REVIEW

The value of bedside Lung Ultrasonography in diagnosis of neonatal pneumonia

Hadeel M. Seif El Dien *, Dalia A.K. Abd ElLatif

Department of Pediatrics, Cairo University, Egypt

Received 15 July 2012; accepted 6 February 2013
Available online 13 March 2013

Abstract  Purpose: The aim of this prospective study was to assess lung ultrasonography as an alternative to bedside radiography for the diagnosis of neonatal pneumonia.

Patients & methods: The study was performed on 75 neonates admitted during the period from October 2011 to October 2012 in the NICU of Cairo University Pediatric Hospital presenting with clinical picture of pneumonia. Chest X-rays and lung US were done.

Results: Chest X-ray findings denoting lung infections were present in 64 cases (85.3%), and the remaining 11 cases (14.6%) had a free chest X-ray. Ultrasonography revealed pneumonic patches in 68 patients (90.6%), 7 (9.3%) had free US scans. US and chest X-rays detected pneumonic patches in 64 cases (85.3%), US detected pneumonic patches in 18 cases (24%) with chest X-rays having signs of chest infections other than pneumonic patches and in 4 cases (5.3%) with clear chest X-rays.

Conclusion: Bedside lung ultrasonography is highly sensitive, specific, and reproducible for ruling out underlying pneumonic process as well as in early detection and follow up of possible complications and can be considered an attractive alternative to bedside chest radiography and thoracic computed tomography with minimal radiation exposure.

© 2013 Production and hosting by Elsevier B.V. on behalf of Egyptian Society of Radiology and Nuclear Medicine. Open access under CC BY-NC-ND license.
Contents

1. Introduction .................................................. 340
2. Materials and methods .................................. 340
3. Image tools .................................................. 341
4. Results ....................................................... 342
5. Discussion ................................................... 344
6. Limitations of the study .................................. 346
References ..................................................... 346

1. Introduction

Pneumonia contributes to between 750,000 and 1.2 million neonatal deaths each year worldwide (1). Diagnosis of pneumonia is sometimes difficult and lack of exact definitions for pneumonia (2) compounds this problem. It was reported that clinical picture and chest X-ray can miss the diagnosis of pneumonia in neonates in 15% cases (3). However, chest X-ray is still considered to be the first imaging step for diagnosing pneumonia in children (4).

In the neonatal intensive care unit (NICU), bedside lung auscultation and chest radiography are routinely performed on a daily basis for assessing lung status in infants with chest problems. Interpretation of the location and nature of an area of increased opacity on chest radiographs is sometimes problematic, particularly in young infants with varied configurations of the normal thymus, and differentiation between pulmonary, pleural, and mediastinal lesions is not always easy. Because of many advantages such as the absence of radiation exposure, non-invasiveness, low cost, safety, and ready availability, transthoracic ultrasonography (TUS) represents an emerging and useful technique in the management of pleural and pulmonary diseases (5).

TUS is helpful in the evaluation of persistent or unusual areas of increased opacity in the peripheral lung, pleural abnormalities, and mediastinal widening; ultrasonography (US) is particularly useful in patients with complete opacification of a hemithorax at radiography. In cases of pulmonary parenchymal lesions, identification of air or fluid bronchograms at US is useful for differentiating pulmonary consolidation or atelectasis from lung masses and pleural lesions (6,7).

The aim of this prospective study was to assess whether lung ultrasonography could be an alternative to bedside chest radiography for diagnosing neonatal pneumonia.

2. Materials and methods

The study was performed on 75 neonates admitted during the period from October 2011 to October 2012 in the NICU of Cairo University Pediatric Hospital. Neonates presenting with clinical picture of pneumonia were enrolled in the study. This included an acute onset of symptoms and signs of respiratory distress including tachypnea, retractions, grunting and cyanosis in addition to auscultatory findings including diminished air entry, fine crepitations and bronchial breath sounds. Only neonates presenting after 48 h of life were included as an attempt to exclude the possibility of Respiratory Distress Syndrome (RDS) and Transient Tachypnea of the Newborn (TTN). Neonates with congenital heart disease (CHD) were excluded from the study to rule out pulmonary edema secondary to congenital heart disease.

