Research Article / Özgün Araştırma

DOI: 10.4274/cayd.galenos.2023.53244
J Pediatr Emerg Intensive Care Med 2023;10:131-8

The Significance of Lung Ultrasonography in Children with COVID-19

Çocuklarda COVID-19 Enfeksiyonunda Akciğer Ultrasonografinin Önemi

Ayla Akca Çağlar[1], Funda Kurt[1], Halise Akça[1,2]

[1]Ankara City Hospital, Clinic of Pediatric Emergency Medicine, Ankara, Turkey
[2]Ankara Yıldırım Beyazıt University Faculty of Medicine, Department of Pediatric Emergency Medicine, Ankara, Turkey

Abstract

Introduction: The infection of new Coronavirus disease-2019 (COVID-19) continues to affect both adults and children worldwide. Although there are studies of adult patients with COVID-19 that defined ultrasound findings, there is limited data available on the diagnostic use of ultrasonography in children. This study is aimed to evaluate the results of bedside lung ultrasonography (LUS) performed in pediatric patients with COVID-19.

Methods: The study included pediatric patients who were diagnosed with COVID-19. All lung areas were visualized on LUS and evaluated together with demographic, clinical, and laboratory data, and chest X-ray (CXR) findings.

Results: An evaluation was made of 102 pediatric patients, comprising 54 girls and 48 boys with a mean age of 9.65±4.78 (min 35 days-max 17) years. Forty-six percent of the patients had respiratory system symptoms, 36% were asymptomatic, and 18% had symptoms other than in the respiratory system. Pathologic findings were determined on CXR in 36% of patients, and on LUS in 57%. The difference in the detection rate of pathologic findings between LUS and CXR was statistically significant (p=0.001). Pathology was observed on LUS in 29 of 65 patients with normal CXR. The sensitivity rate for detecting pathology in patients with respiratory symptoms was 49% on CXR and 77% on LUS (p=0.001).

Conclusion: We determined that the sensitivity of LUS is higher than CXR in demonstrating lung involvement in patients with COVID-19 with respiratory symptoms. LUS may be helpful in the evaluation of pediatric patients with COVID-19 but more studies are needed to prove its feasibility in children.

Keywords: Lung, ultrasound, pediatric, COVID-19, emergency

Öz

Giriş: Yeni Koronavirüs hastalığı-2019 (COVID-19) enfeksiyonu dünya çapında hem yetişkinleri hem de çocukları etkilemeye devam etmektedir. COVID-19'lu yetişkin hastalarda ultrasonografi bulgularını tanımlayan çalışmalar olmasına rağmen, çocuklarda ultrasonografinin tanısal kullanımına ilişkin sınırlı veri mevcuttur. Bu çalışmada, COVID-19'lu çocuk hastalarda yapılan yatak başı akciğer ultrasonografisi (LUS) sonuçlarının değerlendirilmesi amaçlanmaktadır.

Yöntemler: Çalışmaya COVID-19 tanısı almış çocuk hastalar dahil edildi. Tüm akciğer alanları LUS ile görüntülendi ve demografik, klinik ve laboratuvar verileri ve akciğer grafisi (CXR) bulguları ile birlikte değerlendirildi.

Bulgular: Yaş ortalaması 9,65±4,78 (en az 35 gün-en fazla 17) yıl olan 54 kız ve 48 erkek olmak üzere 102 çocuk hasta değerlendirildi. Hastaların %46'sında solunum sistemi semptomları, %36'sı semptomsuz ve %18'inde solunum sistemi dışında semptomlar vardı. Hastaların %36'sında CXR'de, %57'sinde LUS'de patolojik bulgular saptandı. LUS ve CXR arasındaki patolojik bulguların saptanma oranlarındaki fark istatistiksel olarak anlamlıydı (p=0,001). CXR'si normal olan 65 hastanın 29'unda LUS'de patoloji gözlendi. Solunum semptomları olan hastalarda patolojiyi saptamadaki duyarlılık oranı CXR'de %49 ve LUS'de %77 idi (p=0,001).

Sonuç: Solunum semptomları olan COVID-19 hastalarında akciğer tutulumunu göstermede LUS'nin duyarlılığının CXR'den daha yüksek olduğunu belirledik. LUS, COVID-19'lu çocuk hastaların değerlendirilmesinde yardımcı olabilir, ancak çocuklarda uygulanabilirliğini kanıtlamak için daha fazla çalışmaya ihtiyaç vardır.

Anahtar Kelimeler: Akciğer, ultrasonografi, çocuk, COVID-19, acil

Address for Correspondence/Yazışma Adresi: Ayla Akca Çağlar, Ankara City Hospital, Clinic of Pediatric Emergency Medicine, Ankara, Turkey
E-mail: dr.aylaakca@hotmail.com **ORCID ID:** orcid.org/0000-0002-3312-2448
Received/Geliş Tarihi: 07.08.2022 **Accepted/Kabul Tarihi:** 05.01.2023

Introduction

Severe acute respiratory syndrome-coronavirus-2 virus emerged in Wuhan, China, at the end of 2019, and was found to be the agent of the novel Coronavirus disease-2019 (COVID-19), which then spread rapidly across the world. In March 2020, COVID-19 was declared a global pandemic and the infection continues to affect both adults and children worldwide. Respiratory problems are very common, and the symptoms of COVID-19 can range from mild clinical symptoms to acute respiratory distress syndrome and may even result in life-threatening multiorgan failure.[1] Throughout the pandemic, physicians have been searching for appropriate diagnostic methods to diagnose or exclude COVID-19 in patients.[2] Although reverse transcription-polymerase chain reaction (RT-PCR) has become the standard diagnostic tool for COVID-19, it only has a sensitivity of 70%.[3] Although computed tomography (CT) is considered the gold standard as the most rational and specific radiologic method for the diagnosis of COVID-19, it cannot be routinely used on children due to the high radiation content.[4] Therefore, chest X-ray (CXR) has become the preferred imaging method for pediatric patients because it is readily available, provides rapid results, and has lower radiation content than chest CT.

