Review Article

Computed tomography findings in 3,557 COVID-19 infected children: a systematic review

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Background: Although it was assumed in the early stages of the coronavirus disease 2019 (COVID-19) outbreak that the novel coronavirus infection was uncommon among children, the number of infected children has since been increasing significantly. Real-time polymerase chain reaction (RT-PCR) is the gold standard modality for the diagnosis of COVID-19 infection. In adults, chest CT is performed as an adjunct for identifying suspected COVID-19 cases along with patients' management and follow-up. However, CT findings in COVID-19 children studies have shown a diverse incidence of abnormal CT and finding patterns that made CT scan necessity to have remained controversial. The aim of the present review was to comprehensively determine the imaging findings of chest CT scans of confirmed COVID-19-infected pediatric patients through a systematic review of the available published studies.

Methods: A systematic literature search was performed in the PubMed, Embase, Scopus, and Web of Science core collection databases (four databases including SSCI, SCIE, AHCI, and ESCI) to find original articles containing chest CT findings in children with COVID-19 through May 7, 2021. This review included 81 articles published in English that in total included 3,557 pediatric patients

Results: This review included 81 articles published in English that in total included 3,557 pediatric patients. Among the total confirmed coronavirus-infected cases (via RT-PCR test), two-thirds had abnormal chest CT findings; among these patients, 549 (37.8%) had bilateral lung involvement, and 475 (32.7%) had unilateral disease. Regarding the types of lung lesions, ground glass opacities were observed in 794 (54.7%) of patients, and consolidation was observed in 10.2%; moreover, halo sign, discrete pulmonary nodules, interstitial abnormalities or reticulations, and vascular thickening shadows were reported in 7.4%, 2.6%, 9.7% and 1.7% of the patients, respectively.

Discussion: This review revealed that chest CT scan manifestations in majority of COVID-19 positive children are mild, so regarding the risk of radiation exposure, it is reasonable to confine CT scan to individual cases that its benefits outweigh the risks.

Keywords: Coronavirus disease 2019 (COVID-19); coronavirus; children; chest CT scan

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Introduction

Coronavirus disease 2019 (COVID-19), the newly emerged highly contagious disease that appeared in December 2019, is caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) agent. SARS-CoV-2 is a member of *the* genus *Betacoronavirus within* the subfamily *Coronavirinae* (1). COVID-19 emerged in December 2019 in Wuhan, China, and since then, millions of people worldwide have contracted the disease. As of June 4, 2021, more than 172 million people worldwide have been infected with SARS-CoV-2, with more than 3,700,000 deaths related to this disease (2).

The common symptoms that the majority of patients with COVID-19 present with include cough (either with or without sputum), shortness of breath, fever, sore throat, chills, nasal congestion, fatigue or myalgia, dizziness, muscle pain, arthralgia, weakness, dyspnea, and chest tightness (3-7). However, the disease can also present with several atypical manifestations, such as acute coronary syndrome, myocardial dysfunction, acute kidney injury, or neurological, gastrointestinal, bleeding, and thrombotic or cutaneous symptoms (8-12). Although it was assumed in the early stages of the outbreak that the disease was uncommon among children, the number of cases of infected children has since increased significantly (13).

The diagnosis of COVID-19 is confirmed using the gold standard reverse transcriptase polymerase chain reaction (RT-PCR) test that has a quite good sensitivity (91%) along with a very high specificity (100%) for the diagnosis of COVID-19 (14-17). However, computed tomography (CT) scans also has been used in the diagnostic workup of patients who are suspected of having COVID-19, especially in cases of false-negative RT-PCR test results, when RT-PCR is not available, or when the results are delayed (18).

Since the emergence of the disease, a vast number of articles have been published that focus on the pathogenesis, clinical manifestations, laboratory and imaging findings, and treatment of the disease, as well as several systematic reviews that summarize all the related findings. However, as the pandemic continues, new aspects of the disease are being discovered, and there is still a need for further investigations to be performed. While several systematic review articles have examined the imaging features of COVID-19 in adults (19-29), only a few have performed such an analysis of child cases (30-33). The aim of this review was to compile the existing data on the CT characteristics of COVID-19 disease in children. Simultaneously, the clinical and laboratory findings of child COVID-19 cases will be summarized based on the articles reviewed.

Materials and methods

Literature search and study selection

We searched seven databases, including PubMed, Embase, Scopus, and Web of Science core collection databases (four databases, including SSCI, SCIE, AHCI, and ESCI) to find the original articles on the use of chest CT for the detection of COVID-19 in children published in English between December 1, 2019, and May 7, 2021.. We used the following queries: "corona virus" OR coronavirus OR "corona-virus" OR "covid_19" OR "covid-19" OR "SARS-cov-2" OR ncov* OR 2019-nCov OR novelcorona* AND child* OR pediat* OR paediat*OR neonate* OR newborn* OR infant* OR adolescen* AND CT OR "computed tomography" OR "computed-tomography" OR tomogram OR "CT-scan" OR "CT scan" OR "Computer Assisted Tomography" OR "Computer-Assisted Tomography" OR "Computerized Tomography."

We also searched the reference lists of the included studies to identify additional articles.

Eligibility criteria

The inclusion criteria were as follows: (I) the age of the study population was 0–18 years; (II) COVID-19 infection was confirmed in patients using RT-PCR; (III) CT findings were mentioned, and (IV) the article was published in English. Articles without available English full text, that did not mention CT findings, that did not confirm cases of COVID-19 using PCR, and that reported CT findings only in adult patients were excluded. We did not exclude case reports or studies that included both adult and pediatric populations separately to widen our research scope.

Data extraction and quality assessment

Three independent radiologists extracted the data from the full text of all articles into a database (Excel; Microsoft, Redmond, WA). Disagreements were solved by discussion and consensus. Duplicates were deleted. Extracted data included the following factors: bibliography (such as the first author's name, country, journal name), demographics (sample size, gender distribution, average age, exposure history), symptoms (asymptomatic, fever, sputum, runny

