

Lung Ultrasound as an Emerging Tool for Monitoring Critically Ill Infants among Neonates

Mohamed M. Elbakry^a, Samar N. Ahmed^b, Nesma F. Elazab^a,
Rania I. Abdelatty^a

Abstract:

Background: Lung ultrasound (LUS) is becoming a crucial tool in the clinical management of newborn babies. The aim of this study is to assess the accuracy of bedside lung ultrasound for early detection and initial treatment of critically ill neonates with pneumonia, atelectasis, and pulmonary hemorrhage in comparison with chest X-ray. **Methods:** From December 2023 to November 2024, 50 neonates with a confirmed diagnosis of pneumonia, atelectasis, or pulmonary hemorrhage were admitted to the Neonatal Intensive Care Unit (NICU) of the Paediatrics Department at Benha University Hospital in Benha, Egypt. This cross-sectional study was conducted. All patients underwent a comprehensive history-taking, thorough clinical examination, laboratory investigations, and radiological chest evaluation by X-ray and ultrasound. Subsequently, a precise comparison of the findings was conducted. **Results:** This study included 50 neonates; 26 males and 24 females, their mean gestational age was 37 ± 2 weeks. The most common diagnosis was pneumonia (58%), followed by atelectasis (28%), then pulmonary hemorrhage (14%). There was no statistical difference between chest X-ray and lung US regarding their diagnostic ability in patients with pneumonia and pneumothorax. However, lung US had statistically higher diagnostic ability in patients with pleural effusion, atelectasis, and pulmonary hemorrhage compared to chest X-ray. **Conclusion:** LUS had statistically higher diagnostic ability in patients with pleural effusion, atelectasis, and pulmonary hemorrhage compared to chest X-ray. Repetitive bedside operation is easy, and radiation exposure is avoided. Intensive care unit doctors and nurses should learn LUS and spread the word.

Keywords: Lung Ultrasound; Neonates; NICU; pneumonia

^a Pediatrics Department, Faculty of Medicine Benha University, Egypt.

^b Chest Department, Faculty of Medicine Benha University, Egypt.

Corresponding to:
Dr. Nesma F. Elazab.
Pediatrics Department, Faculty of Medicine Benha University, Egypt.
Email: nesmafayez43@gmail.com

Received:

Accepted:

Introduction

Lung ultrasonography (LU) is a safe and effective way to diagnose common respiratory diseases in newborns. Pulmonary effusion, pneumothorax, respiratory distress syndrome (RDS), Transient tachypnea of newborn (TTN), meconium aspiration syndrome (MAS), lung consolidations (common in pneumonia), pleural effusion, and pleural effusion are all examples of such complications. Compared to chest X-rays, LU provides more accurate diagnoses for the majority of respiratory disorders, such as RDS, pneumothorax, consolidation, and pleural effusion⁽¹⁾.

Ultrasonography is safe, non-invasive, and easily available at the bedside, since most modern NICUs today are equipped with ultrasound machines. LU is also a valuable tool for predicting the need for ventilation and/or surfactant administration, and for monitoring progression towards bronchopulmonary dysplasia (BPD) in preterm infants. Conducted by a neonatologist, LU is capable of providing the clinician at the bedside with precise real-time information, thereby enabling the timely and accurate diagnosis and the appropriate implementation of specific therapeutic interventions⁽²⁾.

The learning trajectory for most neophytes is precipitous, and the acquisition of LU is regarded as more straightforward and expeditious than that of certain other forms of ultrasound and echocardiography. However, proper education and expertise are still necessary for reliable and consistent diagnosis of major diseases, with minimal room for error in picture interpretation and clinical decision-making based on the results. Implementing individualized precision medicine safely and effectively requires an in-depth knowledge of technical details as well as, most importantly, sufficient experience in integrating LU findings into the clinical setting⁽³⁾.

Because the neonatal lung is susceptible to viral and bacterial infections, neonatal

pneumonia is a significant global cause of illness and death. Annually, pneumonia results in the deaths of between 152,000 and 490,000 infants under the age of one. Despite the fact that these figures indicate a decrease from previous projections, neonatal pneumonia continues to be a significant global health issue that disproportionately affects developing countries⁽⁴⁾.