Ultrasound is a non-invasive imaging technique, which is widely used in pediatric emergency departments, and lung ultrasound (LUS) can be used as a reasonable alternative to CXR in the diagnosis of COVID-19. Most of the data related to LUS has been reported to be of benefit in detecting pulmonary pathology in adult patients with COVID-19, and there is little information about the role of LUS in the diagnosis and management of pediatric patients with COVID-19.[5-7] This study is aimed to compare LUS and CXR in respect of the accuracy rates of COVID-19 diagnosis in children.

Materials and Methods

This prospective observational study was conducted between November 2020 and December 2020 in the Pediatric Emergency Department of a tertiary level pediatric referral pandemic hospital in Ankara City Hospital with an average of 75,063 annual pediatric emergency visits, 6750 of them were COVID-19 positive. Ethics Committee approval was obtained for the study (Ankara City Hospital date: 14/10/2020, number: 1170). Informed consent for participation in the study was obtained from the parents or legal guardians of all the patients. The study was conducted with a convenience sample that included both symptomatic and asymptomatic patients aged <18 years with a confirmed diagnosis of COVID-19 and admitted to the hospital by the on-duty physician who performed the ultrasounds. Sample CXR is taken in the routine evaluation of COVID-19, and LUS was also performed on all the current study patients. Data were recorded in respect of age, sex, clinical symptoms and signs on presentation, comorbidities, laboratory test results [hematology parameters, standard C-reactive protein (detection limit 5 mg/L)], radiologic results, and supportive treatment administered on hospital admission. All the medical diagnostic procedures were performed as part of the standard clinical care.

On confirmation of COVID-19 positivity, LUS was performed irrespective of the patient's symptoms. Cases, where suspicion was based on symptoms and/or clinical history, were confirmed through nasopharyngeal PCR before inclusion in the study. Patients were excluded from the study if they were aged <1 month or ≥18 years, if they had comorbidities of chronic lung disease, congenital heart disease, immunodeficiency, congenital or anatomical defects of the airway, or if their parents were not willing to participate in the study.

The patients were assessed according to the symptoms and classified as asymptomatic, if they are with respiratory symptoms (the presence of fever with nasal congestion, tachypnea, dyspnea, cough, or chest pain), and patients with non-respiratory symptoms (fatigue, weakness, sore throat, nausea, vomiting, diarrhea, fatigue, headache). The severity of the disease was defined according to the clinical symptoms and CXR imaging. Disease severity was classified as asymptomatic infection (no clinical sign or symptom, CXR normal), mild (symptoms of upper respiratory tract infection, congestion of the pharynx, no auscultatory abnormalities), moderate (pneumonia, frequent fever, cough, and auscultatory abnormalities with wheezing or rales, and patients with no clinical signs or symptoms, but subclinical lung lesions on CXR), or severe/critical disease [obvious hypoxemia requiring respiratory support (invasive or non-invasive) and intensive care].[8]

All CXR findings were quantitatively evaluated using a 5-point scoring system, which is detailed in reference[9]; score 1: Normal, score 2: Patchy atelectasis and/or hyperinflation and/or bronchial wall thickening, score 3: Focal alveolar consolidation involving no more than one segment or one lobe, score 4: Multifocal consolidation, and score 5: Diffuse alveolar consolidation. Two pediatric emergency physicians with 8 years of experience in pediatric emergency, who were blinded to the all patient's data and LUS findings of patients evaluated the CXR scoring according to this 5-point scoring system. Both specialist physicians' joint decisions was accepted as scoring results. The CXR was considered positive if the score result was 2, 3, 4, or 5.

LUS was performed on all patients in the pediatric emergency department by only one same pediatric emergency physician

with 3 years of point-of-care ultrasound experience, who was blinded to all clinical information such as symptoms, history, other diagnostic tests, outcomes, and findings of CXR. Serial images and video records were obtained from LUS performed with an 7.5-11 MHz linear array transducer. Following the COVID-19 lung ultrasound in emergency department protocol, an examination was made of each hemithorax in six intercostal spaces of the superior and inferior sections of the anterior, lateral, and posterior regions.[10] LUS was performed using a posterior approach with the patient seated or held in the mother's arms, depending on their age. All the necessary precautions were taken against infection transmission including the wearing of personal protective equipment by the operator. The probe was covered with a single-use plastic sheath and the US device was disinfected after each patient to prevent the spread of the virus. Approximately 10-fifteen minutes per patient was allocated for all these procedures.

In the LUS examination of each child, an evaluation was made of the presence of pleural irregularities, subpleural consolidations, B-lines, patchy areas of the white lung, and pleural effusions. The lung was accepted as normal with the visualization of multiple horizontal A-lines (reverberation artifacts of the pleural line appear as a hyperechoic parallel line to the pleural, horizontal artifacts) with normal sliding of the pleural line. B-lines or comet-tail artifacts were defined as hyperechoic vertical lines arising from the pleural line and moving with sliding lung (representing interstitial syndrome) and erased A-lines.

