55.6)	46 (42.6)	1.69 (0.88-3.24)	0.117
Vaginal delivery	24 (44.4)	62 (57.4)	Ref	—
Maternal Occupation				
Working	9 (16.7)	12 (11.1)	1.60 (0.62-4.11)	0.321
Housewife	45 (83.3)	96 (88.9)	Ref	—
Parity				
Primigravida	25 (46.3)	39 (36.1)	1.52 (0.79-2.95)	0.210
Multigravida	29 (53.7)	69 (63.9)	Ref	—
Smoker in Family				
Yes	7 (13.0)	8 (7.4)	1.86 (0.64-5.44)	0.248
No	47 (87.0)	100 (92.6)	Ref	—

OR = odds ratio; CI = confidence interval; Ref = reference category, *Statistically significant at p-value <0.05

In multivariable logistic regression (**Table 3**), with 11 variables, the model showed signs of overfitting due to a low number of events per variable (EPV = 4). Although preterm birth (aOR = 3.06, 95% CI: 1.28-7.34, p = 0.012) and lack of antenatal breastfeeding counseling (aOR = 2.60, 95% CI: 1.10-6.14, p = 0.029) remained significant, several confidence intervals were wide, indicating

Table 3: Fully saturated multivariable logistic regression analysis of risk factors for pneumonia (n=162).

Variables	Comparison *vs.* Reference Group	Adjusted OR	95% CI	p-value
Gestational Age	Preterm *vs.* Term	2.45	1.13-5.32	*0.024
Antenatal breastfeeding Counselling	No *vs.* Yes	2.51	1.10-5.72	*0.028
Maternal Education	Illiterate /Matric *vs.* ≥Intermediate	1.68	0.76-3.71	0.201
Maternal Occupation	Working *vs.* Housewife	1.45	0.52-4.04	0.477
Socioeconomic Status	Lower *vs.* Middle / Upper	1.40	0.61-3.23	0.430
Breastfeeding Status	Non-exclusive vs. Exclusive	1.36	0.62-2.98	0.445
Gender	Male *vs.* Female	1.88	0.82-4.31	0.135
Residence	Rural *vs.* Urban	1.91	0.68-5.38	0.221
Mode of Delivery	Cesarean Section *vs.* Vaginal	1.58	0.76-3.29	0.225
Parity	Primigravida *vs.* Multigravida	1.20	0.56-2.58	0.640
Smokers in Family	Yes *vs.* No	1.91	0.57-6.38	0.291

OR = odds ratio; CI = confidence interval; Ref = reference category, *Statistically significant at p-value <0.05
Model Diagnostics & Fit Specifications: Likelihood Ratio Test: χ2=29.1, df=11, p=0.002, Nagelkerke Pseudo-R2: 0.233, Hosmer-Lemeshow Goodness-of-Fit: χ2 test p=0.658 (indicates satisfactory model calibration), Events per Variable (EPV): 54/11=4.9 (indicates model saturation/ potential overfitting risks)

Table 4: Final parsimonious multivariable logistic regression model for pneumonia (n=162).

Variables	Comparison *vs.* Reference Group	Adjusted OR	95% CI	p-value
Antenatal Breastfeeding Counseling	No *vs.* Yes	3.01	1.45-6.25	*0.003
Gestational Age	Preterm *vs.* Term	2.89	1.42-5.88	*0.003
Maternal Education	Illiterate /Matric *vs.* Intermediate	2.34	1.15-4.76	*0.019

OR = odds ratio; CI = confidence interval; Ref = reference category, *Statistically significant at p-value <0.05

unstable estimates. Therefore, a parsimonious model was constructed using three clinically relevant predictors. No multicollinearity was detected (all VIFs < 1.2).

Model Diagnostics & Fit Specifications: Likelihood Ratio Test: χ2=29.1, df=11, p=0.002, Nagelkerke Pseudo-R2: 0.233, Hosmer-Lemeshow Goodness-of-Fit: χ2 test p=0.658 (indicates satisfactory model calibration), Events per Variable (EPV): 54/11=4.9 (indicates model saturation/potential overfitting risks)

In the final model in Table **4**, preterm birth (aOR=2.89, 95% CI: 1.42-5.88, p=0.003), no antenatal breastfeeding counselling (aOR=3.01, 95% CI: 1.45-6.25, p=0.003), and lower maternal education (below intermediate) (aOR=2.34, 95% CI: 1.15-4.76, p=0.019) were independent predictors of confirmed pneumonia.

