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Original Article

A Comparison Study in Children with Lower Respiratory Tract Infections: Chest X-ray and Lung Ultrasound

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ABSTRACT

Aim: Lower respiratory tract infections (LRTIs) are one of the leading causes of mortality and morbidity in children. Chest X-rays, which are frequently used in diagnosis, cause ionizing radiation exposure and a loss of time. We aimed to compare the diagnostic accuracy of chest radiography (CR) and lung ultrasonography (US) in patients with LRTIs.

Materials and Methods: This study was designed as methodological research. Of the 62 patients evaluated in our study, four refused to participate, and eight were excluded from the study due to their underlying chronic diseases. All 50 remaining patients (between the ages of 0-18 years) were evaluated with a preliminary LRTI diagnosis. Lung US was performed by a 3rd-year pediatric resident who had six hours of online US training. CR was taken after lung US.

Results: The mean age of the 50 cases included in this study was five years and three months; 35 of the 50 patients (70%) had a clinical diagnosis of pneumonia, 15 (30%) of them had a clinical diagnosis of bronchiolitis. Statistically significant interobserver agreement was found between US and CR [Kappa value 0.772, 95% confidence interval (0.590-0.925) (p=0.000)]. The sensitivity of lung US was 95%, and its specificity was 85.7% when CR was accepted as the gold standard.

Conclusion: Our study demonstrates that lung US can be used instead of CR to diagnose and follow-up pediatric cases with LRTIs.

Keywords: Pediatric emergency medicine, pneumonia, lung ultrasonography, chest radiography

Introduction

Lower respiratory tract infections (LRTIs) are one of the leading causes of mortality and morbidity in children worldwide (1). Chest radiography (CR) is the standard diagnostic method in children with LRTI and it is frequently used. This situation causes potential complications due to ionizing radiation exposure, a loss of time, and unnecessary antibiotic use in children. Therefore, in recent years, many quality improvement methods suggest limiting the use of X-rays in pediatric patients (2).

With the application of bedside lung ultrasonography (US) in the pediatric emergency department, we propose a faster, cost-efficient, repeatable, portable, and radiation-free method for diagnosis. A pediatric resident who had

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no previous US experience performed lung US after a six-hour online US training course. We aimed to compare the diagnostic accuracy between CR and ultrasonographic evaluations of lungs in patients with a preliminary diagnosis of LRTI.

US has significant advantages over CR and computed tomography (CT), such as real-time imaging, accessibility, its portability and suitability for bedside use, the elimination of radiation exposure, and the fact that it does not require the use of contrast materials (3). With the developments in US technology and increased scientific evidence in recent years, the use of lung US has gradually expanded. US has been called "the visual stethoscope of the 21st century" (4). US has been accepted as a good bedside "gold standard" method in critically ill patients (5). The upper and lower points on both hemithorax and the posterolateral alveolar/pleural syndrome points are evaluated by using the Bedside Lung Ultrasound in Emergency (BLUE) protocol, which is a method for diagnosing acute respiratory failure (5). The BLUE protocol algorithm defines normal lung, pleural effusion, consolidation, interstitial syndrome, and pneumothorax conditions. In this protocol, it is recommended to evaluate critical lung pathologies by considering gravity, assessing the pleural line, determining lung sliding findings from the standard points, interpreting artifacts, and considering that many essential pathologies of the lungs are superficial (5-7).

Materials and Methods

This study was designed as a single-center, prospective methodological study. The families of the patients' who participated were informed about the research and agreed to sign consent forms. Those patients diagnosed with LRTI and who were scheduled to have chest X-ray by the pediatric emergency physician were included in this study. Sixty-two patients (0-18 years) were admitted to the pediatric emergency department between 10/1/2020 and 4/1/2021. Out of these 62 patients, eight were excluded because of their chronic lung diseases, and four were excluded because they chose not to participate. Therefore, 50 patients prospectively participated in our study. Lung US was performed by a medical doctor who had graduated from a 6-year medical school and was a 3rd year pediatric resident (pediatric residency is a four-year program in our country, Turkey), and who had received six hours of online US training but had no previous US experience. The six-hours training course consisted of four hours of theoretical and two hours of practical training.