All included neonates were subjected to

- History taking including; sex, gestational age, postnatal age, mode of delivery, weight, presenting symptoms and their onset.
- Full clinical examination including general, cardiac, abdominal and chest examination was performed. Signs of respiratory distress (respiratory rate, presence of retractions, grunting or cyanosis) were observed and meticulous chest auscultation was done. Auscultation was performed by the same investigator immediately before performing the US scanning. Twelve lung regions were systematically examined: the upper and lower parts of the anterior, lateral, and posterior regions of the left and right chest walls with the patient in the supine position. Abnormal auscultatory findings included diminished breath sounds, presence of bronchial breath sounds and presence of fine crepitations. The extent of lung injury was assessed as the number of regions where auscultation was abnormal.
- Laboratory investigations including complete blood count with differential, C reactive protein, blood culture and endotracheal aspirate in ventilated cases were done.
- Chest radiography with the patient in the supine position, anterior portable radiographs were obtained using a Philips Mobile Medical X-ray system D-22335 Hamburg, Germany before US scanning that was read by the same radiologist. Exposure time, focus-film distance, and degree of exposure were standardized for each patient to obtain the best radiographic quality. Lung parenchyma was divided into 12 regions by a cephalocaudal mid-axillary line and a transversal hilar line. Upper lung regions were defined as lung regions delineated by the apex, mid-axillary line, mediastinal line, and hilar line. Upper and lower lateral lung regions were defined as lung regions delineated by the external limit of the chest wall, mid-axillary line, and apex (upper) or diaphragm (lower). Upper and posterior lower lung regions were defined as lung regions with radiologic signs erasing the mediastinum border (“silhouette sign”) and delineated by the mediastinum, mid-axillary line, hilar line, and apex (upper) or diaphragm (lower) (8). The extent of lung injury was assessed as the number of lung regions with radiologic signs suggestive of alveolar consolidation.
- Lung ultrasonography was performed immediately after the chest radiography, with a Toshiba Diagnostic Ultrasound System, Nemio XG SSA-580A, and a linear 7 MHz. The lung regions that were explored by auscultation were also
explored by lung ultrasonography. For a given region of interest, multiple sites were analyzed. If an ultrasound abnormality was detected in a single site or several sites, then the region of interest was considered characterized by this abnormality. A given region of interest could be characterized by several ultrasound abnormalities. Antero-lateral parts of the chest wall were examined with the patient in the supine position, whereas posterior parts were examined with the patient in the lateral position. Lung ultrasound examinations were also performed for a control group of 20 healthy neonates to determine a normal ultrasound lung pattern. Transsternal, parasternal, and intercostal approaches are good for imaging of the lung, pleura, and anterior mediastinum (Fig. 1). Sector transducers are used in subxiphoid and transdiaphragmatic approaches with the liver used as the acoustic window for evaluating juxta-phrenic paravertebral lesions. Suprasternal and supraclavicular approaches facilitate evaluation of the upper mediastinum and lung apexes. 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. Color flow imaging may be helpful in characterizing the lesion by demonstrating the vascularity and flow pattern and in searching for anomalous vessels, such as those that occur in pulmonary sequestration (5). All scans were done by the same radiologist.

Ethics approval from the Research Ethics Committee, Faculty of Medicine, Cairo University, was taken, according to University and Research Ethics Committee guidelines.

3. Image tools

In normal scans, the ribs, on longitudinal scans, appear as curvilinear structures that cause posterior acoustic shadows. The pleura appears as a regular echogenic line (pleural line) that moves continuously during respiration. Pleural motion has been described as the lung sliding sign. Beyond the pleura-lung interface, the lung is filled with air and does not allow further visualisation of the normal lung parenchyma (4) (Fig. 2).

