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Chest Radiographic Findings in Hospitalized Children with COVID-19: A Cross-Sectional Study in Yazd, Iran

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ABSTRACT

Background: Chest X-ray (CXR) patterns in pediatric COVID-19 are not well described. We aimed to characterize CXR findings in hospitalized children and to examine their associations with clinical and laboratory features.

Methods: This cross-sectional study included all children (<18 years) with PCR-confirmed or clinically/radiologically diagnosed COVID-19 admitted to Shahid Sadoughi Hospital, Yazd, Iran, between February 2020 and March 2021. Admission CXRs were interpreted by a single radiologist and scored (0–18) across six lung zones. Clinical, laboratory, and outcome data were retrieved from a registry. Associations were tested with Chi-square, Mann–Whitney U, or Kruskal–Wallis tests.

Results: Among 108 children (61.1% male; mean age 5.7 ± 4.8 years), 68 (62.9%) had an abnormal CXR. The most frequent patterns were ground-glass opacity (86.8%), peribronchial thickening (54.4%), and consolidation (45.6%). Lesions were predominantly peripheral (50.0%), bilateral (82.4%), and involved the right lower zone (52.2%). Pleural effusion (14.7%) strongly predicted mortality (risk difference 32.5%, P<0.001). Consolidation was more common with shortness of breath (68.0% vs. 20.0%, P = 0.001) but less common in respiratory distress (36.7% vs. 64.7%, P = 0.045). Higher CXR severity scores were associated with underlying comorbidities, hypoxia, PICU admission, and critical illness in previously healthy children (P = 0.002).

Conclusion: Bilateral peripheral ground-glass opacity and peribronchial thickening are common in pediatric COVID-19. Consolidation, pleural effusion, and high radiographic scores correlate with severe disease and poor outcomes, supporting CXR as a useful adjunct for risk stratification in moderate-to-severe cases, rather than universal screening.

Introduction

The coronavirus disease 2019 (COVID-19) pandemic, caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has placed an unprecedented burden on healthcare systems globally. Although children of all ages are susceptible to SARS-CoV-2 infection, they generally exhibit a milder clinical course than adults and have a markedly lower risk of developing severe pneumonia, acute respiratory distress syndrome, or death[1, 2]. Nevertheless, severe and critical presentations can occur in pediatric patients, including progressive respiratory failure, multisystem inflammatory syndrome in children (MIS-C), and myocarditis, particularly in those with underlying medical conditions[2, 3]. Early and accurate recognition of pulmonary involvement is therefore essential to enable timely supportive care, appropriate isolation measures, and judicious allocation of intensive care resources. However, clinical assessment alone may underestimate the extent of lung pathology, and definitive virological diagnosis by reverse transcriptase polymerase chain reaction (RT-PCR) can be hampered by limited availability, delayed turnaround times, or false-negative results, especially early in the disease course[4].

In this context, chest imaging assumes a critical complementary role in the diagnostic work-up and risk stratification of children with suspected or confirmed COVID-19. Chest computed tomography (CT) is regarded as a highly sensitive modality for the detection of COVID-19 pneumonia and may demonstrate characteristic findings, such as ground-glass opacities, consolidations, and peripheral lung involvement, even before reverse transcriptase polymerase chain reaction (RT-PCR) yields a positive result[5-7]. However, the routine use of CT in children is constrained by several important considerations. Because developing tissues are more radiosensitive, children face a higher lifetime attributable risk of radiation-induced malignancy per unit of radiation exposure, making radiation stewardship paramount in pediatric practice. Moreover, young children frequently require sedation or anesthesia to achieve motion-free images, which introduces additional logistical demands, costs, and potential adverse events. These factors have led to a strong preference for chest radiography (CXR) as the first-line imaging modality in most pediatric settings, in line with consensus guidelines that recommend CXR for initial evaluation of suspected pneumonia and reserve CT for cases with clinical deterioration or diagnostic uncertainty[8-10]. Compared with CT, CXR offers several practical advantages, including wide availability, portability for bedside imaging in isolation units and intensive care units, lower radiation exposure, and rapid acquisition without the need for sedation in most cases. In adults with COVID-19, the radiographic manifestations on CXR have been well described. Large observational studies and systematic reviews have consistently identified bilateral, multifocal, peripheral opacities, with ground-glass opacity and consolidation most commonly affecting the lower lung zones[11–13]. Furthermore, radiographic severity assessed by zonal scoring systems has been shown to correlate with disease progression, intensive care requirement, and mortality in adult populations, underscoring the prognostic value of CXR, particularly in resource-limited settings[9, 11].

