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RESEARCH ARTICLE

Usefulness of lung ultrasound in the evaluation of children with lower respiratory tract infection in the emergency room

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Abstract

Background: *Lung ultrasound is a bedside tool that allows the evaluation of pulmonary parenchymal involvement in pediatric patients through the lung ultrasound score (LUS). We aimed to evaluate a group of patients under 3 years of age with lower respiratory tract infections using LUS at the Hospital Infantil del Estado de Sonora.* **Methods:** *We included patients younger than 3 years admitted to the emergency department with lower respiratory tract infections. A lung ultrasound was performed within the first 24 h of admission to the emergency department and evaluated using LUS. We analyzed age, sex, etiology of infection, days of stay, use of mechanical ventilation, Downes scale, failure of mechanical ventilation on admission, and mortality. Descriptive analysis was performed with frequencies and percentages for qualitative variables and medians and interquartile intervals for quantitative variables. Differences in the distribution of LUS variables were evaluated with the Fishers' exact test and Student's t-test.* **Results:** *We included a total of 19 patients with lower respiratory tract infections, 73.7% with bronchiolitis. Fifty percent of the cases scored 7 on the LUS, 91.7% were admitted to the pediatric intensive care unit, and 53.8% required invasive mechanical ventilation.* **Conclusions:** *The use of LUS in lower respiratory tract infections can predict the need for PICU admission, the use of invasive ventilatory support, and prolonged hospital stay.*

Keywords: *Ultrasonography. Child. Bronchiolitis. Critical care*

Utilidad de ecografía pulmonar en la valoración de niños con infección respiratoria baja en urgencias

Resumen

Introducción: *El ultrasonido pulmonar es una herramienta a pie de cama que permite evaluar la afectación del parénquima pulmonar en pacientes pediátricos por medio de la escala de LUS (lung ultrasound score, por sus siglas en inglés). El objetivo del estudio fue evaluar a niños menores de 3 años con infección respiratoria baja mediante la escala de LUS, en el Hospital Infantil del Estado de Sonora.* **Métodos:** *Se incluyeron pacientes menores de 3 años que ingresaron al Servicio de Urgencias con infección respiratoria baja. Se realizó ecografía pulmonar en las primeras 24 horas de ingreso a urgencias y se evaluó mediante la escala de LUS. Se analizó, edad, sexo, etiología de la infección, días de estancia, uso de terapia ventilatoria, escala de Downes, fracaso a la terapia ventilatoria de ingreso y mortalidad. Se realizó un análisis descriptivo por medio de frecuencia y porcentaje para las variables cualitativas y para las cuantitativas con mediana e intervalo intercuartil.*

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Date of reception: 29-04-2023
Date of acceptance: 31-07-2023
DOI: 10.24875/BMHIM.23000073

Available online: 21-12-2023
Bol Med Hosp Infant Mex. 2023;80(6):361-366
www.bmhim.com

Las diferencias en la distribución de las variables por la escala de LUS con la prueba exacta de Fisher y la t de Student.
Resultados: *Se identificaron 19 pacientes con infección pulmonar aguda, de los cuales el 73.7% presentó bronquiolitis. El 50% de los casos obtuvo 7 puntos de la escala de LUS, el 91.7% ingresó a UCIP y el 53.8% requirió ventilación mecánica asistida.*
Conclusiones: *El uso de la escala LUS en infección respiratoria baja puede predecir la necesidad de ingreso a Unidad de Cuidados Intensivos Pediátricos, así como la utilización de soporte ventilatorio invasivo y una estancia hospitalaria prolongada.*