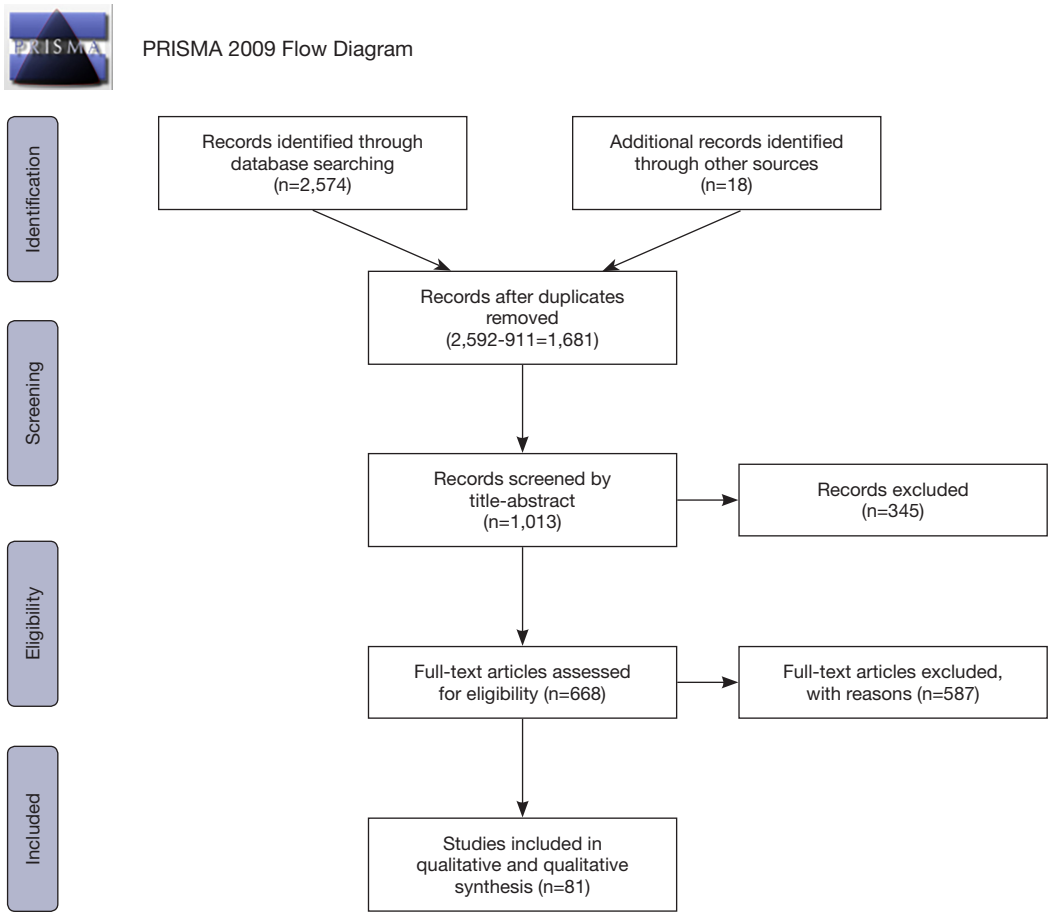

Figure 1 Preferred reporting system for systematic reviews and meta-analyses (PRISMA) flow diagram. Diagram represents the review process and selection of included studies. Adopted from Moher *et al.* (doi.org/10.1371/journal.pmed.1000097)©2009, under terms of Creative Commons Attribution 4.0 International License (creativecommons.org/licences/by/4.0/legalcode).

nose, abdominal pain, etc.), lab data, and chest CT findings, including the following aspects: (I) lesion distribution (bilateral lung, peripheral, central, involved lobes); (II) lesion morphology (nodular, patchy, parenchymal band); (III) density of the lesions(GGO, consolidation, GGO mixed consolidation, crazy paving, halo sign); and (IV) accompanying signs (pleural effusion, pericardial effusion, lymphadenopathy).

Statistical analysis

For categorical variable, we used frequency and percent and to estimate the 95% confidence interval we used binomial distribution. STATA 11 (Stata Corp., College Station, TX) used for analysis.

Results

Study selection

From the initial search of four databases (PubMed, Embase, ISI, and Scopus) that was performed on May 7, 2021, 2574 unique articles were identified (*Figure 1*). In addition, 18 articles were added after hand searching of the reference lists of previous systematic reviews after deleting duplicates, 1,681 records remained. Through screening the abstracts, reviews, meta-analyses, irrelevant studies, and studies in languages other than English were removed. Out of these articles, 1,013 records were retained for full-text review, and 81 studies met the inclusion criteria and were included in our analysis. A quality assessment of included articles was performed using the NIH Quality Assessment Tool (*Table 1*),

Table 1 NIH quality assessment

First author (reference No.)	Criteria									Quality rating	Number of cases
	1	2	3	4	5	6	7	8	9		
Hong-Rui Chen (34)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	1
Qihong Fan (35)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	No	poor	1
Li-Na Ji (36)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	No	Poor	2
Ke Bai (37)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	No	Fair	25
Zhong Zheng (38)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Good	9
Fang Zheng (39)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	25
Liang Su (40)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	9
Qinxue Shen (41)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	9
Wei Xia (42)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	20
Jafar Soltani (43)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	30
Xiaoping Yin (44)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	1
Buyun Shi (45)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	1
Sharon Steinberger (46)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Good	30
Tongqiang Zhang (47)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	3
Yu-Pin Tan (48)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	10
Yanli Wang (49)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	No	Poor	43
Yang Li (50)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Good	8
Li-Juan Mao (51)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	1
Wei Lai (52)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Good	2
Y. Lu (53)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Good	9
Mengqi Liu (54)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Good	5
Guiqing He (55)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	1
Bo Li (56)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Good	22
Jilei Lin (57)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	No	Poor	1
Ji Young Park (58)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Good	1
Huanhuan Liu (59)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	4
Yuanzhe Li (60)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Good	2
Weiyong Liu (61)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	6
Wei Li (62)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	5
Dasheng Li (63)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Good	1
Huan Wu (64)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Poor	148
Hui Du (65)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	182
Muhammet Furkan Korkmaz (66)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	No	Poor	81
Lan Zhang (67)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	No	Poor	33

Table 1 (*continued*)

Table 1 (*continued*)

First author (reference No.)	Criteria									Quality rating	Number of cases
	1	2	3	4	5	6	7	8	9		
Huijing Ma (68)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Good	50
Setareh Mamishi (69)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	24
Pablo Caro-Dominguez (70)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	91
Shima Mahmoudi (71)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	35
Figen Palabiyik (72)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Good	59
Zhiliang Hu (73)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	No	Poor	5
Hui Yu (74)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	82
Che Zhang (75)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Poor	34
Anjue Tang (76)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	No	Poor	26
Xiaoxia Lu (77)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	171
Qin Wu (78)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	74
Bin Zhang (79)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	46
Haiyan Qiu (80)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	No	Poor	36
Wenliang Song (81)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Good	16
Lan Lan (82)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Good	4
Dan Sun (83)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	74
M. Oualha (84)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	No	Poor	27
Muhammad Adel (85)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	1
David M. Biko (86)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Good	1
Francesca I. Calò Carducci (87)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	No	Poor	2
Gaoyan Chen (88)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	No	Poor	8
Juan Chen (89)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	No	Poor	12
Qiang Chen (90)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	11
Karuna M. Das (91)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Good	56
Burcu Bursal Duramaz (92)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	No	Fair	30
Ahmed Elghoudi (93)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	14
Fang Wang (94)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Good	33
Farideh Gharekhanloo (95)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	1
Eliana P. C. Giorno (96)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Good	12
Ladan Goshayeshi (97)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	1
Yu Guo (98)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	No	Poor	80
Mina Hizal (99)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	34
Hong Jiang (100)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	10