The LUS features were evaluated using the following scores (10); 0: Normal lung sliding, regular pleural line, A-lines with <3 B-lines per vertical inter-costal space, 1: Irregular or thickened pleura and/or ≥3 B-lines, 2: Confluent B-lines, and/or subpleural consolidations (height <1 cm), 3: Confluent B-lines appearing as a "white lung" and/or subpleural consolidations (height ≥1 cm), and 4: Pleural effusion.

Statistical Analysis

Data obtained in the study were analyzed statistically using the Statistical Package for the Social Sciences for Windows Version 20.0 software. Conformity of the data to normal distribution was assessed using the Kolmogorov-Smirnov. Categorical variables were stated as frequency (n) and percentage (%). Continuous variables with normal distribution were stated as mean ± standard deviation values, and those not showing normal distribution as median (minimum-maximum) values. The chi-square test was used in the comparisons of categorical variables, Student's t-test was used in the comparisons of quantitative data with normal distribution, and the Mann-Whitney U test was used in comparisons of continuous variables without normal distribution. The MedCalc Statistical Software was used for the calculations of sensitivity, specificity, and positive and negative predictive values for CXR and LUS. When calculating sensitivity, specificity, and predictive values the CXR was considered negative if the score was 1 and positive if the score was 2, 3, 4, or 5. The LUS was considered negative if the score was 0, and positive if the score was 1, 2, 3, or 4. All statistical tests were two-tailed and a value of $p<0.05$ was considered statistically significant.

In a similar study, the sensitivity of LUS in COVID-19 infection was found to be 88.9%, and the sensitivity of CXR was 51.9%.[11] To determine the appropriate sample size required according to these rates, a power analysis was conducted. To obtain sufficient power (0.80) at the α=0.05 level of significance, a sample size of 46 patients was required.

Results

From the initial enrollment of 114 children, 12 were excluded from the study analyses because of comorbidities (chronic lung disease and congenital heart diseases) or unavailable CXR (Figure 1). Thus, an evaluation was made of 102 children with confirmed COVID-19, comprising 54 girls and 48 boys with a median age of 10 (min: 35 days-max: 17) years. The demographic data and clinical findings of all the patients in the study are shown in Table 1. Of the total patients, 24 were hospitalized, 15 of whom had respiratory symptoms and nine had non-respiratory symptoms. Clinically, the classification of the disease was moderate with respiratory symptoms in six patients, and these patients received oxygen and antibiotic treatments. In nine patients who were classified as mild, monitoring without treatment was performed. None of

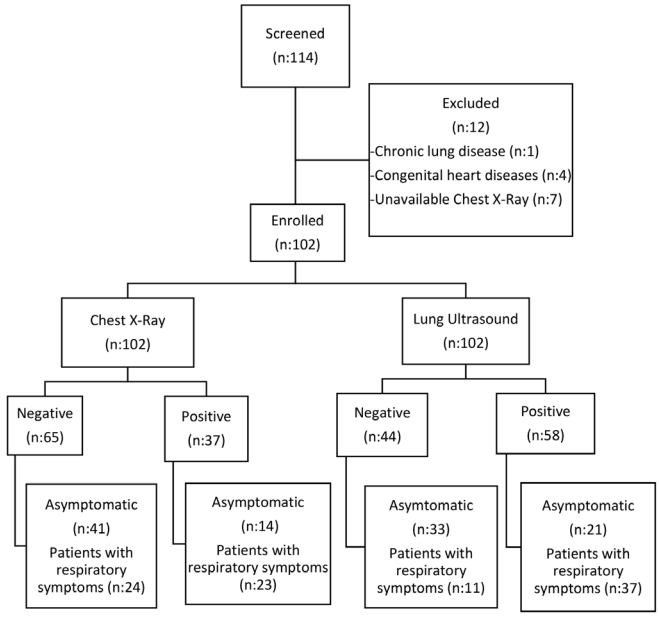

Figure 1. Flow chart documenting participants included in the study

the patients required invasive or non-invasive ventilation. According to the laboratory test results, leukopenia was determined in 55 patients, lymphopenia in 32, and a slight alteration in C-reactive protein levels in 20 patients. During hospitalization, all patients were stable, and all were discharged after follow-up.

CXR was performed on all patients. The CXR images were categorized as normal (score 1) in 65 patients. Abnormal CXR findings were detected in 37 patients (score 2; patchy atelectasis and/or hyperinflation and/or bronchial wall thickening) (Figure 2). Of the 65 patients with a normal radiograph, 41 (63.1%) were asymptomatic, and of the 37 patients with abnormal CXR, 14 (37.8%) were asymptomatic, 20 (54.0%) had mild disease, and three (8.2%) had moderate disease. The radiologic findings were unilateral in 12 (32%) patients (8 right, 4 left) and bilateral in 25 (68%) patients.