In terms of the standardization of ultrasonographic evaluation, the BLUE protocol was used. Lung US imaging was performed from the BLUE points in both hemithorax for each patient. The inclusion criteria were being aged between 0-18 years, having a clinical diagnosis of LRTI (The American Academy of Pediatrics criteria were taken as the basis for the clinical diagnosis), and a signed patient consent form. The exclusion criteria were specified as follows: The presence of a chronic lung disease (asthma, cystic fibrosis, bronchiectasis) and/or morbid obesity. All sonographic examinations were performed using a standard US device (Mindray DC-60 Expwith X-Insight) with a linear 13-3 and a convex 6-2 probe. The US images obtained by using the BLUE protocol were recorded. The patients' ages, gender, underlying diseases, complaints, physical examinations and laboratory findings, clinical diagnoses, and respiratory support status were recorded on a study form. US evaluation was performed by a pediatric resident regardless of other imaging tests; the presence of lung consolidation, subpleural consolidation, pleural effusion, A-lines, and B-lines were examined. In addition, specific accompanying sonographic findings were noted on the study form. The pediatric resident who performed lung US did not see the results of the CR. The CR was taken after the lung US. The CR images of the patients were evaluated by the radiology physician independently and without knowledge of the different imaging methods and the US results available in the system. Ethical approval was received from the Ethics Committee of Manisa Celal Bayar University Medical Faculty of Health Sciences (decision no: 108, date: 21.09.2020). The study protocol conforms to the ethical guidelines of the 1975 Declaration of Helsinki.

Statistical Analysis

The Statistical Package for the Social Sciences version 22.0 package program was used for the data analysis. Numbers and percentages are specified as descriptive statistical data (mean, standard deviation, minimum, maximum, median). Minimum and maximum values are specified as categorical variables, and mean values are given for numerical variables. The McNemar-Bowker chi-squared test was used to analyze categorical variables and evaluate diagnostic accuracy, and Kappa statistics were calculated. A value of $p<0.05$ was considered statistically significant in all analyses.

Results

Of the 62 patients evaluated in our study, four declined to participate, and eight were excluded from the study due to their underlying chronic diseases. Fifty patients

were included in the final analysis. The clinical diagnosis was pneumonia in 35 (70%) patients and bronchiolitis in 15 (30%) patients (Figure 1) (The criteria of the American Academy of Pediatrics were taken as a basis for the clinical diagnoses).

The mean age of the patients was 63.6 months (3-204 months) with a male predominance (54%). The most frequent symptom on admission was cough (54%), followed by dyspnea (46%), fever (44%), rhinorrhea (26%), and fatigue (20%) (Table I). Physical examination revealed rales (52%), rhonchus (42%), tachypnea (28%), retraction (28%), and tachycardia (22%). The mean values of the laboratory parameters were as follow; white blood cell: 12,270 /mm^3, absolute neutrophil count: 7,810 /mm^3, absolute lymphocyte count: 3,450 /mm^3, hemoglobin: 11.8 g/dL, platelet: 299,000/mm^3, C-reactive protein (CRP): 17.19 mg/L, procalcitonin: 6.35 ng/mL, and lactate: 1.74 mmol/L. The most common oxygen therapy methods were simple mask (16%) and high-flow nasal cannula oxygen therapy (16%), followed by mechanical ventilation (6%) and non-invasive ventilation (2%). The remaining thirty (60%) patients did not require oxygen (Table I).