When the lung is airless, as in consolidation or atelectasis, there is a thorough transmission of the ultrasound beam, thus showing the lung with atypical internal architecture and echogenicity instead of the bright reflections of the aerated lung. 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 bronchogram, which is analogous to the air bronchogram seen on standard chest radiographs (9–12).

In consolidation, the lung volume is increased by fluid or tissue, but the bronchi are spared and retain their normal branching pattern (13). In atelectasis, the overall lung volume is decreased; as a result, supplying bronchi of the involved lung can be crowded together in very close apposition in one plane. In atelectasis, the US appearance of the air bronchogram is still present as long as bronchi are not obstructed. However, the scattered dotlike and branching pattern of the air bronchogram seen in consolidation may become crowded and parallel running. The latter finding may be seen in passive atelectasis of the peripheral lung due to a large pleural effusion, adhesive pleural thickening, or pneumothorax (11).

The usefulness of US is in differentiation of pleural abnormalities from pulmonary parenchymal lesions; when both pulmonary and pleural lesions are present, distinction between these two lesion types is not always easy at chest radiography.

![Fig. 1](image1.png) Transducer positions for imaging intrathoracic structures. A = supraclavicular, B = suprasternal, C = transsternal, D = parasternal, E = intercostal, F = subxiphoid, G = transdiaphragmatic (1).

![Fig. 2](image2.png) Normal lung, longitudinal thoracic scan. Note the horizontal artifacts (A lines), the echogenic line of normal pleura and posterior acoustic shadowing of the ribs (arrows). (4).
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 the consolidated lung. Demonstration of fluid filled bronchi, an appearance termed as sonographic fluid or mucus bronchogram, is a specific indicator of pulmonary parenchymal consolidation, equivalent to the air bronchogram. Sonographic air or fluid bronchograms may not be visible, particularly in the peripheral lung. In this situation, color flow US demonstrates the normally branching pattern of pulmonary vessels in the consolidated lung. Identification of a normal pulmonary vessel is another indicator of pulmonary parenchymal consolidation (9,10).

However, anechoic pulmonary vessels within the consolidated lung mimic fluid bronchograms at gray-scale US. Color flow imaging allows distinction of color-coded pulmonary vessels from anechoic or hypoechoic fluid-filled bronchi. In a practical sense, such distinction is not necessary because the existence of branching patterns of both fluid-filled bronchi and pulmonary vessels implies pulmonary parenchymal consolidation. In some patients, pneumonic consolidation may appear as a round area of increased opacity, thus mimicking a tumor. Differentiation between a tumor and a pseudomass is not always easy with chest radiography alone, and further evaluation with CT may be required. The application of US and identification of the characteristic of US appearance of consolidation may eliminate the need for further imaging evaluation.

4. Results

Seventy-five neonates were included in this study; 39 females and 36 males, their postnatal ages on admission ranged from 3 to 26 days with a mean (± standard deviation (SD)) of 9.5 ± 5.72 days. Their mean (± SD) weight was 2644.6 ± 821.19 g and mean gestational age was 37 weeks. Forty cases were delivered vaginally (53.3%) and 36 (46.6%) were delivered by caeserian section.

All cases were diagnosed clinically as neonatal pneumonia with different presentations. (Table 1)

Respiratory support was needed using mechanical ventilation in 20 cases (26.6%); nasal continuous positive airway pressure (CPAP) in 15 cases (20%) and in the rest i.e. 40 neonates (53.3%) of the cases oxygen via nasal prongs only was necessary.

C reactive protein was positive in 38 cases (50.6%); total leucocytic count was elevated (>20,000/mm³) in 12 neonates (16%) and reduced (<5000/mm³) in eight neonates (10.6%). There was elevated I.T (immature to total) ratio (I.T > 0.2) in 18 neonates (24%). Blood culture was positive in only eight neonates (10.6%) and culture of endotracheal aspirate done only in ventilated cases was positive in five of the 20 cases (25%).

