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Original Article

Chest imaging for COVID-19: a single-center comparative results in pediatric patients

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ABSTRACT

Background. Chest computed tomography (CT) appears to be an important radiological modality for the diagnosis of COVID-19 in adults. Studies comparing the findings of such children with those of other viral infections have not been reported either. The aim of this study was to present comparative imaging findings of 75 pediatric COVID-19 patients and four patients with other viral upper respiratory tract infections. We also aimed to demonstrate the possible association between the radiological and laboratory findings in the COVID group.

Methods. From 11 March 2020 to 20 June 2020, 79 children (aged < 18 years) were enrolled. COVID-19 was detected by RT-PCR or antibody testing. A plain chest X-ray was obtained from all subjects. Non-contrast chest CT was performed for symptomatic patients.

Results. Seventy-five patients had COVID-19 and 4 were infected with other pathogens i.e. adenovirus, rhinovirus, parainfluenza virus B, respiratory syncytial virus. The ages of the patients (36 M, 43 F) ranged from 7 months to 17 years old. The sensitivity of chest X-ray (as compared to RT-PCR) was 10.67% (95 CI%: 4.72 - 19.94%). From 23 chest CT's five of them were normal and nine of them had only nodules (< 5mm). The sensitivity of CT was 78.26% (95CI%: 54.30 - 92.54%), false-negative rate was 21.7%.

Conclusions. The sensitivity of chest CT was found to be low and any significant correlations could have not been depicted, between the radiological parameters and the presence of lymphopenia. Clinical follow-up combined with corresponding pathogen detection, and chest CT of the symptomatic COVID-19 patients might be a feasible/prompt protocol in children.

Key words: SARS-COV-2, children, radiology, CT, X-ray.

An outbreak of 2019 novel coronavirus (COVID-19) infection was first discovered in Wuhan City, China - turning into a global health pandemic thereafter.[1,2] Likewise, the number of patients is rapidly increasing out of China; and especially Europe and America are currently severely affected.

In the early days of the COVID-19 infection outbreak, pediatric patients were extremely rare.[3] Later on, it has been reported that COVID-19 can be spread within the whole age spectrum.[4,5] One of the recent epidemiologic studies has revealed that children of all ages appeared susceptible to COVID-19.[6] Additionally, newborns of COVID-19 infected mothers have also increased the concern further.[7]

Upper respiratory tract infections due to different viral etiologies are common in the pediatric age group. Additionally, the total positive rate of

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reverse transcription polymerase chain reaction (RT-PCR) for nasopharyngeal swab samples was reported to be 30-60% at the initial presentation of COVID-19.[8] Distinguishing COVID-19 from other common respiratory tract infections in the pediatric population is a big dilemma. In adults, chest computed tomography (CT) appears to be an important radiological modality for the diagnosis of COVID-19 showing typical imaging features like ground-glass opacities, multifocal patchy consolidation, and/or interstitial changes with a peripheral distribution.[9] Disease severity in COVID-19 is associated with blood cell alterations, C-Reactive Protein levels and inflammatory markers. The relationship between radiological and laboratory findings were displayed in a few studies in adult patients.[10,11] To this end, however, there is limited data reported for pediatric COVID-19 patients. Further, to the best of our knowledge, studies comparing the findings of such children with those of other viral infections have not been reported either. Accordingly, the purpose of this study was two-fold. First, we aimed to present comparative imaging findings of 75 pediatric COVID-19 patients and four patients with other viral upper respiratory tract infections. Second, we also aimed to demonstrate the possible association between the radiological and laboratory findings in the COVID group.

Material and Methods

Subjects and study design

This was a single-center, retrospective, observational study conducted at a tertiary hospital. From 11 March 2020 to 20 June 2020, a total of 79 children (aged < 18 years) were enrolled. Written informed consent was obtained from the patients or their parents, and the study protocol was approved by the ethics committees of the Ministry of Health and Hacettepe University (GO 20/392). Demographic data and clinical features as well as laboratory (white blood cell, absolute lymphocyte count, C-reactive protein, procalcitonin) and imaging findings were obtained for each enrolled patient. Viral respiratory panel tests were performed on all patients, to exclude the superimposed or concomitant pneumonia due to different infectious agents.

