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Ultrasonography in Pneumonia: A Narrative Review

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Abstract

Pneumonia is the leading cause of death in children but confirmation of the clinical diagnosis, still remains difficult. Chest radiography (CXR) is generally considered the first-line imaging modality to investigate suspected pneumonia. Alveolar consolidation or interstitial infiltrates combined with high serum C-reactive protein is considered fairly diagnostic for bacterial pneumonia. Ultrasound (US) has played a small role in the diagnosis of pneumonia, serving mostly as a supplement to routine radiography in complex illness. Recently, the lower cost and improved availability of portable US technology, as well as its potential to prevent radiation exposure, have reignited interest in using lung US as a first-line imaging modality for the diagnosis of pneumonia, particularly in children. Evidence suggests that when performed by appropriately trained clinicians, a structured lung US examination can detect lung consolidation and other features suggestive of pneumonia in children with the same accuracy and reliability as chest radiographs, with the added benefits of no ionising radiation exposure and potential cost and time savings. In this review, we have focused on the important aspects of ultrasonography in childhood pneumonia.

Keywords:

Introduction

Pneumonia is the leading cause of death in children but confirmation of the clinical diagnosis, still remains difficult. Chest radiography (CXR) is generally considered the first-line imaging modality to investigate suspected pneumonia. Alveolar consolidation or interstitial infiltrates combined with high serum C-reactive protein is considered fairly diagnostic for bacterial pneumonia. However, CXR cannot be considered as a gold standard due to wide inter- and intraobserver variability in interpretation, differing radiologic manifestations of pneumonia and also lack of sensitivity and specificity[1–7]. Considering the potentially harmful effects of radiation exposure, some guidelines advise against use of CXR routinely, in uncomplicated acute lower respiratory infections in children, especially with high coverage for Haemophilus influenzae type B and Pneumococcus vaccination[8, 9].

Ultrasound (US) has played a small role in the diagnosis of pneumonia, serving mostly as a supplement to routine radiography in complex illness. Recently, the lower cost and improved availability of portable US technology, as well as its potential to prevent radiation exposure, have reignited interest in using lung US as a first-line imaging modality for the diagnosis of pneumonia, particularly in children.

Technique And Equipment:

The type and size of the transducer used for US, depends on the age of the child. Small linear or micro-convex probes are suitable for an intercostal approach. In lung US, a high frequency transducer (5-15 MHz) is appropriate for examination of the pleura and sub-pleural space. Children can be scanned in the upright, supine or decubitus positions. Scanning an uncooperative child can be done with the child seated on caregiver's lap (even while

breastfeeding) to minimise anxiety and agitation. To improve control of the probe, the base of the operator's hand can be stabilized against the chest wall, to minimise movement and improve visualisation.

A systematic approach is recommended to ensure both lungs are visualised completely, when using US as a primary imaging modality. Things are different when a focused approach is taken while assessing a specific region of suspected pathology identified on prior CXR. One approach, is dividing each of the hemithorax into anterior, lateral and posterior zones, subdivided into upper and lower halves. Every zone is then scanned along anatomical lines: parasternal, midclavicular, anterior axillary, mid-axillary, posterior axillary, mid-scapular and para-vertebral[10]. The lung is visualised through the intercostal window and the probe is rotated both perpendicular and parallel to the ribs and moved from one intercostal space to the next, in a caudal direction from the apices to the costo-phrenic angles. If a pathological area is visualised, a detailed assessment of that area is done. Dependent lung areas, which change according to patients' position, should be specifically checked to diagnose a pleural effusion. When scanning the posterior chest, it is helpful to ask a cooperative child to move their shoulders forward to expose as much of the retro-scapular regions as possible.

