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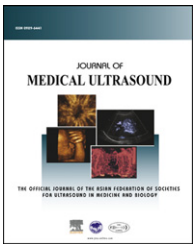

BRIEF COMMUNICATION

Chest Ultrasound Helps to Diagnose Pulmonary Consolidations in Pediatric Patients

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The diagnosis of pneumonia in pediatric patients relies on physical examination, blood tests, and chest X-rays. Physical examination, blood tests, and chest X-rays have a low accuracy, that is even greater in the critically ill. These limitations along with the risk of ionizing radiations, mandate the search for a safe diagnostic tool for patients with suspected pneumonia. Ultrasound (US) imaging offers several advantages over traditional radiographic techniques: it is non-invasive, painless, and involves minimal contact. In case of pulmonary parenchymal lesions, US is useful for differentiating pulmonary consolidation or atelectasis from lung masses and pleural lesions. Detection of air or fluid bronchograms at US and of pulmonary vessels with color flow imaging, is essential for the differential diagnosis of parenchymal consolidations. Furthermore US has a role in the evaluation of mediastinal masses and characterization of pleural fluid collection. Chest US is an ideal modality for serial examinations in rapidly evolving disease processes.

Introduction

The diagnosis of pneumonia in pediatric patients relies on physical examination, blood tests, and chest X-rays. Interpretation of the location and the nature of an area of increased opacity on chest radiographs is sometimes problematic, particularly in young infants with varied configurations of the thymus, and differentiation between pulmonary, pleural, and mediastinal lesions is not always easy [1].

Physical examination, blood tests, and chest X-rays have a low accuracy in the adult population, that is even greater in the critically ill [2]. The chest radiograph has been used as the reference standard for the diagnosis of pneumonia in most studies on adult patients. Nevertheless, technical limitations in the interpretation of chest radiograph of patients with possible pneumonia are well known [3].

Although chest radiography is regarded as the reference standard for the diagnosis of community-acquired

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pneumonia, the reliability of this test is limited by significant interobserver and intraobserver variability in radiographic interpretation [4]. Children have a 10 times the sensitivity to radiation as compared with adult patients, and the mortality from radiation exposure approaches and possibly exceeds that of a laparotomy for a negative appendectomy [5].

Lung scan using a portable bedside ultrasound (US) machine can be adopted as a simple and non-invasive method for evaluating children with pneumonia. It is easy to perform at the patient's bedside, as it allows close follow-up and avoids the use of ionizing radiation [6].

US may be helpful in evaluation of areas of increased opacity of the peripheral lung and mediastinal widening. Consolidation and atelectasis can be differentiated from lung masses and pleural lesions by typical US findings. Furthermore pleural fluid collections can be characterized as simple, complicated, or fibrohadhesive. In young children with widening of the superior mediastinum, US may differentiate normal thymus from medistinal masses. This technique may aid in diagnosis of chest wall lesions, by allowing localization and defining them as cystic or solid [1].

Here, we describe our experience in US practice and provide some useful techniques, diagnostic characteristics in pulmonary consolidations, and some related sonographic illustrations in this article.

Scanning Technique

Neonates and infants are best imaged with a high resolution 5—10-MHz linear-array transducer; children and adolescents may require a 2—4 or 4—7 MHz sector or linear-array transducer. In older children a 3.5—5-MHz convex probe can be used as well. The probe is placed perpendicular, oblique, and parallel to the ribs. The thorax is scanned from the apices to the bases in the anterior, lateral, and posterior areas. Transternal, parasternal, and intercostal approaches are good for imaging of the lung, pleura, and anterior mediastinum. In the sub-xyphoid and transdiaphragmatic approaches the liver is used as an acoustic window for evaluating juxtaphrenic paravertebral lesions. Suprasternal and supraclavicular approaches facilitate evaluation of the upper mediastinum and lung apices. US is performed in the supine, prone, or decubitus position. Images are obtained in the transverse, longitudinal, and inclined transverse or inclined longitudinal planes to maximize demonstration of the lesion [1,6].

Normal Findings

The normal pediatric lung picture does not differ from that of the adult lung. The superficial layers of the thorax consist of subcutaneous tissues and muscles. The ribs, on longitudinal scan, appear as curvilinear structures associated with posterior acoustic shadowing (Fig. 1A). The ribs and the pleural line, in the longitudinal view, outline a characteristic pattern, the "bat sign" (Fig. 1B).