Table 1 (*continued*)

Table 1 (*continued*)

First author (reference No.)	Criteria									Quality rating	Number of cases
	1	2	3	4	5	6	7	8	9		
Kuanrong Li (101)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	No	Poor	21
Ying Li (102)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Good	57
Xuehua Peng (103)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Good	201
Fatemeh Zamani (104)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	12
Nadia Nathan (105)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	No	Poor	4
Leila Shahbaznejad (106)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	10
Hayrettin Temel (107)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Good	81
Carlos F. Ugas-Charcape (108)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	No	Fair	32
Lanqiong Zhou (109)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	7
Xiaoli Li (110)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	No	Poor	14
Ruichao Niu (111)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	No	Fair	21
Niccolò Parri (112)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Fair	3
Rita Pina Prata (113)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	No	Poor	17
Arnaldo Prata-Barbosa (114)	Yes	Yes	NA	NA	Yes	Yes	CD	NA	Yes	Good	38

Criteria: 1. Was the study question or objective clearly stated? 2. Was the study population clearly and fully described, including a case definition? 3. Were the cases consecutive? 4. Were the subjects comparable? 5. Was the intervention clearly described? 6. Were the outcome measures clearly defined, valid, reliable, and implemented consistently across all study participants? 7. Was the length of follow-up adequate? 8. Were the statistical methods well-described? 9. Were the results well-described? NIH, National Institute of Health; NR, not reported; CD, cannot determine; NA, not applicable.

and most of the articles were scored as fair according to these criteria.

Characteristics of included studies

The basic and bibliographic characteristics of the included papers are summarized in Table S1. The interested reader can find them in a supplementary appendix online. This review included 81 articles published in English that in total included 3,557 pediatric patients. Of these, 2 were from the USA (46,86), 1 was from Kore (58), 1 was worldwide (70), 5 were from Turkey (66,72,92,99,107), 7 were from Iran (43,69,71,95,97,104,106), 2 were from Italy (87,112), 2 were from Brazil (96,114), 1 was from Egypt (85), 1 was from the Latin America (108), 1 was from France (105), 2 was from the UAE (91,93), 1 was from Portugal (113) and the remained 55 studies were from China. All of them were published in 2020-21.

Among the 81 studies, 14 investigated children and adults (36,38,40,59,79,89,91,93,94,96,99,101,107,108), and the rest of them studied only children. There were 14 case reports (37,44,45,54,55,57,58,63,85,87,95,97), 8 case series (46,47,75,81,82,90,104,108), 2 letters (77,79), 1 brief report (36), 2 case-control study (49,101), 2 cohort studies (66,70), 1 observational (84) and 5 observational cohort study (80,93,99,100,113) and the remained articles were descriptive studies. A total of 84 variables were extracted for this review.

Demographic characteristics of the patients

The demographic characteristics and the clinical and laboratory findings are summarized in *Table 2*. Of the 3,557 cases, 1,926 (54.1%) were male, and 1,610 (45.2%) were female. In addition, 1,387 (39%) of these children had a recent exposure history to COVID-19-infected patients. The age of participants ranged from less than 1 month to 18 years. One study reported the median BMI of the patients, which was 17.4 (49).

Among the 81 included papers, 27 studies reported

Table 2 Demographic characteristics and clinical and laboratory findings

Variables	Number of cases (%) or range	Number of studies
Demographic pooled data		
Age (years)	0–18	
Gender		
Male	1,926 (54.1)	
Female	1,610 (45.2)	
Not reported	21 (0.6)	
Mean time between onset and diagnosis (days)	1.5–10	
Contact history		
Yes	1,387 (39.0)	
No/not reported	2,170 (61.0)	
Accompanied comorbidity		
Yes	613 (17.2)	
Co-infection	36 (1.0)	
No	1,716 (48.2)	
Not reported	1,228 (34.5)	
Clinical manifestations pooled data		
Asymptomatic	658 (18.5)	
Cough	1,129 (31.7)	
Fever	1,241 (34.9)	
GI findings	261 (7.3)	
Dyspnea	327 (9.2)	
Tachypnea	175 (4.9)	
Sore throat	172 (4.8)	
Fatigue	94 (2.6)	
Lethargy or dizziness	26 (0.7)	
Headache	39 (1.0)	
Lab findings		
WBC count	986	44
Increased	125 (12.6)	
Decreased	184 (18.6)	
Normal	677 (68.6)	
Lymphocyte count	1,266	44
Increased	229 (18.0)	
Decreased	207 (16.3)	
Normal	830 (65.5)	
Neutrophil count	761	26
Increased	130 (17.0)	
Decreased	107 (14.0)	
Normal	524 (69.0)	
Platelet count	467	17
Increased	49 (10.5)	
Decreased	38 (8.1)	
Normal	380 (81.4)	
CRP	1,272	36
Increased	351 (27.6)	
Normal	921 (72.4)	
AST	738	25
Increased	148 (20.0)	
Normal	590 (80.0)	
ALT	796	29
Increased	127 (16.0)	
Normal	669 (84.0)	
Urea	416	13
Increased	31 (7.5)	
Decreased	6 (1.5)	
Normal	379 (91.0)	
Cr	630	15
Increased	43 (6.8)	
Decreased	107 (17)	
Normal	480 (76.2)	
LDH	491	19
Increased	151 (30.7)	
Normal	340 (69.3)	
D-dimer	542	14
Increased	49 (9.0)	
Normal	493 (91.0)	
Procalcitonin	173	17
Abnormal	78 (45.0)	
Normal	95 (55.0)	

accompanying comorbidities(such as immunocompromised status (post-transplant, immunosuppressive medication, malignancies), congenital heart diseases, long-term respiratory conditions (asthma, bronchial hyperreactivity, aspiration syndrome, preterm chronic lung disease), allergic rhinitis, atopic dermatitis, drug allergy, chronic kidney disease, neurological disorders, cardiovascular disease, liver cirrhosis, leukemia, polyarthritis, X-linked lymphoproliferative (XLP). According to these studies, 613 (17.2%) of the patients had underlying predisposing conditions. Moreover, co-infection with other agents [including CMV (Cytomegalovirus), influenza B, influenza A, mycoplasma, and Respiratory Syncytial Virus (RSV)] was detected in 36 (1%) of the patients (42,50,74,78,99).

Clinical features of the patients

Among all 3,557 cases, 658 patients (18.5%) were asymptomatic. Among the symptomatic patients, the main clinical features were fever, cough, dyspnea, gastrointestinal symptoms (including diarrhea, vomiting, nausea, abdominal pain, lack of appetite, and intussusception), sore throat, accounting for 1,104 (31%), 1,018 (28.6%), 313 (8.8%), 261 (7.3%), 175 (4.9%), and 171 (4.8%) cases, respectively. Fatigue was present in 92 (2.6%) of the cases, headache in 39 (1.1%), and lethargy or dizziness in 26 (0.7%).