All patients underwent LUS without any problems. The time taken to perform LUS was 5-10 minutes. A normal pattern (score 0) was seen on LUS in 44 patients (Figure 3), and abnormalities were determined in 58. In 40 patients, the score was 1 (irregular or thickened pleura and/or ≥3 B-lines) (Figure 4), and the score was 2 in 15 patients (confluent B-lines and/

Table 1. Demographic and clinical findings in a series of 102 children with COVID-19

	Number of patients (%) (n=102)
Age, (median) (min-max)	10 years (35 days-17 years)
Gender	
Female	54 (52.9%)
Male	48 (47.1%)
Symptoms, n (%)	
Respiratory	47 (46.0%)
Non-respiratory	18 (17.6%)
Asymptomatic	37 (36.4%)
Cough	43 (43.1%)
Fever	30 (29.4%)
Fatigue	13 (12.7%)
Headache	10 (9.8%)
Sore throat	7 (6.9%)
Dyspnea	6 (5.9%)
Noisy	5 (4.9%)
Myalgia	5 (4.9%)
Diarrhea	4 (3.9%)
Abdominal pain	4 (3.9%)
Other (loss of smell and taste, joint pain, eye pain)	10 (9.8%)
Duration of symptoms (mean ± SD) (min-max)	2.69±1.43 (2-7) days
Lung disease severity	
Mild	41 (40.2%)
Moderate	6 (5.9%)
Severe	0 (0%)
Laboratory findings, n (%)	
Neutropenia	55 (53.9%)
Lymphopenia	32 (31.3%)
High CRP	20 (19.6%)
Chest X-ray findings	
Normal	65 (63.7%)
Anormal (patchy atelectasis and/or hyperinflation and/or bronchial wall thickening)	37 (36.3%)
Lung ultrasound findings	
Normal (A-line, normal sliding, <3 B-lines per vertical inter-costal space)	44 (43.1%)
Score 1 (Irregular or thickened pleura and/or ≥3 B-lines)	40 (39.3%)
Score 2 [Confluent B-lines and/or subpleural consolidations (height <1 cm)]	15 (14.7%)
Score 3 (Confluent B-lines appearing as a "white lung" and/or subpleural consolidations (height ≥1 cm)	3 (2.9)

COVID-19: Coronavirus disease-2019, SD: Standard deviation

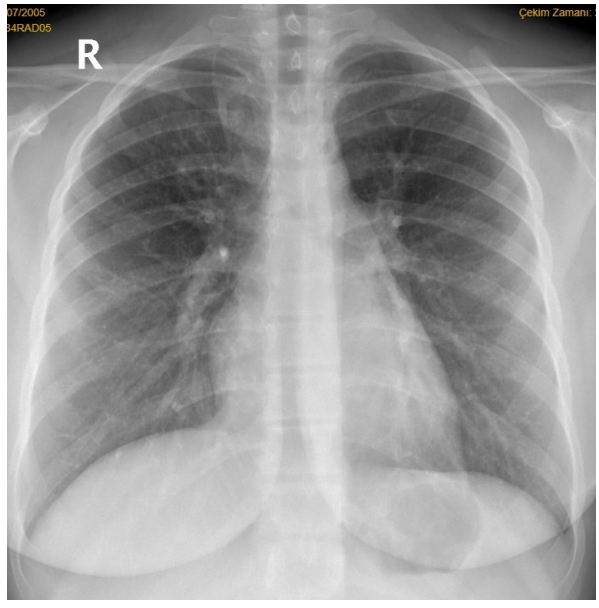

Figure 2. Abnormal chest X-ray image with bronchial wall thickening

Figure 3. Normal lung ultrasound image with a regular pleural line and A-lines

or subpleural consolidations, height <1 cm) (Figure 5), and the score was 3 in three patients (confluent B-lines appearing as a "white lung" and/or subpleural consolidations, height ≥1 cm) (Figure 6). No patient presented with pleural effusion that required mechanical ventilation or admittance to the intensive care unit. Of the 58 patients with LUS abnormalities, 21 (36.2%) were asymptomatic, 33 (56.9%) had mild disease, and four had moderate disease (6.9%). No statistically significant difference was determined between patients with mild disease and those with moderate disease in respect of the LUS scores. Involvement of only the right lung was determined in 14 (24.2%) patients, only the left lung in five (8.6%), and both lungs in 39 (67.2%) patients. The infection was seen to be diffuse in the anterior, lateral, and posterior sections of the lung in four (6.9%) patients and only in the posterior section in the remainder (93.1%).

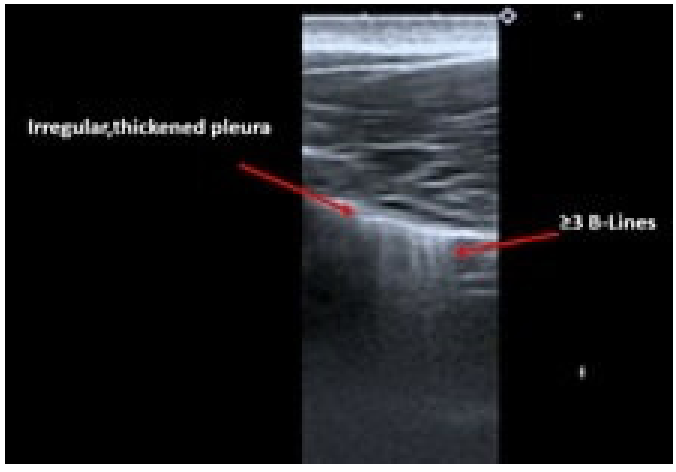

Figure 4. Abnormal lung ultrasound image (score 1) with irregular and thickened pleura and/or ≥3 B-lines