Newborn pneumonia can be hard to diagnose. Neonatal patients often show no outward signs of pulmonary infection, in contrast to older children. Pneumonia often causes systemic deterioration affecting various organ systems. Common, non-infectious respiratory problems of prematurity can mask the clinical impression and often accompany or worsen pneumonia. In small neonates, the technical challenges of lower airway sampling may render it impossible to definitively identify the etiologic organism, despite a strong suspicion of pneumonia. Consequently, cautious consideration of empiric therapy is required⁽⁴⁾.

Atelectasis is not a distinct illness; rather, it is a prevalent complication of numerous diseases. Neonatal dyspnea, protracted illness, and difficulty discontinuing a ventilator are frequently caused by atelectasis. The accurate diagnosis of atelectasis is crucial for the patient's prognosis, reasonable treatment, and improvement of their condition⁽⁵⁾.

The appearance of red fluid oozing out of the endotracheal tube or upper respiratory tract is a hallmark of acute catastrophic pulmonary hemorrhage (PH). As a result of this severe case of pulmonary edema, red blood cells and capillary filtrate build up in the lungs. When a newborn is under 1500 g, has a patent ductus arteriosus (PDA), needs mechanical ventilation, and must be treated with surfactants, they are the most typical symptoms. A significant portion, up to 68%, of infant fatalities in the first week of life are attributed to PH.⁽⁶⁾

The aim of this study is to assess the accuracy of bedside lung ultrasound for early detection and early treatment of critically ill infants such as pneumonia, atelectasis and pulmonary hemorrhage in comparison with chest X-ray.

Patients and methods

This observational comparative study included 50 neonates admitted to neonatal intensive care unit (NICU) of pediatrics department of Benha University hospital, with respiratory diseases as pneumonia, atelectasis and pulmonary hemorrhage, during the period from to December 2023 to November 2024.

Inclusion criteria:

- Both sexes.
- Critically ill neonates with proven diagnosis of pneumonia, atelectasis or pulmonary hemorrhage.
- **The diagnosis of neonatal pneumonia** is based on a mix of verified laboratory results, imaging evidence, and results from the physical examination. When a child is younger than one year old, the CDC will diagnose pneumonia if radiographs show a persistent consolidation, cavitation, or pleural effusion; the youngster must also meet three additional clinical and/or laboratory criteria, and their gas exchange must be worsening ⁽⁷⁾.
- **The diagnosis of atelectasis** was predominantly formed in accordance with the subsequent criteria: 1) pneumonia, RDS, and other primary lung diseases that may induce atelectasis. 2) dyspnea that was not explicable by primary pulmonary disease; 3) The lung exhibits dullness on percussion and breath sounds are diminished or absent on auscultation. On top of that, auscultation can reveal coarse, moist rales during deep breathing as a hallmark of neonatal atelectasis. 4) The CXR or CT scan results will be determined by the radiologists' assessment of whether the entire lung or a section of the lung is airless, as well as direct evidence such

the airless lobe being opaquer or fissures moving. The ipsilateral hemidiaphragm was elevated, the ipsilateral intercostal gaps were narrowed, and the hilar and cardio mediastinal structures were shifted. These were indirect signs. Furthermore, compensatory hyperinflation of the adjacent regions may transpire ⁽⁸⁾.

- **Pulmonary hemorrhage in the newborn was defined as** Severe clinical worsening, including aspiration of blood into the airway along with respiratory distress, required intubation or increased support in critically ill neonates who had a significant amount of red fluid expelled from their endotracheal tube or respiratory tract. Suctioning secretions from the respiratory tract that contained blood was not considered a case of PH ⁽⁹⁾.

Exclusion criteria:

- Cases with congenital anomalies.
- Parents who will refuse to share in the study.

Ethical considerations:

At Benha University's Faculty of Medicine, the local ethics committee authorized the entire research design (Approval code: MS 22-12-2023). After the researcher provided an explanation of the study's objectives and the methods that would be used, the legal guardian of each participant was asked to sign an informed consent form. At every phase of the investigation, personal privacy and confidentiality were maintained.

Sample size:

Epiinfo program was used to calculate the least sample size at 0.05 level of significance and power 0.8, it was 50 neonates.

All neonates were subjected to full history taking, complete clinical examination, laboratory investigations, chest X ray and lung US.

