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Association between chest radiographic findings and clinical outcomes in pediatric patients with bronchiolitis at King Abdulaziz University Hospital

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ABSTRACT

Background: Acute lower respiratory infections (ALRI) affect between 120 million and 156 million people worldwide. Patients who have been diagnosed with bronchiolitis frequently have chest X-rays (CXR). However, local guidelines advocate not using CXR regularly. *Aim:* To assess the relationship between radiologic findings and clinical outcomes in pediatric patients with bronchiolitis and the usefulness of CXR findings as prognostic factors in acute bronchiolitis. *Methodology:* We conducted a retrospective cohort study in the Department of Pediatrics at King Abdulaziz University Hospital (KAUH), Jeddah, Saudi Arabia during 2021-2022. The study included pediatric patients <2 years old, admitted due to acute bronchiolitis, who underwent CXR. *Results:* Interstitial infiltration was the most common abnormal radiologic finding (n=132; 62.9%). Atelectasis was significantly associated with longer hospital stays (p=0.018), and hyperinflation was observed to be an independent predictor of intensive care unit (ICU) admission (p=0.048). *Conclusion:* In addition to respiratory distress, patients with atelectasis should be considered high risk patients requiring more aggressive treatment to shorten their hospital length of stay and reduce the risk of ICU admission and ventilator use.

Keywords: radiography, pediatric, bronchiolitis, atelectasis, length of hospital stay

1. INTRODUCTION

Bronchiolitis is the most common acute viral infection of the lower respiratory tract in children < 2 years old (Nicolai et al., 2013). According to current

estimates, approximately 120–156 million cases of acute lower respiratory tract infections occur annually worldwide, with approximately 1.4 million cases resulting in mortality (Sonego et al., 2015). Bronchiolitis is among the ten most common diagnoses in the emergency medicine department during late fall and winter (Atay et al., 2020). It is commonly caused by respiratory syncytial virus (RSV), which is the principal cause of hospitalization in infants <12 months old (Mazur et al., 2015; Kenmoe et al., 2020). Peak rates of RSV infection among Saudi pediatric patients were documented in those less than six months of age (Ahmed et al., 2018).

Chest X-rays (CXR) are commonly used in patients diagnosed with bronchiolitis (Hartling et al., 2011). A study covering 42 hospitals has reported that the rate of ordering CXR for patients with bronchiolitis is 24–76% (Florin et al., 2014). Interestingly, before these studies, the American Academy of Pediatrics as well as Saudi Pediatric Pulmonology Association guidelines have advocated not using CXR regularly in patients with bronchiolitis and have suggested saving it for cases with comorbidities, secondary bacterial infections, or aspiration (Ralston et al., 2014; Alharbi et al., 2018).

Two studies have shown no correlation between the severity of bronchiolitis and CXR findings (Macias et al., 2015; Abdoun et al., 2020). By contrast, another study in Portugal found that patients with abnormal CXR findings had a more severe disease course (Gonçalves et al., 2012). There are limited studies that correlate radiographic findings with the disease outcomes despite the magnitude of its burden on the pediatric population (Gonçalves et al., 2012). Therefore, this study aimed to determine whether there is a link between radiologic findings and clinical outcomes in pediatric patients with bronchiolitis.

2. METHODS AND MATERIALS

Study Design and Population (Ethical approval, place, and time)

We performed this retrospective cohort study at the Department of Pediatrics at King Abdulaziz University Hospital (KAUH), a tertiary center in Jeddah, Saudi Arabia. This study included all pediatric patients <2 years old admitted due to acute bronchiolitis who underwent CXR from January 2015 to September 2021 at KAUH. We excluded patients who were >2 years old. The ethical committee at the King Abdulaziz University Faculty of Medicine's Unit of Biomedical Ethics approved this study (Reference No. 535-20) Obtaining an informed consent was waived by the ethical committee as the study was a retrospective.