Palabras clave: *Ultrasonido. Niños. Bronquiolitis. Cuidados intensivos.*

Introduction

Bronchiolitis is the most common viral respiratory infection in children under 2 years of age, followed by community-acquired pneumonia[1]; up to 30% of children with bronchiolitis have superimposed pneumonia[2]. The COVID-19 pandemic radically changed the epidemiology of other viral respiratory infections in children. In 2023, Guerrero del Cueto et al. described the incidence of bronchiolitis in the last 12 years and its epidemiologic changes[3]. These authors observed 2,138 admissions with a diagnosis of bronchiolitis during the 2010-2019 period[3]. In 2020, hospitalization reduced in 94.4%; however, in the summer of 2021, cases increased for 6 months, reaching a total of 171 cases, with a torpid evolution and requiring admission to the pediatric intensive care unit (PICU), similar to what had been reported by Moreno et al., where admission to the PICU was 9.4%[4,5]. Another study found that 33.4% of children with bronchiolitis were admitted to the PICU, 44.6% required supplemental oxygen with a conventional nasal cannula, and 10.6% required assisted mechanical ventilation (AMV) but with a low mortality rate[6]. Therefore, risk stratification of each patient is essential to intensify monitoring and tailor early initiation of ventilatory support. Lung ultrasound is a bedside tool that has proven helpful in early detection of the adverse course of these conditions. Several clinical scales assess these types of conditions, but none of them is accurate[7].

Manzur-Sandoval et al. (2021) used the lung ultrasound score (LUS) in adults to predict in-hospital mortality in patients diagnosed with COVID-19; they found that the median score was 19 points, the overall mortality rate was 39.4%, and in cases above 19 points, mortality increased to 50%[8].

The LUSBRO scale has been used in children with bronchiolitis. The investigators defined 6 points as a cut-off to indicate greater severity and to predict PICU admission, need for mechanical ventilation, duration of mechanical ventilation, and hospital stay; they reported that 55% of patients were admitted to the PICU, and 6.3% required invasive mechanical ventilation[9].

In 2022, the LUS was used to assess 85 pediatric patients with acute respiratory infection (ARI): 5.4% were admitted to the PICU. Moreover, the association between the pediatric early warning score and days of hospital stay and oxygen use was not statistically significant[10]. However, there is limited literature on this scale in pediatric patients.

This study aimed to evaluate children under 3 years of age with pulmonary pathology of infectious origin using the LUS at the Hospital Infantil del Estado de Sonora (HIES).

Methods

We conducted a descriptive observational study of a consecutive case series of patients under 3 years of age with lower respiratory tract infection. This study was approved by the Research Ethics Committee of the HIES. The study group consisted of patients diagnosed with community-acquired pneumonia and bronchiolitis who were admitted to the Emergency Department of the HIES from January to February 2023.

All patients under 3 years of age admitted to the Emergency Department with a lower respiratory tract infection diagnosed with bronchiolitis and community-acquired pneumonia, according to the American Association of Pediatrics, were included. Bronchiolitis was defined as the first episode of wheezing in a child under 24 months of age, of viral etiology, with expiratory dyspnea and the presence of a catarrhal prodrome[11]. Community-acquired pneumonia was defined as an acute infection of the pulmonary parenchyma with systemic manifestations, causing acute respiratory symptoms, accompanied by an infiltrate on chest radiography, who had not been hospitalized for at least 1 week or whose symptoms appeared more than 48 h after hospital discharge[12].

Neonates with < 37 weeks of gestational age, patients with chronic lung disease (bronchopulmonary dysplasia), bronchial asthma, and congenital heart disease were excluded.

Data were collected within the first 24 h after admission to the emergency department. The clinical score was defined by the Wood-Downes scale modified by Ferres, which was calculated considering the presence of wheezing and subcostal, intercostal, supraclavicular, suprasternal retractions; respiratory frequency and heart rate; symmetric, regular symmetric, or decreased ventilation; and the presence of cyanosis. Patients were graded as follows: mild, with the presence of 1-3 points; moderate, 4-7 points; and severe, 8-14 points[13]. Oxygen saturation was determined by pulse oximetry.

The etiologic agent was determined by real-time polymerase chain reaction for influenza A (H1N1) PDM09, seasonal influenza A/H3, influenza B, respiratory syncytial virus (RSV), metapneumovirus, adenovirus, and enterovirus. Blood tests and chest radiographs were obtained as part of the routine clinical practice. Respiratory support included invasive and noninvasive ventilation, such as low-flow nasal prongs, continuous positive airway pressure (CPAP), and high-flow nasal cannula. PICU admission was defined as patients requiring invasive mechanical ventilation.