Radiological evaluations

Plain chest X-rays were obtained from all subjects. Non-contrast chest CT was performed for symptomatic patients i.e. having fever, cough, respiratory distress. Only one asymptomatic patient received a chest CT due to strong family positivity (seven people from the family were covid positive). Chest CT studies were performed using the SOMATOM Definiton AS 64 unit (Siemens Medical System; Siemens, Germany) with the following parameters: 80 kV, 45 to 70 mA, 1.2-mm collimation, and 1:5 pitch. The scanning range covered from lung apex to diaphragm on axial plane taken under free breathing with the patients in the supine position. Thin-section CT images were reconstructed with 1.25-mm collimation with a standard algorithm and then sent to the picture archiving and communication system (PACS) for analysis. CT images were evaluated using a lung window with a window level of −600 HU and window width of 1500 HU, and the soft-tissue window with a window level of 40 HU and window width of 300 HU. All the images were stored in PACS and reviewed by three expert pediatric radiologists (having, 25, 17 and 7 years of background in pediatric radiology) by consensus who were blinded to the symptoms and laboratory tests. The CT features were evaluated for: (a) ground-glass opacities (GGO), (b) nodules, (c) consolidations, (d) crazy paving, (e) atelectasis, (f) peribronchial thickening, (g) tree-in-bud sign, (h) pleural effusion, (i) lymphadenopathy (short axis dimension > 1.0 cm) and (j) white lung. The anatomic distribution (unilateral, bilateral, subpleural, central or mixed), zonal predominance (upper, middle, lower lung; central, middle, or peripheral location), and extent (focal, multifocal, and diffuse) of the lesions were also recorded. Visual quantitative assessment score (VQAS) was performed

according to the extent of opacities (including GGOs, crazy paving and consolidation) in each lobe. Scores were defined as following: 0 (none), 1 (affecting <5% of the lobe), 2 (affecting 5%–25% of the lobe), 3 (affecting 26%–49% of the lobe), 4 (affecting 50%–75% of the lobe) and 5 (affecting >75% of the lobe). A maximum CT score of 5 was possible for each lobe. Total CT score was reached by summing the scores in five lobes (range from 0 to 25).[12]

COVID-19 diagnosis

COVID-19 was detected by RT-PCR obtained from the nasopharyngeal swab and/or tracheal aspirate specimens or antibody testing (Ig M and Ig G) via COVID-19 [SARS-CoV-2] Antibody Test Kit; Colloidal Gold.[13] Multiplex Real time PCR (RT-PCR) method was used for the detection of other respiratory viral agents, as well. Nucleic acid isolation was performed by Gene All Ribospin vRD II Isolation Kit, Seoul, Korea and RT- PCR method was carried out by Seegene RV16 Detection Kit, Seoul, Korea.

Disease severity

We categorized the severity of cases based on the clinical characteristics, laboratory results and imaging findings as described elsewhere:[6] a) asymptomatic infection; no clinical and/or radiological findings, b) mild disease; acute upper respiratory tract infection without clinical and radiological pneumonia, c) moderate disease; pneumonia with the symptoms of respiratory tract infection, d) severe disease; progressive respiratory disease with dyspnea and central cyanosis, e) critically ill cases; acute respiratory distress syndrome or respiratory failure, shock, organ dysfunction including encephalopathy, myocardial injury, coagulation abnormalities, and acute kidney injury.

Statistical analysis

IBM SPSS software package version 23.0 was used for all the statistical analyses. Categorical variables are expressed as frequencies and percentages. Mean±standart deviation was given as descriptive statistics for the numeric variables. Fisher exact test was used to compare the distribution of a categorical variable. In order to evaluate the accuracy of the diagnosis, sensitivity and its confidence intervals (CI) were obtained as a test performance measures of CT.[14] The sensitivity value of CT obtained for children from this study was compared with the sensitivity value obtained from a previously published study in adults.[15] Two sample proportion test was used to determine whether the proportions of two independent groups differ. The results of X-ray and CT were compared with McNemar test. The relationship between lymphopenia and RT-PCR positivity were examined with the "Yates (Continuity Correction) Chi square" test.

Results

Demographic and clinical characteristics of patients with COVID-19 are given in Table I. Ages of the patients (36 M, 43 F) ranged from 7 months to 17 years with a mean value of 10.5 years (SD 5.2). Overall; 75 patients had COVID-19 and 4 were infected with only other pathogens i.e. adenovirus, rhinovirus, parainfluenza virus B and respiratory syncytial virus (RSV). All four patients with other infections had a chest CT, as they suffered from similar symptoms and/or suspicion pertaining to COVID-19. Of the 75 COVID-19 patients 67 received the diagnosis with RT-PCR and eight of them had positive antibody tests.

Among the COVID-19 patients, 23 had a chest CT and plain X-ray while the remaining 52 had only a chest X-ray whereby 23 of them were asymptomatic, 42 had mild, 7 had moderate, and 3 had a critically ill disease course. Since one of the critically ill patients had severe cardiac failure and was later on lost, a CT could not be performed. Extracorporeal membrane oxygenation was used in another critically ill patient with refractory acute respiratory distress syndrome secondary to Stevens-Johnson syndrome and was later on lost.