Data collection

Medical records were reviewed and the following data collected for all patients who fulfilled the inclusion criteria: Demographic characteristics, including age, sex, date of birth, nationality, patient's weight, and birth weight Comorbidities (congenital heart disease, prematurity, Down syndrome). Clinical features, including symptoms (cough, fever, and shortness of breath), signs (tachypnea, apnea, wheezing, cyanosis, and respiratory distress defined as nasal flaring, grunting, or intercostal retraction), and medication with salbutamol.

Radiologic findings were based on the primary chest radiograph taken before, at, or after admission. The findings were classified as normal, interstitial infiltrate (defined as interstitial or airspace opacity), atelectasis (defined as collapsed lung tissue), and hyperinflation (defined as increased intercostal space, increased lung lucency, or flattening of the diaphragm). Data were collected from the radiology reports. Additionally, a consultant radiologist with >10 years of experience examined cases with no available reports. A severe disease course was defined as a long hospital stay (>3 days, admission to the intensive care unit (ICU), or the need for ventilatory support.

Data entry and analysis

Demographic characteristics, comorbidities, clinical features, radiographic findings, and disease severity were presented. The Shapiro-Wilk and Kolmogorov-Smirnov tests were performed to ensure data normality, and the results revealed that the continuous data were normally distributed. Consequently, age, body weight, and birth weight are presented as means and standard deviations. The remaining variables were categorical and presented as central tendencies.

Categorical variables indicating severe disease, including ICU admission and ventilatory support, were compared with the other variables. These were compared with continuous variables such as age, body weight, birth weight, and length of stay using an independent samples t-test. Additionally, they were compared with the remaining categorical variables, including sex, comorbidities, clinical features, radiologic findings, and medication usage using the Chi-square test. The statistical significance level was set at $p<0.05$. Binary logistic regression analysis was used to determine factors that independently predicted severe disease. Not all variables could be included in the multivariate analysis because of the limitations on the required number of cases per variable. The analysis was performed with a 95% confidence interval (CI) using the Statistical Package for Social Science (SPSS), version 23.0 (IBM, Armonk, NY, USA).

3. RESULTS

Descriptive statistics

A total of 457 patients with bronchiolitis were admitted. Patients with missing data and no chest radiographs were excluded. Of the remaining 210 patients, 125 (59.5%) were male and 127 (60.5%) were Saudi citizens. Their mean age, body weight, and birth weight were 4.23±4.05 months, 5.26±1.91 kg, and 2.72±0.71 kg, respectively. Seventy-five (35.7%) patients had comorbidities: congenital heart disease, Down syndrome, and prematurity in 34 (16.2%), 8 (3.8%), and 33 (15.7%), respectively. Among the presenting clinical features, the most common chief complaint was shortness of breath in 90 (42.9%) patients. The most common and rarest symptoms were cough and apnea in 187 (89%) and 11 (5.2%) patients, respectively.

Bivariate analysis

Radiographic Findings

Forty-seven patients had normal chest radiographs (22.4%). The most common abnormal radiologic finding was interstitial infiltration (n=132, 62.9%), followed by hyperinflation (n= 124, 59%), and atelectasis (n=23, 11%) (Figure 1). The presence of atelectasis was significantly associated with longer hospital stays (p=0.018), ICU admission (p=0.025), and the need for ventilatory support (p=0.025) (Tables 1 and 2, respectively).

