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Review

Point-of-care chest ultrasound in the Neonatal Intensive Care Unit

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Abstract

Chest ultrasound is a useful diagnostic tool in adult emergency medicine. Echography does not generate a clear image of the lung but is able to generate artifacts that are combined in disease-specific profiles. Reflections of the pleural image appear as short straight lines also known as A-lines. Vertical, comet-tail artifacts departing from the pleura are named B-lines. The former are present in the normal lung while the latter have been described in the adult wet lung. Lung ultrasonography outperforms conventional radiology in the emergency diagnosis of pneumothorax and pleural effusions. Neonatologists and pediatricians are now adapting lung ultrasound to their specific clinical issues. The normal image is relatively unchanged throughout the age span, while progressively fading B-lines describe the fluid-to-air transition of the neonatal lung. Also, an homogeneous white (hyperechogenic) lung with pleural image abnormalities and absence of spared areas is accurate in diagnosing Respiratory Distress Syndrome (RDS). The prevalence of A-lines in the upper lung fields with B-lines at the bottom fields (aka double lung point artifact) is highly sensitive and specific in describing Transient Tachypnea of the Newborn. Infantile pneumonia has recently been proved an accurate diagnosis by ultrasound after a short training.

In summary, chest ultrasonography has no ground to replace conventional chest radiology tout court. However, when appropriately applied, a lung ultrasound scan can save time and radiation exposure to achieve a critical diagnosis.

Keywords

Ultrasound, lung, artifacts, comets, neonate, pneumonia.

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Introduction

Neonatal respiratory disease is currently diagnosed on the basis of clinical signs and chest radiograph. Wilson-Costello has estimated an average of 31 radiographs taken during the hospital admission of an extremely low birth weight infant [1]. The relevance of this radiation exposure is still debated. Moreover, the interpretation of a chest radiograph has a significant interobserver variability. Ultrasound imaging of the lung has been traditionally neglected because the high acoustic impedance of its air content prevents a clear image of the organ. The pleura is the only lung structure clearly visible with ultrasounds appearing as an homogeneous, hyperechogenic line moving synchronous with respiration.

The pioneering work of Lichtenstein and other adult emergency physicians has shown that the interpretation at the patient bedside of these findings together with some reproducible artifacts (see below) can be very useful in critical situations where echography outperforms conventional radiology. The fundamentals of this technique, that hold true irrespective of the patient's age, have been recently reported in international evidence-based recommendations [2].

Pediatricians and neonatologists have learned the lesson and are now applying point-of-care lung ultrasound to their practice. This paper is a concise but comprehensive summary of their work.

From artifacts to clinical correlates

A microconvex probe is generally used to explore the adult chest. A linear, high frequency device is often preferred in neonates where it grants a wide view of the anterior, lateral and possibly posterior fields both in the sagittal and transverse projections. Useful information can be gained in B-mode as well as in M-mode.

In the healthy infant (**Fig. 1**), a periodically moving line will be evident in B-mode below the superficial plans and between the rib images. This horizontal motion corresponds to the sliding of the pleural leaflets (the sliding sign). A vertical motion (aka lung pulse) is also normally detected.

Inferiorly, the pleural image is reflected a number of times in straight and short repetitions also known as A-lines.

A different artifact is named B-line, a vertical hyperechoic image that recalls the tail of a comet (**Fig. 2**). B-lines can be seen as individual or multiple artifacts with a trend to coalesce into a white lung image of sicker patients. In the adult, B-lines have been linked to the interstitial syndrome and may also be useful in evaluating the patient with heart failure [3-6]. In the neonate, sporadic B-lines are often present after birth but a white lung image is seldom regarded as normal (see below).

Lung consolidation ultrasonography is visualized as a subpleural echopoor or tissue-like region with blurred margins or wedge-shaped borders [7]. Sonographic air bronchograms are hyperechoic linear elements representing air in bronchioles that appear within the hypoechoic consolidated lung (**Fig. 3**). In adults on mechanical ventilation, dynamic air bronchograms have proven to accurately discriminate pneumonia from resorptive atelectasis [8].

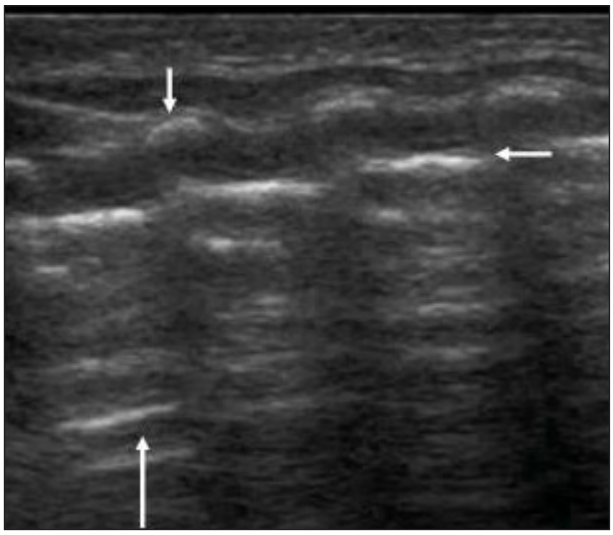

Figure 1. Longitudinal scan of a normal lung. Between the ribs image (downward pointing arrow), a thick hyperechogenic line represents the pleura (horizonatal arrow). Several short straight reflections of the pleural image are seen (*A-lines* – upward pointing arrow).