A high-frequency linear 9-12 MHz probe (LOGIQ P5 - GE Ultrasound Korea, Ltd) was used to conduct the bedside lung ultrasound. The probe was positioned

parallel to the ribs. While they were peaceful, the babies were placed in various positions, including supine, lateral, or prone. Using the anterior and posterior axillary lines as a dividing line, three sections of each lung were examined and recorded. Ultrasound results included pleural effusion, lung sliding, lung pulse, interstitial syndrome, A-lines, B-lines, consolidation of the lungs with or without fluid or air bronchograms, dynamic air bronchograms, and pleural lines⁽¹⁰⁾.

- **Pleural line:** A smooth, curvilinear, and brightly echogenic line that is the result of the pleural surface's reflection is referred to as a pleural line. By joining this line with the two neighboring rib shadows, "the bat sign" is created. To ensure the probe is perpendicular to the thorax and obtain good pictures, it is necessary to acquire this indication.
- **Lung sliding:** 'Lung sliding' is the term used to describe the movement of the parietal against the visceral pleura during respiration. This dynamic phenomenon, which is a sign of a healthy lung, manifests visually as a shimmering line. The "seashore sign" is caused by a granular or "sandy" look deeper to the pleural line (the "shore") and a linear pattern in the tissues that are superficial to the line (the "sea"). The picture in M-mode shows this.
- **A-lines;** Distal to the pleural line, the A-lines are horizontal, hyperechogenic, and equidistant. The reverberation artifact occurs when the transducer and the pleura repeatedly reflect ultrasound pulses. By using an a-line pattern and lung sliding, we can guarantee that the scanned area is free of lung pathology.
- **Abnormal LUS patterns:** The underlying pathology is highly correlated with the pleural line artifacts that were obtained.
- **B-lines;** The B-lines are hyperechoic, vertical lines that extend from the pleura to the far field without fading. Their movement is synchronized with the lung sliding, and they eliminate A-lines (Figure X). A B-line may be unilateral

(pneumonia) or bilateral (pulmonary oedema, TTN) depending on the pathology.

- **Lung consolidation:** Any process that results in the alveoli being devoid of air or loaded with fluid is the cause of the lung consolidation pattern. Atelectasis, pneumonia, and extensive pulmonary oedema are the most prevalent causes. The ultrasound appearance of the consolidated lung is characterized by a tissue-like density, which is referred to as "hepatization of the lung."
- **Pleural effusion:** The principles outlined in adult literature apply to the advent of fluid in the perinatal pleural space. Accumulating in the most vulnerable spots, the fluid is anechoic, or black. The diaphragm, the interior of the chest wall, and the lung surface line usually define the boundaries of the effusion in an erect patient.
- **Pneumothorax:** However, in the event of a pneumothorax, the lung sliding on B-mode imaging is prevented by the presence of air between the visceral and parietal pleura. 'Barcode or stratosphere sign' is revealed by M-mode imaging. Using an instrument with a frequency of 10 MHz or lower is recommended for the purpose of achieving an optimal "barcode sign," as illustrated in the comparison. An additional sign that is quite well described is the "lung point." The lung pattern is represented by the transitional zone between normal (lung sliding) and abnormal (no lung sliding).

Statistical analysis

Using SPSS (version 24), the data were coded, inputted, and processed on a computer. Tables and diagrams were created to display the data, which were subsequently analyzed. Statistical measures used for description were percentage, range, standard deviation, and mean. For categorical data, the association factors were tested using the Chi-Square test χ^2 . A p-value of 0.05 was considered significant.

Results

This study included 50 neonates admitted to the NICU with respiratory diseases such as pneumonia, atelectasis, and pulmonary hemorrhage. They were 26 males and 24 females, with a mean gestational age of 37 ± 2 weeks. The most common diagnosis was pneumonia (58%), followed by atelectasis (28%) and pulmonary hemorrhage (14%) (Figure 1).

Chest X-ray showed that 78% of patients had consolidations, 16% had pleural effusion, and 6% had pneumothorax (Table 1).

Lung US revealed that 78% of patients had consolidations, 64% had a shred sign, 58% had dynamic air bronchograms, 32% had fluid bronchograms, 24% had pleural line irregularities, 24% had pleural effusion, 6% had pneumothorax, and 70% had multiple B-lines (Table 2).