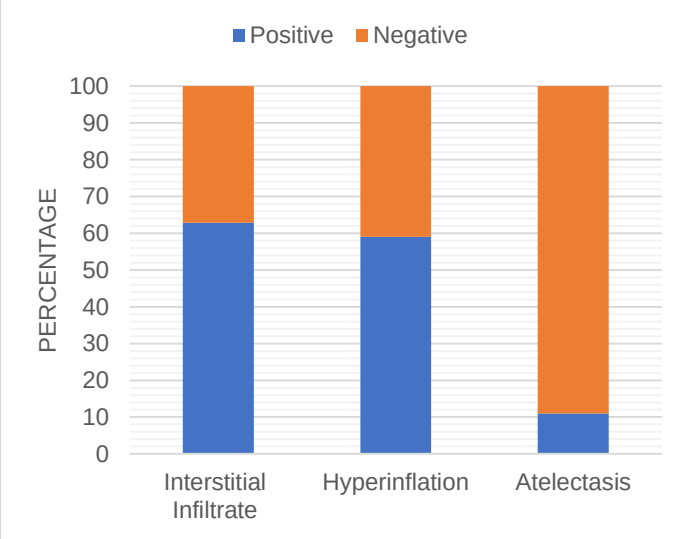

Figure 1 Radiological findings (%)

Table 1 Overall frequency of chest radiographic findings

Radiologic Findings	No. of Chest X-rays With Positive Findings (%)	No. of Chest X-rays With Negative Findings (%)
Interstitial Infiltrate	132 (62.9%)	78 (37.1%)
Hyperinflation	124 (59%)	86 (41%)
Atelectasis	23 (11%)	187 (89%)

Table 2 The frequency in percentage of CXR findings in correlation with the prognosis and their significance

		LOS			ICU admission			Ventilatory support		
		<3 days	≥3 days	p-value	Not admitted	Admitted	p-value	Not needed	Needed	p-value
Interstitial infiltrates:	Present	58.7%	64.6%	0.418	60.9%	74.2%	0.157	61.7%	68.6%	0.157
	Absent	41.3%	35.4%		39.1%	25.8%		38.3%	31.4%	
Hyperinflation:	Present	50.8%	63.3%	0.58	57.5%	67.7%	0.286	58.3%	62.9%	0.286
	Absent	49.2%	36.7%		42.5%	32.3%		41.7%	37.1%	
Atelectasis:	Present	3.2%	85.7%	0.018*	8.9%	77.4%	0.025*	9.7%	17.1%	0.025*
	Absent	96.8%	14.3%		91.1%	22.6%		90.3%	82.9%	

* p-value <0.05, indicating significant correlation. Abbreviation: LOS: Length of hospital stay, ICU: Intensive care unit.

Clinical Features

Length of hospital stay, ICU admission, and the need for ventilatory support were compared across categorical and continuous variables. Decreased length of stay was associated with salbutamol use (p=0.028). Patients with low birth weights were more likely to be admitted to the ICU (p=0.047). Prematurity, tachypnea, apnea, and cyanosis were significantly associated with higher ICU admission rates and the need for ventilatory support (p<0.05) (Table 3).

Table 3 Clinical features correlated with patient outcomes (p-values)

Variable	Length of stay	Intensive care unit admission	Ventilatory support
Male sex	0.645	0.858	0.858
Congenital heart disease	0.120	0.992	0.992
Prematurity	0.107	0.006*	0.006*
Down syndrome	0.440	0.854	0.854
Cough	0.962	0.806	0.806
Fever	0.553	0.288	0.288
Shortness of breath	0.420	0.530	0.053
Tachypnea	0.697	0.047*	0.047*
Apnea	0.380	0.038*	0.038*
Wheezing	0.712	0.812	0.812
Respiratory distress	0.104	0.234	0.234
Cyanosis	0.621	<0.001*	<0.001*
Salbutamol	0.028*	0.159	.159

* p-value <0.05, indicating significant correlation

Multivariate analysis

Among the radiologic findings, the only significant association was observed between hyperinflation and ICU admission (p=0.048). Another predictive factor for ICU admission was tachypnea (p=0.023). The only factor predictive of length of hospital stay for ≥ 3 days was respiratory distress (p=0.008) (Tables 4 and 5, respectively).