Subsequently, lung ultrasound was performed by a pediatric resident trained in lung ultrasound and supervised by a pediatric intensivist and critical care sonographer during the first 24 h after admission to ED. A Sonoscape S2 portable color Doppler ultrasound unit with a 12 MHz linear probe was used. The lung ultrasound score was assessed using the LUS. Six areas of each lung were examined: anterior (superior and inferior), lateral (superior and inferior), and posterolateral (superior and inferior). Scoring for each area was 0-3 points: 0 points pleural sliding with A-lines and < 2 isolated B-lines per intercostal space; 1 point ≥ 3 isolated B-lines (not coalescing); 2 points: coalescing B-lines ("white lung") with or without small subpleural consolidations; 3 points: extensive lung consolidation pattern (small subpleural consolidations are excluded); X lung zone not evaluated (patient could not be mobilized). The total score was the sum of the 12 lung zones assessed. The minimum score was 0 and was considered normal, with a maximum of 36 points[14].

Statistycal analysis

Statistical analysis was performed using medians and interquartile ranges for quantitative variables and frequencies and percentages for qualitative variables. In addition, differences in distribution were evaluated using the Student's t-test and Fisher's exact test. All p-values ≤ 0.05 were considered statistically significant. The analysis was performed with the Statistical Package for Social Sciences version 22 for personal computers.

Results

During the study period, 19 patients with pulmonary pathology of infectious origin were identified, of whom 12 (63.1%) were young infants, four (21.1%) were old infants, and three (15.7%) were preschool children. Ten (52.6%) were males. Bronchiolitis was diagnosed in 14 (73.7%) patients and community-acquired pneumonia in five (26.3%) patients. The median hospital stay was 9 (1-37) days. The Wood–Downes scale was moderate in 18 (94.7%) cases. Of the patients, 89.5% were admitted with intercostal retraction; 52.6% had chest radiographs with interstitial infiltrate, 15.8% had unilateral consolidation, and 31.6% had bilateral consolidation. Laboratory tests revealed the presence of RSV in 14 (73.6%) cases, HADV in one case (5.2%), and negative results in four (21%); 12 (63.1%) patients had a positive procalcitonin. The type of ventilatory support on admission to the emergency department was as follows: nine (47.36%) cases with low-flow nasal prongs, seven (36.84%) with invasive mechanical ventilation, two (10.5%) with a high-flow nasal cannula, and one (5.3%) with CPAP; 12 (63.2%) cases required admission to the PICU (Table 1).

All patients underwent lung ultrasound and were scored according to the LUS. The median LUS was 7 points, the IOR 25% received a value of 5, the IOR 75% of 8 (range 4-11). According to the analysis, scores ≥ 7 points were considered less severe, and scores of 7 or more points were considered more severe. Of the 19 hospitalized patients, six (31.6%) had a score of 6 or less, of which five (83.3%) received nasal prongs and one (16.7%) required a high-flow nasal cannula (Table 2).

Thirteen (53.8%) patients scored ≥ 7 LUS points and required AMV; however, in seven (36.8%) cases, ventilation therapy failed on admission (Fig. 1). In contrast, only one patient (8.3%) required invasive mechanical ventilation on admission with an LUS score of 6 or less, compared to 91.7% with invasive mechanical ventilation and LUS scores > 7 (Fishers' exact test; p = 0.010). When we analyzed LUS and days of hospital stay of patients, we found that those with ≤ 6 points had a mean length of stay of 5.3 (± 2.3) days, compared to patients with LUS > 7 points in which the mean was 20 (± 13.3) days (p = 0.017).

Of the patients admitted to the PICU, 91.7% had a score > 7 points, and 71.4% of the cases not admitted

Table 1. Clinical characteristics of patients with lower respiratory tract infections in children under 3 years of age, Hospital Infantil del Estado de Sonora

Variable	n = 19	%
Age		
Young infants	12	63.1
Old infants	4	21.1
Preschoolers	3	15.78
Sex		
Male	10	52.6
Female	9	47.4
Disease		
Bronchiolitis	14	73.7
Community-acquired pneumonia	5	26.3
Type of ventilatory support		
Nasal prongs	5	26.3
High flow	1	5.3
CPAP	1	5.3
AMV	12	63.2
PICU		
Yes	12	63.2
No	7	36.8
Chest X-ray		
Interstitial infiltrate	10	52.6
Unilateral consolidation	3	15.8
Bilateral consolidation	6	31.6
Wood-Downes scale		
4-7	18	94.7
8-14	1	5.3
Intercostal retraction		
Yes	17	89.5
No	2	10.5

AMV: assisted mechanical ventilation; CPAP: continuous positive airway pressure; PICU: pediatric intensive care unit.

