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Original Contribution

Point-of-care lung ultrasound in children with community acquired pneumonia☆

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ABSTRACT

Objectives: To present lung ultrasound findings in children assessed with suspected pneumonia in the emergency department and to show the benefit of lung ultrasound in diagnosing pneumonia in comparison with chest X-rays.
Methods: This observational prospective study was performed in the pediatric emergency department of a single center. Point of care lung ultrasound was performed on each child by an independent sonographer blinded to the patient's clinical and chest X-ray findings. Community acquired pneumonia was established as a final diagnosis by two clinicians based on the recommendations in the British Thoracic Society guideline.
Results: One hundred sixty children with a mean age of 3.3 ± 4 years and a median age of 1.4 years (min–max 0.08–17.5 years) were investigated. Final diagnosis in 149 children was community-acquired pneumonia. Lung ultrasound findings were compatible with pneumonia in 142 (95.3%) of these 149 children, while chest X-ray findings were compatible with pneumonia in 132 (88.5%). Pneumonia was confirmed with lung ultrasound in 15 of the 17 patients (11.4%) not evaluated as compatible with pneumonia at chest X-ray. While pneumonia could not be confirmed with lung ultrasound in seven (4.6%) patients, findings compatible with pneumonia were not determined at chest X-ray in two of these patients. When lung ultrasound and chest X-ray were compared as diagnostic tools, a significant difference was observed between them ($p = 0.041$).
Conclusions: This study shows that lung ultrasound is at least as useful as chest X-ray in diagnosing children with community-acquired pneumonia.

1. Introduction

Pneumonia in children is a major public health and economic problem with a considerable impact on morbidity and mortality. According to the World Health Organization (WHO), pneumonia is the most common infectious cause of death among children worldwide. Approximately 920,000 children under 5 years died from pneumonia in 2015 [1]. Since pneumonia is the main cause of high mortality in low-income countries and due to the growing incidence of complicated pneumonia in industrialized countries, the management of community acquired pneumonia is based on 'prompt diagnosis and appropriate treatment' [2]. Community-acquired pneumonia must be considered in a previously healthy child of continuous or recurring high fever accompanied by tachypnea and intercostal retractions [3]. Criteria for diagnosis are not highly specific. While fever, tachypnea, breathing difficulty, cough, chest pain and pulmonary rales and wheezing may be observed in a child with community-acquired pneumonia, patients may also present with abdominal pain, vomiting and headache. The majority of these symptoms and findings can be observed in infectious conditions commonly seen in childhood and in wheezing accompanied by upper airway infection and mild fever. It is therefore sometimes difficult to identify bacterial pneumonia in a prompt and accurate manner [3]. In addition, many children diagnosed with pneumonia and not admitted to hospital do not require chest X-rays [3,4]. However, in clinical practice chest X-ray is frequently requested by physicians in terms of differential diagnosis or complications, and diagnosis of pneumonia is confirmed by the observation of a new infiltrate on chest X-rays [5]. Although not routinely recommended by the Pediatric Infectious Diseases Society, the Infectious Diseases Society of America or the British Thoracic Society (BTS), chest X-rays are performed at levels as high as 90% for children with suspected pneumonia [6].

Point of care ultrasound is increasingly used by physicians in the evaluation of adult and child patients. This is employed not only as a point of care imaging modality, but also as a complementary tool to physical examination. Lung ultrasound has a particularly high level of accuracy in the diagnosis of children with pneumonia and appears capable of replacing chest X-ray

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[6-18]. Characteristics such as being rapid, mobile, repeatable and easily performed at the bedside and not involving exposure to radiation make point of care lung ultrasound particularly valuable. The purpose of this study was to present lung ultrasound findings from children assessed with suspected pneumonia in the emergency unit and to show the benefit of lung ultrasound in diagnosing pneumonia in comparison with chest X-ray.

2. Methods

2.1. Study design, setting and population

This observational prospective study was performed in the pediatric emergency department of a single center receiving approximately 35,000 child presentations annually. The study protocol was approved by the local ethical committee (Çukurova University). Informed consent was obtained from parents or guardians before the study commenced.

The study was performed at the Çukurova University Medical Faculty Pediatric Emergency Department between February 2015 and May 2016. Inclusion criteria were (1) age between 1 month and 18 years, (2) previous good health apart from signs and symptoms suggestive of pneumonia (fever, dyspnea, cough and abnormal auscultation findings or combinations thereof) (3), chest X-ray being performed concurrently (4) and presence of a study sonographer for lung ultrasound during patient evaluation. Patients with nosocomial infection, receiving treatment for pneumonia in the preceding month, with major cardiac anomaly, with any airway anomaly (including laryngomalacia), with previous diagnosis of chronic lung disease (cystic fibrosis, bronchiectasis etc.), asthma, or reactive airway disease, with acute bronchiolitis, diagnosed with upper airway infection in the absence of symptoms and findings of pneumonia, receiving antibiotic therapy for any reason or for pneumonia, with hemodynamic impairment or in a state of shock were excluded from the study. Patients' medical history, physical examination characteristics and vital signs at triage were noted by clinicians at the beginning of the study, and data collection forms were kept. Children with community acquired pneumonia received a preliminary diagnosis by two clinicians based on the diagnostic criteria for pneumonia set out in the BTS guideline [3,8]. These two clinicians were physicians working in the pediatric emergency department. They assessed children with pneumonia concurrently, but were blinded to one another. Both were in full agreement in all cases they did not consider represented pneumonia.

