Lung ultrasound findings in pediatric patients with COVID-19.

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Research Article

Abstract

During the pandemic caused by the novel coronavirus (COVID-19), lung ultrasound has been used to diagnose and monitor respiratory condition. The aim of the study was to describe lung ultrasound findings in children with a COVID-19 infection. Patients younger than 18 years old and positive for COVID-19, admitted to pediatric tertiary referral hospital were included. They were divided into two groups depending on the presence of respiratory symptoms. Lung ultrasound results were categorized into three degrees of aeration loss: normal, moderate, and severe; and into three patterns: viral or bacterial pneumonia, and atelectasis.

Sixteen patients were recruited. The median age was 11 years old (IQR 2.8-12). Four children (25%) required admission to the intensive care unit. Six patients (37.5%) presented with respiratory symptoms. All of them (100%) showed moderate-to-severe aeration loss on lung ultrasound. A viral pneumonia pattern was observed in four cases (66.6%). Ten patients (62.5%) presented with non-respiratory symptoms, lung ultrasound showed moderate-to-severe aeration loss in nine (90%). Three (30%) were diagnosed of multisystem inflammatory syndrome and lung ultrasounds showed severe aeration loss and bilateral pleural effusion.

Conclusions: Children with COVID-19 and respiratory symptoms showed a viral pneumonia pattern with moderate-to-severe aeration loss upon the lung ultrasound assessment.

Introduction

In recent years, lung ultrasound (LUS) has emerged as a bedside tool that's useful to identify and monitor many respiratory pathologies[1,2], especially in intensive care units.

When the pandemic related to the novel coronavirus (COVID-19) emerged in China in December 2019, computed tomography (CT) was initially recommended in order to detect early alterations in infected patients and to monitor lung changes[3]. Due to the high contagiousness of COVID-19 and the hemodynamic and respiratory instability of some patients, a CT scan did not seem to be the best option. A recent article suggested that children present milder forms of COVID-19 than adults and therefore the use of CT scans should be limited in this population[4]. Chest X-ray (CXR) is also a routinely used tool for diagnosing respiratory diseases, including COVID-19 pneumonia, but it has relatively low sensitivity and accuracy[5]. For these reasons, LUS has been increasingly used for the diagnosis of respiratory conditions, including COVID-19[5,6]. In a recent Chinese report reflecting a study performed on adults, LUS features were related to the severity of the disease[7]. Moreover, CT and LUS have been compared and have shown a good correlation[8]. Some ultrasound patterns are currently being identified in COVID-19 patients, and having the ability to define and recognize these patterns might be extremely helpful in determining which patients are most at risk[9]. What's more, when LUS is performed by trained clinicians, it may help to stratify the risk of respiratory failure in suspected COVID-19 patients[10]. Despite most of the available

information referring to the adult population[6], there are recent studies that describe the use of LUS in children with COVID-19[11].

The aim of the study was to describe LUS patterns in children with a COVID-19 infection and respiratory symptoms and LUS patterns in COVID-19 patients with non-respiratory symptoms. A secondary objective was to analyze if the LUS pattern correlated with the severity.

Materials And Methods

This was a prospective observational study performed at the Hospital Sant Joan de Déu, a pediatric tertiary referral hospital. Patients younger than 18 years old admitted to the hospital with a positive real-time polymerase chain reaction (PCR) result for COVID-19 or a positive COVID-19 IgM/IgG enzyme-linked immunosorbent assay (ELISA) result, were included. PCR was carried out in accordance with European Centre for Disease Prevention and Control standards, using nasopharyngeal swabs. The study was approved by the institutional review board and by the local Ethics Committee, and parental informed consent was required. The research study followed Declaration of Helsinki recommendations.

For each patient, we obtained data on the age at admission, sex, severity as measured by the Pediatric Risk of Mortality Score III [PRISM III][12], length of pediatric intensive care unit (PICU) and hospital stay, respiratory and hemodynamic support needed, and mortality.

Respiratory symptoms were described as the presence of tachypnea, shortness of breath, and/or cough. Acute respiratory failure was defined as a PaO_2 of < 60mmHg or an SaO_2 of < 88% on room air and/or an acute increase in $PaCO_2$ above 50mmHg[13]. Multisystem inflammatory syndrome in children (MIS-C) was defined following the WHO case definition[14].

LUS performance

LUS examinations were performed by trained physicians from the PICU, who wore the appropriate personal protective equipment. The LUS was carried out at the patient's bedside, using a 12 MHz lineal probe, screening the six pulmonary sections (parasternal, anterolateral, and posterior areas)[15]. In order to minimize the spread of the virus and other microbes, LUS was performed with the probe protected by a single-use plastic cover, and an ultrasound transmission gel in a single use package. After the examination, all the material was cleaned correctly[16,17].