Laboratory findings

Forty-four articles with a total of 986 cases reported the total white blood cell count, and it was decreased in 184 (18.6%) and increased in 125 (12.7%) of the patients. Forty-four studies with a total of 1,266 patients reported the lymphocyte count, and it was lower than normal in 207 (16.3%) and high in 229 (18%) of the patients. Only 36 articles reported CRP, which was normal in 921 (72.4%) of cases and increased in 351 (27.6%). O_2 saturation in breathing room air was mentioned in 20 papers for 208 patients, and it was decreased in 54 cases (26%).

Chest CT imaging features

Among the 3,557 Corona virus-infected patients, 2,202 have undergone a chest CT scan; 66% [1,451] of them had some abnormalities on their chest CT scans, while 34% [751] had normal chest CT scans. Among the 1,451 children with abnormal chest CT findings, the site of involvement was recorded in 63 articles, and around 53.6% (549/1,024) of cases had bilateral lung involvement, and the other 46.4% (475/1,024) had unilateral lung involvement. Based on these reports, the right lung was involved slightly more frequently than the left lung. When the left lung was involved, there was a predilection for lower lobe involvement, and when the right lung was involved, the infection sites in the order of frequency were the right lower, right upper, and right middle lobes. Thirty-three studies with a total of 352 cases reported the distribution of lung involvement, and summarizing these findings revealed that 81.2% had a peripheral pattern, about 15.6% had a diffuse pattern, and about 3.1% had a peribronchovascular pattern.

Regarding the type of lung lesions in children with COVID-19 infection and abnormal chest CT findings, ground glass opacities were observed in 54.7% (794/1,451) and consolidation in 10.2% (149/1,451) of the patients. Other common features were halo sign, discrete pulmonary nodules, interstitial abnormalities or reticulations, and vascular thickening shadows in 7.4%, 2.6%, 9.7%, and 1.7% of the patients, respectively. Based on these publications, a crazy paving pattern (0.6%), pleural effusion (2.7%), and lymphadenopathy (0.5%) were not common features in COVID-19-infected children (*Table 3*).

Additional findings

We also extracted the mean time between the onset and diagnosis of Corona virus infection in children. A total of 28 articles with a total of 1,139 cases recorded this item, and it ranged from 1.5 to 10 days.

Discussion

During the global spread of the coronavirus infection throughout the world, it was found that the previous epidemiologic knowledge that suggested relatively few cases were seen among children was not accurate (58) and many children were diagnosed infected with clinical manifestations of the disease such as dry cough, fever, dyspnea, tachypnea, and sore throat in addition to corresponding laboratory (e.g., changes in white blood cell count, lymphocyte count, CRP, O_2 saturation, …) and imaging findings including ground glass opacities and consolidations, and also less common features of halo sign, discrete pulmonary nodules, interstitial abnormalities or reticulations, and vascular thickening shadows.

Although RT-PCR is considered the gold standard tool for the diagnosis of COVID-19 infection, some studies

Table 3 Frequency of chest CT findings of COVID-19 in children (chest CT imaging features)

CT findings	Number of studies	Number of cases (%)
Abnormal chest CT	76	1,451 (66.0)
Normal chest CT	62	751 (34.0)
Distribution		
Bilateral	49	549 (37.8)
Unilateral	40	475 (32.7)
Not reported	20	427 (29.4)
Peripheral pattern	23	286 (19.7)
Diffuse pattern	7	55 (3.8)
Peribronchovascular pattern	8	11 (0.7)
Not reported	46	1,099 (75.7)
Patterns of the lesion		
Ground glass opacities	66	794 (54.7)
Consolidation	39	149 (10.2)
Halo sign	17	108 (7.4)
Discrete pulmonary nodules	17	38 (2.6)
Interstitial abnormalities or reticulation	21	141 (9.7)
Vascular thickening shadows	5	25 (1.7)
Crazy paving pattern	4	9 (0.6)
Patchy morphology	21	334 (23.0)
Other findings		
Pleural effusion	15	39 (2.7)
Mediastinal lymphadenopathy	4	7(0.5)

have discussed the diagnostic role of chest CT scans. For example a study conducted by Ai and colleagues is the first study thus far to determine the diagnostic value of chest CT in patients with COVID-19. The authors analyzed 1,014 patients with suspected COVID-19, and all these patients underwent both chest CT scan and nucleic acid test (RT-PCR). Of the 1,014 patients, 601 (59%) had positive RT-PCR results, and positive chest CT findings were detected in 97% of the 601 patients. With RT-PCR as the diagnostic reference for COVID-19, their results depicted that the sensitivity, specificity, positive predictive value, and negative predictive value of CT were 97%, 25%, 65% and 83%, respectively. The high false positive of CT scan according to this study could be due to extensive overlap between imaging findings of corona virus lung infection and other kinds of pneumonia. Although as Ai *et al*. pointed out, their results may only be valid in epidemic areas with high pre-test probability for this disease and for milder cases, the chest CT positive rate will be much lower (25,115,116); however, it seems crucial to identify the imaging patterns of lung involvement and to determine the role of chest CT scan in pediatric infected patients.

In the current review, we evaluated the chest CT findings in 2,202 children, from 81 articles, with a positive COVID-19 RT-PCR test result (ages ranged from less than one month to 18 years), as well as the demographic characteristics and clinical and laboratory manifestations. This is the largest systematic review to date to survey all of these items in COVID-19-infected children. According to the quality assessment of included articles using the NIH Quality Assessment Tool, 20 studies were of poor quality due to imperfect clinical and CT scan data, and the others were scored as fair or good.

We also included 10 case reports conducted during the first months of epidemic when it was believed that children were not susceptible to COVID-19. In addition, most of the studies were descriptive, but we included 7 cohort studies, which provided information about the use of CT scans during the follow-up of pediatric COVID-19-infected patients; although most radiologists believe that CT scan, because of its relatively high radiation dose, should not be used for follow-up in corona virus infected children and considering the much lower radiation effect, serial chest radiographs can be used for monitoring of the disease regression or progression (117).

In this review, 55 articles were from China, representing 1,760 cases, and 26 articles from other countries, representing 1,797 cases. These values regarding the latest Worldometer statistics of total cases of about 90,973 in China, which is a small percentage of the total worldwide cases compared to that of several other countries, indicates that Chinese authors have made more of an effort to report on pediatric patients with the corona virus infection. Thus, it would be of value if other countries with a high number of total cases, such as the USA, India, and Brazil, would publish investigations on the corona virus infection in children. A Multilanguage systematic review of local databases would be of great help in this area. In this review, 18.5% of COVID-19-infected children were asymptomatic, while for adult patients, this rate has been reported to be about 13.3% (115,116) to 15.6% (118). However, we need

also to emphasize the background where these data were collected. Most studies were conducted in tertiary hospitals, and the results from hospital-based patients usually do not represent the patients in general population, where the proportion of asymptomatic virus carriers and mild cases must be much higher (116).