The pleura appears as a regular echogenic line (pleural line) moving continuously during respirations (Fig. 2). Pleural movement has been described as the "lung sliding" sign. The amplitude of the lung sliding is minimal at the apices and maximal at the bases. Lung sliding can be objectified and documented with M-mode [1,2].

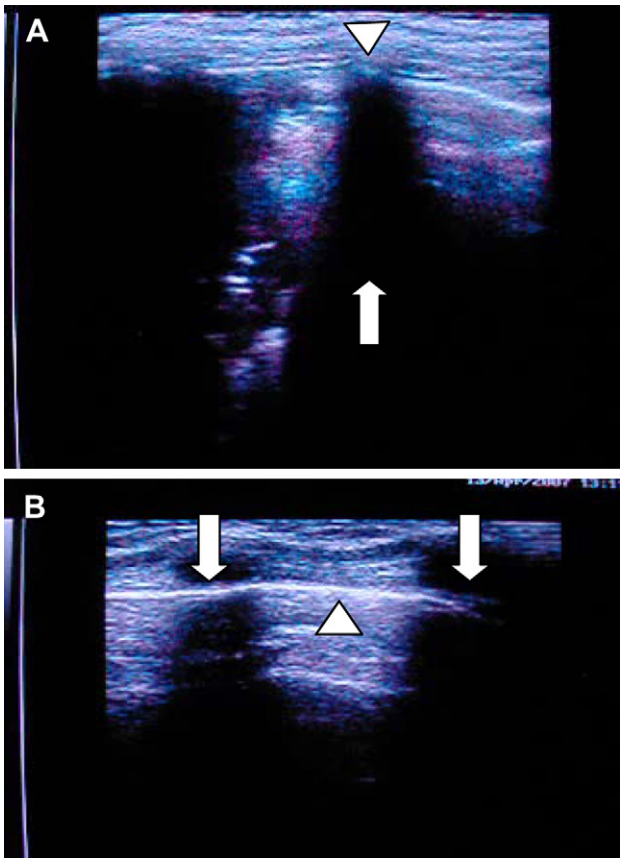

Fig. 1. (A) Posterior acoustic shadowing (arrow) of a rib (arrowhead). (B) The bat sign: two adjacent ribs and their shadows (arrows) resemble the wings, the pleural line in the middle resembles the body of the bat (arrowhead).

Beyond the pleura-lung interface, the lung is air-filled and does not allow further visualization of normal lung

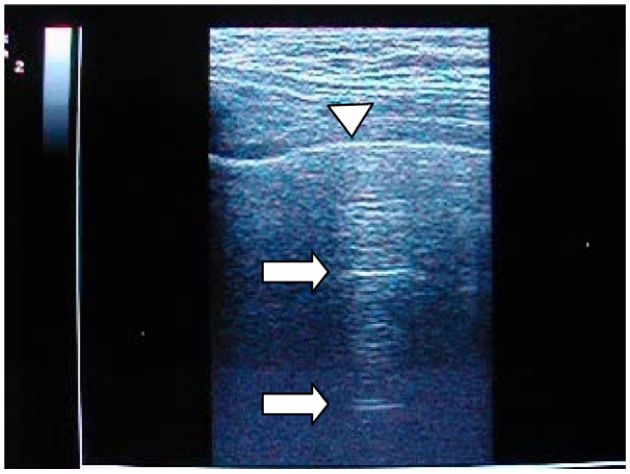

Fig. 2. The pleural line appears as an echogenic line (arrowhead) below the superficial layers of the skin. A lines are parallel horizontal lines below the pleural line (arrows).

parenchyma. However the large change in acoustic impedance at the pleura-lung interface results in horizontal parallel artifacts below the pleural line. Those artifacts have been termed "A lines" (Fig. 2). Vertically oriented "comet-tail" artifacts arising from the pleural line, also called "B lines", are absent in the normal lung. They arise from the pleural line, are well defined, reach the lower edge of the screen, erase A lines and move with lung sliding [2,6]. The presence of B lines, or comet tails, are related to pathological findings and results from the fluid-rich subpleural interlobular septae, which are surrounded by air and identify an alveolar-interstitial syndrome [7] (Fig. 3).

