Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Pediatric radiologic manifestations of COVID-19

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ABSTRACT

Purpose: While full description of pediatric COVID-19 manifestations is evolving, children appear to present less frequently, and often display a less severe disease phenotype. There is correspondingly less data regarding pediatric radiologic findings. To describe the imaging findings of pediatric COVID-19, we evaluated the radiologic imaging of the initial patient cohort identified at our institution.

Methods: In this IRB approved study, all patients at our institution aged 0–21 with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) based on PCR or immunoglobulin testing were identified. Imaging was reviewed by the co-authors and presence of abnormalities determined by consensus. Pre-existing comorbidities and alternative diagnoses were recorded. Rates of each finding were calculated. Findings were compared to published data following review of the available literature.

Results: Out of 130 Covid-19 positive patients, 24 patients underwent imaging, including 21 chest radiographs and 4 chest CT scans. Chest x-rays were normal in 33%. Patchy or streaky opacities were the most common radiographic abnormality, each seen in 38% of patients. CT findings included ill-defined or geographic ground glass opacities, dense opacities, septal thickening and crazy paving, and small pleural effusions. Results are similar to those reported in adults. Multiple COVID-19 positive children presented for symptoms due to an additional acute illness, including appendicitis and urinary infection.

Conclusions: Radiologic findings of COVID-19 in pediatric patients range from normal to severe ARDS type appearance. During this ongoing pandemic, these radiographic signs can be useful for the evaluation of disease status and guiding care, particularly in those with comorbidities.

Precis: Radiologic findings of COVID-19 in pediatric patients are similar to those seen in adults, and may range from normal to severe ARDS type appearance.

1. Introduction

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is the coronavirus that causes the disease COVID-19, initially identified in late 2019 in Wuhan, the capital city of the Hubei province of China.[1] Since disease tracking began, it has spread rapidly and was declared a pandemic by the World Health Organization (WHO) on March 11, 2020.[2] It is the first pandemic caused by a coronavirus. While most coronavirus infections result in mild upper respiratory tract infections, such as the common cold or pharyngitis, there is precedent of coronaviruses causing severe illness such as Severe Acute Respiratory Syndrome (SARS) and Middle East Respiratory Syndrome (MERS).[3,4]

COVID-19 was first confirmed in the United States January 20th, 2020. The first case occurred in Washington state, in a person who had just returned to the US from Wuhan.[5] While initial scattered US cases also originated in patients returned from Wuhan, community spread of disease *not* originating in China was reported in late February.[6] The first death, in Kirkland, Washington, was also reported in late February.[7] Soon thereafter, there was rapid acceleration of reports across the US, with the largest initial outbreak occurring in Washington State.[8] Initially in the US, state-by-state social distancing measures and various lock down procedures were implemented to slow the spread of COVID-19. In late 2020 however, many states and regions in the US have seen additional surges in cases and deaths, speculated to be a function of the relaxation of these precautions.

The early experience in Wuhan described significant reliance on

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radiology in diagnosis and treatment monitoring of COVID-19, with assertions that computed tomography (CT) provided faster and more accurate diagnosis than the available laboratory testing and often-negative chest x-ray.[9] Given the novelty of the disease, clinical accuracy of the laboratory tests, including the gold standard polymerase chain reaction (PCR) test, has been difficult to ascertain. However, in the US, official policy has remained focused on PCR over radiology as the method of screening and diagnosis, despite significant early variability in testing availability and initial uncertain clinical accuracy.

Likewise, consensus statements regarding imaging in COVID-19 positive or suspected patients, both in adult and pediatric populations, have been published.[10,11] While Foust et al. note a lack of robust imaging data for COVID-19 positive pediatric patients, they reference ACR appropriateness criteria[12] to support the recommendation that imaging an otherwise well, immunocompetent child with mild symptoms is not indicated. Notably, this applies to the majority of the pediatric cohort, for whom symptoms are usually mild or even lacking.[13] However, if a child has underlying comorbidities, fails outpatient management or presents with moderate or severe symptoms, chest radiograph should be considered despite its reported low sensitivity.[9,10] While not recommended as a screening exam, CT may be indicated, particularly in medically complex patients or those not responding to therapy. Moreover, if CT findings are suspicious for COVID, results may prompt re-testing in patients with negative initial tests.[10]

As such, recognizing imaging findings of COVID-19, and understanding the limitations of imaging in diagnosing this disease, is of importance. There is literature describing pediatric imaging findings in COVID-19,[14–18] the majority of which use data obtained from China, though more recent systematic reviews includes pediatric data from other countries.[13] While there have been some reports out of other large pediatric centers,[19] we describe our early US experience of radiology findings in COVID-19 patients so as to add to the existing data on imaging findings in this cohort. We evaluate both chest x-ray (CXR) and computed tomography (CT) scans of the chest in COVID-19 positive patients and describe disease severity as well as other pertinent clinical findings in each case.