Lung patterns were classified according to the degree of aeration loss (normal lung sliding, moderate loss of aeration, and severe loss of aeration), and to the presence and type of consolidation (subpleural consolidation pattern of <1 cm as viral pneumonia, consolidation with the "shred sign" and bronchogram as bacterial pneumonia, and consolidation with a tissue-like pattern without bronchogram as

atelectasis)[18,19,20,21]. Figure 1 shows how the patients were classified based on the LUS findings as regards aeration loss and lung patterns.

A statistical analysis was performed using the IBM SPSS 25.0 Statistics® program. Categorical variables were indicated as frequency (n) and percentage (%), whereas continuous variables were summarized as median and interquartile range (IQR). The comparison of categorical variables was performed using the χ2-test or Fisher's exact test. Continuous variables were compared with the Mann-Whitney U test. Probability values of less than 0.05 were considered statistically significant.

Results

Sixteen patients were recruited during the study period. The patients' median age was 11 years old (IQR 2.8-12) and 11 (68.8%) cases were males. Patients were divided into two groups: there were six patients with respiratory symptoms and ten patients with non-respiratory symptoms. The second group was comprised of three patients with MIS-C, two with febrile syndromes, one with a urinary tract infection (UTI), one with gastroenteritis, two with lymphadenitis, and one with appendicitis. From the total sample, four patients required PICU admission: two suffering from acute respiratory failure, requiring mechanical ventilation, and two due to MIS-C (Table 1 and Figure 2). Table 1 summarizes the main characteristics of the patients. A schematic distribution of the patients by their clinical features and the LUS findings is included in Figure 2. The median time required to carry out LUS was 8 minutes (IQR 6.5-9). No complications were detected during the procedure.

- *Patients with respiratory symptoms*

There were 6/16 (37.5% of the total sample) patients with a positive PCR test for COVID-19 and respiratory symptoms. Four of these patients (4/6, 66.6%) were admitted to the hospitalization ward: three with pneumonia and one with a diagnosis of MIS-C. All four presented mild symptoms, requiring a maximum FiO_2 of 0.36 through either a nasal cannula or an oxygen mask. LUS showed moderate-to-severe aeration loss in all patients (4/4, 100%). Regarding the pattern found: 2/4 cases (50%) had viral pneumonia, one had no consolidation (25%), and the MIS-C patient (25%) had basal atelectasis due to pleural effusion. Two of these patients required PICU admission (2/6, 33.3%) and mechanical ventilation due to respiratory failure, and both of them had severe aeration loss and a viral pneumonia pattern on LUS (Figure 2).

- *Patients with non-respiratory symptoms*

There were 10/16 (62.5% of the total sample) COVID-19 patients with other, non-respiratory symptoms; eight of these patients were admitted to the hospitalization ward. LUS showed moderate-to-severe aeration loss in eight of these patients (80%), a viral pneumonia pattern in two of them (20%), and atelectasis in two other patients (20%). Of the patients with a MIS-C diagnosis, 2/3 (67%) required PICU admission because of their hemodynamic condition. LUS showed severe aeration loss in both; one had a

large consolidation with air bronchograms in the right base of the lung and was eventually diagnosed with a community-acquired bacterial infection (Figure 2).

Discussion

During this global respiratory pandemic, LUS has been referred to as a key tool in the clinical management of patients with COVID-19-related lung injury[22].

Even though we describe a small sample of pediatric patients, it might be a representative picture of what we could expect to find on the lung ultrasounds of children with a COVID-19 infection. In adults, it has been described that LUS findings in COVID-19 patients are similar to those extensively described in patients with other types of pneumonia, including various forms of B-lines, an irregular or fragmented pleural line, consolidations, pleural effusion, and absence of lung sliding[23]. In the COVID-19 patients described in this study, LUS showed multiform vertical artifacts and separate and coalescent B-lines, classified as moderate-to-severe aeration loss. The viral pneumonia pattern has been found to be the most predominant pattern and alveolar consolidation was described in some cases. These results and patterns have been likely defined in adults[7,23]. However, consolidations are less common in our pediatric patients than what is typically described in adults[23].

The classification of both findings seems to be correlated with the severity of the lung injury. A recent paper concludes that there is a high concordance between radiologic and LUS findings, suggesting that LUS is a reasonable method to detect lung abnormalities in children with COVID-19[17].

Recently, clusters of children and adolescents with a multisystem inflammatory condition sharing features with Kawasaki disease and toxic shock syndrome have been described. In our sample, four patients presented with MIS-C[14, 24,25,26]. Even though three of those patients presented with non-respiratory symptoms, LUS showed severe loss of aeration in all of them. This was probably secondary to the associated capillary leakage, and also to the cardiogenic shock in those who required PICU admission.