According to Wang *et al.*, COVID-19 patients commonly have symptoms of fever, fatigue, dry cough, dyspnea, chest tightness, nasal congestion, runny nose or other upper respiratory symptoms (119). In our review, the most prevalent symptoms in pediatric patients were fever and cough, in 35.0% and 31.8% of patients, respectively, while 9.2% of patients had dyspnea. These manifestations are nearly similar to the most common symptoms reported in adults, although the frequencies of fever and cough were higher in adult, and about 80% and 60%, respectively (8). Gastrointestinal findings, including diarrhea and abdominal pain, were fairly common in children with COVID-19 infection (12%), possibly because during the pathogenesis of COVID-19, the SARS-CoV-2 virus attaches to the ACE2 receptor, which is highly expressed in the GI tract (29).

We evaluated the laboratory findings of COVID-19-infected children, and the most common findings were decreased numbers of leukocytes and lymphocytes, in 18.4% and 15.4% of patients respectively, whereas in adults, these findings are more frequently reported (41%) (120). Increased WBC and lymphocyte counts are rare findings in adult patients (1–2%) (26), but they were reported in 12.7% and 18.1% of pediatric patients, respectively. Overall, normal CRP was more prevalent in children (72.4%) than in adults (13–44%) (26,29).

Based on these studies, 34 % of COVID-19-infected children had normal chest CT scans, in contrast to only 2% of infected adults (26). The most common finding in the chest CT scans of the pediatric patients with COVID-19 was GGO without consolidation (54.7%), indicating that the patients were in the early stage of the disease or the lesions had started to heal (121). The second most common feature in the chest CT scans of the patients was consolidation (10.2%), and progression to consolidation indicates that the immune system of the patient is not strong enough to defeat the virus, potentially increasing the risk of pulmonary fibrosis (121). Furthermore, a consolidative pattern might be indicative of a more severe disease (19). The prevalences of these two features in children were slightly lower than those reported in adult patients; a review by Wan *et al.* reported rates of 86% and 47% for GOO and consolidation, respectively, and a review by Vieeto Ojha *et al.* reported rates of 50.2% and 24% for GGO and consolidation, respectively (21,29).

Other reported lesions in the chest CT scans of COVID-19-infected children were interstitial abnormalities or reticulation, halo sign, vascular thickening shadows, and pulmonary nodules, in 9.7%, 7.4%, 1.7%, and 2.6% of patients, respectively. Among these, halo sign has not been reported in adults, and the other patterns has been reported more frequently in adult patients (9–27%) (21,26,29). A crazy paving pattern, a feature of the severe involvement of the lungs, was not found as frequently as it is in adult patients, as it was reported in only 0.6% of pediatric cases in our review versus reported rates of 12%, 15%, and 19.5% in adults (21,26,29). Pleural effusion and lymphadenopathy are rare findings in chest CT scans for both children and adult patients, with rates of 2.7% and 0.5%, respectively (21,26).

In our review, around 549 (37.8%) of cases had bilateral lung involvement, and the other 475 (32.7%) had unilateral lung involvement. In adults, however, bilateral disease is much more common than a unilateral pattern, with rates of 80% and 20%, respectively (26); this is consistent with the milder symptoms of disease observed in the pediatric age group. In children, the distribution of the disease in the lungs is mostly peripheral, which is similar to the distribution seen in adults (26,29).

Some CT scan findings that have been detected in adult patients were rare or not seen in children in our review. For example, Roncon *et al.* analyzed 7,178 patients with COVID-19 (mean age 60.4 years) and reported that 14.7% of hospitalized patients had PE (or pulmonary thrombosis) (122), but based on our review, PE was not seen in the chest CT scans of pediatric patients.

Generally in our review, we noticed that the CT findings of COVID-19 are mild in most of the pediatric population, especially in comparison to adult patients. So, as we need to keep the patients' radiation exposure as low as possible, particularly in children who are much more sensitive than adults to the induction of cancer by radiation, the application of CT scan as a diagnostic tool may be unjustified among regions with low COVID-19 prevalence (119). Considering the radiation exposure exists for chest CT exams (WHO guideline mentions a typical effective dose of 3.5 mSv for a chest CT in a 10-year-old child) (123) and thanks to the improvements in technical aspects of performing RT-PCR for detection of COVID-19 infected cases, it seems that performing chest CT scan should be

limited to individual cases that its benefits outweigh the risks such as selected suspected cases where RT-PCR tests have been negative more than once (119), suspected cases with severe symptoms or when the CT results are supposed to affect the treatment plan.

One of the weak points of our review was that the number of published studies reporting chest CT scan findings in COVID-19-infected children was not very large, the patient populations in the included studies were not very diverse, and most of them had a small sample size. In addition, the majority of the studies were retrospective and descriptive in nature. Another limitation was that the timing of the CT scan was not the same among the studies; for example, in one study, it was done on the first day that clinical symptoms manifested, and in another, it was obtained several days later. In this review, we found that the reporting template of the CT scan findings was not identical among studies. In many articles, ambiguous terms were used, or the site and expanse of the lesions were not clear. Furthermore, a diagnosis of coronavirus infection based on a chest CT scan is dependent on the radiologist's experience. In most of the articles, the severity of the illness and the imaging and laboratory findings were not recorded separately for each patient, so it was not possible to assess the correlation between the disease severity and pattern of chest CT scan findings.

Moreover, in this review, we included studies with CT scan findings for children who had positive RT-PCR test results. Thus, considering the fact that the median false-negative rate of RT-PCR for the detection of coronavirus infection is about 10.1% (124), there might have been some children with flu-like symptoms, negative RT-PCR test results, and imaging findings indicating coronavirus infection in their chest CT scans, possibly increasing the risk of bias in interpreting the chest CT scan findings.

Conclusions

CT scan plays a pivotal diagnostic role in patients suspicious of COVID-19 that their PCR tests failed to show positive results and their disease is severe and life-threatening. However, as the overwhelming majority of COVID-19 positive children only show mild CT scan findings and CT results possibly do not affect their treatment, given the risk of radiation exposure, CT seems unjustifiable in children and could be replaced by CXR in most patients except for individual cases when its benefits outweigh the risks.

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Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://dx.doi.org/10.21037/qims-20-1410). The authors have no conflicts of interest to declare.