2. Methods

This observational study was approved by our hospital's Institutional Review Board. Between 3/12/2020 and 7/1/2020, inpatients and outpatients with positive laboratory examinations for SARS-CoV-2 were identified through the hospital's COVID-19 Emergency Command Center, created to identify and treat patients and manage resources during the COVID-19 pandemic. Diagnoses of COVID-19 infection were made by one of 3 RT-PCR assays:

- Institutional SARS-CoV-2 Real-time RT-PCR assay, which targets two distinct regions within the N gene of SARS-CoV-2 (the causative agent for COVID-19).
- The Hologic Emergency Use Authorization (EUA) SARS-CoV-2 Real-time RT-PCR assay, which targets two conserved regions of the of SARS-CoV-2 ORF1ab gene.
- The CDC designed "2019-nCoV CDC qPCR Probe Assay," distributed through Integrated DNA Technologies.

Of note, our institution implemented universal PCR screen for all inpatient admissions on 3/28/2020, and routine outpatient pre-procedure testing on 3/23/2020.

Any patient 21 years or younger with imaging temporally related to their COVID diagnosis available in our hospital's system was included. All imaging was reviewed and findings graded using Infinitt PACS, version G3 (Infinitt Healthcare Co., Seoul, South Korea) by 6 board certified pediatric radiologists and results were recorded by consensus. Clinical data was abstracted from the patient's electronic medical record.

Pulmonary opacities on radiographs were classified as patchy, dense, streaky, or wedge-like. Radiographs were also reviewed for any additional abnormalities including pleural effusion, pneumothorax, bronchial wall thickening, and hyperinflation. The severity of pulmonary findings was graded subjectively by consensus as mild, moderate, or severe. However, given the small number of cases and relative difficulty in obtaining consensus between the moderate and severe categories, the findings were classified into two groups for analysis: "mild" and "moderate/severe". If patients underwent multiple chest radiographs associated with their illness, all radiographs were evaluated by consensus, however the radiograph with the worst severity grading was used in numeric analysis. CTs were descriptively evaluated for any abnormalities, as determined by consensus.

3. Results

Between 3/12/2020 and 7/1/2020, 130 pediatric patients in our hospital system tested positive for SARS-CoV-2. The majority of patients (n = 106, 81.5%) diagnosed with COVID-19 did not undergo medical imaging. The remaining 24 (18.5%) patients had at least one imaging examination performed in relation to their SARS-CoV-2 positive presentation and were included for review. Demographics are given in Table 1. Twenty-one patients underwent at least 1 chest radiograph, for a total of 37 evaluated chest radiographs. Four patients underwent chest CT scans, while 3 patients received CT scans of the abdomen or pelvis. Two patients underwent abdominal ultrasounds only.

Breakdown of patients with chest radiographs by normal, mild abnormalities, or moderate/severe abnormalities is given in Table 2. Of the 21 patients with CXR, 7 patients had only normal CXRs (33%). The most common abnormality on CXR was a patchy or streaky opacity, each of which occurred in 38% of patients [Figs. 1, 2]. Other abnormal findings included dense opacity (n = 1, 5%), bronchial wall thickening (n = 3, 14%), hyperinflation (n = 1, 5%), wedge-like opacity (n = 1, 5%), and pleural effusion (n = 2, 10%) [Figs. 3–4].

Four patients underwent chest CT. The given clinical reasons for obtaining chest CT were as follows: rule out pulmonary embolism in setting of tachypnea and tachycardia (2 patients), concern for fungal disease in an immunocompromised patient with persistent fevers, and unknown source of fevers/sepsis in a patient with multiple prior negative COVID PCR tests, with PCR returning positive later that day. For the 4 patients who received a chest CT, findings were similar to those reported in adults and in prior pediatric studies, including areas of ill-defined or geographic ground glass opacities (GGO) and denser consolidation with air bronchograms [Fig. 5]. Two patients displayed mild septal thickening with a crazy paving type pattern [Figs. 6, 7].