Pathological Findings

Consolidation and atelectasis

The airless lung is similar in echogenicity and echotexture to the liver and spleen. Within the solid-appearing area of echogenicity, multiple bright dotlike, and branching linear structures are found. These findings represent air in the bronchi and scattered residual air in alveoli within the consolidated or atelectatic lung. This appearance is termed a sonographic air bronchograms (Fig. 4A).

In consolidation, the lung volume is increased by fluid or tissue, but the bronchi are spared and retain their normal branching pattern.

In atelectasis, overall lung volume is decreased; supplying bronchi of the involved lung can be crowded together in very close apposition in one plane, appearing as parallel-running bright lines (Fig. 4B).

Furthermore, consolidation can be differentiated from atelectasis by the presence of dynamic air bronchogram: a centrifugal inspiratory movement of air bronchograms, movement greater than 1 mm is required to confirm the diagnosis [8].

Occasionally, when the bronchial tree is filled with fluid rather than air, as in mucoid impaction, US may demonstrate a branching pattern of anechoic or hypoechoic tubular structures within consolidated lung (Fig. 5).

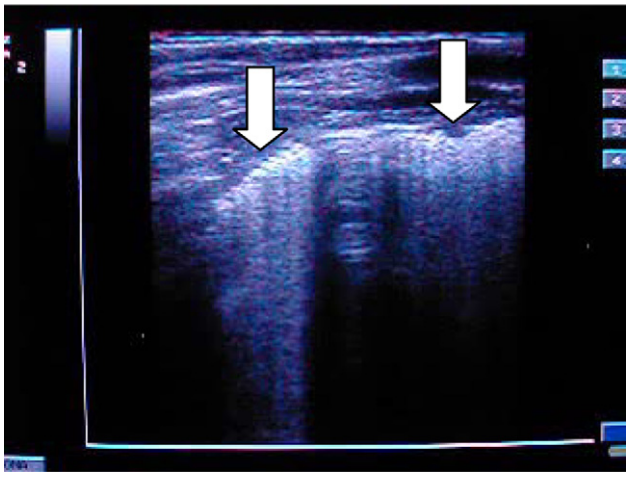

Fig. 3. Multiple comet tails or B lines arising from the pleural line (arrows). Comet tails erase A lines.

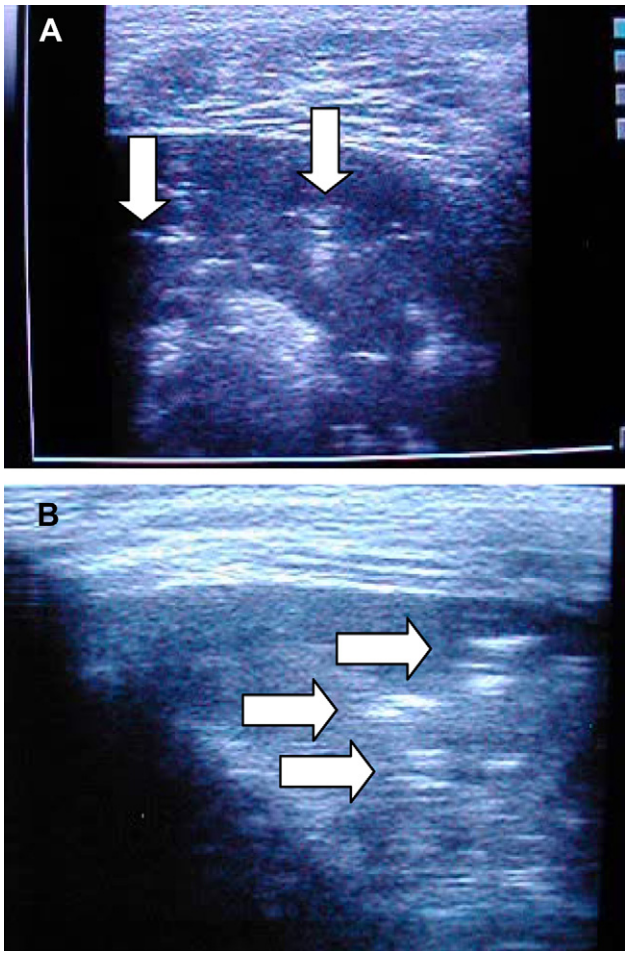

Fig. 4. (A) Consolidation with branching air bronchograms (arrows). (B) Atelectasis with parallel air bronchograms (arrows).