Table I. Demographic and clinical characteristics of pediatric cases with COVID-19.

Patient number	Age/Sex (yo)	Severity of COVID-19	Underlying conditions	Family history for COVID-19	Day from illness onset to diagnosis	Complications	ALS (/μL)	WBC (/μL)	CRP (mg/dl) (0-0.8)	PCT (ng/ml) (0-0.1)	Chest X-Ray	Chest CT	Outcome
1	1/M	Critical	No	Yes	5	Myocarditis	5500	8700	0.06	0.09	Positive	N/A	Died
2	7/M	Critical	No	No	19	MODS	900	9300	0.08	3.87	Positive	Yes	Died
3	4/F	Mild	No	Yes	0	No	2500	4400	1.24	N/A	Normal	Yes	Recovered
4	3/F	Asymptomatic	No	Yes	0	No	3000	4300	0.01	N/A	Normal	N/A	Recovered
5	2/F	Asymptomatic	No	Yes	0	No			0.19	0.14	Normal	N/A	Recovered
6	14/M	Asymptomatic	No	Yes	0	No	3500	7000	0.03	N/A	Normal	N/A	Recovered
7	11/F	Asymptomatic	No	Yes	0	No	2400	6800	0.08	N/A	Normal	N/A	Recovered
8	14/F	Moderate	No	Yes	7	No	1300	4500	0.08	N/A	Positive	Yes	Recovered
9	16/F	Asymptomatic	No	Yes	0	No	2100	5200	0.11	N/A	Normal	N/A	Recovered
10	15/M	Asymptomatic	No	Yes	0	No	2200	5300	0.13	N/A	Normal	N/A	Recovered
11	4/M	Asymptomatic	No	Yes	0	No	2900	4500	0.12	N/A	Normal	N/A	Recovered
12	1/F	Asymptomatic	No	Yes	0	No	10800	18700	0.14	0.04	Normal	N/A	Recovered
13	4/F	Mild	No	Yes	0	No	3000	4800	0.18	N/A	Normal	Yes	Recovered
14	13/M	Asymptomatic	No	Yes	0	No	2600	5800	0.22	N/A	Normal	Yes	Recovered
15	17/M	Mild	No	Yes	1	No	1600	4900	0.23	N/A	Positive	Yes	Recovered
16	11/M	Mild	No	Yes	1	No	1400	5000	0.29	0.08	Normal	Yes	Recovered
17	16/F	Mild	No	Yes	4	No	2000	7500	0.31	N/A	Normal	Yes	Recovered
18	17/F	Moderate	No	Yes	9	No	600	5800	0.48	.01	Normal	Yes	Recovered
19	16/F	Mild	No	Yes	8	No	1700	5100	0.58	N/A	Normal	Yes	Recovered
20	13/F	Asymptomatic	No	Yes	0	No	1400	8600	0.58	N/A	Normal	N/A	Recovered
21	7mo/M	Mild	No	No	1	No	2400	4000	0.61	0.08	Normal	N/A	Recovered
22	10/F	Mild	No	Yes	3	No	2100	8100	1.02	N/A	Normal	Yes	Recovered
23	3/F	Mild	No	Yes	1	No	7000	10300	1.35	N/A	Normal	N/A	Recovered
24	11/M	Mild	No	Yes	0	No	900	6500	1.68	N/A	Normal	Yes	Recovered
25	6/M	Asymptomatic	No	Yes	0	No	2400	7000	1.88	0.02	Positive	N/A	Recovered
26	9/M	Mild	Asthma	Yes	1	No	1300	11600	9.47	6.26	Normal	Yes	Recovered

yo: years old, mo: months old, WBC: White blood cell, ALS: Absolute lymphocyte count, CRP: C-reactive protein, PCT: Procalcitonin,
MODS: Multiple organ dysfunction syndrome, HLH: Hemophagocytic lymphohistiocytosis, N/A: Not applicable, Chest X-ray Positive: Ground glass opacities, peribronchial thickening, consolidation

Table I. Continued.

