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COMMENTS

Neonatal lung diseases: lung ultrasound or chest x-ray

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ABSTRACT

Chest X-ray (CXR) examination is a well-recognized imaging modality in the diagnosis of neonatal lung diseases. On the other hand, lung ultrasound (LUS) has been an emerging and increasingly studied modality. However, the role of LUS as well as its potential to replace CXRs in the detection of neonatal lung diseases has been debated. We combine the present research progress and our own clinical experience to elaborate on various aspects of the potential routine use of lung ultrasound in neonatal intensive care units. We conclude that both LUS and CXR have a number of advantages and disadvantages. They should serve as complementary diagnostic methods in providing accurate, timely, and reliable information.

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Chest X-ray (CXR); lung diseases; lung ultrasound (LUS); newborn

Introduction

Thirty years ago, lung ultrasound (LUS) was not even considered as a potential diagnostic modality in detecting lung diseases. However, our understanding of LUS has changed throughout the last decade. Nowadays, both clinicians and radiologists accept and recognize the value of using LUS in the diagnosis of neonatal lung diseases (NLDs). Many clinicians are increasingly interested in learning and mastering this technology [1–4]. Nevertheless, they are skeptical about LUS becoming a diagnostic modality of choice and its potential for replacing chest X-ray (CXR). By reviewing the research progress on the topic in conjunction with our clinical experiences, we attempt to share our insights and provide important answers.

Lung ultrasound in diagnosing neonatal lung diseases

LUS research in neonatology has been well acknowledged. A variety of NLD commonly evaluated by CXR can now be equally, if not better, assessed by LUS. NLDs, such as respiratory distress syndrome (RDS) [5–7], transient tachypnea of the newborn (TTN) [8–10], meconium aspiration syndrome (MAS) [11,12], pneumonia [13,14], pulmonary hemorrhage [15], pneumothorax [16,17], atelectasis [18] and pleural effusion [7,8], have their own characteristic LUS imaging features. In general, ultrasound has been accepted as an important tool in the diagnosis of NLDs [19,20].

Sensitivity and specificity of lung ultrasound in the diagnosis of neonatal lung diseases

Lung ultrasound in diagnosis of lung atelectasis

LUS can identify 100% of atelectasis whereas CXR detects only ~75% [18]. Lung atelectasis visualized by ultrasound but not by CXR and confirmed by chest CT is referred to as "occult atelectasis" [18]. Conversely, in clinical practice, there are neonates falsely diagnosed with lung atelectasis by CXR, termed 'pseudoatelectasis'.

Case 1

A 5-day-old 38 weeks gestational age (GA) male was hospitalized due to 'infectious jaundice'. On CXR examination, 'the suspicion of right upper lung atelectasis' was reported (Figure 1(A)). LUS showed a normal left lung. Examination of the right lung showed B lines and subpleural focal consolidations involving less than one intercostal space. No atelectasis was observed (Figure 1(B)). Further examination by moving the probe across the chest confirmed that the 'right upper

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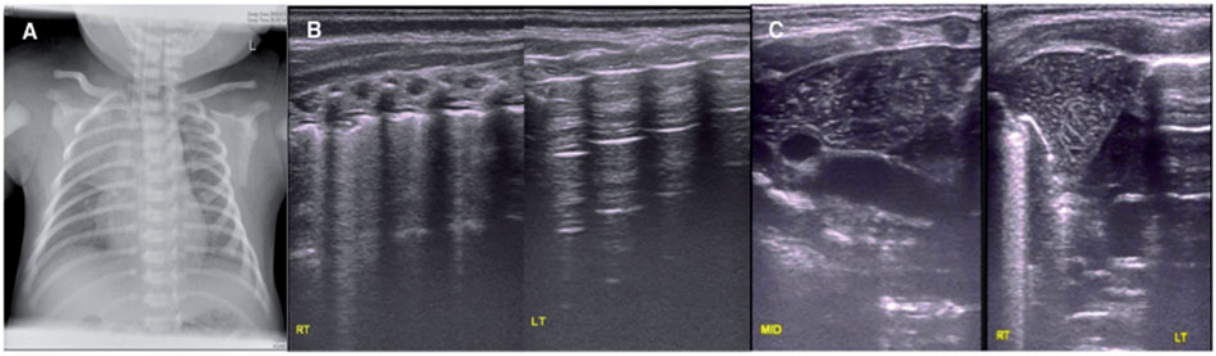