However, existing pediatric studies are limited by relatively small sample sizes, retrospective methodologies, and a lack of standardized radiographic scoring systems with systematic correlation with clinical and laboratory parameters[12-15]. Numerous studies have not distinguished children with mild disease managed in outpatient settings from those requiring hospitalization, and they have also not examined associations with critical outcomes such as pediatric intensive care unit (PICU) admission and mortality. In addition, the effect of age, underlying comorbidities, and laboratory

markers of inflammation on the radiographic phenotype remains poorly defined.

A validated and reproducible CXR severity scoring system, analogous to those employed in adult acute respiratory distress syndrome, has rarely been applied in pediatric COVID-19 research. To our knowledge, there was no validated pediatric CXR severity score for COVID-19, which constituted a gap in the quantitative assessment of lung involvement and its prognostic utility. To address these knowledge gaps, the present study aimed to provide a comprehensive description of admission CXR patterns in a relatively large cohort of hospitalized children with COVID-19 in Yazd, Iran, and to explore the associations among radiographic findings, clinical and laboratory characteristics, and disease outcomes. It employed a standardized zonal severity scoring approach, interpreted all images by a single radiologist blinded to clinical data, and stratified analyses by comorbidity status to identify predictors of severe radiographic disease in different risk groups. It was hypothesized that, consistent with adult data, certain CXR features (such as consolidation, pleural effusion, and high severity scores) would be associated with more severe illness and worse outcomes, and that CXR could serve as an adjunctive tool for risk stratification in pediatric COVID-19, particularly in settings where advanced imaging and repeated molecular testing are not readily accessible.

Materials and Methods

Study Design and Participants

This cross-sectional study was conducted at Shahid Sadoughi Hospital, a tertiary referral center in Yazd, Iran. Eligible participants included all pediatric patients under the age of 18 admitted with a diagnosis of COVID-19 between February 20, 2020, and March 20, 2021. Diagnosis was established based on either a positive nasopharyngeal real-time reverse transcription-polymerase chain reaction (RT-PCR) assay for SARS-CoV-2 or, in RT-PCR-negative cases, a combination of representative clinical features (fever, cough, dyspnea) and characteristic chest imaging findings, in accordance with the Iranian national consensus guidelines[16] Patients with medical records lacking baseline chest radiographs (CXRs) or key clinical data were excluded. Utilizing a census sampling approach, a total of 108 children were enrolled in the study. The study was approved by the Institutional Ethics Committee of Islamic Azad University, Yazd Branch (approval code: IR.IAU.KHUISF.REC.1401.248). The requirement for informed consent was waived because data were anonymized. This cross-sectional study was not registered in a clinical trial registry, as it is an observational study.

Data Collection

Data were extracted from the hospital's pediatric COVID-19 registry. The extracted variables comprised age, sex, underlying diseases, symptoms (cough, fever, shortness of breath, respiratory distress), duration of symptoms, vital signs, oxygen saturation, laboratory parameters (complete blood count, C-reactive protein [CRP], erythrocyte sedimentation rate [ESR], lactate dehydrogenase [LDH], blood urea nitrogen [BUN], RT-PCR result), disease severity, admission to the pediatric intensive care unit (PICU), length of hospital stay, and clinical outcome (survival or death). Disease severity was classified according to WHO criteria as non-severe (mild symptoms, no pneumonia or mild pneumonia), severe (pneumonia with respiratory distress, oxygen saturation <94% on room air, or inability to feed), and critical (acute respiratory distress syndrome, sepsis, or multiorgan failure)[17].