Patient number	Age/Sex (yo)	Severity of COVID-19	Underlying conditions	Family history for COVID-19	Day from illness onset to diagnosis	Complications	ALS (/μL)	WBC (/μL)	CRP (mg/dl) (0-0.8)	PCT (ng/ml) (0-0.1)	Chest X-Ray	Chest CT	Outcome
27	13/F	critical	Osteopetrosis, chronic osteomyelitis	Yes	4	HLH	500	1200	10.78	N/A	Positive	Yes	Recovered
28	11mo/M	Mild	No	Yes	2	No	6100	9900	1.56	0.14	Normal	N/A	Recovered
29	3/F	Asymptomatic	No	Yes	0	No	5490	7700	0.14	0.03	Normal	N/A	Recovered
30	5/F	Mild	No	Yes	0	No	1780	11800	4.00	0.27	Normal	N/A	Recovered
31	10/F	Mild	No	Yes	1	No	1370	6000	0.60	0.04	Normal	N/A	Recovered
32	15/M	Mild	No	Yes	2	No	1450	5500	0.23	0.05	Normal	N/A	Recovered
33	17/M	Mild	No	Yes	0	No	830	4800	0.25	0.08	Normal	Yes	Recovered
34	14/F	Moderate	Kartagener syndrome	Yes	4	No	420	7400	1.16	0.03	Positive	Yes	Recovered
35	7/F	Asymptomatic	No	Yes	0	No	3520	7800	0.04	0.03	Normal	N/A	Recovered
36	16/F	Mild	No	Yes	2	No	1820	4800	0.19	N/A	Normal	Yes	Recovered
37	14/M	Moderate	No	Yes	3	No	2000	4600	0.65	0.02	Normal	Yes	Recovered
38	16/F	Mild	No	Yes	3	No	1820	3900	1.03	0.02	Normal	N/A	Recovered
39	15/M	Mild	No	Yes	0	No	2170	6300	0.03	N/A	Normal	N/A	Recovered
40	10/M	Mild	No	Yes	0	No	1440	9000	6.40	0.08	Normal	N/A	Recovered
41	11/F	Mild	No	Yes	1	No	3270	6500	1.97	0.07	Normal	Yes	Recovered
42	14/F	Moderate	No	Yes	1	No	1800	3900	0.22	0.05	Normal	Yes	Recovered
43	10/M	Asymptomatic	No	Yes	0	No	1770	3400	0.26	0.06	Normal	N/A	Recovered
44	14/F	Mild	No	Yes	3	No	1150	4900	0.20	0.03	Normal	N/A	Recovered
45	13/M	Mild	No	Yes	3	No	2050	3600	0.01	0.02	Normal	Yes	Recovered
46	8/F	Mild	Midaortic stenosis	Yes	0	No	1080	5300	0.14	0.05	Normal	N/A	Recovered
47	2/M	Asymptomatic	Hirschsprung disease	Yes	0	No	3800	7300	0.01	0.03	Normal	N/A	Recovered
48	13/F	Mild	No	Yes	1	No	2490	5200	0.09	0.03	Normal	N/A	Recovered
49	16/F	Mild	No	Yes	4	No	2250	6000	0.34	0.03	Normal	Yes	Recovered

yo: years old, mo: months old, WBC: White blood cell, ALS: Absolute lymphocyte count, CRP: C-reactive protein, PCT: Procalcitonin,
MODS: Multiple organ dysfunction syndrome, HLH: Hemophagocytic lymphohistiocytosis, N/A: Not applicable, Chest X-ray Positive: Ground glass opacities, peribronchial thickening, consolidation

Table I. Continued.

Patient number	Age/Sex (yo)	Severity of COVID-19	Underlying conditions	Family history for COVID-19	Day from illness onset to diagnosis	Complications	ALS (/μL)	WBC (/μL)	CRP (mg/dl) (0-0.8)	PCT (ng/ml) (0-0.1)	Chest X-Ray	Chest CT	Outcome
50	17/F	Mild	No	Yes	1	No	2850	6500	0.43	0.02	Normal	N/A	Recovered
51	13/M	Asymptomatic	No	Yes	0	No	1950	6600	0.07	0.07	Normal	N/A	Recovered
52	2/M	Asymptomatic	No	Yes	0	No	3200	6400	0.06	0.02	Normal	N/A	Recovered
53	15/F	Mild	No	Yes	4	No	1990	3900	0.02	0.02	Normal	N/A	Recovered
54	8/F	Asymptomatic	No	Yes	0	No	2450	4500	0.48	0.32	Normal	N/A	Recovered
55	16/M	Moderate	Von Gierke	Yes	2	No	1680	6900	5.75	1.22	Normal	Yes	Recovered
56	14/M	Mild	No	No	0	No	1350	6700	0.11	.03	Normal	N/A	Recovered
57	15/M	Mild	No	Yes	1	No	1160	7400	1.00	.03	Normal	N/A	Recovered
58	4/M	Mild	No	Yes	1	No	2350	4100	0.10	.04	Normal	N/A	Recovered
59	16/F	Mild	No	Yes	0	No	1790	5100	1.01	.03	Normal	N/A	Recovered
60	12/F	Mild	Asthma	Yes	1	No	2820	5200	0.25	.04	Normal	N/A	Recovered
61	1/M	Mild	Asthma	Yes	2	No	5710	10500	0.94	.22	Positive	N/A	Recovered
62	3/M	Asymptomatic	No	Yes	0	No	4230	6400	0.27	.05	Normal	N/A	Recovered
63	8/F	Asymptomatic	No	Yes	0	No	2870	4700	0.07	.05	Normal	N/A	Recovered
64	11/F	Moderate	No	Yes	2	No	2010	4500	0.18	.04	Normal	N/A	Recovered
65	17/F	Mild	Pontine glioma	Yes	4	No	2480	5900	0.37	.02	Normal	N/A	Recovered
66	5/F	Mild	No	Yes	2	No	6000	10300	0.19	0.04	Normal	N/A	Recovered
67	6/M	Asymptomatic	No	Yes	0	No	3990	14300	0.00	.02	Normal	N/A	Recovered
68	14/M	Mild	No	Yes	1	No	1990	4600	0.03	0.03	Normal	N/A	Recovered
69	15/F	Mild	No	Yes	1	No	1180	6800	0.37	.04	Normal	N/A	Recovered
70	9/F	Asymptomatic	No	Yes	0	No	1840	4800	0.13	.04	Normal	N/A	Recovered
71	12/M	Mild	Obesity	Yes	1	No	1810	5900	0.47	.09	Normal	N/A	Recovered
72	17/F	Mild	No	Yes	1	No	1730	10000	N/A	.03	Normal	N/A	Recovered
73	12/F	Mild	No	Yes	0	No	1540	6500	0.02	0	Normal	N/A	Recovered
74	10/M	Mild	No	Yes	1	No	6440	8700	0.23	0	Normal	N/A	Recovered
75	15 /F	Asymptomatic	No	Yes	0	No	2960	13300	0.21	0.05	Normal	N/A	Recovered