Figure 1. A male infant with a gestational age of 38 + 1 weeks was hospitalized due to "pathological jaundice". CXR was performed to exclude lung infection and "the suspicion of right upper lung atelectasis" was reported (A). LUS: the probe was placed on the back to perform the scan, which revealed that the left lung had a small subpleural consolidation that was localized to less than one intercostal space, while the right lung was completely normal (B). The probe was placed on the front of the chest to perform the scan and a homogeneous parenchymal viscus with an intact capsule and a medium to low echo was visible above the heart in the right thoracic cavity. No similar echogenic mass was detected in the left thoracic cavity and the left lung echo was normal suggesting that the thymus had been detected on CXR (C).

lung atelectasis' on the original CXR was actually thymic tissue (Figure 1(C)).

Lung ultrasound in the diagnosis of pneumothorax

The use of LUS in diagnosing pneumothorax is very sensitive and specific. Both a prospective controlled study and a meta-analysis have shown that LUS is advantageous over CXR for the detection of pneumothorax [21,22]. Recently, in a study performed on dogs, Hwang et al. [23] compared LUS to computerized tomography (CT) in detection of pneumothorax. The study found that the sensitivity of LUS in detection of pneumothorax was 100%.

Case 2

A 2-day-old 41-week GA male was hospitalized due to hypoglycemia. Physical examination revealed that the patient's respiratory rate was increased with some subcostal retractions. His white blood cells count was 22×10^9/L, neutrophils 69%, platelets 87×10^9/L, C-reactive protein 31 mg/L and procalcitonin 1.94 ng/mL. CXR showed that the lung markings were increased and blurred bilaterally. 'Pointed and flaky' opacities were visible within the entire right and the upper left lung. The appearance on the CXR was suggestive of pneumonia (Figure 2(A)). LUS (M-mode) showed a 'granular sign' in the left lung and 'lung point' in the right lung (Figure 2(B)). 'Lung point' is very specific in LUS diagnosis of pneumothorax. The patient had 35 ml of air removed upon successful thoracocentesis. The patient was confirmed to have a right pneumothorax and 35 ml of gas was evacuated by thoracocentesis.

Lung ultrasound in diagnosis of pneumonia

A systematic review and meta-analysis regarding the use of LUS in diagnosing adult pneumonia revealed that both sensitivity and specificity were very high, 94 and 96%, respectively [24]. Also, a randomized controlled trial that studied the use of LUS in diagnosing neonatal and childhood pneumonia showed both the sensitivity and specificity of LUS to be superior to CXRs. It was suggested that LUS might replace CXR when diagnosing pneumonia in children and neonates [25]. Our long-term clinical practice demonstrated similar experience (Figure 3).

Lung ultrasound in the diagnosis of RDS and TTN

RDS and TTN are common causes of dyspnea in newborn infants. They may have similar clinical manifestations making it difficult to distinguish them clinically. In clinical practice, TTN is frequently treated as RDS with a misdiagnosis rate based on CXR alone as high as 62–77% with a potential for the subsequent increase in adverse outcomes [26,27]. Conversely, LUS has been found to clearly differentiate RDS from TTN. TTN mainly manifests as varying degrees of lung edema while RDS mainly manifests as varying degrees of lung consolidations [10,28,29], thus avoiding misdiagnosis and mistreatment.

Case 3

A 20-min-old newborn 34-week GA male presented with dyspnea that started 20 min after the birth. The patient quickly developed grunting with a respiratory rate >120 breaths/minute. The CXR showed significantly decreased aeration of most of the lung fields