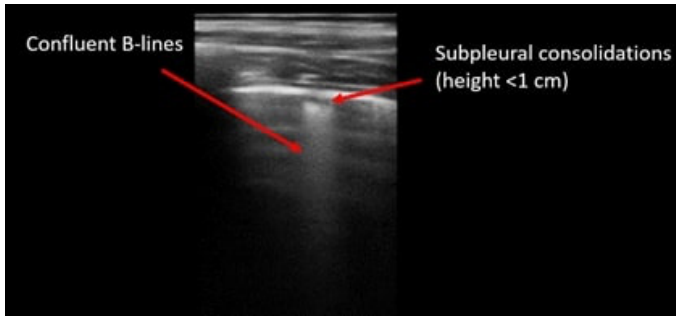

Figure 5. Abnormal lung ultrasound image (score 2) with confluent B-lines, and subpleural consolidations (height <1 cm)

All the CXR and LUS imaging findings are shown in Table 1. Pathologic findings were determined on CXR in 36% of patients, and on LUS in 57%. The difference in the detection rate of pathologic findings between the two imaging modalities was statistically significant (p=0.001). The radiologic findings were determined to be concordant in 29 of 102 patients, and despite a normal CXR in another 29 patients, there was an interstitial B-lines pattern on LUS (grade 1 in 24 and grade 2 in five). In total, eight patients with abnormal CXR were not identified with LUS. Of the 47 patients with respiratory symptoms, the LUS examination showed signs of pulmonary involvement in 36 (77%). The sensitivity in the diagnosis of lung abnormalities in the patients with COVID-19 with respiratory symptoms was determined as 77% [95% confidence interval (CI) 62-88] for LUS and 49% (95% CI: 34-64) for CXR. The specificity values of LUS and CXR were 60% (95% CI: 46-73) and 74% (95% CI: 61-85), respectively. The diagnostic performance comparisons of CXR and LUS are summarized in Table 2. A statistically significant difference was determined between CXR and LUS in respect of sensitivity (p=0.001).

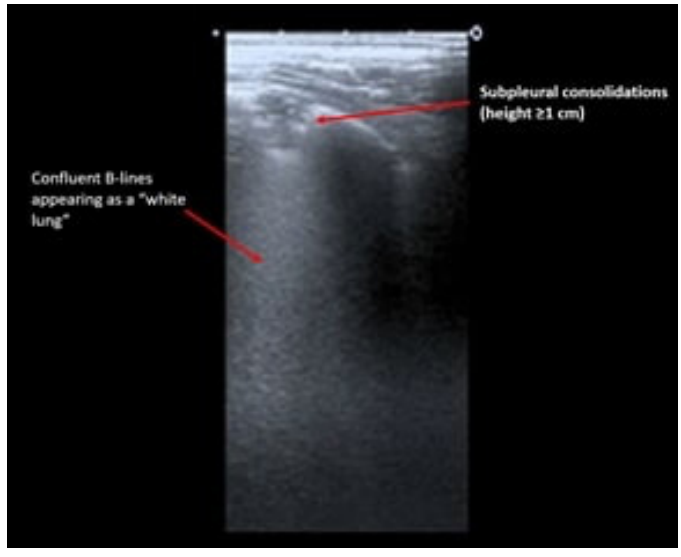

Figure 6. Abnormal lung ultrasound image (score 3) with confluent B-lines appearing as a "white lung" and subpleural consolidations (height ≥1 cm)

Table 2. Comparison of the lung ultrasound and chest X-ray in detection of COVID-19-related lung abnormalities in patients with respiratory symptoms

	Chest X-ray	Lung ultrasound	p
Sensitivity	49% (95% CI 34-64)	77% (95% CI 62-88)	0.001
Specificity	74% (95% CI 61-85)	60% (95% CI 46-73)	0.07
Positive predictive value	62% (95% CI 48-73)	62% (95% CI 53-70)	-
Negative predictive value	63% (95% CI 55-70)	75% (95% CI 63-84)	-

COVID-19: Coronavirus disease-2019, CI: Confidence interval

Chest CT was performed because of symptoms of dyspnea in four patients, two of whom with mild COVID-19 had no abnormal chest CT lung findings, and abnormal findings of ground-glass opacity were determined in the other two children with moderate COVID-19. These findings were compatible with the LUS findings.

Discussion

Imaging has a highly important role in the diagnosis of COVID-19.[12] Although COVID-19 guidelines are well established for adults, data related to the radiologic features of children with COVID-19 remain limited. Chest CT has been suggested to be the most sensitive method for the diagnosis of COVID-19 in adults. RT-PCR positivity of 30-60% has been reported in COVID-19 diagnosis in adults, and 97% sensitivity of chest CT.[13] Considering the adverse effects of ionizing radiation, pediatricians must choose the best radiologic options in terms of benefit and harm. There are several restrictions to the use of chest CT scans in children, including the increased risk of radiation-induced cancer, the rational use of resources, and the risk of contagion to healthy personnel, without providing any additional benefit to the child. It is thought that chest CT may not be necessary for the evaluation of disease severity in children because COVID-19 is relatively mild in children compared with adults, and pediatric patients with COVID-19 have been reported to have a better prognosis with very low mortality.[14-18] Therefore, the use of chest CT is avoided for screening children with COVID-19. The current study results specifically revealed that children were more often classified as asymptomatic or mild, although some studies have reported that moderate cases were more prevalent.[19,20] There have been very few reports of respiratory complications such as dyspnea and hypoxemia and there are limited data in respect of the frequency and extent of lung involvement in pediatric COVID-19.[21] In the current series, 46% of the children had respiratory symptoms, and the most common symptom was cough.