yo: years old, mo: months old, WBC: White blood cell, ALS: Absolute lymphocyte count, CRP: C-reactive protein, PCT: Procalcitonin,
MODS: Multiple organ dysfunction syndrome, HLH: Hemophagocytic lymphohistiocytosis, N/A: Not applicable, Chest X-ray Positive: Ground glass opacities, peribronchial thickening, consolidation

Sixty-seven patients had normal chest X-ray findings. A total of eight children had remarkable abnormalities (GGO, peribronchial thickening, consolidation) on X-ray. The sensitivity of chest X-ray (as compared to RT-PCR) was 10.67% (95 CI%: 4.72 - 19.94%). More than half of the chest CTs were obtained on the same day with chest X-rays (58%), while 25% were obtained the next day. The remaining 16% percent of chest CTs were obtained between 2-6 days.

The CT findings of pediatric patients with COVID-19 infection are given in Table II. Visual quantitative assessment score (VQAS) and the comparison with the clinical severity of the COVID-19 patient are given in Table III. From 23 chest CT's five of them were normal and nine of them had only subpleural and/or intraparachymal nodules (< 5mm). The sensitivity of the CT (as compared to RT-PCR) was 78.26% (95CI%: 54.30 - 92.54%), the false negative rate was 21.7%. The most frequent chest CT findings were nodules, GGO, GGO and consolidation and peribronchial thickening (Fig. 1 and Fig. 2). Of note, most of the patients had bilateral chest CT findings.

Table II. Computed tomography findings of patients with COVID-19 (N=23).

Findings	Asymptomatic (n=1)	Mild (n=13)	Moderate (n=7)	Critically ill (n=2)
	N (%)	N (%)	N (%)	N (%)
Ground glass opacities	1 (4.54)	-	7 (30.4)	1 (4.54)
Nodule	1 (4.54)	7 (31.8)	5 (22.7)	-
Consolidation	-	-	-	-
Crazy Paving	-	-	-	1 (4.54)
Atelectasis	-	-	-	-
Ground glass opacities and consolidation	-	-	1 (4.54)	2 (9.09)
Peribronchial thickening	-	-	4 (18.1)	1 (4.54)
Tree in buds	-	-	-	-
Pleural effusion	-	-	-	-
Bronchiectasis				
Lymhadenopathy	-	-	-	-
White lung	-	-	-	1 (4.54)
Lung region distribution				
Unilateral	-	2 (9.09)	1 (4.54)	-
Bilateral	1 (4.54)	5 (22.7)	5 (22.7)	2 (9.09)
Subpleural	1 (4.54)	8 (36.3)	5 (22.7)	1 (4.54)
Central	-	-	-	-
Mixed	-	-	4 (18.1)	1 (4.54)
Lung lobe involved				
Right upper lobe	1 (4.54)	4 (18.1)	3 (13.6)	2 (9.09)
Right middle lobe	1 (4.54)	3 (13.6)	2 (9.09)	1 (4.54)
Right lower lobe	1 (4.54)	5 (22.7)	5 (22.7)	2 (9.09)
Left upper lobe	1 (4.54)	3 (13.6)	4 (18.1)	1 (4.54)
Left lower lobe	-	6 (27.2)	6 (27.2)	2 (9.09)
Distribution				
Focal	-	1 (4.54)	1 (4.54)	-
Multifocal	1 (4.54)	-	5 (22.7)	1 (4.54)
Diffuse	-	-	-	1 (4.54)
Normal CT	-	5 (22.7)	-	-

Table III. Visually calculated total CT scores of the pulmonary involvement in 23 COVID-19 patients.