Anatomical orientation can be difficult during lung US as the operator usually sees only a part of any structure at any given time. Knowing where the probe is placed on the patient helps the operator to identify which structures are being visualised. A better approach is to start in the upper zones, ensuring the probe is over lung and identify the pleural line deep to the ribs and then move the probe caudally until the sub-diaphragmatic organs are seen. When the probe is held still at the lung base, the diaphragmatic line and abdominal structures can be seen moving in and out of view with respiration. This appearance and disappearance of aerated lung is referred to as the curtain sign. This is helpful in distinguishing the sub-diaphragmatic viscera from lower lobe consolidation.

Ultrasound Findings In Pneumonia:

Only the pleura, which appears as a smooth hyper-echoic line deep to the ribs in a healthy aerated lung, may be directly seen by US. The US beam is unable to penetrate calcified bone, and the ribs create an acoustic shadow, which is seen as an anechoic segment deep to each rib. The pleural line appears shimmering when the visceral pleura is seen slipping across the parietal layer during breathing. When there is no lung slippage, a pneumothorax should be suspected. Normal air-filled lung parenchyma cannot be directly seen by US, but it produces a distinctive artefactual pattern known as A-lines, which are hyper-echoic lines running parallel to the pleural line that are really pleural line reverberation artefacts (Fig. 1). B-lines (also known as lung comets) are hyper-echoic lines that arise from and travel perpendicular to the pleura up to the deep edge of the picture, obliterating the Alines where they intersect.

Initially, Lichtenstein et al. proposed that enlarged B-lines were caused by thicker, oedematous inter-lobular septa [11]. Recent research, however, suggests that B-lines are formed in the lung parenchyma by arbitrary air-fluid interfaces produced by adjacent fluid and air-filled structures such as alveolar air and interstitium, which become increasingly dense with a corresponding increase in extravascular lung water or decrease in aeration. [12–14] B-lines are associated with enlarged interlobular septae or a ground-glass appearance on computed tomography (CT) [11, 15]. Although B-lines may be found on occasion in a normal lung, particularly in dependent zones, an increase in the number and density of B-lines is considered unhealthy. Using CT in adults, three or more distinct B-lines seen at the same time (in any view) or when they become confluent have been linked to thickening of the interlobular septae due to increased interstitial fluid or infiltration [11, 16]. (Fig. 2). We must keep in mind that enlarged B-lines are a generic sign that cannot reliably differentiate underlying disease, such as separating exudative from transudative causes of interstitial oedema or an infective from a non-infective inflammatory process.

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Fig. 1: Ultrasound image from right anterior upper lung zone demonstrating normal lung echo pattern with smooth hyper-echoic pleural line and A-lines

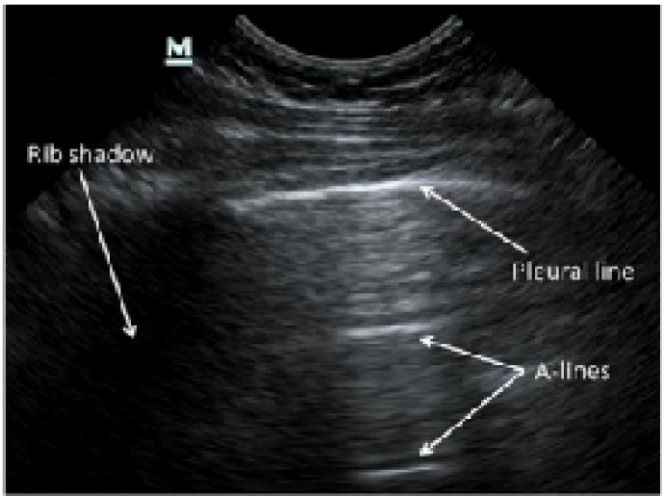
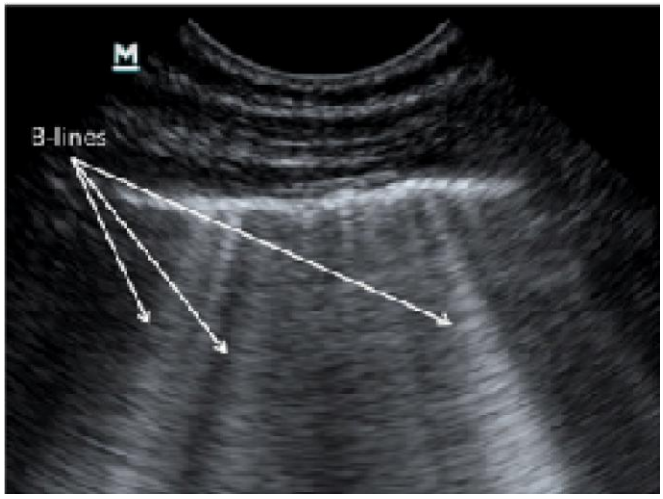