Five (6%), of the studied cases died while the remaining 70 (94%) cases improved and were discharged.

Chest X-ray findings were present in 64 cases (85.3%) in the form of pneumonic patches in 46 cases (61.3%) and other findings including hyperinflation, fine atelectatic bands or thickened pulmonary interstitium in 18 cases (24%).

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Clinical presentation of studied cases.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sign</td>
<td>No.</td>
</tr>
<tr>
<td>Tachypnea (&gt;60 breaths/min)</td>
<td>69</td>
</tr>
<tr>
<td>Retractions</td>
<td>65</td>
</tr>
<tr>
<td>Grunting</td>
<td>22</td>
</tr>
<tr>
<td>Cyanosis</td>
<td>20</td>
</tr>
<tr>
<td><strong>Auscultatory findings</strong></td>
<td></td>
</tr>
<tr>
<td>Decreased air entry</td>
<td>62</td>
</tr>
<tr>
<td>Fine crepitations</td>
<td>75</td>
</tr>
<tr>
<td>Bronchial breathing</td>
<td>5</td>
</tr>
</tbody>
</table>

Fig. 3 (a) Normal lung, (b) scattered and branching dot like echogenic air bronchogram seen within subpleural consolidation patch.

Fig. 4 Branching vessels in consolidated lung segment seen by color Doppler study.
remaining 11 cases (14.6%) had a free chest X-ray; 4 (5.3%) of whom also had free US.

US revealed pnemonic patches in 68 patients (90.6%) that appear as oblong or wedge shaped subpleural isoechoic areas, branching or scattered echogenic bright dots that represent the air bronchogram were seen within these areas, (Fig. 3). Color Doppler imaging revealed the branching pattern of the pulmonary vessels within the consolidated segment, (Fig. 4). Color imaging also helped in differentiation between the pulmonary vessels and the anechoic branching mucoid bronchogram, (Fig. 5). Seven (9.3%) had free US examinations. Of the 68 patients with US detected pneumonic consolidation, 46 patients had pnemonic patches detected by both US and chest X-ray and of these 46 patients, seven (15%) had more extensive lesions detected by US than those seen by X-rays while in the 18 (39.1%) patients without clear evidence of pnemonic patches in the chest X-ray, US detected small apical or basal patches of pnemonic consolidation (Fig. 6). Illustration of these results is included in (Fig. 7). (Table 2) reveals the concordance between US and chest X-ray findings.

One of our female cases, 2900 g, gestational age ± 40 - weeks, delivered by caeserian section and mechanically venti- lated with positive US and chest X-ray findings showed poor response to antibiotic treatment. After 14 days early basal paracardiac cystic changes were detected in the X-ray, appear- ing by US as a triangular pleural based paracardiac lung seg- ment having internal multiple variable sized anechoic cystic areas, these cystic areas represent microabscesses (Fig. 8). Follow up US scans were done for this patient until complete res- olution of these changes.

Two patients had radiographically suspected atelectasis; US confirmed these findings demonstrating crowdedness of the echogenic air bronchograms (Fig. 9).

The five neonates diagnosed clinically as pneumonia (with 1 or 2 positive sepsis screening laboratory parameter) with no significant findings in the X-ray and sonar showed improve-
ment with antibiotic therapy and their course followed that of pneumonia.

5. Discussion

Acute lower respiratory tract infection, primarily pneumonia, is the leading cause of death in childhood in developing countries, resulting in an estimated 1.9 million deaths annually (14). The diagnosis of pneumonia has been highly dependent upon imaging since physical examination is anecdotal for detection of pneumonia (15). The need to rule out pneumonic process is important in the NICU, so there is a continuous concern about the balance between the diagnostic value and the potential harmful effects of chest X-rays frequently done for neonates in NICU.