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Supplementary

Table S1 Chest CT findings of COVI D-19 in children

First author (reference No.)	Year	Country	Children sample size	Female number	Male Number	Average age (years)	Normal CT	Abnormal CT, N %, (95% CI)	Sample size (CT)	CT findings	Number of cases
Hong-Rui Chen (34)	2020	China	1	0	1	12	0	1	1	Unilateral	1
										Right lung	1
										RUL	1
										Upper zones	1
										GGO	1
										Pleural effusion	1
Qihong Fan (35)	2020	China	1	1	0	0.25	1	0	1	Normal	1
Li-Na Ji (36)	2020	China	2	0	2	12	2	0	2	Normal	2
Ke Bai (37)	2020	China	25	11	14	11	12	13, 52% (31–71%)	25	Consolidation	2
										GGO	7
										Blurred bronchovascular bundle	4
										Normal	12
Zhong Zheng (38)	2020	China	9	5	4	6.5	2	7	9	Unilateral	6
										Bilateral	1
										Right lung	3
										Left lung	3
										RUL	1
										RML	1
										RLL	1
										LLL	3
										Upper zones	1
										Middle zones	1
										Lower zones	4
										Subpleural distribution	2
										Peribronchovascular distribution	1
										Consolidation	2
										GGO	5
										Normal	2
Fang Zheng (39)	2020	China	25	11	14	3	9	16, 64% (42–82)	25	Unilateral	4
										Bilateral	12
										Consolidation	17
										Patchy morphology	17
										Normal	9
Liang Su (40)	2020	China	9	6	3	3	5	4	9	Bilateral	4
										Right lung	4
										Left lung	4
										Consolidation	1
										GGO	1
										Patchy morphology	1
										Reticulation	2
										Tree-in-bud	3
										Bronchiolar dilatation	2
										Bronchial wall thickening	2
										Normal	5
Qinxue Shen (41)	2020	China	9	6	3	8	7	2	9	Unilateral	2
										Bilateral	0
										GGO	2
										Normal	7
Wei Xia (42)	2020	China	20	7	13	2.1	4	16, 80% (56–94)	20	Unilateral	6
										Bilateral	10
										Subpleural distribution	20
										Consolidation	10
										GGO	12
										Halo sign	10
										Nodular morphology	3
										Reticulation	4
										Normal	4
Jafar Soltani (43)	2020	Iran	30	16	14	5.5	4	26, 86% (69–96)	30	Consolidation	11
										GGO	19
										Halo sign	2
										Nodular morphology	4
										Reticulation	5
										Pleural effusion	5
										Mediastinal LAP	1
										Normal	4
Xiaoping Yin (44)	2020	China	1	0	1	9	0	1	1	Unilateral	1
										Right lung	1
										RML	1
										Middle zones	1
										Reticulation	1
Buyun Shi (45)	2020	China	1	0	1	0.225	0	1	1	Bilateral	2
										Right lung	1
										Left lung	1
										RML	1
										LLL	1
										Middle zones	1
										Lower zones	1
										Consolidation	1
										GGO	1
Sharon Steinberger (46)	2020	US	30	15	15	10	23	7, 23% (9–42)	30	Bilateral	2
										Right lung	1
										Left lung	1
										RML	1
										LLL	1
										Middle zones	1
										Lower zones	1
										Consolidation	1
										GGO	1
										Bilateral	2
										Right lung	1

Table S1 (*continued*)

https://dx.doi.org/10.21037/qims-20-1410

Table S1 (*continued*)

First author (reference No.)	Year	Country	Children sample size	Female number	Male Number	Average age (years)	Normal CT	Abnormal CT, N %, (95% CI)	Sample size (CT)	CT findings	Number of cases
										Left lung	1
										RML	1
										LLL	1
										Middle zones	1
										Lower zones	1
										Consolidation	1
										GGO	1
										Normal	23
Tongqiang Zhang (47)	2020	China	3	0	3	7.6	0	3	3	Bilateral	3
										Right lung	3
										Left lung	3
										RLL	1
										LLL	2
										Lower zones	3
										Subpleural distribution	2
										GGO	2
										Reticulation	1
Yu-Pin Tan (48)	2020	China	10	7	3	7	5	5, 50% (10–33)	10	Unilateral	1
										Bilateral	4
										Lower zones	4
										Air bronchogram	1
										GGO	4
										Nodular morphology	1
										Reticulation	1
										Bronchial wall thickening	1
										Normal	5
Yanli Wang (49)	2020	China	43	16	27	6.6	17	26, 60% (44–75)	43	Consolidation	9
										GGO	19
										Normal	17
Yang li (50)	2020	China	8	5	3	2.5	1	7	8	Unilateral	4
										Bilateral	3
										Right lung	6
										Left lung	4
										RUL	2
										LUL	1
										Upper zones	3
										Middle zones	2
										Lower zones	3
										Peribronchovascular distribution	1
										Consolidation	4
										GGO	2
										Halo sign	1
										Nodular morphology	2
										Patchy morphology	3
										Lucency shadows	2
										Normal	1
Li-Juan Mao (51)	2020	China	1	0	1	1.16	0	1	1	Unilateral	1
										Right lung	1
										RLL	1
										Lower zones	1
										Subpleural distribution	1
										GGO	1
										Patchy morphology	1
Wei Lai (52)	2020	China	2	0	2	14	0	2	2	Unilateral	1
										Bilateral	1
										RUL	1
										LUL	1
										RLL	1
										Subpleural distribution	1
										GGO	2
										Halo sign	1
										Nodular morphology	2
										Patchy morphology	2
										Vascular dilatation	1
Y. Lu (53)	2020	China	9	4	5	7.8	4	5	9	Bilateral	5
										Right lung	5
										Left lung	5
										Subpleural distribution	4
										GGO	4
										Halo sign	1
										Patchy morphology	4
										Vascular thickening shadowing	1
										Interstitial abnormality	1
										Normal	4
Mengqi Liu (54)	2020	China	5	1	4	6	1	4	5	Unilateral	3
										Bilateral	1
										Right lung	3
										Left lung	2
										RUL	1
										RLL	1
										LLL	1
										Upper zones	2
										Lower zones	2
										Subpleural distribution	2
										Consolidation	1
										GGO	4
										Patchy morphology	4
										Normal	1

Table S1 (*continued*)

https://dx.doi.org/10.21037/qims-20-1410

Table S1 (*continued*)