Chest Radiograph Interpretation and Scoring

The initial frontal CXR obtained at admission was available for all participants. All radiographs were independently interpreted by a single board-certified radiologist who was blinded to clinical information. Each lung was divided into three zones (upper, middle, and lower) using two horizontal lines drawn at the

inferior wall of the aortic arch and the inferior margin of the left hilum, resulting in six zones in total[18]. Each zone was assigned a score as follows: 0 = normal; 1 = interstitial infiltrates; 2 = interstitial and alveolar infiltrates (interstitial predominance); and 3 = interstitial and alveolar infiltrates with alveolar predominance. The CXR score was calculated as the sum of the six zonal scores, with possible values ranging from 0 to 18. Radiographic patterns recorded included GGO, consolidation, peribronchial thickening, airspace opacity, white lung appearance, and pleural effusion. The distribution of infiltration (central, peripheral, or both; unilateral or bilateral) and the zone with the most marked involvement were documented. Statistical Analysis.

Data were analyzed using SPSS version 25 (version 25, IBM Corporation, Armonk, NY). Continuous variables are presented as mean ± standard deviation or median (interquartile range), whereas categorical variables are presented as frequencies and percentages. The Chi-square or Fisher's Exact test was used to compare categorical variables. For continuously distributed variables that were not normally distributed, as determined by the Shapiro-Wilk test, the Mann–Whitney U test or Kruskal–Wallis test was applied. Risk difference with a 95% confidence interval was calculated for the mortality outcomes. A two-tailed $P < 0.05$ was considered statistically significant.

Results

Baseline Characteristics

The 108 children had a mean age of 5.7 ± 4.8 years (ranging from 1 month – 17 years); 66 (61.1%) were male. Forty-five patients (41.7%) presented with at least one underlying disease, the most common of which were asthma (n = 12), congenital heart disease (n = 8), and neurologic disorders (n = 7). The most frequent clinical symptoms were fever (88.0%) and cough (65.7%). According to WHO criteria, 39 patients (36.1%) had non-severe disease, 46 (42.6%) had severe disease, and 23 (21.3%) had critical illness. Thirty-one children (28.7%) required admission to the PICU, and 12 (11.1%) died (Table 1).

Table 1. Baseline Characteristics of Hospitalized Children with COVID-19 (N = 108)

Characteristic	Value
Demographics	
Age (years), Mean ± SD	5.7 ± 4.8
(range)	(1 month – 17 years)
Male sex, n (%)	66 (61.1)
Underlying disease	
Any underlying disease, n (%)	45 (41.7)
Asthma	12 (11.1)
Congenital heart disease	8 (7.4)
Neurologic disorders	7 (6.5)
Presenting symptoms, n (%)	
Fever	95 (88.0)
Cough	71 (65.7)
WHO severity classification, n (%)	
Non-severe	39 (36.1)
Severe	46 (42.6)
Critical	23 (21.3)
PICU admission, n (%)	31 (28.7)
Outcome, n (%)	
Survived	96 (88.9)
Died	12 (11.1)

Abbreviations: SD, standard deviation; WHO, World Health Organization; PICU, pediatric intensive care unit.

Note: The 45 children with any underlying disease had a variety of diagnoses; because some children had more than one condition, the total number of diagnoses exceeds the number of children. The most common individual diagnoses were asthma (n = 12), congenital heart disease (n = 8), and neurologic disorders (n = 7). Other conditions included hematologic/*oncologic diseases, renal disorders, and genetic syndromes.*

Radiographic Findings

Among the 108 initial CXRs, 68 (62.9%) showed at least one abnormal finding. Within these 68 abnormal radiographs, the observed patterns consisted of GGO in 59 (86.8%), peribronchial thickening in 37 (54.4%), consolidation in 31 (45.6%), air-space opacity in 2 (2.9%), white lung appearance in 3 (4.4%), and pleural effusion in 10 (14.7%). Pulmonary infiltration was peripheral in 50.0%, central in 13.2%, and both in 36.8% of cases, with bilateral involvement observed in 82.4%. The right lower zone was the most frequently affected region (52.2%), whereas the left middle zone was the least affected (3.0%) (Table 2).