Findings of lung US in neonates with pneumonia showed that 89.7% had consolidation, 86.2% had shred sign, 100% had dynamic air bronchogram, 31% had fluid bronchogram, 6.9% had pleural line irregularities, 13.8% had pleural effusion, and 86.2% had multiple B-lines. Diagnosis was confirmed in 93.1% of cases. In patients with atelectasis, 42.9% had consolidation, 57.1% had pleural line irregularities, 50% had pleural effusion, and 21.4% had multiple B-lines; diagnosis was confirmed in 100% cases. In neonates

with pulmonary hemorrhage, 28.6% had consolidation, 100% had shred sign, 100% had fluid bronchogram, 28.6% had pleural line irregularities, 14.3% had pleural effusion, and 100% had multiple B-lines; diagnosis was confirmed in 100% cases. There was a statistically significant difference between neonates with pneumonia, atelectasis, and pulmonary hemorrhage regarding lung US findings. However, no statistical difference was observed between groups in terms of diagnostic ability (Table 3).

When comparing chest X-ray and lung US regarding diagnostic features, no significant differences were found for consolidations, pleural effusion, or pneumothorax (Table 4). However, lung US showed statistically higher diagnostic ability in cases of pleural effusion, atelectasis, and pulmonary hemorrhage compared to chest X-ray, while there was no significant difference in patients with pneumonia and pneumothorax (Table 5).

In addition, beyond the P values, diagnostic accuracy metrics such as sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and Kappa values should be presented. These measures would provide a more comprehensive evaluation of the comparative diagnostic performance of lung ultrasound and chest X-ray, especially since the study aims to assess diagnostic accuracy.

Table 1: Chest X ray of the studied group

			Study group	
			50	%
Chest X ray	Consolidation	No	11	22.0%
		Yes	39	78.0%
	Pleural effusion	No	42	84.0%
		Yes	8	16.0%
	Pneumothorax	No	47	94.0%
		Yes	3	6.0%

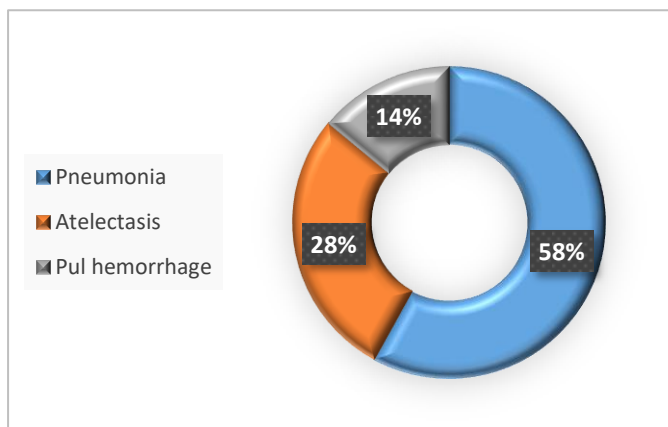


Figure 1: Final diagnosis in the studied group

Table 2: Lung US of the studied group

			Study group	
			50	%
Lung US	Consolidation	No	15	22.0%
		Yes	35	78.0%
	Shred sign	No	18	36.0%
		Yes	32	64.0%
	Dynamic Air Bronchogram	No	21	42.0%
		Yes	29	58.0%
	Fluid Bronchogram	No	34	68.0%
		Yes	16	32.0%
	Pleural line irregularities	No	38	76.0%
		Yes	12	24.0%
	Pleural effusion	No	38	76.0%
		Yes	12	24.0%
	Pneumothorax	No	47	94.0%
		Yes	3	6.0%
	Multiple B lines	No	15	30.0%
		Yes	35	70.0%