Demonstration of fluid-filled bronchi, an appearance termed as sonographic or mucous bronchogram, is a specific indicator of pulmonary parenchymal consolidation, equivalent to the air bronchogram [2,8].

Sonographic air or fluid bronchograms may not be visible, particularly in the peripheral lung. In this case, color flow US demonstrates the normally branching pattern of pulmonary vessels in consolidated lung. A normal pulmonary vessel pattern is another indicator of parenchymal consolidation [9].

Pleural effusion and pleural thickening

Pathological processes that involve the pleura and manifest as fluid collections, are ideal for imaging with US because of their acoustic properties. The different types of pleural effusion depend on the nature of the fluid collection: serous, purulent, hemorrhagic, or chylous. Serous fluid is usually a transudate, and purulent fluid is an exudate or empyema. At US, pleural fluid may be characterized as a simple effusion, a complicated effusion, or fibrothorax (pleural thickening or fibrosis) (Fig. 6). A simple effusion appears as a clear anechoic or cloudy hypoechoic fluid with or without swirling particles (Fig. 7). A complicated

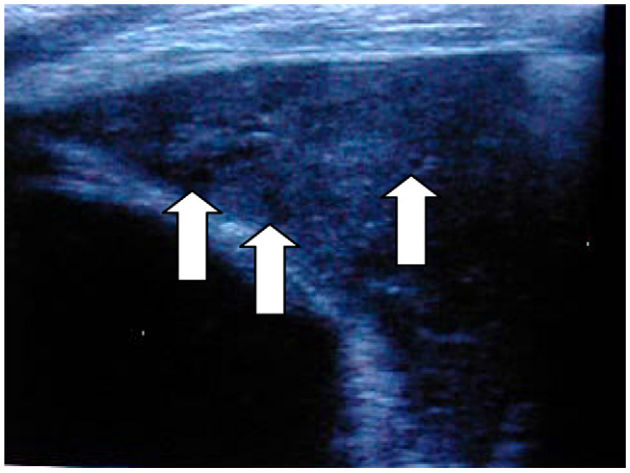

Fig. 5. Mucoid impaction with fluid-filled bronchi (arrows).

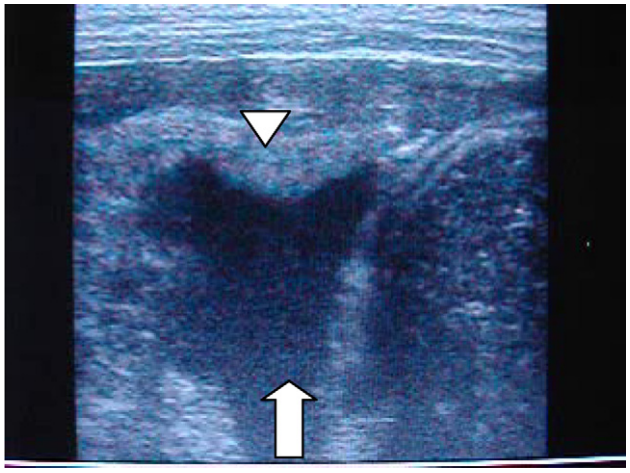

Fig. 7. Pleural effusion (arrow) with atelectatic lung (arrowhead).

effusion appears as a septated or multiloculated, hypoechoic fluid, partitioned by fibrin strands, with no clear demarcation between the lung and the pleural components [10]. Fibrothorax appears as a thickened, echogenic rind of pleural plaque [1].

Lung abscess

Lung abscess, a localized area of suppuration with destruction of the lung parenchyma, and empyema share common radiologic US findings (Fig. 8). Color Doppler US vessel signals in a pericavitary consolidation has been shown to be a powerful tool for differentiating the peripheral air-fluid abscess from empyema, with high specificity and without any risk [11].

Discussion

Lung US has become an invaluable tool, to diagnose pneumonia in adult patients. From intensive care units, where it has been used for intubated patients, it has spread to many emergency departments. Only peripheral pulmonary lesions that extend into the visceral pleura may be visualized by US. About 98.5% of alveolar consolidation abut the pleura, a mandatory condition for its US detection [12].