Table 2. Radiographic Findings in 68 Children with Abnormal Admission CXR

Finding	n (%)
Ground-glass opacity	59 (86.8)
Peribronchial thickening	37 (54.4)
Consolidation	31 (45.6)
Airspace opacity	2 (2.9)
White lung appearance	3 (4.4)
Pleural effusion	10 (14.7)
Type of infiltration	
Peripheral	34 (50.0)
Central	9 (13.2)
Both	25 (36.8)
Laterality	
Bilateral	56 (82.4)
Unilateral	12 (17.6)
Zone of maximum involvement	
Right upper	14 (20.9)
Right middle	3 (4.5)
Right lower	35 (52.2)
Left upper	7 (10.4)
Left middle	2 (3.0)
Left lower	6 (9.0)

Note. Missing data account for slight variations in denominators; detailed numbers are presented in the text.

Associations between CXR Findings and Clinical/Laboratory Variables

Several significant associations emerged (Table 3). Consolidation was significantly more frequent in children with shortness of breath (68.0% vs. 20.0%, P = 0.001) but, paradoxically, less common in those with documented respiratory distress (36.7% vs. 64.7%, P = 0.045). Pleural effusion was strongly associated with mortality: 41.6% of non-survivors had effusion versus 9.1% of survivors (risk difference 32.5%, 95% CI 10.7%–54.3%; P < 0.001). Bilateral infiltration was universal in children with fever duration ≥5 days (100% vs. 66.7%, P = 0.002) and more common in PICU-admitted patients (93.5% vs. 72.2%, P = 0.023). Peribronchial thickening was less frequent in adolescents aged 13–18 years (9.1% vs. 72.7% in infants, P = 0.007) and more frequent when LDH was normal (72.7% vs. 37.5%, P = 0.017). No significant differences were observed for sex, PCR status, or most laboratory markers (WBC, CRP, ESR, lymphocyte count).

CXR Severity Score

Among the 68 children with abnormal CXR findings, the mean CXR score was 9.58 ± 4.72 (range 0–18). The score did not differ significantly across different age groups, although the highest mean score was observed in the 13–18 years cohort (11.45 ± 5.66, P = 0.181). Children with underlying diseases had a significantly higher mean score (11.03 ± 4.47 vs. 8.33 ± 4.47, P = 0.019). Stratified analyses revealed distinct predictors of radiographic severity based on clinical subgroups. Among children with comorbidities, those with oxygen saturation <94% had higher CXR scores (14.14 ± 2.85 vs. 9.46 ± 4.71, P = 0.032), and PICU-admitted children scored higher (12.70 ± 4.04 vs. 8.45 ± 3.98, P = 0.015). Conversely, in children without underlying comorbidities, CXR scores were significantly higher in those experiencing respiratory distress (11.10 ± 5.10

Table 3. Summary of Key Significant Associations

Variable	Finding	With Variable	Without Variable	P
Shortness of breath	Consolidation present	68.0%	20.0%	0.001
Respiratory distress	Consolidation present	36.7%	64.7%	0.045
Mortality	Pleural effusion	41.6%	9.1%	<0.001
Fever duration ≥5 days	Bilateral infiltrates	100%	66.7%	0.002
PICU admission	Bilateral infiltrates	93.5%	72.2%	0.023
Age 13–18 years	Peribronchial thickening	9.1%	72.7%	0.007
LDH normal	Peribronchial thickening	72.7%	37.5%	0.017
Underlying disease	CXR score (Mean ± SD)	11.03±4.47	8.33±4.47	0.019
With comorbidity				
O_2 saturation <94%	CXR score	14.14 ± 2.85	9.46 ± 4.71	0.032
PICU admission	CXR score	12.70 ± 4.04	8.45 ± 3.98	0.015
Without comorbidity				
Critical illness	CXR score	14.50 ± 1.22	6.90–7.69	0.002

Table 4. CXR Severity Score by Clinical Characteristics (n = 68 with abnormal CXR)