LUS findings differ depending on the presence of respiratory symptoms and their severity. In our experience, we would say that on the one hand, patients with acute COVID-19 disease with severe respiratory failure have a moderately or severely altered LUS, with no cases of a normal or mildly altered LUS. On the other hand, patients with mild or non-respiratory symptoms have surprisingly impressive LUS alterations. LUS findings always should be interpreted in light of the clinical context[17].

We would like to mention that we're aware that there may be concern about the safety of using this technique in these patients due to the contagiousness of COVID-19. However, it has been demonstrated that the same clinician can safely perform the clinical examination and the bedside LUS during the same exploration[11]. Therefore, no other clinicians need to come into contact with the patient[11]. When pulmonary condition can be monitored using LUS, the patient does not need to be moved around the

hospital to undergo a CT scan or a chest X-ray, so neither people moving in the corridors nor the radiology technicians come into contact with the patient. All these strategies help to reduce physicians' exposure and halt the spread of the virus. Moreover, combined with the clinical evaluation, LUS may help clinicians to monitor the evolution of lung disease until its resolution[22]. We would like to highlight that no physician got infected despite doing bedside LUS.

Based on our experience, we consider that LUS might have major utility for the management of children with COVID-19, regardless of whether they have respiratory symptoms, due to its safety, low cost, and point-of-care use. It could be used to quickly assess the severity of acute COVID-19-induced pneumonia, and to track the evolution of the disease during follow-up. It might also allow physicians to identify the patients who are at a higher risk of poor evolution.

We acknowledge that this study has some limitations. The sample might be quite small, and it is a single-center study, so the results may not be able to be extrapolated to other populations. Another limitation of LUS is that it cannot detect lesions that are deep within the lungs. Despite this, we believe that it provides valuable information, as there is limited data regarding pediatric patients with this condition.

Conclusions

LUS could improve how we assess children diagnosed with COVID-19. Two LUS patterns were ascertained: patients with acute respiratory symptoms had moderate-to-severe aeration loss with a viral pneumonia pattern. Patients with MIS-C had moderate-to-severe aeration loss without a viral pneumonia pattern. The presence of consolidation on an LUS may be due to bacterial cross-contamination. Therefore, LUS can be a useful tool to diagnose and monitor patients throughout their battle with COVID-19.

Declarations

Author Contributions:

Dra C. Guitart conceptualized and designed the study, drafted the initial manuscript, and reviewed and revised the manuscript.

Drs Suárez, Girona, Bobillo-Pérez, Hernández, Cambra designed the data collection instruments, collected data, carried out the initial analyses, and reviewed and revised the manuscript.

Prof Balaguer and Prof Jordan conceptualized and designed the study, coordinated and supervised data collection, and critically reviewed the manuscript for important intellectual content.

All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

Compliance with Ethical Statements

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Tables

Table 1. Demographic and clinical data.

	Total (n=16)	COVID-19 and RS (n=6)	COVID-19 and n-RS (n=10)	p value
Male sex n (%)	11 (68.8)	5 (83.3)	6 (54.5)	0.635
Age (days) Median (IQR)	9.4 (0.82-12.7)	13.3 (10.5-17.2)	2.1 (0.33-11)	0.123
Comorbidities None Bronchitis Oncologic disease Congenital malformation	13 (81.3) 1 (6.3) 1 (6.3) 1 (6.3)	4 (66.7) 1 (16.7) 1 (16.7) 0 (0)	9(90) 0 (0) 0 (0) 1 (10)	0.845
PRISM III (Median (IQR)	0 (0-9.5)	0 (0-14)	0 (0-2)	0.335
PICU length (days) Median (IQR)	7 (4-25)	0 (0-10)	0 (0-1.75)	0.652
Ward length (days) Median (IQR)	5 (4-9.5)	7 (4-15.2)	4 (3-7)	0.297
Oxygen therapy n (%)	8 (50)	6 (100)	2 (25)	<0.01
HFNC n (%)	2 (12.5)	2 (33.3)	0 (0)	0.125
NIV n (%)	3 (18.8)	2 (33.3)	1 (10)	0.304
CMV n (%)	3 (18.8)	1 (16.7)	2 (20)	0.696
Inotropes n (%)	3 (18.8)	1 (16.7)	2 (20)	0.696