Model Diagnostics & Fit Specifications: Likelihood Ratio Test: χ2=23.1, df=3, p<0.001 (highly significant global model fit), Nagelkerke Pseudo-R2: 0.188, Hosmer-Lemeshow Goodness-of-Fit: χ2 test p=0.811 (indicates excellent model calibration), Events per Variable (EPV): 54/3=18.0 (exceeds standard thresholds, indicating strong structural stability)

DISCUSSION

Our study has documented confirmed pneumonia in 33.3% of the suspected infant cohort. This frequency is lower than the community-based estimates from Pakistan of 40.8% in infants aged 2 to 11 months from peri-urban slums in Karachi [15], and substantially lower than the 67.6% reported in hospitalized children from South Asia [16]. This discrepancy reflects referral bias inherent to facility-based research, as the infants were enrolled from the outpatient department only if they had clinically suspected pneumonia later confirmed radiologically. Thus, our findings reflect the burden of radiologically confirmed pneumonia among infants with suspected pneumonia, not the population-level incidence. The predominance of pneumonia in early infancy is biologically plausible, as infants have narrow airways, a highly compliant chest wall, and immature innate and adaptive immune responses [17]. These factors impair pathogen clearance and predispose them to lower respiratory tract infections.

Non-exclusive breastfeeding was associated with pneumonia in our univariate analysis. Yu-Lan Kang and co-authors studied the effect of the duration of exclusive breastfeeding (EBF) on the occurrence and course of pneumonia in 218 infants aged 6 months or younger in China. They observed a direct relationship between EBF duration and pneumonia incidence: the longer the breastfeeding duration, the lower the incidence of pneumonia and, hence, the health care costs [18]. Vassilopoulou *et al.,* studying the role of breastfeeding in acute respiratory infections in infancy in Italy, concluded that breastmilk-being rich in immunoglobulins, antimicrobial peptides and immunomodulatory factors-provides defense against respiratory pathogens; they further investigated microRNAs in breastmilk unveiling its antiviral properties [19]. Moreover, Sutriana VN and co-authors reported that children who were not exclusively breastfed until six months of age had an approximately eight-fold increased risk of pneumonia compared to those who were exclusively breastfed [20]. The extended protective role of breastfeeding on respiratory outcomes later in childhood was reported by Paola Di Filippo and colleagues in Italy, who studied 110 prepubertal children and observed a protective effect of breastfeeding on their airways and lung function [21].

We found that 42% of infants in our cohort were exclusively breastfed, which is significantly below the national rate of 48% and the national target of 60% by 2030 [8]. Breastmilk is rich in bioactive compounds that help prevent allergies and inflammation while promoting immunity. A systematic review of 145 primary studies reported that breastfed infants have a reduced risk of respiratory, gastrointestinal, and ear infections, as well as asthma, inflammatory bowel disease, and type 1 diabetes [22]. In addition, breastfeeding positively affects children's cognitive scores, as reported by McGowan and Bland in their literature review [23]. Wang *et al.* reported that non-breastfed infants had a higher risk of both upper and lower respiratory infections and subsequent hospitalization; they inferred that exclusive breastfeeding for 6 months, with continuation until 1 year, was associated with a lower risk of subsequent lower respiratory tract infections (LRTIs) and hospitalization [24]. A similar study from Turkey, involving a cohort of 125 hospitalized preterm infants with LRTIs, reported that the duration of hospitalization was shorter among those breastfed for at least 6 months than among those breastfed for less than 6 months [25]. A prospective cohort analysis in the United States also reported that early initiation of breastfeeding significantly reduced the odds of post-perinatal deaths, including mortality from pneumonia and other infections [26].

Beyond host susceptibility and breastfeeding status, our study identified preterm birth, lack of antenatal breastfeeding counseling, and lower maternal education as independent, modifiable predictors of pneumonia. Preterm infants had nearly threefold higher odds of pneumonia compared with term infants. consistent with their immature lungs, surfactant deficiency, and weak immune regulation, all of which impair pathogen clearance [27, 28]. Our stratified analysis found that the protective effect of exclusive breastfeeding was entirely lost among preterm infants (p = 0.472), whereas it remained profoundly protective among term infants (p = 0.014). This suggests that the physiological fragility of prematurity can override standard behavioral immunoprotection, indicating that preterm infants require aggressive, multi-faceted clinical safeguarding beyond breastfeeding promotion alone.