Variable	n	Mean CXR Score	SD	P
Overall associations				
Age group (WHO)				0.181
1 mo – 1 y	11	7.09	4.50	
1 – 5 y	27	9.96	4.58	
5 – 13 y	19	9.42	4.16	
13 – 18 y				11
Underlying disease				0.019
Present	28	11.03	4.47	
Absent	39	8.33	4.47	
Subgroup: Children with underlying disease (n = 28)				
O_2 saturation				0.032
≥ 94%	13	9.46	4.71	
September	7	14.14	2.85	
PICU admission				0.015
No	11	8.45	3.98	
Yes	17	12.70	4.04	
Subgroup: Children without underlying disease (n = 39)				
Respiratory distress				0.032
Absent	29	7.37	3.89	
Present	10	11.10	5.10	
Disease severity				0.002
Non-severe	13	7.69	4.92	
Severe	20	6.90	3.16	
Critical	6	14.50	1.22	

The total mean CXR score for the 68 abnormal radiographs was 9.58 ± 4.72 (range 0–18). Within each subgroup, all other tested variables (gender, cough, fever, shortness of breath, prognosis, WBC, PLAT, ESR, LDH, PCR, BUN, lymphocyte, CRP, and length of hospital stay) were not significantly associated with CXR score (P > 0.05).
Oxygen saturation data were available for 20/28 children with comorbidities; all other subgroup analyses used complete data.

vs. 7.37 ± 3.89, P = 0.032) and in patients with critical illness compared to non-severe or severe cases (14.50 ± 1.22 vs. 7.69 ± 4.92 and 6.90 ± 3.16, P = 0.002). In both subgroups, scores did not show a significant correlation with length of hospitalization, PCR test results, or the majority of evaluated laboratory parameters.

Discussion

This cross-sectional study provides a detailed description of CXR abnormalities within a relatively large sample of hospitalized children with COVID-19. More than 60% of initial radiographs demonstrated abnormalities, which predominantly manifested as bilateral, peripheral GGO, often accompanied by peribronchial thickening and, less frequently, consolidation. These findings align with the known pattern of viral pneumonia and are consistent with adult COVID-19 literature, where GGO and consolidation with peripheral and lower-zone distribution are hallmark features[11, 19, 20]. Our results also generally concur with smaller pediatric series that reported GGO and peribronchial cuffing as the most common CXR patterns[12-14, 21].

The high frequency of peribronchial thickening (54.4%) is noteworthy. In children, viral infections commonly produce airway-centered inflammation, manifesting radiologically as peribronchial thickening and interstitial prominence[14]. The decline in this finding with increasing age (only 9.1% in adolescents) may reflect age-related differences in immune response or airway anatomy. The higher prevalence of peribronchial thickening in children with normal LDH levels might indicate a less severe systemic inflammatory state, consistent with the predominantly bronchocentric, rather than alveolar, involvement in milder pediatric COVID-19 cases.

An unexpected observation was the lower rate of consolidation in children with respiratory distress compared to those without. While seemingly contradictory, this may be explained by the nature of respiratory distress in our cohort, which could have been predominantly due to upper airway obstruction, metabolic acidosis, or non-pulmonary causes rather than extensive parenchymal consolidation. Alternatively, early presentation with respiratory distress may precede the development of radiographic consolidation, a phenomenon described in some viral pneumonias[7]. Furthermore, concomitant asthma exacerbation, present in 11.1% of patients, can cause significant respiratory distress without frank consolidation, potentially confounding the association. Future studies with serial CXRs could clarify this temporal relationship.

Pleural effusion was uncommon overall (14.7%); however, its presence served as a robust predictor of mortality, with an absolute risk increase of 32.5% (95% CI: 10.7%–54.3%). In adult COVID-19, pleural effusion is similarly infrequent and associated with severe disease and poor prognosis[20, 22]. Our findings extend these observations to children, suggesting that the detection of effusion should alert clinicians to a higher risk of adverse outcomes.

The CXR severity score, originally developed for adult ARDS [18] and not specifically validated for pediatric viral pneumonia, was adapted for this study to provide an objective, quantitative measure of lung involvement. Despite its adult origins, the score proved useful: children with underlying medical conditions had significantly higher scores, underscoring the well-documented vulnerability of this subgroup[1-3]. Within this group, hypoxia and the need for intensive care were paralleled by greater radiographic involvement. Among previously healthy children, critical illness status was the strongest determinant of a high CXR score, while severity categories based solely on clinical criteria (non-severe, severe) were not discriminative until the critical stage. This suggests that in otherwise healthy children, CXR changes may lag behind clinical deterioration or that clinical severity scales capture factors beyond pulmonary parenchymal disease. Accordingly, in such patients, a low CXR score should not be interpreted as reassuring when clinical signs are worsening.