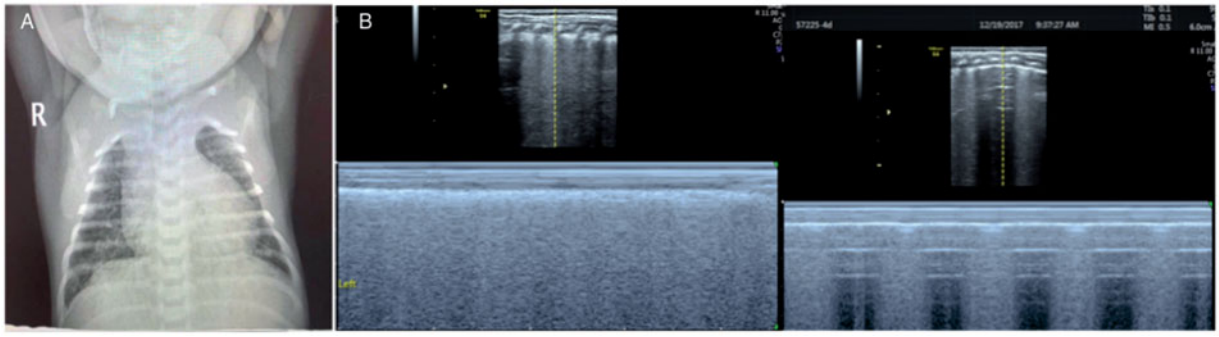

Figure 2. CXR showed lung markings were increased and blurred, "pointed and flaky" shadows were visible and no clear pneumothorax signs were detected (A). LUS (M-mode): the left lung showed a "granular sign" and the right lung showed a typical "lung point" sign confirming the presence of a right pneumothorax (B).

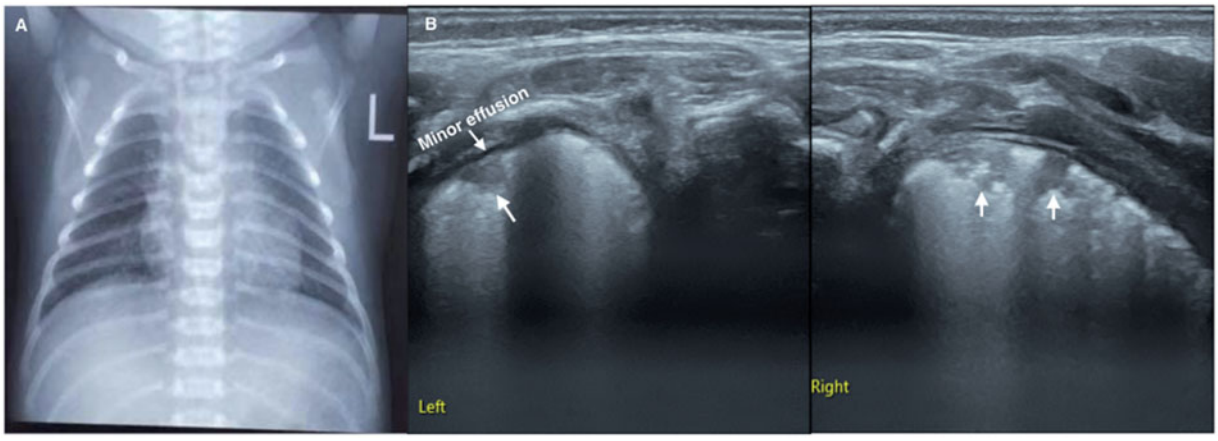

Figure 3. LUS is superior to chest x-ray in diagnosing pneumonia. A 13-day baby was admitted to the hospital because of cough and fever with moist rale in bilateral lungs on auscultation. Blood tests showed an increased white blood cell counts and C-reactive protein. No abnormality findings on chest X-ray examination (A), while the LUS (B) showed that significant subpleural focal lung consolidation in both lungs. In addition, a small amount of pleural effusion was seen in the left thoracic cavity, which was consistent with the LUS imaging characteristics of pneumonia.

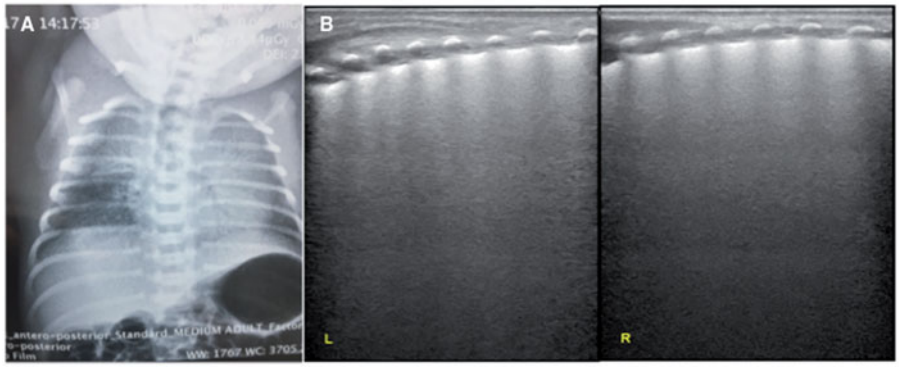

Figure 4. CXR changes (A). LUS at 5 h after birth showed double pulmonary edema, no consolidation, and bronchial aeration signs. The patient was diagnosed with TTN (B).