Clinical severity	Calculated total CT scores								
	0	1	2	3	4	5	7	10	25
Asymptomatic (n=1)				1					
Mild (n=13)	5	2	2	2	1	1			
Moderate (n=7)		1	1			1	1	3	
Critical (n=2)									2

n: Number of patients

Significant positive correlations were found between disease severity and most common CT findings of COVID-19 (peripheral, subpleural and perilymphatic GGO) (p=0.001). One asymptomatic patient had peripheral GGO. The most common CT findings of COVID-19 were present in 7.7% of the mild group, 71.4% of the moderate group and 100% of the critical ill group. The sensitivity rate of the most common CT findings of COVID-19 (peripheral, subpleural and perilymphatic GGO) as compared to RT-PCR was 39.13% (95CI%: 19.71 - 61.46%). The time interval from symptom onset to chest CT was between 2-9 days (median 2.5 days). Chest X-ray and the most common CT findings of COVID-19 were similar (p=0.453).

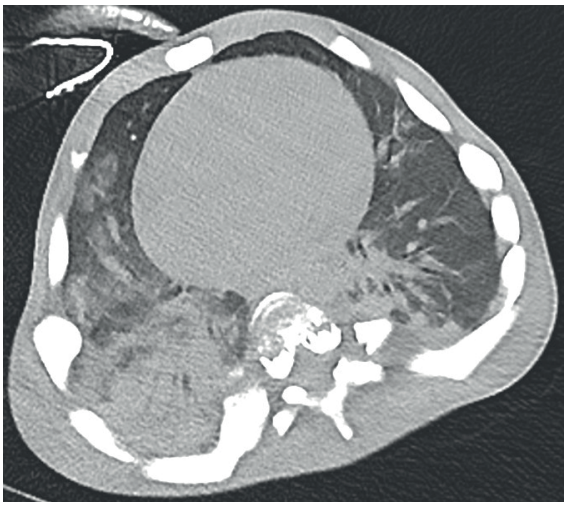

Fig. 1. A-13-year-old girl with COVID-19 pneumonia. Axial non-contrast enhanced chest CT image demonstrates diffuse consolidation in the right lower lobe, peribronchial patchy ground-glass opacities in the right middle lobe, and subpleural consolidation in the left lower lobe. Note that the diffuse osteosclerosis of all bony structures in the thoracic cage is compatible with osteopetrosis.

Five patients had a normal chest CT, and they were asymptomatic or had a mild disease course as well. Statistically significant positive correlations were found between disease severity and lymphopenia (p=0.009). Lymphopenia was present in 4.3% of the asymptomatic group, 28.6% of the mild group, 42.9% of the moderate and 66.7% of the critically ill group. No significant correlations were depicted between the radiological parameters and lymphopenia. Yet, 77.8% of patients with lymphopenia and 78.6% of those without had positive CT findings. No significant correlations were depicted between RT-PCR positivity and lymphopenia (p=0.671).

Table IV demonstrates the imaging features of patients with other infections. These

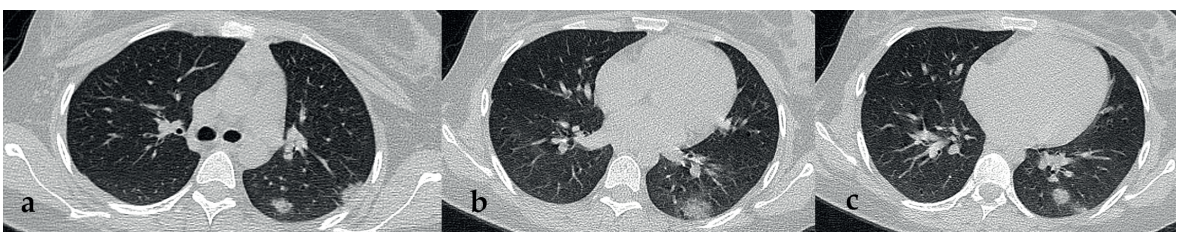

Fig. 2a-c. A-17-year-old girl with COVID-19 pneumonia. **(a-c)** Axial non-contrast enhanced chest CT images demonstrate subpleural ground-glass nodules in the left lower lobe.