Table 3: Comparison between lung US findings according to final diagnosis

		Pneumonia		Atelectasis		Pulmonary hemorrhage		Test	P value
		N=29	%	N=14	%	N=7	%		
Consolidation	No	3	10.3%	8	57.1%	5	71.4%	$X^2=12.2$	0.002*
	Yes	26	89.7%	6	42.9%	2	28.6%		
Shred sign	No	4	13.8%	14	100.0%	0	0.0%	$X^2=35.3$	<0.001*
	Yes	25	86.2%	0	0.0%	7	100.0%		
Dynamic Air Bronchogram	No	0	0.0%	14	100.0%	7	100.0%	$X^2=45.5$	<0.001*
	Yes	29	100.0%	0	0.0%	0	0.0%		
Fluid Bronchogram	No	20	69.0%	14	100.0%	0	0.0%	$X^2=21.4$	<0.001*
	Yes	9	31.0%	0	0.0%	7	100.0%		
Pleural line irregularities	No	27	93.1%	6	42.9%	5	71.4%	$X^2=13.1$	<0.001*
	Yes	2	6.9%	8	57.1%	2	28.6%		
Pleural effusion	No	25	86.2%	7	50.0%	6	85.7%	$X^2=7.2$	0.027*
	Yes	4	13.8%	7	50.0%	1	14.3%		
Multiple B lines	No	4	13.8%	11	78.6%	0	0.0%	$X^2=22.3$	<0.001*
	Yes	25	86.2%	3	21.4%	7	100.0%		
Diagnostic (US)	No	2	6.9%	0	0.0%	0	0.0%	$X^2=1.1$	0.34
	Yes	27	93.1%	14	100.0%	7	100.0%		

X^2 : Chi-square test, * significant

Table 4: Comparison between chest X ray and lung US regarding diagnostic features

		Chest X ray		Lung US		Test	P value
		N=50	%	N=50	%		
Consolidation	No	11	22.0%	15	30.0%	$X^2=0.87$	0.59
	Yes	39	78.0%	35	70.0%		
Pleural effusion	No	42	84.0%	38	76.0%	$X^2=1.8$	0.24
	Yes	8	16.0%	12	24.0%		
Pneumothorax	No	47	94.0%	47	94.0%	$X^2=0$	1
	Yes	3	6.0%	3	6.0%		

 X^2 : Chi-square test**Table 5:** Comparison between chest X ray and lung US as regards their diagnostic ability in the studied group

		Chest X ray		Lung US		Test	P value
		N	%	N	%		
Pneumonia (n=29)	Diagnostic	27	93.1%	27	93.1%	$X^2=0$	1
	Not diagnostic	2	6.9%	2	6.9%		
Pleural effusion (n=12)	Diagnostic	8	66.7%	12	100.0%	$X^2=3.7$	0.032*
	Not diagnostic	4	33.3%	0	0.0%		
Pneumothorax (n=3)	Diagnostic	3	100.0%	3	100.0%	$X^2=0$	1
	Not diagnostic	0	0.0%	0	0.0%		
Atelectasis (n=14)	Diagnostic	11	78.6%	14	100.0%	$X^2=3.1$	0.031*
	Not diagnostic	3	21.4%	0	0.0%		
Pulmonary hemorrhage (n=7)	Diagnostic	2	28.6%	7	100.0%	$X^2=5.2$	<0.001*
	Not diagnostic	5	71.4%	0	0.0%		

 X^2 : Chi-square test, * significant

Discussion

The clinical care of newborns is increasingly reliant on lung ultrasonography. One of the many pulmonary disorders that lung ultrasonography can detect is community-acquired pneumonia, which can affect both adults and children ⁽¹¹⁾.

In the present study, in patients with pneumonia; 89.7% had consolidation, 86.2% had shred sign, 100% had dynamic air bronchogram, 31% had fluid bronchogram, 6.9% had pleural line irregularities, 13.8% had pleural effusion, 86.2% had multiple B lines. Diagnosis was confirmed in 93.1% of cases.

Our results run in accordance with a previous study ⁽¹²⁾, Twenty-one out of forty cases (52.5%) of severe neonatal pneumonia were found to have dynamic

air bronchograms by the researchers studying lung ultrasonography for this diagnosis. Nonspecific ultrasound findings in neonatal pneumonia include interstitial syndrome and abnormalities in the pleural lines; these findings are associated with the severity of the inflammatory response and the amount of inflammatory exudate. Pleural effusion is another possible complication in extreme instances.

Ultrasound of the lungs in a baby with pneumonia revealed interstitial syndrome, pleural line abnormalities, air bronchograms, and big areas of consolidation with uneven borders. The appearance of extensive areas of lung consolidation with irregular margins demonstrated a 100% specificity and 100% sensitivity in confirming the diagnosis of newborn pneumonia.