and the heart contour was blurred giving the impression of a 'white-out lung' (Figure 4(A)). Arterial blood gas analysis revealed a $PaCO_2$ of 65.3 mmHg and a PaO_2 of 52 mmHg. Based on the CXR and blood gas findings the infant was diagnosed with RDS. However, LUS showed isolated pulmonary edema at 30 min, 5 h, and 9 h after birth that completely normalized by 24 h of life without any consolidation (Figure 4(B)). LUS findings and further clinical development were consistent with TTN. Noninvasive respiratory support was

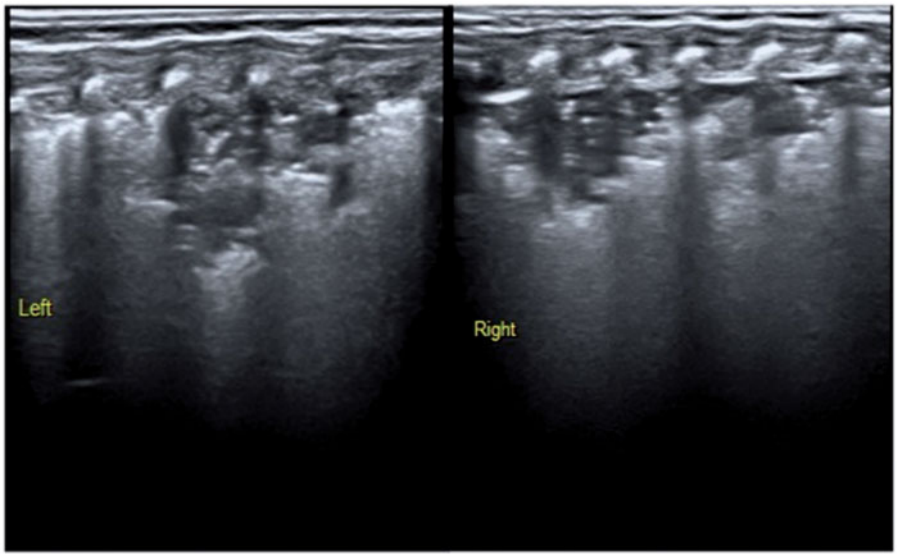

Figure 5. The patient was clinically diagnosed with BPD, but the ultrasound finding revealed pneumonia.

given for 17 h and the patient recovered after 3 days. Had the LUS examination not been performed, the patient would have been subjected to invasive ventilation and surfactant administration.

Lung ultrasound in diagnosing of BPD comorbidities

Long-term oxygen dependence is a common problem in preterm infants. The need for oxygen support for more than 28 days defines bronchopulmonary dysplasia (BPD) [30]. Recently, LUS exams were conducted in a group of 50 babies diagnosed with BPD. Interestingly, 9 of the cases were found to have atelectasis, 4 of the cases had pneumonia, 2 of the cases had severe pulmonary edema, and 3 of the cases of pulmonary edema with focal lung consolidation were found [31]. After these disorders were treated, the dependence on oxygen either completely disappeared or the degree of oxygen dependence was significantly reduced. This study was during the era that LUS was not widely accepted. The new term 'iatrogenic BPD' was suggested to raise awareness in potentially misdiagnosing BPD with the use of CXR only. These patients underwent long-term oxygen therapy that could have been avoided. It is caused by insufficient understanding or improper clinical treatment of the main disease. That being said, LUS for only help clarify and identify the causes of oxygen dependence, but also helps guide treatment, improve the prognosis of patients, and avoid misdiagnosis of BPD (Figure 5).