Although some guidelines have been created for the diagnosis, treatment, and prevention of COVID-19 in children,[22-24] there is no consensus on which imaging modality is most appropriate for the evaluation of the extent of lung involvement in children. CXR has been traditionally used as the preferred imaging modality for lower respiratory diseases in children, accordingly, CXR is generally performed in pediatric cases of COVID-19.[12] Previous case series have reported that despite COVID-19 positivity, most children had no findings on CXR, and a normal CXR was seen in most patients with a mild presentation of COVID-19.[20,25,26] In the current study cohort, 36.9% of symptomatic children had a normal radiograph, which was consistent with the literature.[12] This study confirmed that patchy atelectasis and/or hyperinflation and/or bronchial wall thickening were frequent findings in pediatric COVID-19, and these findings were more frequently identified bilaterally in patients on CXR. The inferior sections were seen to be the most affected area. Chest CT was performed in four patients and not performed in the remainder as there was no clinical requirement. Children must be protected from radiation, so if a child is generally well, not performing chest CT can be considered not to be of any clinical significance.

It has been reported to be significant that the auscultatory findings of COVID-19 may be subtle or normal even in the presence of advanced lower airway disease, and screening with CXR may not be sufficient.[27] Therefore, LUS may be of benefit in the evaluation of lung involvement in pediatric cases of COVID-19. Performing LUS in patients with COVID-19 pneumonia has several advantages, including that it is low-cost, readily available, portable, user-friendly, easy to disinfect, and provides accurate, high-quality examinations in the assessment of the progression of pulmonary pathology, without exposure to ionizing radiation.[14] Although there are studies of adult patients with COVID-19 which defined ultrasound findings, there is still a lack of data related to the role of LUS in the diagnosis and management of children with COVID-19.[12,28-30] In a study by Musolino et al.[31], it was reported that in the evaluation of suspicious cases, LUS could support the diagnosis and could be of benefit in the follow-up of patients. Studies in the literature evaluating the CXR and LUS findings in children are few and have only included small patient series. LUS findings are more sensitive than CXR and can successfully identify two-thirds of abnormal cases.[32-34] Most studies in the literature have given sensitivity and specificity for comparing two diagnostic techniques in COVID-19. In the studies, the sensitivity rates were 80.6% (69.1 to 88.6) and 86.4% (72.7 to 93.9) for CXR and LUS, the specificity rates were 71.5% (59.8 to 80.8) and 54.6 (35.3 to 72.6 for CXR and LUS, respectively. In the literature, while the sensitivity of LUS was higher, its specificity was found to be lower than CXR, similar to our study.[35] In the current study with a greater number of patients, LUS was determined to have good accuracy in detecting lung abnormalities compared with CXR. Based on these results, it can be considered that LUS could have a major role in the management of children with COVID-19, irrespective of the presence of respiratory symptoms, because it can be used at the bedside, and it is non-invasive, fast, reproducible, and does not involve radiation.

Peripheral lung lesions, which are easily detected on LUS, are characteristic findings of COVID-19.[31,36,37] In studies of adult patients, the most frequently observed LUS findings have been reported to be separate or confluent B-lines, and thick irregular pleural and subpleural consolidations.[38-40] The most predominant pattern is subpleural consolidations <1 cm, and

in some adult cases, alveolar consolidation has also been described.[41-43] However, in the pediatric patients in this study, consolidations were seen to be less common than the rates reported for adults.[43] The LUS findings in this study showed mostly ≥3 B-lines, and subpleural consolidations <1 cm were seen in only a few patients. In a previous case, a series of 13 pediatric patients with COVID-19, 11 (84%) were determined with positive sonographic findings of the interstitial syndrome and in five cases, these were accompanied by consolidation.[14] Some studies stated that pleural effusion might be seen in severe cases.[12,44,45] In the current study, pleural effusion was not determined in any patients and all patients with mild illness were treated on an outpatient basis with no requirement for additional treatment.

Based on current experience and the results of this study, it can be considered that LUS could play a major role in the management of pediatric patients with COVID-19. LUS could be used to rapidly assess the severity of acute COVID-19-induced pneumonia, and monitor disease progression during follow-up. Changes in LUS findings would also allow the identification of patients at a higher risk of developing respiratory failure, thereby providing the opportunity for these patients to be monitored more closely and for necessary changes to be made to the treatment.[28,41]

Study Limitations

This study had some limitations, primarily that it was conducted in a single center with a limited number of patients. Patients were excluded if they had a negative RT-PCR test result, despite a high suspicion of COVID-19 positivity because of symptoms or close contact with an infected person plus abnormal CXR or chest CT findings. There is a known possibility of false-negative RT-PCR results in patients with abnormal radiologic findings. A second limitation was that all the scans were performed by a single pediatric emergency physician, and the accuracy of the image evaluations could not be confirmed by an ultrasound expert. In addition, the LUS and chest CT could not be confirmed because of the low number of cases, that there may have been selection bias, which also constitutes a limitation. The major limitation of our study was that our results cannot be compared with the gold standard chest tomography, unfortunately, routine tomography could not be performed in children due to high radiation exposure.

All the ultrasound scans were performed during only one same pediatric emergency physician's working hours, which limits the generalizability. False-negative ultrasound or CXR results may have been obtained in the initial stage of the disease, before lung involvement, and therefore, imaging studies should have been repeated after several days. Nevertheless, this study can be considered to provide valuable information because the data in the literature related to pediatric patients with COVID-19 are limited.