Table I. Patient demographics and clinical information

Patient characteristics	**n (%)***
Age (mean) (min.-max., ±SD)	5.38 (0.25-17.0) (±5.26)
Male	27 (54)
Complaints on admission	
Fever	22 (44)
Cough	27 (54)
Dyspnea	23 (46)
Rhinorrhea	13 (26)
Fatigue	10 (20)
Physical examination findings	
Rales	26 (52)
Rhoncus	21 (42)
Tachypnea	14 (28)
Retraction	14 (28)
Tachycardia	11 (22)
O_2 therapy methods	
Room air	30 (60)
Simple mask	8 (16)
HFNC	8 (16)
NIV	1 (2)
MV	3 (6)

*Unless otherwise specified
min.-max.: Minimum-maximum, SD: Standard deviation, NIV: Non-invasive ventilation, MV: Mechanical ventilation, HFNC: High-flow nasal cannula

The US revealed infiltration in 46% of the patients, hyperinflation in 4%, and no abnormality in 50%. CR showed infiltration in 40% of the patients, hyperinflation in 2% of the patients, and normality in 58%. US findings were inconsistent in 5 patients (4 infiltrations, one hyperinflation), whereas no abnormality was detected via CR. CR revealed infiltration in 1 patient, whereas US showed no pathological finding.

A statistically significant correlation was found between US and CR [Kappa value 0.772, 95% confidence interval (0.590-0.925) (p=0.000)]. The sensitivity of the US was 95%, its specificity was 85.7%, its positive predictive value was 82.6%, and its negative predictive value was 96% when the patients with hyperinflation were excluded and CR was accepted as the gold standard (Table II).

Discussion

One of the most appropriate definitions for the diagnosis of pneumonia in primary health care settings in children is the definition of the World Health Organization (WHO). The WHO defines pneumonia as the clinical picture, with fever not associated with another cause, and accompanying tachypnea, cough, and respiratory distress. The purpose of this definition is to facilitate access to life-saving antibiotics in underdeveloped countries with a very high incidence of pneumonia, however, it is not a specific definition (8).

In our study, the complaints of the cases were cough which was the most common (54%), dyspnea (46%), fever

Table II. Sensitivity, specificity, positive predictive value, and negative predictive value of lung ultrasonography vs chest radiography in diagnosing LRTI. The two patients with hyperinflation in US imaging were excluded and CR was accepted as the gold standard (n=48)

	US		**Se (%)**	**Sp (%)**	**PPV (%)**	**NPV (%)**
CR	**Negative**	**Positive**	**(95% CI*)**	**(95% CI*)**	**(95% CI*)**	**(95% CI*)**
Negative	24	4	95	85.7	82.6	96
Positive	1	19	(75.13-99.87)	(67.33-95.97)	(65.59-92.21)	(77.93-99.39)

*CI: Confidence interval, Se: Sensitivity, Sp: Specificity, PPV: Positive predictive value, NPV: Negative predictive value, US: Ultrasonography, CR: Chest radiography, LRTI: Lower respiratory tract infection

(38 °C and above) (44%), rhinorrhea (26%), and fatigue (20%). Compared to the literature, the rates of admission with fever and cough were found less commonly in our study (9-11). This difference may be due to the inclusion of all LRTI cases clinically diagnosed with pneumonia and bronchiolitis in our study. In addition, unlike other studies, outpatients were included in this study.

The most common findings were rales, rhonchus, tachypnea, retraction, and tachycardia. In our study, similar to the literature, the elevation of acute phase reactants such as CRP and procalcitonin correlated with the physical examinations and imaging findings of those patients with suspected bacterial pneumonia (12-15). Respiratory support requirement was less common in our study when compared to the literature (10,16,17). This lower rate could be due to our study's inclusion of outpatients.