Consolidation of the lungs with air bronchograms is a highly significant ultrasonography finding in infancy pneumonia. Atelectasis and respiratory distress syndrome are two additional lung disorders that might cause this result ⁽¹³⁾.

In the current study, in patients with atelectasis; 42.9% had consolidation, 0% had shred sign, 0% had dynamic air bronchogram, 0% had fluid bronchogram, 57.1% had pleural line irregularities, 50% had pleural effusion, 21.4% had multiple B lines. Diagnosis was confirmed in 100% of cases.

Regarding atelectasis; Our results were in agreement with other researchers ⁽⁸⁾, The study included 80 infants with atelectasis and 50 healthy controls. Ultrasound in neonatal pulmonary atelectasis (NAP) patients primarily revealed wide areas of lung consolidation with distinct borders, abnormalities in the air bronchogram and pleural lines, the lack of A-lines, the existence of a lung pulse, and the lack of lung sliding.

Moreover, a previous study ⁽¹⁴⁾, found that neonates with atelectasis, when examined with a lung ultrasound, exhibited punctate air bronchograms and small areas of consolidation with irregular edges. Although lung sliding is detected, no pulse is detected in the lungs.

It is common to observe atelectasis in critically sick newborns. Ventilation and hospitalization times can be extended due to these lesions. Depending on whether they are obstructive or non-obstructive, unilateral or bilateral, and segmental or lobar, atelectatic areas categorized accordingly. Atelectasis can appear either as a focal or occult image on ultrasound. A focal atelectasis is characterized by a consolidation spot with distinct borders and the presence of air and/or fluid bronchograms ⁽¹⁵⁾.

In the present study, in patients with pulmonary hemorrhage; 28.6% had consolidation, 100% had shred sign, 0% had dynamic air bronchogram, 100% had fluid bronchogram, 28.6% had pleural line

irregularities, 14.3% had pleural effusion, 100% had multiple B lines. Diagnosis was confirmed in 100% of cases.

Regarding pulmonary hemorrhage; other researchers ⁽¹⁶⁾, Lung consolidation (92.9%), air bronchograms (92.9%), fluid bronchograms (81%), pleural effusion (85.7%), shred signs (83.3%), B-lines (100%), and pleural line abnormalities (100%). These were the most common and significant LUS manifestations in neonates with pulmonary hemorrhage. One of the uncommon ultrasonic signs of PH, fibrin deposition, was detected in 12 patients, or 28.6% of the total.

Also, a previous study ⁽¹⁷⁾, investigation of the primary findings of lung ultrasound in patients with PHN. In every instance, the results showed the following: a shred sign (91.2% of instances), pleural effusion (84.2% of cases; pleurocentesis verified that the fluid was bleeding), atelectasis (33.3% of cases), anomalies in the pleural lines (100% of cases), and the disappearance of A-lines (100% of cases). Another interesting finding is that 11.9% of these individuals displayed the main signs of alveolar-interstitial syndrome (AIS). When it came to diagnosing PHN, the shred sign was 100% specific and had a sensitivity of 91.2%.

Other researchers ⁽¹⁸⁾, found that infectious pneumonia and pulmonary haemorrhage share certain sonographic characteristics. Pleural effusions can be quite large and accompanied by large areas of consolidation in pulmonary haemorrhage. Floating fibrinous strands in these effusions may indicate incomplete coagulation. The amount of effusion may be indicative of how bad the bleeding is and how sick the patient is overall. Consolidation of the lungs might be a sign of the underlying illness, like pneumonia or RDS, but it can also indicate atelectatic areas caused by secretions or thrombi blocking the airway.

Pulmonary haemorrhage is also characterized by the shred sign. Distinctive features of this discovery

include thick, uneven, and broken hyperechoic lines that demarcate the aerated and consolidated lung areas. Examples of non-specific features include an alveolar interstitial pattern, aberrant pleural lines, and the absence of A-lines⁽¹⁹⁾.