Table 4 CXR findings independent factors in correlation with the patient outcome

Variable	Length of stay	ICU admission	Ventilatory support
Interstitial Infiltrate	0.111	0.970	0.583
Hyperinflation	0.856	0.048*	0.230
Atelectasis	0.084	0.702	0.386

* p-value <0.05 indicates significant correlation

Table 5 Clinical features as independent factors correlated with patient outcomes (p-values)

Variable	Length of stay	ICU admission	Ventilatory support
Gender	0.174	0.348	0.394
Cough	0.280	0.611	0.626
Fever	0.806	0.150	0.959
Shortness of breath	0.977	0.697	0.491
Tachypnea	0.597	0.023*	0.363
Apnea	0.343	0.430	0.588
Wheezing	0.322	0.600	0.378
Respiratory distress	0.008*	0.374	0.172
Cyanosis	0.220	0.134	0.110
Salbutamol	0.038*	0.660	155

* p-value <0.05 indicates significant correlation

4. DISCUSSION

This study focused on assessing the relationship between radiologic findings and clinical outcomes of the disease and the usefulness of CXR findings as a prognostic factor in acute bronchiolitis. Additionally, this study considered other factors, such as comorbidities and clinical features, as secondary findings. In this study, the age group ranged between 1 and 24 months, with a mean of 4.23±4.05 months. The sex frequency was 59.5% for males and 40.5% for females. The mean birth weight was 2.72±0.71 kg. According to a publication in Riyadh, Saudi Arabia, the mean Saudi newborns' birth weight is slightly lower than other internationally documented values, which explains, the lower birth weight in this study's patient population than in others (Wong, 1990).

This study showed that the most common CXR findings in bronchiolitis are interstitial infiltrates as well as hyperinflation, which was the most common finding in other studies (Gonçalves et al., 2012; Abdel-Kader et al., 2018; Shoshan, 2019; Abdoun et al., 2020). However, few studies that investigated the impact of CXR findings in patients with bronchiolitis (particularly RSV) reported that patients with radiographic findings of interstitial infiltrate and hyperinflation had a greater need for mechanical ventilation, a longer length of stay, and ICU admissions (Tasker et al., 2000; Prodhan et al., 2008; Pezzotti et al., 2009; Papoff et al., 2011; Gonçalves et al., 2012). Conversely, in this study, atelectasis showed a significant correlation with a prolonged hospital stay, ICU

admission, and mechanical ventilatory support as a non-independent factor, in agreement with a retrospective study by Prodhan et al., (2008) in Massachusetts General Hospital (Figure 2). Prodhan et al., (2008) found that children with areas of lung atelectasis on days 1 and 2 after intubation required prolonged mechanical ventilation for >8 days.

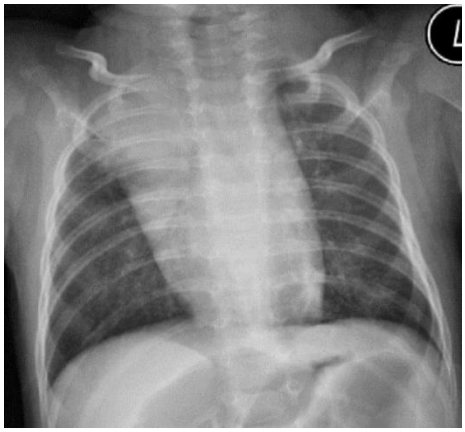

Figure 2 Chest radiograph of a 3-month-old male patient demonstrating right upper lobe atelectasis

Hyperinflation was another predictive factor for a worse prognosis and was found to be significantly correlated with ICU admission (p=0.048), as previously reported (Figure 3) (Shoshan, 2019). There was no consistency in the definition of interstitial infiltrates between prior reports. Some studies grouped all lung opacities and infiltration, including atelectasis, as one finding, whereas others separated them into atelectasis, consolidation, and interstitial opacities. In the present study, interstitial infiltration was not significantly correlated with length of stay, ICU admission, or mechanical ventilatory support. This inconsistency with previous reports might be related to the different definitions, especially since atelectasis revealed a significant association with worse outcome (Prodhan et al., 2008; Gonçalves et al., 2012; Shoshan, 2019).