Fig.2 : Ultrasound image from left anterior lower lung zone showing multiple and confluent B-lines in a single view, representing an interstitial disease pattern



Fluid can displace alveolar air as a result of infectious and inflammatory diseases. When this disease of air-space consolidation spreads to the pleura, it can be seen with US as a poorly defined, hypo-echoic sub-pleural region with a variety of accompanying characteristics (Fig. 3). These include: a) loss of pleural line echogenicity over the area of consolidation and the absence of A-lines within the area, b) increased B-lines surrounding the area of consolidation, c) B-lines frequently arising from the deep edge of the consolidation rather than the pleura, and d) sonographic air bronchograms seen as multiple hyperechoic punctate or lenticular specs within the area of consolidation. Large consolidations have a distinct liver-like look, which is referred to as hepatisation. The look of atelectasis or lung collapse is similar to that of consolidation. A variety of related characteristics that might possibly distinguish consolidation from collapse have been identified, although the difference cannot be achieved reliably, especially when there are limited pockets of consolidation [17–19]. Pleural effusions appear as anechoic or hypoechoic fluid in the pleural space, with or without internal structures and debris. US has a high sensitivity for detecting extremely minor effusions and may be used to characterise effusions by confirming the presence of loculations and fibrin stranding [20].

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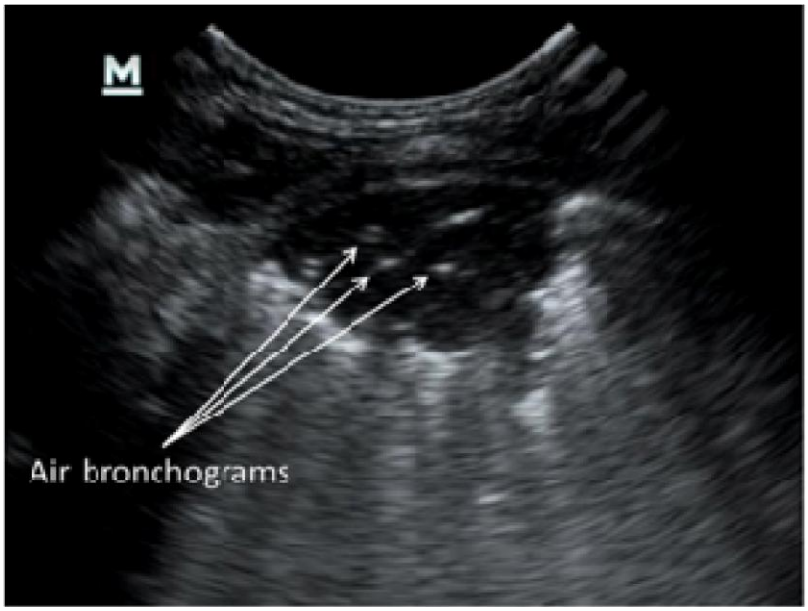
Fig.3 :Ultrasound image from right posterior upper lung zone showing wedge-shaped hypo-echoic area of sub-pleural consolidation. Also seen are air bronchograms represented by punctate hyper-echoic specs within the lesion, a hypo-echoic pleural line over the lesion and mustiple B-lines that arise from the deep edge of consolidation, rather than from pleura