Case 4

A newborn male with a GA of 29 weeks was transferred to the NICU under positive pressure ventilation required for RDS. The infant was still oxygen dependent at 2 months of age with a clinical diagnosis of BPD. LUS showed consolidations with irregular edges accompanied by air bronchograms within both lungs and the disappearance (left lung) or blurred (right lung) pleural line, consistent with imaging features of pneumonia. Appropriate antibiotic therapy was initiated and resulted in the resolution of oxygen dependence.

LUS has changed the traditional understanding of lung disease

Using RDS as an example: (1) Usually, RDS manifests with expiratory grunting, "white-out lungs" changes on CXR together with severe hypoxemia and hypercapnia. However, the development of LUS showed that this clinical picture is not completely specific. Some premature infants may actually have TTN rather than RDS. (2) The description of the typical manifestation of RDS on CXR is "homogeneously reduced aeration of the lungs" emphasizing uniformity of the changes on both sides of the lungs. However, it is rarely mentioned that pleural effusion can be present with RDS. These changes may not be visible on CXR. Therefore, LUS exam findings in infants with RDS show not only that the nature and degree of lesions in the bilateral lungs can be inconsistent, but the degree and nature of lesions in different lung fields of the ipsilateral lung can also be diverse with occasional unilateral or bilateral pleural effusions present [7,28].

Lung ultrasound has changed the traditional management concept of lung disease

LUS monitoring has many advantages in guiding the treatment of many NLD [32]. As an example: (1) LUS significantly reduces the rate of ventilator use in hospitalized patients. Many patients with severe meconium aspiration or severe pneumonia who require mechanical ventilation no longer need to receive prolonged support after bronchoalveolar lavage is performed under careful LUS guidance. Our clinical application showed a decrease in invasive respiratory support by more than 40% [33]. (2) LUS monitoring has significantly shortened the time spent on mechanical ventilation in neonates with RDS. In practice, weaning under ultrasound guidance significantly reduced ventilatory time where 60% of patients are being weaned within 24 h, 80% within 48 h and 90% within 72 h [33]. (3) LUS further helps to reduce the usage rate of expensive medicaments such as exogenous pulmonary surfactant [33]. In these cases, the complications that may be caused by the surfactant administration can be avoided. Finally, LUS may shorten the duration of the hospital stay. Otherwise you would need to have a reference for this statement.

LUS application in our clinical practice

The risks associated with CXR exposure are well-known [34]. The effects of radiation may be more harmful in newborns, especially preterm infants. Therefore, the use of ultrasound to diagnose lung diseases appears to be the best current solution [35]. From March 2017, LUS has been routinely performed in the Department of Neonatology and NICU, Beijing Chaoyang District Maternal and Child Healthcare Hospital, largely replacing CXR for the diagnosis and differential diagnosis of NLDs.

CXR disadvantages in the diagnosis of NLDs

The position of the infant and the direction of the radiation beam may hinder the detection of the pathological focus within some lung areas, such as posterior, parasternal or paravertebral lung segments. Spontaneous breathing or mechanical ventilation may result in CXR images during expiration or poor resolution due to respiratory movements. Conversely, LUS with its dynamic imaging is not affected by respiratory movements where even the smallest sections of the lungs are readily available to the ultrasound probes.

Limitations of LUS

LUS has certain limitations. Proper training is required before it is implemented. Subscapular regions and subcutaneous emphysema can limit detection of pulmonary pathological changes. Diagnosis of hyperinflation, pneumomediastinum, and BPD still exhibit uncertainties. It is important that LUS findings are carefully correlated with the clinical picture, physical exam, and laboratory findings. One should be trained rigorously for a certain time before being competent in using ultrasound to diagnose lung diseases. Several guidelines provided should help with shortening the learning time [36,37].

Conclusions

The literature shows that LUS plays a very important role in contemporary neonatal care and research. Both CXR and LUS as diagnostic modalities have their advantages and disadvantages. Clinicians are encouraged to be familiar with the benefits of each procedure with a goal of advancing neonatal research and improving patient outcomes. However, for clinicians with sufficient experience, well understanding and mastery of LUS, use of ultrasound instead of CRX as the preferred method for NLDs is not only necessary but also feasible [38], or at least, to reduce the neonatal radiation exposure significantly is beyond doubt [39].

Disclosure statement

No potential conflict of interest was reported by the authors.

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