Table 1
Demographics of COVID-19 positive patients with imaging.

Age	
Range	4 months–21 years
Avg	12.2 years
Median	13 years
Sex	13 Female (54%)
	11 Male (45%)
Hospitalized	17 (71%)
Comorbidities	
Asthma (3 patients)	
Developmental delay and Autism	
Eosinophilic granulomatosis with polyangiitis and asthma	
Cystic Fibrosis	
Lupus with lung disease	
Leukemia	
Abnormal uterine bleeding	
Medulloblastoma	
Type 2 Diabetes and hepatic steatosis	
Presumed inflammatory bowel disease based on clinical history	
Medically complex child (2 patients) - Chronic respiratory support, multiple significant comorbidities	

Table 2
Breakdown by CXR abnormalities.

	Normal CXR	Mild abnormalities	Mod to severe abnormalities
Patients	7 (33%)	7 (33%)	7 (33%)
Age range	7–20 years	4 mo-17 years	2–21 years
# hospitalized	3	5	6
# of patients with prior comorbidities	3	3	6

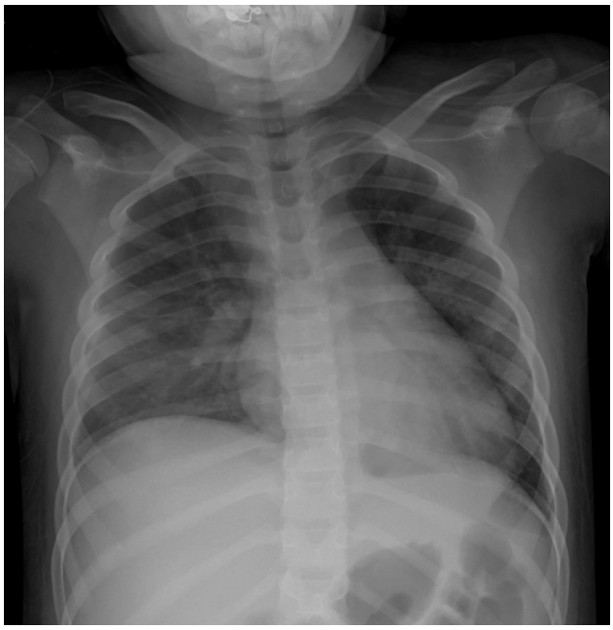

Fig. 1. AP chest radiograph in an 8-year-old COVID-19 positive girl with increased work of breathing and hypoxia. Moderate patchy opacities can be seen in the bilateral lower lobes and there is a small right effusion.

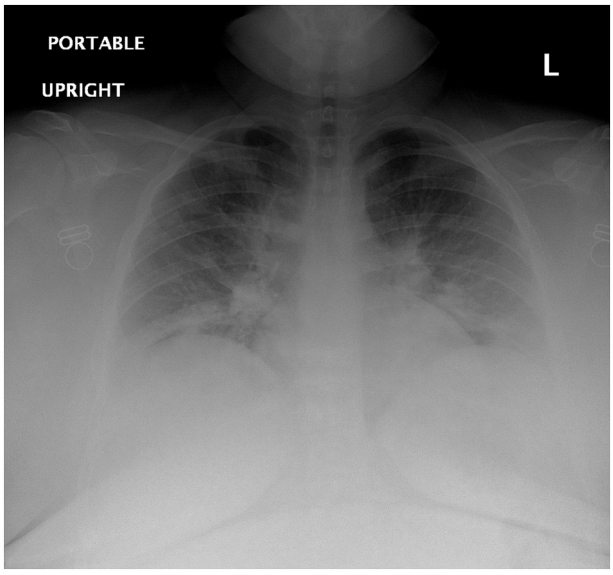

Fig. 2. AP chest radiograph in a 16-year-old COVID-19 positive girl with respiratory distress. Moderate streaky central opacities are seen bilaterally.