Although both consolidation and interstitial diseases have been recorded in noninfectious situations, in the context of a feverish kid with respiratory symptoms, both of these sonographic patterns are often considered indicative of lower respiratory tract infection. Most authors found consolidation, air bronchograms, and pleural effusions to be diagnostic of bacterial pneumonia in majority of the trials reviewed. There appears to be widespread agreement in both adult and paediatric research that an interstitial pattern suggests viral illness [21, 22]. While this interpretation is compatible with the World Health Organization's standardised interpretation of chest radiographs [5] there is no clear microbiological evidence tying the interstitial pattern to infection.

There is a scarcity of pathogens. Initially, air bronchograms were not necessary to characterise a consolidation, but some writers regarded consolidation without bronchograms to constitute atelectasis. [21, 23, 24] Formalized paraphrase

Strengths and limitations of lung ultrasound:

Despite having diagnostic accuracy and reliability comparable to or better than chest radiography for identifying lung consolidation, the application of lung ultrasound in clinical practise has been limited. The United States is not yet included in clinical treatment guidelines for paediatric community-acquired pneumonia. The instant availability of data by lung US at the bedside is typically regarded as a strength, but it is negated by the time necessary to do the scan, which physicians must invest per patient. The median duration per scan has been reported to be 6.4–10 minutes, with no notable difference between experienced and inexperienced operators [21, 23, 24, 25]. A recent randomised controlled study found that, while physicians spent more time per patient, the total duration of stay in the emergency department was reduced when lung US was used [26]. This also resulted in a 38% reduction in chest radiograph use, with no statistically significant difference in the rates of unscheduled health care visits, missed pneumonia cases, or adverse events (death or resuscitation required) between the interventional arm, in which lung US was performed first and chest radiographs were optional, and the control arm, in which chest radiographs and lung US were both performed routinely. The use of lung US for monitoring the resolution of lung consolidation has also been proven in a number of trials in children, providing another another possibility to reduce the usage of chest radiography [27, 28, 29]. The training requirements for doctors to conduct and interpret lung US in children are a key practical problem. The training includes both theoretical and practical hands-on instruction focused on illness detection and possible mistakes [21,

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[23, 26, 30]. A recent study found that US functioned well in the hands of general practitioners after they received tailored instruction from an expert radiologist over a 7-day period [23]. The importance of providing a sufficient training facility should not be ignored, since it is required to successfully execute and interpret lung US scans. As part of any training programme, supervised instruction and quality assurance by documenting and evaluating scans with an experienced radiologist is recommended. Other limitations of lung US include the inability to visualise consolidations that do not extend to the pleura or are covered by bony structures, the inability to reliably differentiate consolidation from atelectasis, and the potential over-diagnosis of pneumonia due to lung US's ability to detect very small sub-centimetre consolidations of uncertain pathological significance. Furthermore, lung US is unable to exhibit many aspects of children presenting with respiratory distress that are frequently examined on CXRs, such as hyperinflation, heart size and shape, as well as airway location, size, and patency [19].

Conclusion:

Evidence suggests that when performed by appropriately trained clinicians, a structured lung US examination can detect lung consolidation and other features suggestive of pneumonia in children with the same accuracy and reliability as chest radiographs, with the added benefits of no ionising radiation exposure and potential cost and time savings. However, the current literature does not fully address a number of clinically relevant questions, such as how to determine when a negative lung US requires further evaluation with chest radiographs or whether it is safe not to prescribe antibiotics in cases of suspected pneumonia when the lung US is normal and only shows interstitial syndrome or very small sonographic consolidations. Evidence also clearly reveals that lung US has intrinsic limitations that prevent it from totally replacing chest radiography when assessing youngsters with respiratory symptoms. When utilising lung US to aid clinical care, it emphasises the significance of applying clinical judgement to interpret imaging data in context.

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