Table 2. Evolution of ventilatory therapy evaluated by LUS in patients under 3 years of age with lower respiratory tract infection, Hospital Infantil del Estado de Sonora

Patient	Ventilatory therapy on admission	LUS	Days for failure	Rescue ventilatory therapy
1	Nasal prongs	9	1	AMV
2	Nasal prongs	7	1	AMV
3	Nasal prongs	6	2	High flow
4	Nasal prongs	5	1	CPAP
5	High flow	5	1	AMV
6	High flow	8	3	AMV
7	CPAP	8	3	AMV

AMV: assisted mechanical ventilation; CPAP: continuous positive airway pressure; LUS: lung ultrasound score.

Table 3. LUS according to score by severity variables in children with lower respiratory tract infection

Variable	LUS				p
	≤ 6 points		≥ 7 points		
	n	%	n	%	
Assisted mechanical ventilation					0.010*
Yes	1	16.7	11	84.7	
No	5	83.3	2	15.3	
PICU admission					0.010*
Yes	1	16.7	11	84.7	
No	5	83.3	2	15.3	
IHDS average	5.3	± 2.3	20	± 13.3	0.017†

*Fisher's exact test.
†Student's t-test.
IHDS: in-hospital days of stay; LUS: lung ultrasound score; PICU: pediatric intensive care unit.

to the PICU had a score of ≤ 6 points, with a statistically significant difference (Fisher's exact test; p = 0.010) (Table 3). Mortality occurred in one patient (5.3%) who required mechanical ventilation since admission, with a LUS of 11 points.

Discussion

In this study, LUS was found to identify patients with an unfavorable course who required early ventilatory support. Various clinical scales have been proposed to determine the severity of the disease, such as the Downes scale modified by Ferres. However, none of them has shown to identify those patients with an unfavorable outcome[7].

The performance of lung ultrasound in these patients represents a diagnostic and staging tool for predicting early ventilatory support and admission to the PICU; performing early interventions by noninvasive ventilatory therapy could improve the patient outcome. Several lung ultrasound scales have been described, such as the LUS for adult patients hospitalized with a diagnosis of COVID-19, the LUSBRO scale for patients with bronchiolitis, and in neonatology, lung ultrasound has been used for the administration of surfactant in premature infants, among other scales in different age groups[8,15].

The scale used in this study to analyze pediatric patients with ARI was LUS. The median of the scale was 7 points; it was observed that 91.7% of the patients were admitted to the ICU, similar to what has been reported in other studies. In the study by Bobillo et al. in 2021,

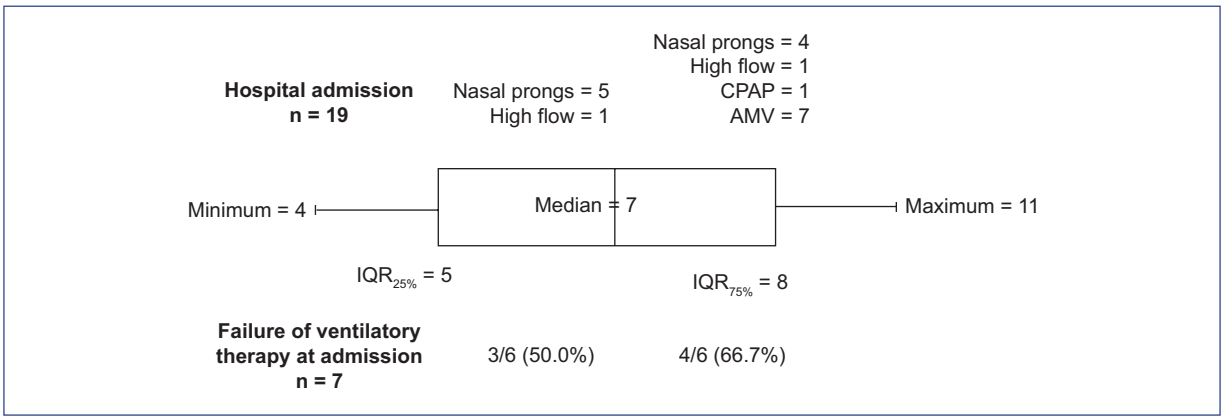

Figure 1. LUS values in 19 children with lower respiratory tract infection and ventilatory management on admission to the Hospital Infantil del Estado de Sonora.
AMV: invasive mechanical ventilation; CPAP: continuous positive airway pressure; LUS: lung ultrasound score.

they used the LUSBRO scale and found that 55% of the cases admitted to the PICU received ≥ 6 points[9].