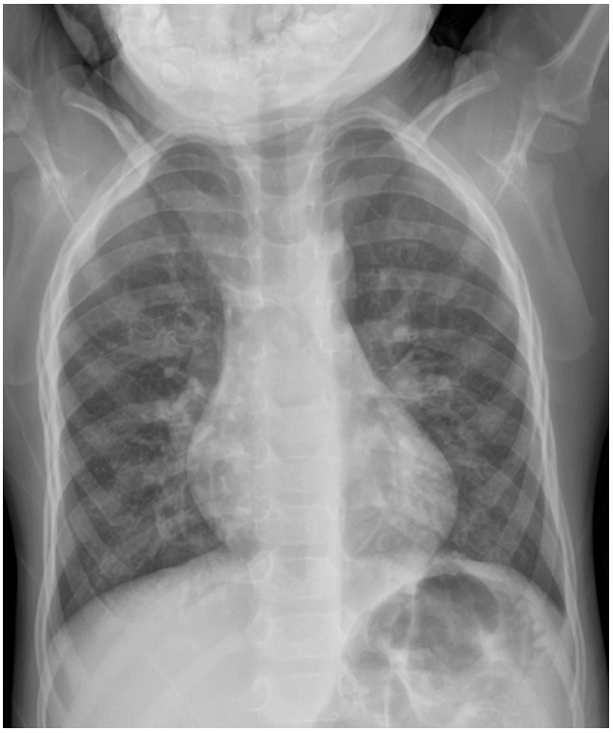

Fig. 3. AP chest radiograph in a 3-year-old COVID-19 positive boy with cough and fever, showing moderate bronchial wall thickening and hyperinflation.

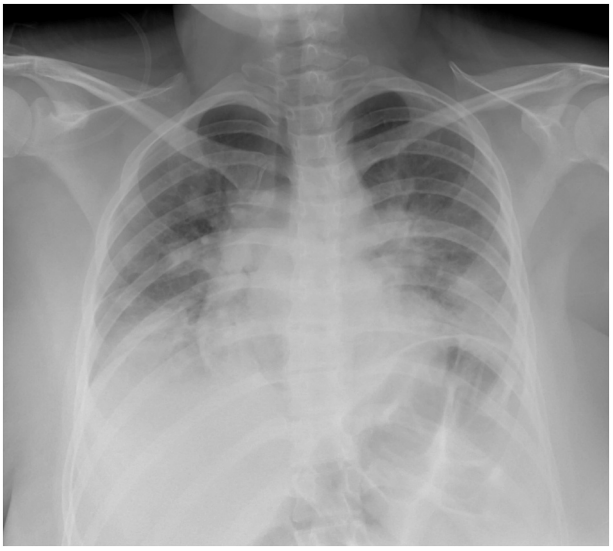

Fig. 4. AP chest radiograph in an 18-year-old female with tachypnea, with underlying lupus and steroid treatment, COVID-19 positive (see Fig. 5). Bilateral moderate to severe dense opacities are seen centrally and at the bases.

Small pleural effusions as well as mild mediastinal and hilar lymphadenopathy were also noted.

Underlying comorbidities were common in patients undergoing imaging related to their COVID-19 diagnosis (Table 1), present in 14 patients (58%), 12 of which underwent CXR. These patients were more likely to have moderate to severe abnormalities on their radiographs. Six out of 12 (50%) patients with CXR and underlying comorbidity had moderate to severe abnormalities on CXR, while only 1 out of 10 (10%) patients with no comorbidities had moderate to severe abnormalities on radiograph.

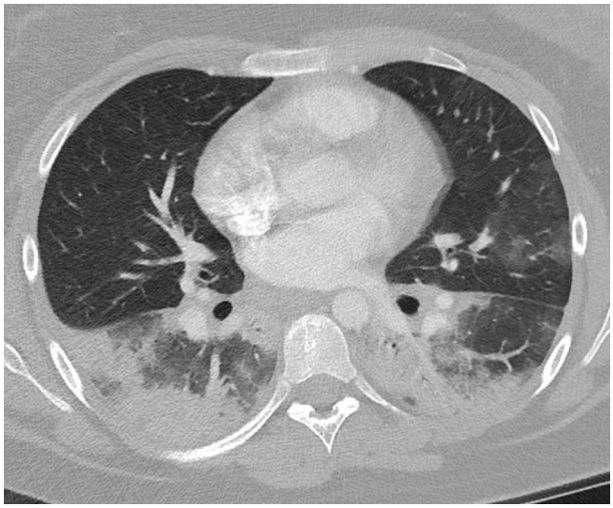

Fig. 5. Axial contrast enhanced CT image in an 18-year-old female with tachypnea, with underlying lupus and steroid treatment, COVID-19 positive (see Fig. 4). Bilateral lower lobe dense opacities are present, with adjacent ill-defined ground glass opacity (GGO) and additional GGO in the peripheral left upper lobe.