Conclusion

We determined that the sensitivity of LUS is higher than CXR in demonstrating lung involvement in patients with COVID-19 with respiratory symptoms. LUS may be helpful in the evaluation of pediatric patients with COVID-19. More studies are needed to prove LUS is applicable in children with COVID-19.

Ethics

Ethics Committee Approval: Ethics committee approval was obtained for the study (Ankara City Hospital date: 14/10/2020, number: 1170).

Informed Consent: Informed consent for participation in the study was obtained from the parents or legal guardians of all the patients.

Peer-review: Internally and externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: A.A.Ç., F.K., H.A., Concept: A.A.Ç., Design: A.A.Ç., Data Collection or Processing: A.A.Ç., F.K., H.A., Analysis or Interpretation: A.A.Ç., F.K., H.A., Literature Search: A.A.Ç., Writing: A.A.Ç.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

References

1. Guan WJ, Ni ZY, Hu Y, Liang WH, Ou CQ, et al. Clinical Characteristics of Coronavirus Disease 2019 in China. N Engl J Med. 2020;382:1708-20.
2. Haak SL, Renken IJ, Jager LC, Lameijer H, van der Kolk BBY. Diagnostic accuracy of point-of-care lung ultrasound in COVID-19. Emerg Med J. 2021;38:94-9.
3. Fang Y, Zhang H, Xie J, Lin M, Ying L, et al. Sensitivity of chest CT for COVID-19: comparison to RT-PCR. Radiology. 2020;296:E115-E17.
4. Prokop M, Van Everdingen W, van Rees Vellinga T, Quarles van Ufford H, Stöger L, et al. CO-RADS: a categorical CT assessment scheme for patients suspected of having COVID-19—definition and evaluation. Radiology. 2020;296:E97-E104.
5. Lerchbaumer MH, Lauryn JH, Bachmann U, Enghard P, Fischer T, et al. Point-of-care lung ultrasound in COVID-19 patients: Inter-and intra-observer agreement in a prospective observational study. Sci Rep. 2021;11:10678.
6. Vetrugno L, Bove T, Orso D, Barbariol F, Bassi F, et al. Our Italian experience using lung ultrasound for identification, grading and serial follow-up of severity of lung involvement for management of patients with COVID-19. Echocardiography. 2020;37:625-7.
7. Soldati G, Smargiassi A, Inchingolo R, Buonsenso D, Perrone T, et al. Proposal for international standardization of the use of lung ultrasound for patients with COVID-19: a simple, quantitative, reproducible method. J Ultrasound Med. 2020;39:1413-9.