Table IV. Computed tomography findings of other viral infections.

Findings	Adenovirus	Rhinovirus	RSV B	RSV A/Parainfluenza
Ground glass opacities	+	+	+	-
Nodule	+	-	-	-
Consolidation	+	-	+	+
Crazy paving	-	-	-	-
Atelectasis	-	+	+	-
Ground glass opacities and consolidation	+	-	-	+
Peribroncial thickening	-	+	+	-
Tree in buds	-	-	-	-
Pleural effusion	-	-	-	+
Bronchiectasis	+	-	-	-
Lympadenopathy	-	-	-	-
White lung	-	-	-	-
Lung region distribution				
Unilateral	-	-	-	-
Bilateral	+	+	+	+
Subpleural	+	+	+	-
Central	+	+	+	+
Mixed	+	+	+	+
Lung lobe involved				
Right upper lobe	-	-	-	+
Right middle lobe	+	+	+	+
Right lower lobe	+	+	+	+
Left upper lobe	+	+	+	+
Left lower lobe	+	+	+	+
Distribution				
Focal	-	-	-	-
Multifocal	+	+	+	+
Diffuse	-	-	-	+
Normal CT	-	-	-	-

RSV: Respiratory syncytial virus

four patients were infected with other viral respiratory viruses and RT-PCR test was negative for COVID-19. The patient with an adenovirus infection was a 10-year-old boy, who had a fever and cough, his father had Covid-19 positivity. The Rhinovirus infected patient was a 12-year-old boy and had respiratory distress. A 1-year-old girl with Respiratory syncytial virus had a fever and cough. An 8-years-old boy with Respiratory syncytial virus A/Parainfluenza had a fever. Their chest CT imaging findings were similar to those of COVID-19 patients with regards to bilateral involvement and the aforementioned most commonly seen patterns (Fig. 3 and 4).

Discussion

In this comparative imaging study, we have shown that CT findings of COVID 19 may be diverse in children. Chest CT sensitivity was found to be moderate low (78.26%) and any significant correlations could have not been depicted between the radiological parameters and the presence of lymphopenia. When compared to the relevant literature whereby

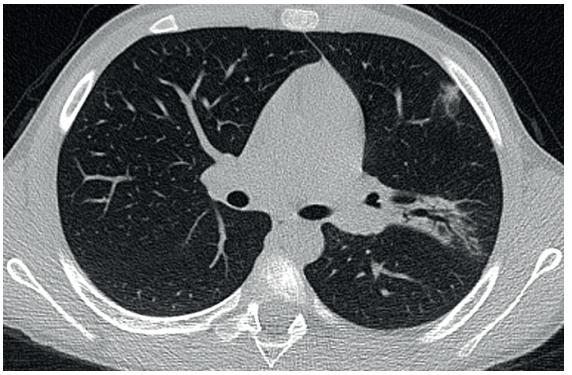

Fig. 3. A-10-year-old boy with adenovirus pneumonia. Axial non-contrast enhanced chest CT image shows subpleural ground-glass nodule in the left upper lobe with consolidation and mild bronchiectasis.

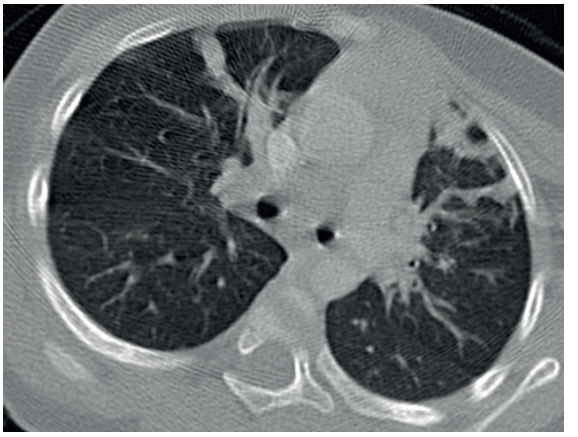

Fig. 4. A-1-year-old girl with respiratory syncytial virus-B infection. Axial non-contrast enhanced chest CT image shows subpleural atelectasis in the upper lobes.

mild pediatric patients showed normal findings on chest CT[16,17], five of our 23 cases had a normal CT and nine of them had only subpleural and parenchymal nodules. Again, GGO (the most frequently observed pattern) mainly in the peripheral, subpleural and posterior lungs was the main finding in our patients. Herein, it is noteworthy that other findings like nodules, GGO with consolidation or peribronchial thickening can also be detected in children. Significant positive correlations were found between disease severity and characteristic COVID-19 CT findings. In our study, both crazy paving pattern and consolidation were more common in critically ill patients. In COVID-19 patients, diffuse alveolar damage has been described with interstitial edema, thickening of alveolar walls and proliferation of interstitial fibroblasts.[18]