Obesity as a comorbidity was evaluated separately, as weight and height measurements were inconsistently available retrospectively in the electronic medical record. Of the 25 patients with imaging, 18 patients had body mass index (BMI) data available and 6 patients only had weight available; 3 patients (17% of BMI available) had a BMI greater than 95th percentile for age and 2 patients (33% of only weight available) had a weight greater than 95th percentile for age. Of these 5 patients: 1 underwent only pelvic ultrasound for abnormal uterine bleeding, 3 had normal CXRs, and 1 patient had moderate to severe patchy opacities on CXR; none underwent CT.

Abdominal imaging was performed in several patients due to pain or concern for acute intra-abdominal process. One patient presented with abdominal pain and was initially COVID-19 negative, but demonstrated adenopathy, mild bowel wall thickening and mesenteric edema on CT. He shortly became PCR positive for SARS-CoV-2 and also developed lung disease. This patient has been previously described by case report.[20] A second COVID-positive patient presented with abdominal pain, fever, emesis and hypotension. Abdominal CT demonstrated minimal lymphadenopathy and trace abdominal free fluid, as well as minimal basilar pulmonary ground glass opacities.

Four patients who received diagnostic imaging were found to be COVID-19 positive, but diagnostic workup revealed an additional diagnosis explaining their presenting symptoms. A 4-month-old child who presented with fever, rigors, and abnormal urinalysis then underwent renal ultrasound to exclude renal abscess in the setting of clinical pyelonephritis. She was found to be COVID-19 positive upon screening for inpatient admission but improved rapidly following initiation of treatment for urinary tract infection.

An 11-year-old patient was diagnosed with acute perforated appendicitis via ultrasound, but did not have any respiratory symptoms during the course of treatment. This is considered likely subclinical COVID-19 disease in the setting of unrelated appendicitis. Likewise, an 18-year-old patient underwent pelvic ultrasound for anemia in the setting of longstanding menorrhagia also tested positive for COVID-19, but was subclinical without respiratory symptoms. Lastly, A 13-year-old patient underwent pelvic CT for evaluation of peri-rectal abscess without any respiratory symptoms, and was incidentally found to be COVID-19 positive upon pre-procedure screening for incision and drainage.

4. Discussion

Children seem to be less frequently affected by COVID-19; in one large review from the Chinese Center for Disease Control of 44,672 patients with COVID-19, only 965 (2.2%) were 0–19 years old.[21] Reports have emerged describing the imaging findings in children, including some systematic reviews of the literature.[22–25] It is uncertain at this time whether children are less frequently infected, less frequently symptomatic, or both. However, other viral infections are known to have

Fig. 7. Axial image from a noncontrast chest CT in a 17-year-old male with abdominal pain, fever, and vomiting, and COVID-19 positive. Ill-defined ground glass opacities can be seen becoming denser posteriorly, with septal thickening.