Ionizing radiations can damage genetic information and induce malignant transformation of biological tissues. Radiated tissues do not recover from the transforming effect of a single exposure but retain the genetic damage in perpetuity. In this regard, diagnostic imaging carries an irreversible lifetime risk that is particularly important among younger patients, especially those with actively dividing somatic cells [9].

US imaging offers several advantages over traditional radiographic techniques: it is noninvasive, painless, and involves minimal contact. Furthermore, US may have a role in the evaluation of mediastinal masses. US may permit clarification of radiographically equivocal findings. It may also partially replace computed tomography and magnetic resonance imaging in certain situations, for example in

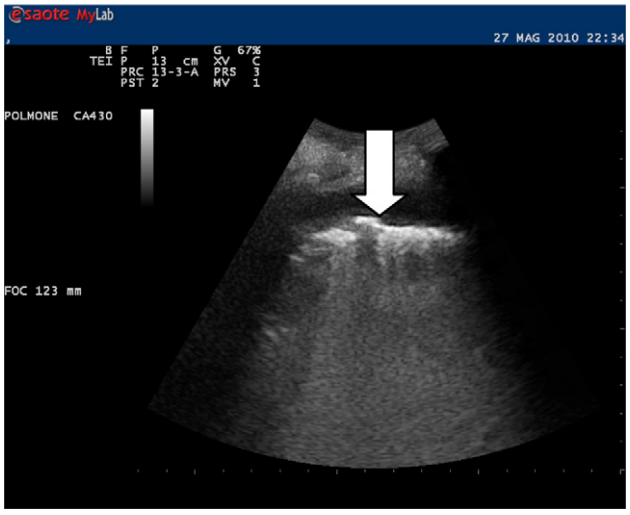

Fig. 6. Pleural thickening (arrow).

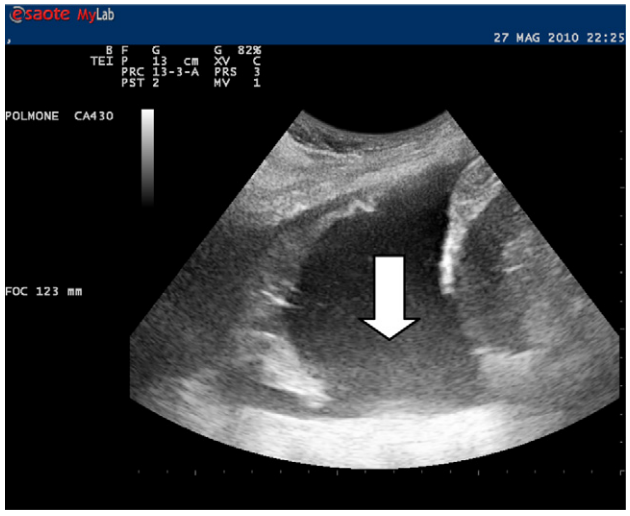

Fig. 8. Empyema: pleural effusion with particulate matter (arrow).

young children with widening of the superior mediastinum to differentiate normal thymus from mediastinal masses and in critically ill patients in intensive care units [3]. The mineral content of the bones and cartilages is lower than in older children. Therefore, there are ample acoustic windows through the sternum, costal cartilages and thymus, and US of the mediastinal structures is easily performed [1].

Emergency chest US study can be performed at the patient's bedside, avoiding the transfer of a potentially unstable patient to the radiology suite. It does not require the patient to remain motionless and does not use ionizing radiation. US is an ideal modality for serial examinations in rapidly evolving disease processes without concerns about cumulative radiation side effects.

Conclusions

US is a useful diagnostic aid to chest radiography in the evaluation of areas of increased opacity. It is easy to perform at the patient's bedside, allows close follow-up and reduces the use of ionizing radiations. Characteristic features of lung lesions are clearly identified by US. In atelectasis, the airless lung is similar in echogenicity and echotexture to liver and the air broncograms appear crowded and parallel. By contrast, in pneumonia, bronchograms appear in a scattered dot-like and branching pattern. Lung atelectasis can be definitely excluded if dynamic air bronchograms are present. Finally, lung US is of utmost importance to determine the characteristic of pleural effusion and to guide thoracentesis.

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