This study has several limitations. Its single-center, retrospective design may introduce selection bias and restrict generalizability. In addition, only admission CXRs were evaluated, precluding assessment of temporal radiographic evolution. Although the applied CXR scoring system is reproducible, it remains relatively coarse and has not been specifically validated for pediatric COVID-19. Inter-observer variability was reduced by using a single radiologist; however, this approach prevents formal assessment of scoring reliability. Finally, although the sample size is among the larger pediatric CXR series, it limited multivariable modeling and detailed subgroup analyses. Prospective, multicenter studies incorporating serial imaging and systematic outcome correlation are warranted.

In contrast to some adult studies[23, 24] we did not find significant associations between CXR score and age, sex, CRP, or lymphopenia. This discrepancy may be attributable to the relative homogeneity of the pediatric population, the timing of imaging, or the modest sample size. Notably, PCR status did not influence CXR positivity or severity, supporting the supplementary role of radiography when RT-PCR is unavailable or negative but clinical suspicion remains high[16].

The limitations of this study include its single-center, retrospective design, which may introduce selection bias and limit generalizability. Only the admission CXR was analyzed, preventing assessment of temporal evolution. Because COVID-19 pneumonia often shows radiographic progression over the first week of illness, an initial low CXR score may not capture peak severity. The lack of

serial imaging may therefore have underestimated the association between radiographic severity and clinical outcomes, and future studies incorporating follow-up radiographs are needed. The CXR scoring system, while reproducible, is relatively crude and has not been specifically validated for pediatric COVID-19. Inter-observer variability was minimized by using a single radiologist, but this also precludes evaluation of reliability. Finally, the sample size, though among the larger pediatric CXR series, constrained multivariate analysis and subgroup comparisons. In particular, the subgroup of critically ill children without underlying disease comprised only six patients, severely limiting statistical power for this analysis; findings in this subgroup should be interpreted with caution.

Despite these limitations, our study demonstrates that CXR provides valuable, readily obtainable information in hospitalized children with COVID-19. Bilateral peripheral GGO and peribronchial thickening are the dominant features; consolidation, pleural effusion, and high radiographic scores correlate with clinical severity and worse outcomes. These findings support the integration of CXR into routine assessment and risk stratification of pediatric COVID-19, particularly in settings where advanced imaging is not feasible or desirable.

Conclusion

Chest radiography in hospitalized children with COVID-19 most commonly reveals bilateral, peripheral ground-glass opacities and peribronchial thickening. The presence of consolidation, pleural effusion, and higher radiographic severity scores identifies children at risk for severe disease, PICU admission, and death. CXR is a widely available, low-radiation tool that, when interpreted with a standardized scoring system, can assist in risk stratification and clinical decision-making, particularly where advanced imaging is not feasible. These data suggest that CXR is most valuable when applied selectively (guided by clinical severity) rather than as a routine screening test for all hospitalized children.

Conflict of Interest

The authors declare no potential conflicts of interest.

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Ethical Considerations

This study was approved by the Ethics Committee of Islamic Azad University (IR.IAU.KHUISF.REC.1401.248).

The requirement for informed consent was waived due to the retrospective, anonymized nature of the data.

AI Disclosure

During the preparation of this manuscript, the authors used DeepSeek (version DeepSeekV3) for language editing and to improve the clarity, conciseness, and overall readability of the text. The AI tool was employed solely to refine the writing; no scientific content, data analysis, or interpretation was generated by the AI. All suggestions were critically reviewed and edited by the authors, who take full responsibility for the accuracy, integrity, and originality of the content presented in this publication.

Author's Contribution

Data curation, Investigation, Writing original draft: S. D. and E. A; Conceptualization, Supervision, Project administration, Writing review & editing: A. Sh., M. K., and S. D.; Investigation, Writing review & editing: A. P. A. S.; Formal analysis, Methodology, Writing review & editing: F. S.; Investigation, Validation, Writing review & editing: R. N.M.

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