First author (reference No.)	Year	Country	Children sample size	Female number	Male Number	Average age (years)	Normal CT	Abnormal CT, N %, (95% CI)	Sample size (CT)	CT findings	Number of cases
Guiqing He (55)	2020	China	1	0	1	11	0	1	1	Unilateral	1
										Left lung	1
										LLL	1
										Lower zones	1
										Subpleural distribution	1
										air bronchogram	1
										GGO	1
										Patchy morphology	1
Bo Li (56)	2020	China	22	10	12	8	2	20, 90% (70–98)	22	Unilateral	2
										Bilateral	15
										Right lung	11
										Left lung	9
										RUL	2
										RLL	9
										LUL	3
										LLL	6
										Upper zones	5
										Lower zones	15
										Subpleural distribution	10
										Peribronchovascular distribution	1
										Diffuse distribution	9
										Consolidation	7
										GGO	3
										Crazy paving	2
										Normal	2
Jilei Lin (57)	2020	China	1	1	0	7	1	0	1	Normal	1
Ji Young Park (58)	2020	Korea	1	1	0	10	0	1	1	Unilateral	1
										Right lung	1
										RLL	1
										Lower zones	1
										Subpleural distribution	1
										Consolidation	1
										GGO	1
										Nodular morphology	1
										Patchy morphology	1
Huanhuan Liu (59)	2020	China	4	2	2	3.7	1	3	4	Unilateral	1
										Bilateral	1
										Consolidation	2
										GGO	1
										Normal	1
Yuanzhe Li (60)	2020	China	2	1	1	4	0	2	2	Bilateral	2
										Right lung	1
										Left lung	1
										RUL	1
										RML	1
										RLL	1
										LUL	1
										LLL	1
										Peribronchovascular distribution	1
										GGO	1
Weiyong Liu (61)	2020	China	6	4	2	3	1	4	5	Bilateral	4
										GGO	4
										Patchy morphology	4
										Normal	1
Wei Li (62)	2020	China	5	1	4	3	2	3	5	Right lung	1
										Left lung	2
										RUL	1
										LLL	2
										Upper zones	1
										Lower zones	2
										GGO	3
										Patchy morphology	3
										Normal	2
Dasheng Li (63)	2020	China	1	0	1	0.83	0	2	2	Unilateral	1
										Bilateral	1
										Right lung	1
										Left lung	1
										RUL	1
										RML	1
										RLL	1
										LUL	1
										LLL	1
										Upper zones	1
										Middle zones	1
										Lower zones	1
										Diffuse distribution	1
										GGO	1
										Patchy morphology	1
Huan Wu (64)	2020	China	148	88	60	7	60	88, 59% (51–67)	148	Unilateral	34
										Bilateral	54
										GGO	51
										Normal	60
Hui Du (65)	2020	China	182	62	120	6	52	130, 71% (64–77)	182	Unilateral	57
										Bilateral	73
										Peribronchovascular distribution	2
										Consolidation	3
										GGO	51
										Patchy morphology	50
										Reticulation	7

Table S1 (*continued*)

https://dx.doi.org/10.21037/qims-20-1410

Table S1 (*continued*)

First author (reference No.)	Year	Country	Children sample size	Female number	Male Number	Average age (years)	Normal CT	Abnormal CT, N %, (95% CI)	Sample size (CT)	CT findings	Number of cases
										Pleural effusion	1
										Bronchial dilatation	1
										Bronchial wall thickening	1
										Normal	52
Muhammet Furkan Korkmaz (66)	2020	Turkey	81	33	48	9.5	24	6, 20% (7–38)	30	Consolidation	3
										GGO	3
										Normal	24
Lan Zhang (67)	2020	China	33	17	16	9.5	19	14, 42% (25–60)	33	Abnormal (findings not reported)	14
										Normal	19
Huijing Ma (68)	2020	China	50	22	28	NR	7	43, 86% (73–94)	50	Unilateral	34
										Bilateral	9
										Upper zones	22
										Middle zones	9
										Lower zones	28
										Subpleural distribution	41
										GGO	29
										Patchy morphology	25
										Pleural effusion	1
										Vascular thickening shadowing	10
										Normal	7
Setareh Mamishi (69)	2020	Iran	24	13	11	6	2	22, 91% (73–98)	24	Consolidation	11
										GGO	7
										Nodular morphology	1
										Cavity	2
										Pleural effusion	5
										Bronchial wall thickening	1
										Normal	2
Pablo Caro-Domingeuz (70)	2020	world-wide	91	42	49	13	2	22, 91% (73–98)	24	Consolidation	14
										GGO	21
										Crazy paving	2
										Nodular morphology	6
										Reticulation	8
										Mediastinal LAP	4
										Tree-in-bud	6
										Vascular thickening shadowing	3
										Normal	2
Shima Mahmoudi (71)	2020	Iran	35	13	22	7.5	3	32, 91% (76–98)	35	Unilateral	26
										Bilateral	6
										Consolidation	6
										GGO	26
										Pleural effusion	1
										Mediastinal LAP	1
										Normal	3
Figen Palabiyik (72)	2020	Turkey	59	25	34	9	3	50, 94% (84–90)	53	Unilateral	7
										Bilateral	12
										RUL	9
										RML	11
										RLL	31
										LUL	8
										LLL	50
										Subpleural distribution	7
										Diffuse distribution	12
										Consolidation	9
										GGO	17
										Halo sign	5
										Bronchial wall thickening	8
										Vascular thickening shadowing	8
										Interstitial abnormalities	8
										Normal	3
Zhiliang Hu (73)	2020	China	5	3	2	8.6	4	1	5	GGO	1
										Normal	4
Hui Yu (74)	2020	China	82	31	51	NR	2	80, 97% (91–99)	82	Unilateral	38
										Bilateral	30
										Consolidation	3
										GGO	18
										Patchy morphology	18
										Pleural effusion	1
										Normal	2
Che Zhang (75)	2020	China	34	20	14	2.75	6	28, 82% (65–93)	34	Unilateral	14
										Bilateral	14
										Patchy morphology	28
										Normal	6
Anjue Tang (76)	2020	China	26	17	9	6.9	8	18, 69% (48–85)	26	Unilateral	11
										Bilateral	7
										Normal	8
Xiaoxia Lu (77)	2020	China	171	67	104	6.7	60	111, 64% (57–72)	171	Bilateral	21
										GGO	56
										Patchy morphology	32
										Interstitial abnormalities	2
										Normal	60
Qin Wu (78)	2020	China	74	30	44	6	37	37, 50% (38–61)	74	Unilateral	21
										Bilateral	16
										Right lung	13
										Left lung	8
										Subpleural distribution	9
										GGO	9
										Patchy morphology	9
										Normal	37

Table S1 (*continued*)

https://dx.doi.org/10.21037/qims-20-1410

Table S1 (*continued*)