RS: respiratory symptoms; n-RS: non-respiratory symptoms; MIS: multi-systemic syndrome; UTI: urine tract infection; PICU: paediatric intensive care unit; O_2: oxygen therapy; HFNC: high flow nasal canula; NIV: non-invasive ventilation; CMV: conventional mechanical ventilation.
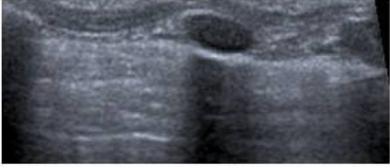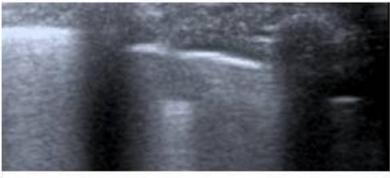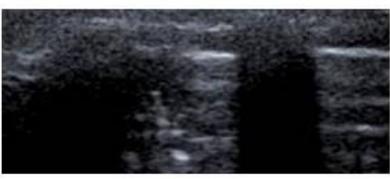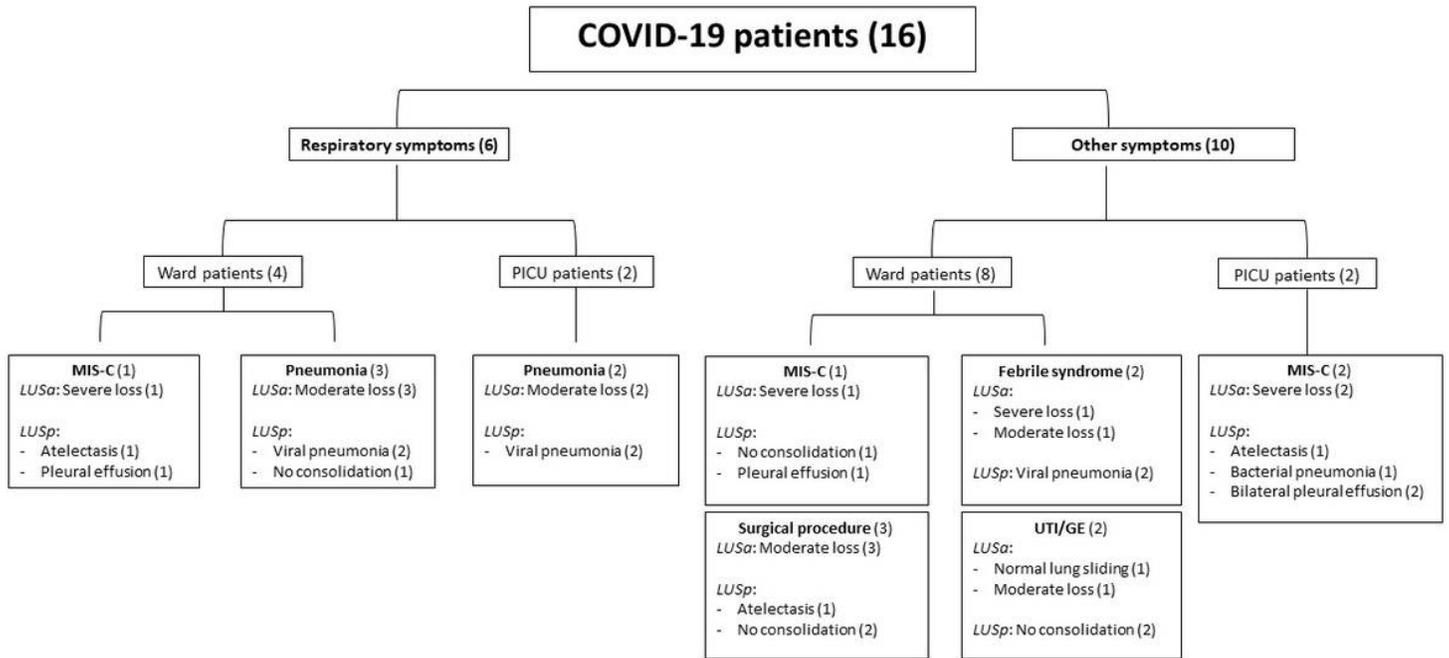
Figures

Aeration patterns	
	Normal Lung sliding: A-lines with less than 2 B-lines
	Moderate loss of aeration: multiple and well defined B-lines
	Severe loss of aeration: multiple and coalescent B-lines
Consolidations	
	Viral pneumonia: confluent B-lines with little subpleural consolidations
	Bacterial pneumonia: Consolidation with bronchogram or small hypoechoic images or subpleural consolidations with bronchogram
	Atelectasis(×): consolidation without bronchogram nor vascularisation **Pleural effusion(*):** anechoic space between the two pleura

Figure 1

Aeration patterns and consolidation.

Figure 2

Abbreviations: GE: gastroenteritis; LUS: lung ultrasound; LUSa: LUS aeration; LUSp: LUS pattern; MIS: multi-system inflammatory syndrome; PICU: pediatric intensive care unit; UTI: urine tract infection.