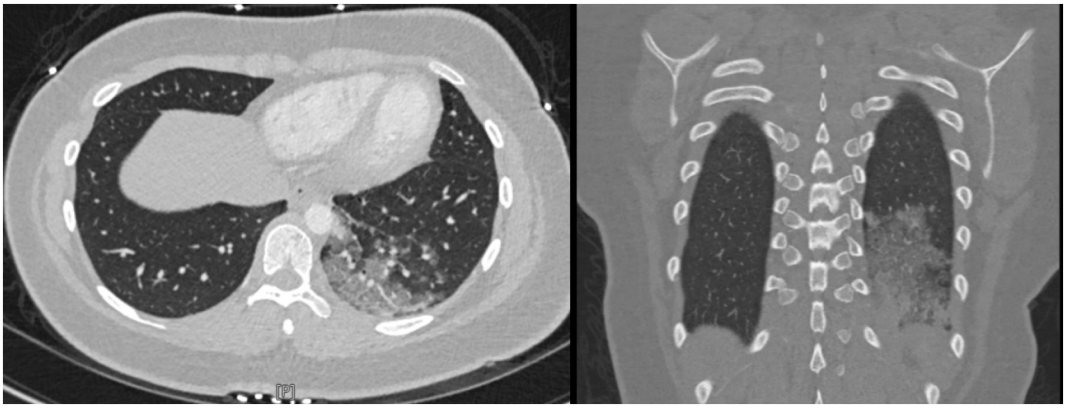

Fig. 6. Axial and coronal contrast enhanced chest CT in a 16-year-old female with cough, fever, and tachycardia, who was COVID-19 positive. The images show geographic ground glass opacities with septal thickening (crazy paving) in the left lower lobe, with increased density near the diaphragm.

significant age variation.[26] Biko et al. also reported only 18% of 313 positive pediatric patients received imaging as a part of their care.[19]

Chest radiograph findings are less commonly reported than CT findings, though some series are present in the literature. Serrano et al. describe radiographs in 44 pediatric patients in Spain.[27] They report findings in 90% of patients, most commonly peribronchial cuffing and ground-glass opacities. A second case series showed 4 out of 10 children had "fluffy infiltrates" on radiograph.[28] Another study showed findings in 27 (46%) of 59 pediatric chest radiographs, described as an increased lung density, usually in the lower lobes, without adenopathy or effusion.[29]

More data are available for the chest CT findings of COVID-19. Adult CT imaging findings have been proposed to fall into four stages: early disease, advanced disease, critical disease, and recovering disease.[16] In early disease, there are few areas of unilateral or bilateral peripheral opacity, which grow to involve many lobes of both lungs in advanced disease. In critical disease lesions become more diffuse and consolidated with dense lung parenchyma and air bronchograms. Recovering disease shows improving opacities. While most current literature describes findings in adults, there are some pediatric case series available.[15–17,28,29] Thirty-one previously healthy children in northern China with COVID-19 had chest CTs, of which 16 were normal. The remainder had mainly peripheral GGO.[17] A similar report of 30 children with CTs collected from multiple sites within China showed only 7 with positive findings.[30] GGO in a peripheral distribution is the predominant pattern of disease and can have associated intra-or interlobular septal thickening (crazy paving pattern). Another case series of 15 children from Wuhan, China with CTs showed 6 normal and 9 with peripheral GGOs.[15] In a series of 20 patients from Wuhan Children's Hospital,[16] 16 were early stage disease with 10 having bilateral lesions. Of these 16 with early disease, consolidation with surrounding ground glass halo was seen in 10, and GGOs were seen in 12. This series included 4 COVID-19 patients with no CT abnormality and none in advanced stages.

Our case series reinforces that overall, imaging is infrequently required in children testing positive for COVID, which concurs with a growing international consensus.[31] Imaging findings on chest radiograph were varied, but as one might expect, tended to be more severe in patients with comorbidities or who required hospitalization. Weight and height data was inconsistently retrospectively available, however most children with recorded BMI or weight greater than 95th percentile for age had normal CXR. Imaging findings on CT were similar to those seen in adults, with ground glass opacities and dense consolidations. Multiple patients demonstrated septal thickening and crazy paving type pattern on CT, which may reflect a degree of superimposed pulmonary edema.

We also found several patients with positive COVID-19 testing who presented with an alternative primary etiology of their symptoms, enforcing the concern for occult COVID-19 infections in children posing a risk for healthcare setting transmission.

5. Limitations

This study was a retrospective review of clinically obtained imaging, and as such subject to variable decision making about which patients required imaging. Imaging was only performed when judged necessary on clinical grounds, so there is likely a higher incidence of undetected imaging abnormalities. In addition, due to the universal screening procedure in place for inpatients and procedural patients, patient collection includes a selection bias towards patients who are COVID positive but without respiratory symptoms. SARS-CoV-2 positivity on PCR was used as the gold standard for infection status. However, the clinical accuracy of this test is difficult to determine in the setting of this sometimes asymptomatic disease.

6. Conclusion

Pediatric COVID-19 has rapidly spread across the globe. Knowledge of the features found both on chest radiographs and on chest CT to identify children with the disease and possibly differentiate from other infections or inflammatory conditions is useful. Importantly, COVID-19 can coexist with unrelated pathology such as appendicitis or urinary tract infection, and all indicated imaging should be pursued with appropriate infection precautions.