The simultaneous absence of B-lines, lung sliding and lung pulse is diagnostic of pneumothorax, even if the boundaries of the air leak are not determined. Pleural effusions appear as an anechoic space between the pleural leaflets. Conventional radiology detects as opacities images that will be differentiated as consolidations or effusion only at ultrasound scan. It is not surprising, then, that echography outperforms the radiograph in ruling in and out both pneumothorax and effusions in the adult [9-12]. In the neonate and child, these comparative studies have not yet been published but experienced pediatric clinicians do not refrain from increasingly recurring to chest ultrasound aid for these diagnoses.

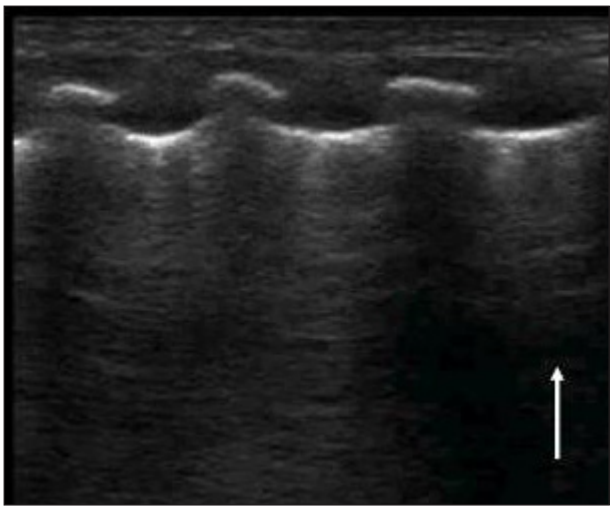

Figure 2. B-lines: A hyperechogenic flurry departing from the pleural image recalls the tail of a comet. The artifact (arrows) is called *B-lined*.

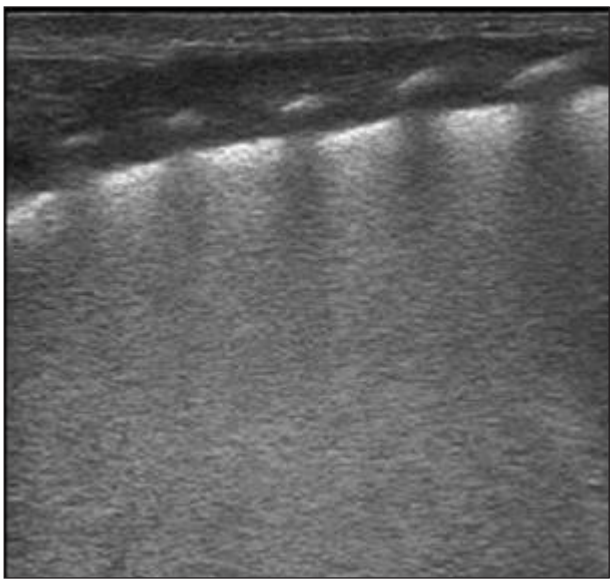

Figure 3. Respiratory Distress Syndrome (RDS): Homogeneously white lung fields with absense of spared areas and irregular pleural images are highly suggestive of RDS.

"Field validation" of lung ultrasound in neonatology and pediatrics

Neonatologists and pediatricians are gathering evidence-based data on ultrasound diagnosis of those respiratory diseases that more frequently affect the developing age.

Respiratory Distress Syndrome (RDS) was diagnosed by Copetti et al. with the simultaneous presence of three ultrasound findings: abnormalities of the pleural line, white lung image and absence of spared areas in all lung fields (**Fig. 3**). This profile had sensitivity and specificity of 100% in their series of 55 premature infants [13]. Unfortunately, since the intratracheal administration of surfactant does not clear the picture [14], chest ultrasound has limited value in the immediate follow-up of RDS.

Copetti et al. found that the presence of a double lung point (normal upper lung fields with coalescent B-lines in dependent areas) was highly sensitive and specific of Transient Tachypnea of the Newborn [15].

A population of 154 unselected term and late preterm newly born infants recently underwent sequential chest ultrasound scans in a well-baby nursery [16]. The normal clearance of lung fluid was documented with progressive disappearance of B-lines to A-lines. Also, a white lung image at 2 hours after birth was strictly associated with clinically significant respiratory distress and need of ventilatory support.

Finally, a large study was conducted on pediatric patients (median age 3 years; interquartile range 1-8) at two American emergency departments testing the ability of point-of-care lung ultrasound to diagnose pneumonia using Chest X-Radiograph (CXR) as a reference standard [17]. Clinicians who had received a training in chest ultrasound as short as one hour were able to accurately diagnose pneumonia with an overall sensitivity of 86% and a specificity of 89% by visualizing lung consolidation with sonographic air bronchograms. In the subgroup analysis of 187 patients having lung consolidation exceeding 1 cm, ultrasonography had a sensitivity of 86% while specificity rose to 97%.

Conclusions

The ultrasound exploration of the lung has rapidly gained an important role in emergency

diagnostics. It complements rather than substituting CXR, but, where appropriately applied, chest ultrasound saves time and radiation exposure. The ultrasound scan of the lungs does not offer a full vision of the organ but generates a number of artifacts that have been interpreted, often after a steep learning curve, to accurately diagnose critical disease in the adult. Neonatologists and pediatricians are now applying with success point-of-care lung ultrasound to provide better care for their fragile patients.

Declaration of interest

The Authors declare that there is no conflict of interest.

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