8. Fang F, Chen Y, Zhao D, Liu T, Huang Y, et al. Recommendations for the diagnosis, prevention, and control of coronavirus disease-19 in children-the Chinese perspectives. Front Pediatr. 2020;8:553394.
9. Taylor E, Haven K, Reed P, Bissielo A, Harvey D, et al. A chest radiograph scoring system in patients with severe acute respiratory infection: a validation study. BMC Med Imaging. 2015;15:61.
10. Manivel V, Lesnewski A, Shamim S, Carbonatto G, Govindan T. CLUE: COVID-19 lung ultrasound in emergency department. Emerg Med Australas. 2020;32:694-9.
11. Pare JR, Camelo I, Mayo KC, Leo MM, Dugas JN, et al. Point-of-care lung ultrasound is more sensitive than chest radiograph for evaluation of COVID-19. West J Emerg Med. 2020;21:771-8.
12. Palabiyik F, Kokurcan SO, Hatipoglu N, Cebeci SO, Inci E. Imaging of COVID-19 pneumonia in children. Br J Radiol. 2020;93:20200647.
13. Ai T, Yang Z, Hou H, Chen C, Lv W, et al. Correlation of chest CT and RT-PCR testing for coronavirus disease 2019 (COVID-19) in China: a report of 1014 cases. Radiology. 2020;296:E32-E40.
14. Parri N, Lenge M, Cantoni B, Arrighini A, Romanengo M, et al. COVID-19 in 17 Italian pediatric emergency departments. Pediatrics. 2020;146:e20201235.
15. Zhang Y, Xie R-M, He Y-L, Xing LH, Dong L, et al. Clinical and imaging features of pediatric COVID-19. Ital J Pediatr. 2020;46:1-9.
16. Han YN, Feng ZW, Sun LN, Ren XX, Wang H, et al. A comparative-descriptive analysis of clinical characteristics in 2019-coronavirus-infected children and adults. J Med Virol. 2020;92:1596-602.
17. Balasubramanian S, Rao NM, Goenka A, Roderick M, Ramanan AV. Coronavirus disease 2019 (COVID-19) in children-what we know so far and what we do not. Indian Pediatr. 2020;57:435-42.
18. Sun D, Li H, Lu XX, Xiao H, Ren J, et al. Clinical features of severe pediatric patients with coronavirus disease 2019 in Wuhan: a single center's observational study. World J Pediatr. 2020:1:251-9.
19. Lu X, Zhang L, Du H, Zhang J, Li YY, et al. SARS-CoV-2 infection in children. N Engl J Med. 2020;382:1663-5.
20. Dong Y, Mo X, Hu Y, Qi X, Jiang F, et al. Epidemiology of COVID-19 among children in China. Pediatrics. 2020;145:e20200702.
21. Gregori G, Sacchetti R. Lung ultrasound in outpatient approach to children with suspected COVID 19. Ital J Pediatr. 2020;46:171.
22. Giorno EP, De Paulis M, Sameshima YT, Weerdenburg K, Savoia P, et al. Point-of-care lung ultrasound imaging in pediatric COVID-19. Ultrasound J. 2020;12:50.
23. Shen KL, Yang YH, Jiang RM, Wang TY, Zhao DC, et al. Updated diagnosis, treatment and prevention of COVID-19 in children: experts' consensus statement (condensed version of the second edition). World J Pediatr. 2020;16:232-9.
24. Zimmermann P, Curtis N. Coronavirus infections in children including COVID-19: an overview of the epidemiology, clinical features, diagnosis, treatment and prevention options in children. Pediatr Infect Dis J. 2020;39:355-68.
25. Lu Y, Wen H, Rong D, Zhou Z, Liu H. Clinical characteristics and radiological features of children infected with the 2019 novel coronavirus. Clin Radiol. 2020;75:520-5.
26. Chung M, Bernheim A, Mei X, Zhang N, Huang M, et al. CT imaging features of 2019 novel coronavirus (2019-nCoV). Radiology. 2020;295:202-7.
27. Walsh P, Hankins A, Bang H. Point of care lung ultrasound is useful when screening for CoVid-19 in Emergency Department patients. medRxiv. 2020.
28. Musolino AM, Supino MC, Buonsenso D, Papa RE, Chiurchiù S, et al. Lung ultrasound in the diagnosis and monitoring of 30 children with coronavirus disease 2019. Pediatr Pulmonol. 2021;56:1045-52.
29. Buonsenso D, Piano A, Raffaelli F, Bonadia N, de Gaetano Donati K, et al. Novel coronavirus disease-19 pnemoniae: a case report and potential applications during COVID-19 outbreak. Eur Rev Med Pharmacol Sci. 2020;24:2776-80.
30. Caro-Dominguez P, Shelmerdine SC, Toso S, Secinaro A, Toma P, et al. Thoracic imaging of coronavirus disease 2019 (COVID-19) in children: a series of 91 cases. Pediatr Radiol. 2020;50:1354-68.
31. Musolino AM, Supino MC, Buonsenso D, Ferro V, Valentini P, et al. Lung ultrasound in children with COVID-19: preliminary findings. Ultrasound Med Biol. 2020;46:2094-8.
32. Hizal M, Aykac K, Yayla BC, Yilmaz A, Altun D, et al. Diagnostic value of lung ultrasonography in children with COVID-19. Pediatr Pulmonol. 2021;56:1018-25.
33. Türe E, Korkmaz MF, Aksoy FD, Ceylan Demirbaş B, Menekşe B, et al. Point-of-care lung ultrasound findings in the pediatric emergency clinic during the COVID-19 pandemic. J Clin Ultrasound. 2021;49:85-90.
34. Feng X, Tao X, Zeng L, Wang WQ, Li G. [Application of pulmonary ultrasound in the diagnosis of COVID-19 pneumonia in neonates]. Zhonghua Er Ke Za Zhi. 2020;58:347-50.
35. Islam N, Ebrahimzadeh S, Salameh JP, Kazi S, Fabiano N, et al. Thoracic imaging tests for the diagnosis of COVID-19. Cochrane Database Syst Rev. 2021;3:CD013639.
36. Soldati G, Smargiassi A, Inchingolo R, Buonsenso D, Perrone T, et al. Is there a role for lung ultrasound during the COVID-19 pandemic? J Ultrasound Med. 2020;39:1459-62.
37. De Rose C, Inchingolo R, Smargiassi A, Zampino G, Valentini P, et al. How to Perform Pediatric Lung Ultrasound Examinations in the Time of COVID-19 J Ultrasound Med. 2020;39:2081-2.
38. Volpicelli G, Gargani L. Sonographic signs and patterns of COVID-19 pneumonia. Ultrasound J. 2020;12:22.
39. Sultan LR, Sehgal CM. A review of early experience in lung ultrasound in the diagnosis and management of COVID-19. Ultrasound in Med Biol. 2020;46:2530-45.
40. Yasukawa K, Minami T. Point-of-care lung ultrasound findings in patients with COVID-19 pneumonia. Am J Trop Med Hyg. 2020;102:1198-202.
41. Guitart C, Suárez R, Girona M, Bobillo-Perez S, Hernández L, et al. Lung ultrasound findings in pediatric patients with COVID-19. Eur J Pediatr. 2021;180:1117-23.
42. Peng QY, Wang XT, Zhang LN; Chinese Critical Care Ultrasound Study Group (CCUSG). Findings of lung ultrasonography of novel corona virus pneumonia during the 2019–2020 epidemic. Intensive Care Med. 2020;46:849-50.
43. Volpicelli G, Lamorte A, Villén T. What's new in lung ultrasound during the COVID-19 pandemic. Intensive Care Med. 2020;46:1445-48.
44. Xia W, Shao J, Guo Y, Peng X, Li Z, et al. Clinical and CT features in pediatric patients with COVID-19 infection: Different points from adults. Pediatr Pulmonol. 2020;55:1169-74.
45. Duan YN, Zhu YQ, Tang LL, Qin J. CT features of novel coronavirus pneumonia (COVID-19) in children. Eur Radiol. 2020;30:4427-33.