In our study, 3 cases (6%) with a pleural effusion of 15 mm or more were detected via US, whereas they were evaluated as normal by CR. The US was performed by an experienced radiologist who confirmed the presence of effusion. US was found to be more sensitive than CR in detecting effusion. Esposito et al. (18) conducted a study comparing the diagnostic values of US and CR; US was found to be more effective in detecting pleural effusion, which supports our results. The findings of this study confirm that lung US is an imaging technique which is almost as reliable as CR in identifying lung lesions diagnostic for LRTI and they show that it is even more effective than CR in diagnosing pleural effusion. When CR is accepted as the gold standard, the sensitivity of lung US was 95%, and its specificity was 85.7%. In the study conducted by Reissig et al. (19), infiltration, air bronchogram, pleural effusion, and pleural irregularities were detected by lung US. It was shown that the diagnosis of pneumonia was made with a sensitivity of 93.4% and a specificity of 97.7% (19). A meta-analysis by Pereda et al. (20) evaluated the accuracy of US in the diagnosis of pneumonia in pediatric patients and it showed that US was successful in diagnosing pneumonia with 96% sensitivity and 93% specificity.

Copetti and Cattarossi (21) compared the diagnostic values of CR and US in 79 children with pneumonia, and US detected pneumonia in 60 out of 79 patients. In contrast, positive CR findings were observed in only 53 patients. CT confirmed the diagnosis of pneumonia in 4 patients found to be negative on CR and positive on US (21). Esposito et al. (18) compared the diagnostic values of US and CR and showed that US had 98% sensitivity and 95% specificity (19). The sensitivity rate in our study was consistent with results in the literature, and the specificity rate was slightly lower (19-21). This result occurred because four false-positive cases were detected in the US evaluation when CR was taken as the reference test. However, pleural effusion was detected sonographically in 3 out of 4 cases where the US detected pathology, but CR was evaluated as normal. This was confirmed when an experienced radiologist performed the US.

Adult studies suggest performing thorax CT if US detects any abnormality, even if CR is normal. Parlamento et al. (22) evaluated adult patients who were positive in US and negative in CR; CT confirmed the positive US results. In the diagnosis of pneumonia, US has been assessed to be a fast, reliable, non-invasive bedside technique. Since CR and US are not the gold standards in adult patients, their sensitivity and specificity could not be specified as CT cannot be applied to every patient, although it is the gold standard (22). We try to avoid radiation exposure in the pediatric age group. Therefore, we did not perform CT to confirm the diagnoses.

Study Limitations

The most important limitation of our study was the low number of patients. Our study, which was carried out during the COVID-19 pandemic, was affected by reduced admissions to the pediatric emergency department. In addition, the increased use of personal protective equipment and isolation methods, such as the closure of schools during the pandemic period, reduced the frequency of admissions to the pediatric emergency service due to LRTI. Another limitation of our study was that, as in other studies evaluating the role of lung US in diagnosing LRTI in children, thoracic CT could not be performed ethically on pediatric cases. Therefore, no comparison with CT, which is reliable in diagnosis, could be made.

Conclusion

Our study demonstrated that lung US can be used instead of CR in the diagnosis and follow-up of pediatric LRTI. This study, carried out after a six-hour online lung US course by a pediatric resident who had no previous US experience, showed that the diagnostic accuracy between US evaluation and CR, even with just six hours of training, was significantly consistent. As a result of a literature review, we determined that this was the first study conducted by a pediatric resident after an online lung US training course.

Ethics

Ethics Committee Approval: Ethical approval was received from the Ethics Committee of Manisa Celal Bayar University Medical Faculty of Health Sciences (decision no: 108, date: 21.09.2020).

Informed Consent: The families of the patients' who participated were informed about the research and agreed to sign consent forms.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: N.G., Concept: N.G., A.B., Design: N.G., A.B., Data Collection or Processing: N.G., N.C.K., F.D., Analysis or Interpretation: N.Z., F.D., A.B., Literature Search: N.G., N.C.K., Writing: N.Z., A.B.

