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The Diagnosis of Neonatal Pulmonary Atelectasis Using Lung Ultrasonography

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BACKGROUND: Ultrasonography has been used for the diagnosis of many kinds of lung conditions, but few studies have investigated ultrasound for the diagnosis of neonatal pulmonary atelectasis (NAP). In this study, we evaluated the usefulness of lung ultrasonography for the diagnosis of NPA.

METHODS: From May 2012 to December 2013, 80 neonates with NPA and 50 neonates without lung disease were enrolled in this study. Each lung of every infant was divided into the anterior, lateral, and posterior regions by the anterior and posterior axillary lines. Each region was scanned carefully with the probe perpendicular or parallel to the ribs. The ultrasound findings were confirmed by chest radiograph (CXR) or CT scan.

RESULTS: Sixty of the 80 patients with signs of NPA on lung ultrasound also had signs of NPA on CXR (termed focal-type atelectasis), and the other 20 patients had signs of NPA on chest CT scan while there were no abnormal findings on CXR (termed occult lung atelectasis). In patients with NPA, the main ultrasound findings were large areas of lung consolidation with clearly demarcated borders, air bronchograms, pleural line abnormalities, and absence of A-lines, as well as the presence of lung pulse and absence of lung sliding on real-time ultrasound. The sensitivity of lung ultrasonography for the diagnosis of NPA was 100%, whereas the sensitivity of CXR was 75%. Large areas of lung consolidation with clearly demarcated borders were only observed in patients with NPA.

CONCLUSIONS: Lung ultrasonography is an accurate and reliable method for diagnosing NPA; most importantly, it can find those occult lung atelectasis that could not be detected on CXR. Routine lung ultrasonography is a useful method of diagnosing or excluding NPA in neonates.

CHEST 2015; 147(4):1013-1019

Manuscript received June 1, 2014; revision accepted September 29, 2014; originally published Online First October 23, 2014.

ABBREVIATIONS: CXR = chest radiograph; FTA = focal type of atelectasis; NICU = neonatal ICU; NPA = neonatal pulmonary atelectasis; OLA = occult lung atelectasis; RDS = respiratory distress syndrome

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FUNDING/SUPPORT: The authors have reported to *CHEST* that no funding was received for this study.

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DOI: 10.1378/chest.14-1306

Neonatal pulmonary atelectasis (NPA) is a common complication of a variety of lung diseases and is one of the most common reasons for difficulty in weaning from mechanical ventilation. Early and accurate diagnosis of NPA is important for enabling appropriate treatment and improving the prognosis. Previously, the diagnosis of NPA depended mainly on chest radiograph (CXR) findings, but these examinations have many disadvantages, such as difficulty in moving severely ill infants, difficulty in controlling the body position, and the risks associated with radiation exposure.[1] Lung ultrasonography has emerged as a reliable technique for the evaluation of various lung diseases[2-6] and has become a first-line tool in critical and emergency care settings, with international consensus guidelines for its use.[7] Lung ultrasonography has been used to diagnose neonatal respiratory distress syndrome and transient tachypnea of the newborn, monitor fluid clearance, and predict the need for respiratory support,[8-12] but there has been almost no research regarding the use of lung ultrasonography for the diagnosis of NPA. This study investigated the usefulness of lung ultrasonography for the diagnosis of NPA.

Materials and Methods

Patients

The institutional review board of the Beijing Military General Hospital approved the study protocol (number 2011-LC- Ped-01). From May 2012 to December 2013, 80 newborn infants with NPA and 50 neonates without lung disease were enrolled in this study. All of the enrolled patients were admitted to the Department of Neonatology and NICU of Bayi Children's Hospital (affiliated to Beijing Military General Hospital, Beijing, China). The clinical characteristics of patients with and without NPA are shown in Table 1.

Lung Ultrasonography

Bedside lung ultrasonography was performed using a high-frequency linear 9 to 12 MHz probe (GE Voluson E6 or E8; GE Medical Systems), with the probe positioned perpendicular or parallel to the ribs. While in a quiet state, the infants were positioned in the supine, lateral, or prone position. The findings were recorded in three areas of each lung, divided by the anterior and posterior axillary lines. The ultrasound findings recorded included pleural lines, A-lines, B-lines, comet-tail artifacts, lung consolidation with or without air or fluid bronchograms, dynamic air bronchograms, interstitial syndrome, pleural effusion, lung sliding, and lung pulse, as described previously.[13]

Examination Procedures

The examination procedures of this study were as follows. The infants first received lung ultrasound examinations, and if there was suspicion of atelectasis, it was then confirmed by CXR; if there were no abnormal findings on CXR, it was further confirmed by chest CT scan. The diagnosis of atelectasis was excluded if there were no findings of atelectasis on chest CT scan. In the present study, those cases of NPA that could be detected on CXR were termed focal-type atelectasis (FTA), while those that could not be detected on CXR and had to be detected by chest CT scan were termed occult lung atelectasis (OLA). The diagnosis of atelectasis was primarily made according to the following criteria[14,15]: (1) existence of primary lung disease that could lead to atelectasis, such as pneumonia, respiratory distress syndrome (RDS), etc; (2) dyspnea that could not be explained by primary lung disease; (3) lung showing dullness on percussion, breath sounds diminished or absent on auscultation; coarse, moist rales on auscultation during deep breathing is also among the important signs of neonatal atelectasis; and (4) CXR or CT scan findings, depending on the radiologists' findings of absence of air in the entire lung or part of a lung, as well as direct signs, including increased opacification of the airless lobe and displacement of fissures. Indirect signs included displacement of the hilar and cardiomediastinal structures, narrowing of the ipsilateral intercostal spaces, and elevation of the ipsilateral hemidiaphragm, and there could be compensatory hyperinflation of the adjacent lobes. However, CT scan was more subtle and accurate than CXR.

Statistical Analysis

The data were analyzed using SPSS for Windows software, version 16.0 (IBM). The ultrasound findings were compared among the patients with and without NPA using the Fisher exact test. A value of $P < .05$ was considered statistically significant.

Results

Normal Neonatal Lung Ultrasound Findings

Normal lungs appear black on ultrasound examination. On longitudinal scans, the ribs appear as curvilinear structures with posterior acoustic shadowing. The pleural line on each side appears as a smooth, clear, echogenic line with a width of < 0.5 mm. A-lines appear as a series of echogenic lines, equidistant from one another and parallel to the pleural line. Fetal lungs have a high fluid content, and B-lines and comet-tail artifacts can be observed in healthy, full-term neonates. In this study, B-lines or comet-tail artifacts were observed in 18 healthy neonates (Fig 1).

Ultrasound Findings in FTA

A total of 625 neonates with various lung diseases underwent lung ultrasonography during the study period, of whom 80 (12.8%) were diagnosed with NPA. In 60 of these 80 patients (75%), NPA was confirmed by CXR (termed FTA). The ultrasound findings of FTA were as follows: (1) large areas of lung consolidation with clearly demarcated borders (60 of 60, 100%); (2) air bronchograms (60 of 60, 100%), fluid bronchograms (nine of 60, 15%), or dynamic air bronchograms on real-time ultrasound (10 of 60, 16.7%); (3) interstitial syndrome adjacent to the area of consolidation; (4) pleural line abnormalities (60 of 60, 100%); (5) absence of A-lines (60 of 60, 100%); (6) lung pulse and absence of lung sliding in patients with severe disease (40 of 60, 66.7%);