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Declaration of competing interest

No disclosures for any author.

References

1. Wuhan Municipal Health Commission. Wuhan municipal health Commission's briefing on the current pneumonia epidemic in our city. Published December 31. Accessed March 14, 2020, http://wjw.wuhan.gov.cn/front/web/showDetail/2019123108989; 2019.
2. Ghebreyesus TA. WHO director-General's opening remarks at the media briefing on COVID-19 - 11 march 2020. Published March 11. Accessed March 14, 2020, https://www.who.int/dg/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19—11-march-2020; 2020.
3. Center for Disease Control. Information about Middle East respiratory syndrome (MERS). Published December. Accessed March 14, 2020, https://www.cdc.gov/coronavirus/mers/downloads/factsheet-mers_en.pdf; 2015.
4. Center for Disease Control. SARS fact sheet. Published January. Accessed March 14, 2020, https://www.cdc.gov/sars/about/fs-SARS.pdf; 2004.
[5] Holshue ML, DeBolt C, Lindquist S, et al. First case of 2019 novel coronavirus in the United States. N Engl J Med 2020;382(10):929–36. https://doi.org/10.1056/NEJMoa2001191.
6. Andone D, Gumbrecht J. New coronavirus cases in California and Oregon are second and third of unknown origin in US. CNN.com. Published February 28. Accessed March 14, 2020, https://www.cnn.com/2020/02/28/health/coronavirus-us-updates-california-patient/index.html; 2020.
7. Acevedo N, Burke M. Washington state man becomes first U.S. death from coronavirus. NBCnews.com. Published February 29. Accessed March 14, 2020, https://www.nbcnews.com/news/us-news/1st-coronavirus-death-u-s-officials-say-n1145931; 2020.
8. Washington State Department of Health. 2019 novel coronavirus outbreak (COVID-19). Accessed March 14, https://www.doh.wa.gov/Emergencies/Coronavirus; 2020.
[9] Mathew RP, Jose M, Toms A. The role of non-contrast chest CT in suspected or confirmed coronavirus disease 2019 (COVID-19) pediatric patients. Indian J Pediatr 2020;87(7):559. https://doi.org/10.1007/s12098-020-03338-4.
[10] Foust AM, Phillips GS, Chu WC, et al. International expert consensus statement on chest imaging in pediatric COVID-19 patient management: imaging findings, imaging study reporting and imaging study recommendations. Radiol Cardiothorac Imaging 2020;2(2):e200214. https://doi.org/10.1148/ryct.2020200214.
[11] Rubin GD, Ryerson CJ, Haramati LB, et al. The role of chest imaging in patient management during the COVID-19 pandemic: a multinational consensus statement from the Fleischner society. Radiology 2020;296(1):172–80. https://doi.org/10.1148/radiol.2020201365.
[12] Expert Panel on Pediatric Imaging, Chan SS, Kotecha MK, et al. ACR appropriateness criteria® pneumonia in the immunocompetent child. J Am Coll Radiol JACR 2020;17(5S):S215–25. https://doi.org/10.1016/j.jacr.2020.01.033.
[13] Patel NA. Pediatric COVID-19: systematic review of the literature. Am J Otolaryngol 2020;41(5):102573. https://doi.org/10.1016/j.amjoto.2020.102573.
[14] Liu T, Huang P, Liu H, et al. Spectrum of chest CT findings in a familial cluster of COVID-19 infection. Radiol Cardiothorac Imaging 2020;2(1):e200025. https://doi.org/10.1148/ryct.2020200025.
[15] Feng K, Yun YX, Wang XF, et al. Analysis of CT features of 15 children with 2019 novel coronavirus infection. Zhonghua Er Ke Za Zhi Chin J Pediatr 2020;58(0):E007. https://doi.org/10.3760/cma.j.issn.0578-1310.2020.0007.
[16] Xia W, Shao J, Guo Y, Peng X, Li Z, Hu D. Clinical and CT features in pediatric patients with COVID-19 infection: different points from adults. Pediatr Pulmonol 2020. https://doi.org/10.1002/ppul.24718. Published online March 5.
[17] Wang D, Ju XL, Xie F, et al. Clinical analysis of 31 cases of 2019 novel coronavirus infection in children from six provinces (autonomous region) of northern China. Zhonghua Er Ke Za Zhi Chin J Pediatr 2020;58(4):E011. https://doi.org/10.3760/cma.j.cn112140-20200225-00138.
[18] Duan Y, Zhu Y, Tang L, Qin J. CT features of novel coronavirus pneumonia (COVID-19) in children. Eur Radiol 2020;30(8):4427–33. https://doi.org/10.1007/s00330-020-06860-3.
[19] Biko DM, Ramirez-Suarez KI, Barrera CA, et al. Imaging of children with COVID-19: experience from a tertiary children's hospital in the United States. Pediatr Radiol 2020. https://doi.org/10.1007/s00247-020-04830-x. Published online September 18.