COVID-19 viral pneumonia is an acute infectious chest disease due to a novel coronavirus. The clinical spectrum of the disease ranges from asymptomatic to critically ill. Although the severity of the disease seems to be milder in pediatric patients as compared with adults, data about various clinical findings of COVID-19, particularly in children are limited.[19,20] As such, one of the challenging issues for radiologists, as well as clinicians remains to be the availability to distinguish CT findings of children with COVID-19 from those of other viral respiratory infections. Herein, CT findings of bilateral multifocal GGO with patchy consolidations and peribronchial thickening were also present in our patients who had pneumonia due to other infections. On the other hand, the characteristics of pneumonia caused by adenovirus had higher density, more consolidations and fewer subpleural lesions. Concerning both RSV and parainfluenza virus; the characteristics of pneumonia were mostly distributed along the bronchi with bronchial wall thickening. Hence, a definite diagnosis cannot be achieved on the basis of imaging features alone. Indeed, chest CT findings of pneumonia due to different pathogens seem to overlap, and COVID-19 pneumonia can be superimposed with lung involvement due to other pathogens - presenting more severe imaging findings. Therefore, radiological assessment should indisputably be coupled with clinical and laboratory examinations.

In China, chest CT was recommended for the diagnosis at the beginning of the pandemic - due to the low positivity of PCR tests as a reflex behavior against a new disease. Moreover, as chest CT was mentioned to be a more sensitive diagnostic tool rather than RT-PCR, CT has been used for screening/diagnosis for adult patients.[15] The sensitivity value of CT obtained

for children from this study was (78.26%) compared with the sensitivity value obtained from adults (97%) a previously published study of Ai et al.[15] Chest CT had higher sensitivity for COVID-19 diagnosis in adults. Most of the pediatric patients with COVID-19 in the present study had asymptomatic or mild disease course, and their radiological findings were also normal or mild. It is apparent that the sensitivity of chest radiographs (the first examination to be preferred) in showing the GGO and small consolidations is low. Therefore, according to our findings, chest CT should rather be performed for symptomatic pediatric patients. Moreover, this approach would also be crucial to prevent high levels of radiation exposure in children. Steinberger et al.[21] drew attention to the same issue, and reported that the low incidence of CT exams with positive findings and the low severity of disease in children's CTs should be noted when handling the utility and restrictions of CT for the assessment of COVID-19 in children and they suggested CT for evaluating suspected complications of COVID-19.

In a recent study, Wang et al.[22] reported that the lung abnormalities on CT progressed rapidly after the symptom onset, reached its peak around 6-11 days, and was followed by a lengthy persistence of high levels in adults. A few studies supporting this information have reported an increase in GGOs over time.[23] Shen et al.[13] reported that progressive and severe stage of CT findings were rarely seen; however, any association between the clinical and radiological course was not reported. Radiological progression of pediatric cases should not be considered as a hallmark of disease severity and clinical status of the cases should be the mainstay in the management. Again, more case examples and long-term follow-up would be necessary to better demonstrate the development of pediatric COVID-19 disease.

There are some limitations of our study. First, the number of patients infected with other viruses was small. Second, studies with a larger sample size and longer follow-up are awaited to better understand the actual disease course of pediatric COVID-19 patients during management. Lastly, we couldn't set any exclusion criteria such as preexisting diseases may mimic COVID-19 related findings, since the number of patients is small and each patient is very valuable.

In conclusion, pneumonia due to COVID-19 is generally mild in children, and chest CT can well be unremarkable. If present, characteristic imaging findings of COVID-19 infection seem to be subpleural ground-glass opacities and peribronchial thickening. The sensitivity of chest CT was found to be low and any significant correlations could have not been depicted between the radiological parameters and the presence of lymphopenia. However, it would be insufficient to diagnose COVID-19 pneumonia only by CT imaging, and it would actually also be difficult as far as its differential diagnosis from other viral infections is concerned. Therefore, clinical follow-up together with detection of the corresponding pathogens, and chest CT of the symptomatic patients might be a feasible/prompt protocol in children.

Ethical approval

Written informed consent was obtained from the patients or their parents, and the study protocol was approved by the ethics committees of the Ministry of Health and Hacettepe University (GO 20/392).

Author contribution

The authors confirm contribution to the paper as follows: study conception and design: HNÖ; data collection: YÖ, PDO, SLG; analysis and interpretation of results: BO, JK, ÖT; draft manuscript preparation: HNÖ, MC, MH. All authors reviewed the results and approved the final version of the manuscript.

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Conflict of interest

The authors declare that there is no conflict of interest.

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