2.2. Study protocol

Sonographic lung evaluation was performed using a SonoSite Edge ultrasound device with 6–13 MHz linear probe by single sonographer (HLY). The probes were placed over the intercostal spaces in a perpendicular oblique and parallel manner in the anterior, lateral and posterior thoracic regions where the images were clearest. Lung ultrasound was performed in the supine position and in lateral decubitus. Ultrasonographic lung evaluation was performed using the method previously described by Copetti et al. [7]. Consolidation at lung ultrasound was defined as hyperechoic elements reflecting air bronchograms in hypoechoic or anechoic areas and pleural irregularities associated with hypoechoic or anechoic areas (Fig. 1). A sample of lung ultrasound images for consolidated areas is available on Video 1. Lung sliding findings had to be absent or decreased in consolidation areas. Tubular anechoic structures with a non-pulsatile hyperechoic wall in the absence of colored Doppler signals were defined as fluid bronchograms [7,19]. A sample of lung ultrasound images for fluid bronchograms is available on Video 2. A-lines are horizontal artifact images parallel to the pleural line seen in the normal lung. Hyperechoic artifact images erasing the A-line, extending from the pleural line to the end of the screen, emerging with lung movements and extending in a vertical manner were defined as B-lines (Fig. 1). These B-lines were classified as focal, multiple or confluent. Anechoic (echo-free) areas in the pleural cavity were regarded as pleural effusion, but minimal fluid (≤3 mm) accumulation in the pleural cavity was not considered as pleural effusion (Fig. 1). Effusion was evaluated with M-mode and color Doppler and confirmed with 'sinusoidal sign' and "fluid color sign" (Video 3), respectively [8,20].

2.3. Measurements

Pathological appearances in the lung were evaluated by a sonographer, and ultrasound images were recorded digitally. The sonographer recorded those images regarded as necessary, and sonographic evaluation was performed in real time in a single session. All lung ultrasound evaluations were performed by the same single sonographer (HLY). The sonographer performed 100 lung ultrasound examinations following one basic and one advanced ultrasound course before the study commenced. At posterior-anterior chest X-ray, peribronchial thickening and consolidated areas were identified separately in terms of pneumonia. Detectable pleural effusions were determined on chest X-rays. Chest X-rays were evaluated by two clinicians with 10 years of experience and blinded to the lung ultrasound results. Patients were again evaluated in terms of missed or occult pneumonia at the end of the study. Occult pneumonia was defined as the presence of radiographic infiltrate without signs and findings of lower airway infection [4,21-23].

2.4. Sample size calculation and data analysis

Power analysis was performed on the basis of previous studies in order to determine the sample size before patients were enrolled. Based on results reported by Caiulo et al., we calculated that 80% power with 95% confidence could be achieved when 137 children with community-acquired pneumonia were included in the study to compare the complementary or confirmatory diagnostic performances of chest X-ray and lung ultrasound [8].

Data were analyzed on IBM SPSS Statistics for Windows, Version 20.0 software. Constant variables were expressed as mean ± standard deviation and continuous variables as number and percentages. Differences between constant variables were investigated using chi square analysis and the McNemar test. Since, in terms of methodology, CXR and/or clinical findings could not be evaluated as a gold standard, overall percent agreement (OPA), positive percent agreement (PPA) and negative percent agreement (NPA) were calculated between chest X-ray and lung ultrasound, rather than measurements such as sensitivity and specificity [17].

3. Results

Two hundred twenty five children with suspected pneumonia were initially evaluated. One hundred sixty children [mean age 3.3 ± 4 years, median age 1.4 years (range 0.08–17.5 years), 88 male] were included in the study. Final diagnosis was community-acquired pneumonia in 149 of the children enrolled [mean age 3.2 ± 3.9 years, median age 1.3 years (range 0.08–17.5 years)], upper airway infection in nine of those in whom pneumonia was not determined and pulmonary edema in two (Fig. 2). Pleural irregularity and/or increased B-lines were determined in four of the children with upper airway infection and pleural irregularity and increased in B-lines (diffuse alveolar-interstitial syndrome) in the children with pleural edema. The clinical features of the children with community acquired pneumonia are shown in Table 1. No statistically significant difference was observed between basic clinical characteristics and sex and age. Lung ultrasound findings were compatible with pneumonia in 142 (95.3%) of the 149 children with pneumonia, while chest X-ray findings were compatible with pneumonia in 132 (88.5%). Sonographic pneumonia findings could not be shown with lung ultrasound in 7 (4.6%) patients. Chest X-ray was also normal in two of these seven patients. Chest X-ray was not compatible with pneumonia in 17 (11.4%) children, and pneumonia was confirmed with lung ultrasound in 15 of these (Fig. 2). A statistically significant difference was observed when lung ultrasound and chest X-