European Journal of Radiology 88 (2017) 82–87

Contents lists available at ScienceDirect

European Journal of Radiology

journal homepage: www.elsevier.com/locate/ejrad

Performance of chest ultrasound in pediatric pneumonia

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ARTICLE INFO

Article history:
Received 8 June 2016
Received in revised form
18 December 2016
Accepted 27 December 2016

Keywords:
Ultrasound
Pediatric
Pneumonia

ABSTRACT

Objective: The objective of this study was to evaluate the performance of ultrasound in detecting lung consolidation in children suspected of pneumonia, in comparison to the current gold standard, chest X-rays.
Materials and methods: From September 2013 to June 2014, a monocentric prospective study was performed on all children between 0 and 16 years-old, referred for chest X-ray for suspected pneumonia. Each child was examined by chest ultrasound by an examiner blinded to the chest X-ray. The presence or absence of areas of consolidation, their number and location were noted for each technique. The size of the consolidations identified only on ultrasound was compared with that of consolidations visible on both techniques.
Results: 143 children (mean age 3 years; limits between 8 days and 14 years) were included. Ultrasound detected at least one area of consolidation in 44 out of 45 patients with positive X-rays. Of the 59 areas of consolidation on X-ray, ultrasound identified 54. In the 8 patients with negative X-ray, ultrasound revealed 17 areas of consolidation. The mean size of consolidations visible only on ultrasound was 9.4 mm; for consolidations visible on both techniques the mean size was 26 mm ($p < 0.0001$).

The sensitivity and specificity of ultrasound were calculated at 98% and 92%. PPV and NPV were 85% and 99%, respectively.
Conclusion: Chest ultrasound is a fast, non-ionizing and feasible technique. With its high negative predictive value, it can replace X-rays in order to exclude lung consolidation in children, thus reducing radiation exposure in this population.

1. Introduction

Lower respiratory tract infections (bronchitis, bronchiolitis and pneumonia) are responsible for a large number of emergency room (ER) consultations in the pediatric population. Furthermore, according to the World Health Organization (WHO), pneumonia is the most common cause of infant mortality globally [1], which renders the importance of an adequate treatment even greater.

Pneumonia may be either viral and treated symptomatically, or bacterial and requiring antibiotic treatment. The differential diagnosis between the two types of causal agent is difficult and must take into consideration the age of the patient, the clinical presentation, lab work and imaging. Typically, bacterial pneumonia causes lung consolidation, which is an added argument for antibiotic treatment.

In everyday pediatric radiology practice, a large number of acute respiratory infections are viral infections, requiring no antibiotic treatment. However, chest X-ray is routinely performed to exclude bacterial pneumonia. In order to prevent unnecessary radiation exposure for the child, the diagnostic and performance of alternative (non-ionizing) imaging techniques should be investigated. Ultrasound is widely available in the emergency room, which recommends it as a possible alternative to X-ray.

Pulmonary consolidation is caused by replacing the normal alveolar air content with a higher density material (fluid, pus, secretions). On chest X-rays areas of consolidation appear as fluid-density opacities, ill-defined or well-defined and containing air

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[1] The authors have nothing to disclose.

http://dx.doi.org/10.1016/j.ejrad.2016.12.032
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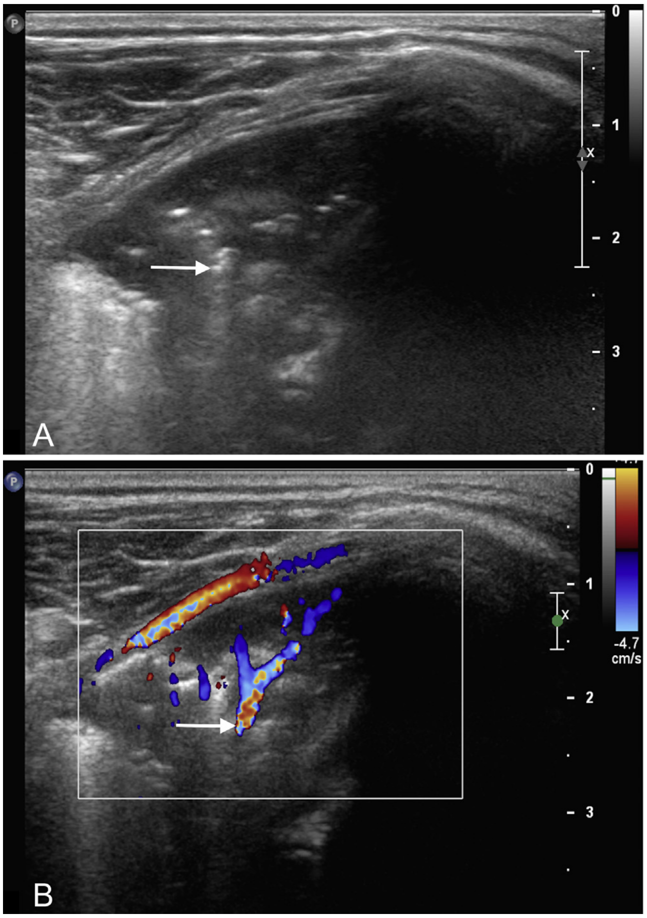