In this study, high LUS values were significantly associated with the use of invasive ventilatory support; more than half of the cases with ≥ 7 points required this therapy. Bueno et al., in 2019, observed that 2/3 of the patients eventually required AMV; in addition, they presented anteroposterior consolidation in the lung and more than 3 confluent B-lines bilaterally[16]. In 2021, 59% of adult patients with COVID-19 with LUS ≥ 19 required mechanical ventilation[8].

Concerning hospital stay, this study found a correlation between greater lung parenchymal involvement (as observed on lung ultrasound) and more days of hospital stay, as reported in the literature. A study published in 2018 found that for every 5-point increase in the global lung ultrasound score, there was a 1.2-day increase in hospital length of stay, which was statistically significant[17].

More than half of the patients with ventilatory failure on admission had a LUS score ≥ 7. Krishna et al., in 2022[18], found an association between high values of the lung ultrasound USS scale and the type of ventilatory support. The authors observed that 13.2% of patients with posterior subpleural consolidation presented failure of noninvasive ventilatory support (low-flow nasal prongs) and required upper respiratory support, CPAP in 71.4% and 14.2% other methods with a high-flow nasal cannula.

In adult patients with COVID-19, in-hospital mortality was observed to be 50% in patients with LUS score ≥ 19. However, in our study, only one patient obtained the highest score. Mortality correlated with greater parenchymal involvement documented on the LUS, suggesting the need for more aggressive ventilatory therapy upon admission to the ED[8].

One situation that needs to be reviewed is the comparison between LUS and chest computed axial tomography (CT), as the results are contradictory in adults. On the one hand, Tung-Chen et al. (2019) described a significant correlation between the results, highlighting a similar accuracy in detecting lung abnormalities[19]. On the other hand, Colombi et al. (2020) showed that CT performed better than LUS in patients with COVID-19 and that LUS was highly sensitive but not specific[20].

Furthermore, studies in pediatric patients have shown that LUS is highly sensitive for detecting normal lung tissue and highly reliable for detecting consolidations. At the same time, CT has a high specificity for excluding pleural effusion and interstitial disease[21]. Carrard et al. (2022) reported that LUS was superior in diagnosing pneumonia in children with pleural effusion and allowed adequate differentiation of consolidations. However, CT showed better visualization of hydroaerial cavities and atelectasis[22]. The study by Musolino et al. in 2022 showed that lung ultrasound was better to CT in detecting small subpleural parenchymal consolidations[23]. However, another study compared the diagnostic performance of LUS and chest CT, and the results were similar. Lung ultrasound was better than chest radiography in identifying consolidations[24]. However, an important consideration is that chest radiography involves radiation, which increases the risk of developing cancer in children[25].

Strengths of the study include the homogeneity of the population studied, which allows for objective ultrasound evaluation in previously healthy lungs. An intensive care physician performed the ultrasound examination. An analysis of the lung regions was performed, allowing a broader assessment of the parenchyma compared to chest radiography. In addition, the portable ultrasound device provided a tool for bedside patient assessment.

Limitations of the study include the sample size, the fact that the interpretation of lung ultrasound is operator-dependent, and that the patients studied were those requiring supplemental oxygen support. Further studies with larger sample sizes and patients with mild respiratory pathology are needed.

In conclusion, this study demonstrated that the use of the LUS in lower respiratory tract infections predicts the need for invasive ventilatory support, PICU admission, and prolonged hospital stay.

Ethical disclosures

Protection of human and animal subjects. The authors declare that no experiments were performed on humans or animals for this study.

Confidentiality of data. The authors declare that they have followed the protocols of their work center on the publication of patient data.

Right to privacy and informed consent. The authors have obtained the written informed consent of the patients or subjects mentioned in the article. The corresponding author has this document.

Use of artificial intelligence for generating text. The authors declare that they have not used any type of generative artificial intelligence for the writing of this manuscript, nor for the creation of images, graphics, tables, or their corresponding captions.

Conflicts of interest

The authors declare no conflicts of interest.

Funding

Funding for this article was provided by the authors.

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