Lack of antenatal breastfeeding counseling was the strongest predictor (aOR=3.01, 95% CI: 1.45-6.25, p=0.0030), supporting evidence that suboptimal breastfeeding practices elevate the risk of pneumonia, particularly when maternal health literacy is limited. This suggests that missed health education during antenatal care (ANC), rather than feeding practices alone, is a critical modifiable risk factor. Abdalla Ali Abdalla and colleagues, in a study of 386 mothers of infants aged six months or younger in Saudi Arabia, reported that antenatal counseling increased the likelihood of breastfeeding initiation. In contrast, postnatal counseling improved its continuation [29]. Structured counseling interventions are needed both antenatally and postnatally to initiate, improve, and sustain exclusive breastfeeding practices to meet our national target [8] and help prevent pneumonia in early infancy. A similar study on the role of postnatal breastfeeding counseling revealed a positive influence on breastfeeding initiation and exclusive breastfeeding practices, underscoring the need to strengthen sustained education for mothers in the immediate postpartum period [30].

Lower maternal education (below intermediate) also conferred more than a two-fold increase in odds (aOR=2.34, 95% CI: 1.15-4.76, p=0.019), likely reflecting poorer health literacy and delayed care-seeking. Maternal education serves as a proxy for healthcare literacy, socioeconomic flexibility, and early symptom recognition. Mothers with higher education (above the intermediate level) demonstrated a much greater capacity to leverage EBF to achieve a protective outcome (23.7% pneumonia rate with EBF *vs.* non-EBF). A similar study done by a group of investigators on infants and children (2-59 months) in a tertiary care hospital in Lahore reported a statistically significant relationship between low maternal/parental educational attainment and the clinical development of severe pneumonia (having odds ratios more than 1) [31]. A multicenter cohort study from northern Pakistan by the CIPAM study group reported that lower parental education severely impedes optimal clinical outcomes and care-seeking success in childhood pneumonia [32].

The findings of this study should be viewed in light of some limitations. It was a single-center, OPD-based study with radiographic confirmation, which introduces referral bias. Additionally, the study was unable to account for certain predictor variables, such as nutritional and immunization status. Lastly, being a prevalence study limits its ability to establish temporal associations.

Despite these limitations, this study is significant in reporting a high burden of radiologically confirmed pneumonia, which remains a leading cause of morbidity among care-seeking infants. Radiological confirmation of pneumonia reduces misclassification bias from bronchiolitis or upper respiratory tract infection (URTI) and improves diagnostic specificity. We targeted a vulnerable age group that is underrepresented in studies from Pakistan, so this data helps fill an important age-specific gap. Multicenter community-based cohort studies are needed to determine the true incidence of pneumonia and to prospectively assess the role of exclusive breastfeeding while controlling for confounders such as vaccination and nutritional status.

CONCLUSION

The frequency of radiologically confirmed pneumonia was seen in one-third of the studied sample, with the strongest association with lack of antenatal breastfeeding counseling, preterm birth, and lower maternal education. Non-exclusive breastfeeding was not independently associated with confirmed pneumonia

after adjusting for confounders; however, it substantially increased pneumonia risk among preterm infants and in the absence of antenatal breastfeeding counseling. Community promotion of exclusive breastfeeding should be prioritized, alongside prospective studies on the roles of immunization and nutrition. Despite a modest sample size, this study reported a highly significant association of pneumonia with preterm birth and antenatal breastfeeding counseling, with potential implications for preventive strategies at the primary care level.

ETHICS APPROVAL

The study was conducted after obtaining approval from the Ethics Committee of Patel Hospital (Approval No. PH/IRB/2022/2004). All procedures performed in the study were conducted in accordance with the ethical standards of the institutional national research committee and the Declaration of Helsinki.

CONSENT FOR PUBLICATION

The study was conducted after obtaining formal written consent from the patient's parents/guardians.

AVAILABILITY OF DATA

Authors confirm that data supporting the results of this study are available and can be provided on request.

FUNDING

None.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest

ACKNOWLEDGEMENTS

The authors gratefully acknowledge all the study participants, their caretakers, and paramedical staff in the OPD for their cooperation during the study period. The authors further extend their acknowledgment to all radiologists who supported the study with their valuable, timely input.

AUTHORS' CONTRIBUTION

HN : Study concept, Study design, Data collection, Manuscript drafting.

ZR : Data collection, Manuscript drafting, Critical review and revision of initial manuscript draft.

ES : Study design, Manuscript drafting, Critical review and revision.

SSS : Data curation, Critical review and revision, Editing.

AK : Data analysis, Manuscript drafting.

SA : Study design, Data analysis, Final approval.

All authors have read and approved the final version.

GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of the manuscript, the authors used Meta AI and Gemini for language editing and grammar refinement, but modified the content as needed.

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