[20] Noda S, Ma J, Romberg EK, Hernandez RE, Ferguson MR. Severe COVID-19 initially presenting as mesenteric adenopathy. Pediatr Radiol 2020:1–4. https://doi.org/10.1007/s00247-020-04789-9. Published online October 10.
21. Novel Coronavirus Pneumonia Emergency Response Epidemiology Team. The epidemiological characteristics of an outbreak of 2019 novel coronavirus diseases (COVID-19) in China. Zhonghua Liu Xing Bing Xue Za Zhi Zhonghua Liuxingbingxue Zazhi 2020;41(2):145–51. https://doi.org/10.3760/cma.j.issn.0254-6450.2020.02.003.
[22] Katal S, Johnston SK, Johnston JH, Gholamrezanezhad A. Imaging findings of SARS-CoV-2 infection in pediatrics: a systematic review of coronavirus disease 2019 (COVID-19) in 850 patients. Acad Radiol 2020. https://doi.org/10.1016/j.acra.2020.07.031. Published online July. S1076633220304542.
[23] Nino G, Zember J, Sanchez-Jacob R, Gutierrez MJ, Sharma K, Linguraru MG. Pediatric lung imaging features of Covid-19: a systematic review and meta-analysis. Pediatr Pulmonol 2020. https://doi.org/10.1002/ppul.25070. Published online September 14. ppul.25070.
[24] Shelmerdine SC, Lovrenski J, Caro-Domínguez P, Toso S, Collaborators of the European Society of Paediatric Radiology Cardiothoracic Imaging Taskforce. Coronavirus disease 2019 (COVID-19) in children: a systematic review of imaging findings. Pediatr Radiol 2020;50(9):1217–30. https://doi.org/10.1007/s00247-020-04726-w.
[25] Salehi S, Abedi A, Balakrishnan S, Gholamrezanezhad A. Coronavirus disease 2019 (COVID-19): a systematic review of imaging findings in 919 patients. Am J Roentgenol 2020;14:1–7. https://doi.org/10.2214/AJR.20.23034. Published online March.
[26] Lee P-I, Hu Y-L, Chen P-Y, Huang Y-C, Hsueh P-R. Are children less susceptible to COVID-19? J Microbiol Immunol Infect 2020. https://doi.org/10.1016/j.jmii.2020.02.011. Published online February.
[27] Oterino Serrano C, Alonso E, Andrés M, et al. Pediatric chest x-ray in covid-19 infection. Eur J Radiol 2020;131:109236. https://doi.org/10.1016/j.ejrad.2020.109236.
[28] Cai J, Xu J, Lin D, et al. A case series of children with 2019 novel coronavirus infection: clinical and epidemiological features. Clin Infect Dis 2020. https://doi.org/10.1093/cid/ciaa198. Published online February 28.
[29] Palabiyik F, Kokurcan SO, Hatipoglu N, Cebeci SO, Inci E. Imaging of COVID-19 pneumonia in children. Br J Radiol 2020;93(1113):20200647. https://doi.org/10.1259/bjr.20200647.
[30] Steinberger S, Lin B, Bernheim A, et al. CT features of coronavirus disease (COVID-19) in 30 pediatric patients. Am J Roentgenol 2020:1–9. https://doi.org/10.2214/AJR.20.23145. Published online May 22.
[31] Caro-Dominguez P, Shelmerdine SC, et al., Collaborators of the European Society of Paediatric Radiology Cardiothoracic Task Force. Thoracic imaging of coronavirus disease 2019 (COVID-19) in children: a series of 91 cases. Pediatr Radiol 2020;50(10):1354–68. https://doi.org/10.1007/s00247-020-04747-5.