Figure 3 Chest radiograph of a 5-month-old female patient presenting with shortness of breath demonstrating hyperinflation

Premature birth was established in our study as one of the risk factors for the need for mechanical ventilation and ICU admission. This topic has been vigorously discussed in the literature, with multiple studies reporting similar results as the present study (Gonçalves et al., 2012; Ghazaly and Nadel, 2018). In previous studies, Down syndrome has been established as another risk factor for more severe outcomes (Sommer et al., 2011; Stagliano et al., 2015); however, this study's findings are contrary. We observed that Down syndrome was not a significant predictor of patient severity outcome; however, this could be attributed to the lack of a sufficient patient population in our data compared to that in the previously mentioned articles. Clinical symptoms observed in this study included cough (89%), shortness of breath (69%), tachypnea (68.6%), fever (63.3), poor feeding (62.4%), and rhinorrhea or congestion (59.5%). The most common symptom was coughing, consistent with another study that also found it to be the most frequently reported symptom (Niles et al., 2018). However, the associated symptoms showed a certain degree of variation in both studies. On the other hand, apnea is a very rare clinical presentation (Alharbi et al., 2018).

We found that the mean length of stay in this study population was 5.45 days compared to that in a study conducted in Suzhou, China (8 days), which was higher (Zhang et al., 2014). Furthermore, that study reported poor feeding and prolonged expiration to be significantly associated with increased length of stay (Niles et al., 2018). Interestingly, another study found that oxygen

saturation and respiratory rate were predictors of respiratory decompensation (Dadlez et al., 2017). Likewise, these data showed that tachypnea, apnea, and cyanosis strongly correlated with the need for both ICU admission and ventilator use. This shows the importance of clinical assessment in patients presenting with respiratory tract infection symptoms. Among this study's patients, 52.9% required treatment with salbutamol, as in another study where albuterol was used in 55.3% cases; this slight difference could be due to the number of patients (13%) who were already asthmatic in the other study (Shoshan, 2019).

Limitations & recommendations

The first limitation was the lack of documentation of the indication for chest radiography in the patients' files or its impact on the management of patients. Second, hypoxia was not discussed among the clinical features in the current study, although it is an important parameter. Lastly, the radiologist's interpretation was not blinded to the patient's diagnosis and was based on a single reader; this could introduce observer bias and affect the accuracy of the results. Therefore, we recommend future multicenter studies with larger, more heterogeneous populations that involve oxygen saturation, as it is a significant predictor of patient outcomes.

5. CONCLUSION

In summary, this study showed that a telectasis and hyperinflation are associated with worse prognoses in pediatric patients with bronchiolitis. In addition, prematurity, tachypnea, apnea, and cyanosis are all strongly correlated with the need for both ICU admission and ventilation, with apnea being the rarest clinical presentation. Hence, we recommend that clinicians be prepared and escalate treatment as necessary if atelectasis on chest radiography and signs of respiratory distress are observed. This might reduce the duration of hospital stay and decrease the risk of ICU admission and the need for ventilatory support.

Author contribution

Alyaa Garout (study supervision, conceptualization, methodology, data collection and processing, manuscript original draft Writing, editing and reviewing the final version)
Mohammed H. Alhomrani, Majed M. Alharbi, Samaher S. Hazzazi, Abdulaziz A. Subyani, Reem A. Alghanmi (data collection and Processing, data analysis, manuscript original draft writing)
Ghofran Ageely (data collection, editing and reviewing the final manuscript)
The final version of the manuscript version was read and approved by all the authors.

Ethical approval

The research ethics committee at the King Abdulaziz University study (Reference No. 535-20).

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Conflicts of interest

The authors declare that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

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