First author (reference No.)	Year	Country	Children sample size	Female number	Male Number	Average age (years)	Normal CT	Abnormal CT, N %, (95% CI)	Sample size (CT)	CT findings	Number of cases
Bin Zhang (79)	2020	China	46	17	29	8.75	26	20, 43% (28–58)	46	Unilateral	15
										Bilateral	4
										Consolidation	5
										GGO	17
										Patchy morphology	1
										Normal	26
Haiyan Qiu (80)	2020	China	36	13	23	8.3	17	19, 52% (35–69)	36	GGO	19
										Normal	17
Wenliang Song (81)	2020	China	16	6	10	8.5	5	11, 68% (41–88)	16	Unilateral	10
										Bilateral	1
										RUL	4
										RML	1
										RLL	4
										LUL	2
										LLL	3
										Upper zone	6
										Middle zone	1
										Lower zone	7
										Peribronchovascular distribution	2
										Consolidation	1
										Air bronchogram	2
										GGO	8
										Halo sign	4
										Nodular morphology	5
										Patchy morphology	6
										Mediastinal LAP	1
										Normal	5
Lan Lan (82)	2020	China	4	2	2	9.75	1	3	4	Unilateral	1
										Bilateral	2
										Right lung	1
										Left lung	3
										RLL	1
										LLL	3
										Lower zones	3
										Subpleural distribution	3
										Consolidation	1
										GGO	3
										Halo sign	1
										Normal	1
Dan Sun (83)	2020	China	74	36	38	5.8	34	40, 54% (42–65)	74	Unilateral	26
										Bilateral	14
										Consolidation	14
										GGO	26
										Interstitial abnormalities	8
										Unilateral	26
										Bilateral	14
										Consolidation	14
										GGO	26
										Normal	34
M. Oualha (84)	2020	China	27	17	10	6	2	14, 87% (61–98)	16	Abnormal (findings not reported)	14
										Normal	2
Muhammad Adel (85)	2021	Egypt	1	0	1	0.2	0	1	1	Bilateral	1
										Consolidation	1
										Pleural effusion	1
David M. Biko (86)	2021	USA	313	29	26	9	1		1	Normal	1
Francesca I. Calò-Carducci (87)	2020	Italy	1	0	1	14	1	0	1	Normal	1
Gaoyan Chen (88)	2020	China	8	3	5	7.43	1	7 , 88% (64–100)	8	Bilateral	7
										GGO	7
										Patchy morphology	7
Juan Chen (89)	2020	China	12	6	6	14.5	2	10, 83% (62–100)	12	Bilateral	10
										GGO	10
Qiang Chen (90)	2020	China	11	4	7	10.61	5	6, 54% (25–83)	11	Normal	5
										GGO	6
										Patchy morphology	4
Karuna M. Das (91)	2021	UAE	187	92	95	14.8	30	26	56	Normal	30
										Bilateral	26
										GGO	6
										Consolidation	1
										Halo sign	11
										Nodules	1
Burcu Bursal Duramaz (92)	2020	Turkey	33	26	17	10.5	11	19, 63% (46–80)	30	Normal	11
										Unilateral	12
										Bilateral	16
										GGO	19
										Peripheral	19
Ahmed Elghoudi (93)	2020	UAE	288	140	148	7.3	0	14	14	Unilateral	8
										Bilateral	6
										GGO	14
Wang Fang (94)	2020	China	33	19	14	6	13	20, 60% (43–77)	33	Normal	13
										Unilateral	9
										Bilateral	11
										GGO	20
Farideh Gharekhanloo (95)	2020	Iran	1	1	0	15	0	1	1	Bilateral	1
										Consolidation	1
										Patchy morphology	1
										Pleural effusion	1
										Peripheral	1
										Nodules	1

Table S1 (*continued*)

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Table S1 (*continued*)

First author (reference No.)	Year	Country	Children sample size	Female number	Male Number	Average age (years)	Normal CT	Abnormal CT, N %, (95% CI)	Sample size (CT)	CT findings	Number of cases
Eliana P. C (96)	2020	Brazil	34	13	21	13	2	10, 83% (62–100)	12	Normal	2
										Bilateral	10
										GGO	10
										Pleural effusion	4
										Peripheral	5
Ladan Goshayeshi (97)	2020	Iran	1	0	1	14	0	1	1	Bilateral	1
										GGO	1
										Peripheral	1
										Diffuse distribution	1
Yu Guo (98)	2020	China	80	28	52	6	24	56, 70% (59–80)	80	Normal	24
										Unilateral	34
										Bilateral	22
										GGO	25
										Consolidation	10
Mina Hizal (99)	2020	Turkey	40	22	18	10.5	16	18, 52% (36–69)	34	Normal	16
Hong Jiang (100)	2020	China	10	4	6	3.8	5	5, 50% (19–80)	10	Normal	5
										Unilateral	2
										Bilateral	3
										GGO	5
Kuanrong Li (101)	2020	China	72	NR	NR	2	7	14, 66% (46–86)	21	Normal	7
										Patchy morphology	5
Ying Li (102)	2020	China	57	22	35	1.6	32	25, 43.8% (30.1–56.7)	57	Normal	32
										GGO	24
										Consolidation	3
Xuehua Peng (103)	2021	China	201	83	118	6	82	119, 59% (52–65)	201	Normal	82
										Unilateral	59
										Bilateral	60
										GGO	83
										Consolidation	44
										Halo sign	44
										Patchy morphology	903
										Crazy-paving pattern	96
										Peripheral	1
										Pleural effusion	2
										Nodules	1
										Diffuse distribution	
Fatemeh Zamani (104)	2021	Iran	12	5	5	9.7	1	11, 91% (76–100)	12	Normal	1
										GGO	4
										Consolidation	2
										Patchy morphology	8
										Peripheral	5
										Nodules	1
										Diffuse distribution	1
Nadia Nathan (105)	2020	France	23	10	13	4.9	0	4	4	GGO	4
										Peripheral	3
Leila Shahbaznejad (106)	2020	Iran	10	4	6	5.37	1	9, 90% (71–100)	10	Normal	1
										Bilateral	9
										GGO	6
										Halo sign	1
										Patchy morphology	3
										Pleural effusion	2
										Nodules	1
Hayrettin Temel (107)	2020	Turkey	81	41	40	9.3	77	4, 5% (0–68)	81	Normal	77
										Unilateral	3
										Bilateral	1
										GGO	4
Carlos F. Ugas-Charcape (108)	2020	Latin American	140	71	69	6.3	0	32	32	GGO	29
										Consolidation	22
										Halo sign	12
										Pleural effusion	8
										Peripheral	45
										Nodules	3
Lanqiong Zhou (109)	2021	China	7	5	2	3	6	1, 14% (0–40)	7	Normal	6
										Unilateral	1
										GGO	1
Xiaoli Li (110)	2020	China	14	6	8	6.33	5	4, 35% (39–89)	14	Normal	5
										Unilateral	3
										Bilateral	6
										GGO	3
										Consolidation	1
										Patchy morphology	4
Ruichao Niu (111)	2020	China	21	NR	NR	NR	0	21	21	GGO	8
										Consolidation	2
										Halo sign	7
										Nodules	4
Niccolò Parri (112)	2021	Italy	170	75	95	3.75	1	2, 66% (13–100)	3	Normal	1
										Bilateral	2
										GGO	2
										Pleural effusion	2
Rita Pina Prata (113)(63)	2021	Portugal	24	12	12	5.7	2	15, 88% (72–100)	17	Normal	2
										Bilateral	15
										GGO	14
										Consolidation	12
										Halo sign	3
										Patchy morphology	14
										Peribronchovascular	3
										Peripheral	6
										Nodules	1
										Diffuse distribution 10	2
Arnaldo Prata-Barbosa (114)	2020	Brazil	79	36	43	4	19	19, 50% (34–65)	38	Normal	19
										GGO	19
										Pleural effusion	3
										Diffuse distribution	21

RUL, right upper lobe; RML, right middle lobe; RLL, right lower lobe; LUL, left upper lobe; LLL, left lower lobe; GGO, ground glass opacity; LAP, lymphadenopathy.

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