Fig. 1. Lung US in a 4-year-old boy with coughing and fever for a week. Longitudinal scan of the lung in B-mode (A) and color Doppler mode (B) demonstrates pulmonary consolidation with air bronchograms (arrow in A) and vascularisation (arrow in B).

bronchograms [2]. On ultrasound, areas of consolidation are visible if they are in contact with the pleural surface; they appear as hypoechoic, ill-defined areas with an air bronchogram and are vascularized on Doppler US [3–5] (Fig. 1).

The aims of this study were (i) to evaluate the performance of ultrasound (US) in detecting lung consolidation in comparison to the current gold standard (chest X-rays), (ii) to explore the possibility of limiting the number of chest X-rays performed for pediatric respiratory infections, by replacing them with US, and thus reducing radiation exposure.

2. Patients and methods

A monocentric prospective study was performed over a period of ten months, from September 2013 to June 2014. The investigation was approved by the ethical committee of our institution.

2.1. Inclusion and exclusion criteria

All children between 0 and 16 years referred to the pediatric radiology department by the emergency room or their pediatrician for a chest X-ray for suspected pneumonia were included, provided the parents gave their informed consent for the investigation. The main reasons stated by the referring physician for excluding pneumonia were the presence of coughing associated with abnormal lung auscultation or percussion and fever of unknown origin lasting longer than 5 days.

Clinically unstable patients were excluded.

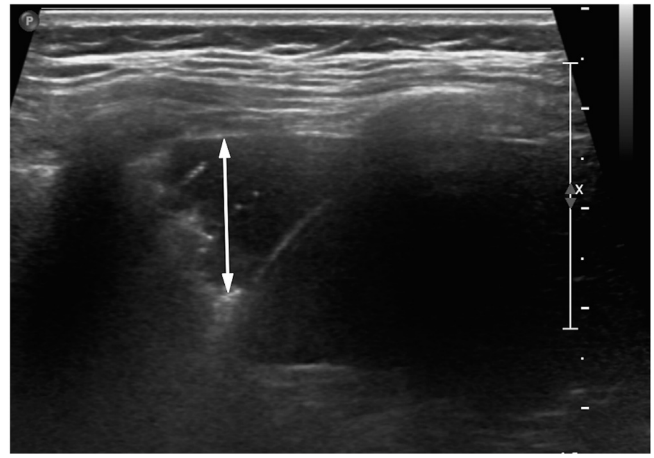

Fig. 2. Measurement of an area of consolidation on lung US in a 2 year-old girl with fever and increasing cough for 3 days: the distance between the superficial and deep limits of the lesion, perpendicular to the lung surface is measured.

2.2. Method

For every child included in the study, a chest X-ray and a thoracic US were performed. Chest X-rays and US data were acquired and reviewed by three pediatric radiologists (PC, RM, DD) and a radiology intern in the final year of training (AC). When assessing one of the two examinations, investigators were blinded to the other examination.

Chest X-rays were performed in frontal view, either in the antero-posterior reclining or in the postero-anterior upright projection, depending on the age of the patient. Thoracic US examinations were performed on a Philips iU-22 machine with a linear probe (L 12–5 MHz). A medium frequency convex probe (C 9–4 MHz) was used in some cases, when this was considered necessary by the examiner, given the depth of the anomaly.

To cover the whole lung surface, the thorax was divided into three regions, anterior, posterior and lateral. Each region was scanned in the longitudinal and the transverse plane, up-down and medial-lateral, respectively. The anterior and lateral regions of the chest were examined with the patient in supine position. The posterior region was examined in prone position or in a sitting position, facing away from the examiner. The duration of each US examination was recorded.

The US findings were reported by the examiner immediately after the investigation on a diagram dividing each lung (left or right) into the three regions mentioned above. Each area of consolidation was represented in the location identified by the examiner on one or several of the three regions. The results of US imaging were compared to the interpretation of chest X-rays, where each consolidation was characterized in terms of laterality (right-left) and projection (superior-inferior, medial-lateral, anterior-posterior).

The preliminary observation that several small areas of consolidation identified on US were not visible on the corresponding chest X-rays, led to the measurement of the size of consolidation on US. The purpose was to compare the size of the consolidations visible on both techniques and those visible only on US. One axis was measured for each lesion: the distance between the superficial and deep limit of the consolidation, perpendicular to the pleural surface (Fig. 2).

2.3. Statistical analysis

To compare the two imaging techniques, patients were first separated into two groups according to whether they were positives or negatives for at least one area of lung consolidation on US and