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References

1. Bezerra PG, Britto MC, Correia JB, et al. Viral and Atypical Bacterial Detection in Acute Respiratory Infection in Children Under Five Years. PLoS ONE 2011;6:e18928.
2. Ralston SL, Garber MD, Rice-Conboy E, et al. A multi-center collaborative to reduce unnecessary care in inpatient bronchiolitis. Pediatrics 2016:137.
3. Sartori S, Tombesi P. Emerging roles for transthoracic ultrasonography in pulmonary diseases. World J Radiol 2010;2:203-14.
4. Gillman LM, Kirkpatrick AW. Portable bedside ultrasound: the visual stethoscope of the 21st century. Scand J Trauma Resusc Emerg Med 2012;20:18.
5. Lichtenstein DA. BLUE-protocol and FALLS-protocol: two applications of lung ultrasound in the critically ill. Chest 2015;147:1659-70.
6. Lichtenstein DA, Mezière GA. Relevance of lung ultrasound in the diagnosis of acute respiratory failure: the BLUE protocol. Chest 2008;134:117-25.
7. Lichtenstein DA, Mezière GA. The BLUE-points: three standardized points used in the BLUE protocol for ultrasound assessment of the lung in acute respiratory failure. Crit Ultrasound J 2011;3:109-10.
8. Scott JA, Brooks WA, Peiris JS, Holtzman D, Mulholland EK. Pneumonia research to reduce childhood mortality in the developing world. J Clin Invest 2008;118: 1291-300.
9. Juven T, Ruuskanen O, Mertsola J. Symptoms and signs of community-acquired pneumonia in children. Scand J Prim Health Care 2003;21:52-6.
10. Saka Ümit P, Cinel G. Effects of Possible Risk Factors on Morbidity in Child Patients Hospitalized With Pneumonia. Turkish Journal of Pediatric Disease 2021;15:262-71.
11. Jain S, Williams DJ, Arnold SR, et al. Community-Acquired Pneumonia Requiring Hospitalization among U.S. Children. N Engl J Med 2015;372:835-45.
12. Toikka P, Irjala K, Juvén T, et al. Serum procalcitonin, C-reactive protein and interleukin-6 for distinguishing bacterial and viral pneumonia in children. Pediatr Infect Dis J 2000;19:598-602.
13. Gendrel D, Raymond J, Coste J, et al. Comparison of procalcitonin with C-reactive protein, interleukin 6 and interferon-alpha for differentiation of bacterial vs. viral infections. Pediatr Infect Dis J 1999;18:875-81.
14. Korppi M, Kröger L. C-reactive protein in viral and bacterial respiratory infection in children. Scand J Infect Dis 1993;25:207-13.
15. Peltola V, Mertsola J, Ruuskanen O. Comparison of total white blood cell count and serum C-reactive protein levels in confirmed bacterial and viral infections. J Pediatr 2006;149:721-4.
16. Söğütlü Y, Biçer S, Kurt G, et al. Outcomes of high-flow nasal cannula oxygenation treatment on the vital signs of children with lower respiratory tract diseases. J Pediatr Emerg Intensive Care Med 2016;3:121-30.
17. Usen S, Weber M, Mulholland K, et al. Clinical predictors of hypoxemia in Gambian children with acute lower respiratory tract infection: prospective cohort study. BMJ 1999;318:86-91.
18. Esposito S, Papa SS, Borzani I, et al. Performance of lung ultrasonography in children with community-acquired pneumonia. Ital J Pediatr 2014;40:37.
19. Reissig A, Copetti R, Mathis G, et al. Lung ultrasound in the diagnosis and follow-up of community-acquired pneumonia: a prospective, multicenter, diagnostic accuracy study. Chest 2012;142:965-72.
20. Pereda MA, Chavez MA, Hooper-Miele CC, et al. Lung ultrasound for the diagnosis of pneumonia in children: a meta-analysis. Pediatrics 2015;135:714-22.
21. Copetti R, Cattarossi L. Ultrasound diagnosis of pneumonia in children. Radiol Med 2008;113:190-8.
22. Parlamento S, Copetti R, Di Bartolomeo S. Evaluation of lung ultrasound for the diagnosis of pneumonia in the ED. Am J Emerg Med 2009;27:379-84.