Given the possibility of evaluating pleural lesions, lungs, and extracardiac mediastinum, lung US in children has been recognized as a potentially useful diagnostic method (6,16). This is supported by the fact that children have a thinner thoracic wall, smaller width of the thorax as well as lung volume, which enables a better image quality and visualization of almost the entire surface of the lungs compared to the adult population (17). Lung ultrasound enables a quick low cost bedside examination of the patient, without carrying the risk of ionizing radiations, the US scan can be easily learned and performed by experienced radiologist, and can be immediately integrated with the clinical data (18). For all these facts, previous studies have evaluated the role of bedside lung US in the NICU in diagnosing as well as following up underlying pleuropulmonary disorders. They stated that combining US with clinical parameters could efficiently reduce the number of chest X-rays in NICU (19).

In adults, lung consolidations extend to the pleura in 98.5% of cases and can be seen on US (20). Because lung mass is smaller in children, extension to the pleura may be much more
frequent. Therefore, US can provide a good alternative to standard chest radiography in the evaluation and follow-up of infants with suspected pneumonia (17).

In our study, 75 neonates with clinical diagnosis of pneumonia had bedside chest X-rays as well as lung US. Good agreement was found between US and clinical findings (90.6%), compared to the agreement (85.3%) between clinical findings and chest X-rays; these results being similar to those reported by Copetti and Cattarossi (100% and 88.3%, respectively) (4). In Iuri et al. study (17), LUS and chest radiograph had similar sensitivity in detecting subpleural consolidation (68%). However in different studies done on cases of RDS, Bober (21) reported an ultrasound sensitivity of 100% and specificity of 92% while Copetti and colleagues reported that the LUS sensitivity and specificity reaches 100% in diagnosis of RDS (22). Ultrasound imaging performed at the patient’s bedside, decreases the delays of chest radiography in diagnosis of pneumonia and was proved superior to chest radiography in almost every setting ranging from intensive care units to emergency departments and outpatient clinics (15).

In 18 patients US pneumonic patches were detected yet not seen in their chest X-rays, however these X-rays were not considered normal since apparent thickening of pulmonary interstitium, fine atelectatic bands and hyperinflated lungs were noted and may indicate chest infection. Hence, combining LUS with chest X-rays would be more accurate in ruling out the presence of underlying pneumonic process.

Although radiological findings are commonly accepted as the “gold standard” for defining pneumonia, there are no validated definitions for X-ray interpretation (2). Also, there is a significant variation in intra- and interobserver agreement.
among radiologists on the interpretation of the same chest X-ray images and on the radiographic features used for diagnosis of pneumonia (2,4). In addition to these facts early chest X-rays sometimes may be confusing as it was reported that clinical signs clearly precede the classic radiographic consolidation (23). All these facts can reduce the need for repeating X-rays in early cases with clinical findings and minimal X-ray changes exposing the neonate to more radiation for serial X-ray.

The chest X-ray of the lone patient in this study having early complication of pneumonia revealed basal paracardiac opaque area with tiny cystic changes, targeted LUS distinguished these changes more clearly as these tiny cysts represented early abscesses (24). LUS was used for following up early complication of pneumonia revealed basal paracardiac abscesses and follow up of possible complications and can be considered an attractive alternative to bedside chest radiography and thoracic computed tomography with minimal radiation exposure.

6. Limitations of the study

One of these limitations is the small size of the sample, CT studies should have been done for these patients but since some were mechanically ventilated, their transport was difficult in addition to the high cost and large radiation exposure. Also, LUS scans have a limited role in evaluation of lesions not in contact with the pleura but the small size of the neonatal chest, small lung volumes compared to adults as well as the more frequent extension of the pulmonary consolidation to the lung surfaces kept these technical limitations to a minimum.

References

(13) Fraser RG, Pare JAP, Pare PD, Fraser RS, Generoux GP. Diagnosis of diseases of the chest. Philadelphia Pa Saunders 1988:1;468–94, Third ed.