When it comes to critically sick newborns, pulmonary haemorrhage is a top emergency. This condition often manifests in very premature infants with hypoxic-ischemic encephalopathy, disseminated intravascular coagulation, and haemodynamically significant patent ductus arteriosus. It is common for chest X-rays to show focal ground-glass, fluffy opacities, and even white-out opacities on occasion. When it comes to emergency bedside management, lung ultrasound can aid in the early detection of pulmonary haemorrhage. The shred sign and pleural effusions are two sonographic signs that support the patient's clinical history⁽¹⁷⁾.

In the current study, there are statistically significant differences between neonates with pneumonia, atelectasis and pulmonary haemorrhage regarding lung US findings. Consolidation and dynamic air bronchogram were statistically more frequent in patients with pneumonia than patients with atelectasis and pulmonary hemorrhage. Shred signs, fluid bronchogram and multiple B lines were statistically more frequent in patients with pneumonia and pulmonary hemorrhage compared to patients with atelectasis. Pleural line irregularities and pleural effusion were statistically more frequent in patients with atelectasis compared to patients with pneumonias and pulmonary hemorrhage. However, there was no statistical difference between groups as regards diagnostic ability.

This was in agreement with a previous study⁽¹³⁾, which found that fluid bronchograms are present in areas where pneumonia has spread. Whereas atelectatic foci show hyperechoic air bronchograms, pneumonic patches can show hypoechoic lesions that are either

dendritic or linear. Ultrasound of the lungs can help distinguish between RDS, pneumonia, and atelectasis, three causes of lung consolidation. In the first few days after birth, RDS-related lesions can appear in premature infants or infants born to diabetic mothers, as well as in cases of pneumonia, atelectasis, high-severity illness, and prolonged mechanical ventilation.

In the current study, there was no statistical difference between chest X ray and lung US regarding their diagnostic ability in patients with pneumonia and pneumothorax. However, Lung Us had statistically higher diagnostic ability in patients with pleural effusion, atelectasis and pulmonary hemorrhage compared to chest X rays.

Consistent with earlier research, our results showed no differences between lung US and chest radiographs. While some of these studies omitted kappa values between 0.64 and 0.89, they did report agreement between chest radiographs and lung US, which is a much stronger indicator of reliability than conventional accuracy metrics^(20,21).

A meta-analysis⁽²²⁾ When compared to a reference standard that included either chest radiographs alone or a mix of chest radiographs, clinical findings, and laboratory results, lung ultrasound was found to have an overall aggregated sensitivity of 96% (95% CI: 94-97%) and specificity of 93% (95% CI: 90-96%). At 95% confidence interval (CI), the negative likelihood ratio was 0.06 and the positive likelihood ratio was 15.3. The meta-analysis comprised 795 children whose ages varied from 0.03-5.6 years, and eight papers were considered in total. With sensitivity and specificity over 90%, both the expert and novice clinician-sonographer groups performed admirably in the subgroup analysis of diagnostic accuracy.

Regarding atelectasis; Our results were in agreement with a previous study⁽⁸⁾, Lung ultrasonography had a 100% sensitivity

rate for NPA diagnosis, while CXR had a 75% sensitivity rate. Only individuals diagnosed with NPA exhibited large, well-defined areas of lung consolidation. Not only that, but additional scholars⁽²³⁾, found that treating neonatal atelectasis with bronchoalveolar lavage while monitored by ultrasound was very effective and had no negative side effects. Hence, LUS can reliably and accurately diagnose neonatal atelectasis.

In the same way, other researchers⁽¹⁷⁾, the neonatal intensive care unit can benefit from the regular use of lung ultrasonography due to its usefulness and reliability in diagnosing pulmonary haemorrhage.

Although neonatal LUS has numerous applications, it does have some limitations, such as the requirement for quality assurance and the involvement of other services like radiology. Appropriate training is required, but no such standards have been published yet. One limitation of LUS is that it can only assess superficial structures, which means that it might not detect pathology that is deep or central⁽²⁴⁾.

Conclusion

For the identification of critical respiratory illnesses in neonates, lung ultrasonography (LUS) is a non-invasive, quick, and accurate method. When compared to chest X-ray, LUS demonstrated significantly superior diagnostic ability in individuals with pleural effusion, atelectasis, and pulmonary bleeding. Repetitive bedside operations are made easier, and radiation exposure is avoided. LUS is one of the major technologies in the detection of lung diseases. It is recommended that medical staff in ICUs become proficient and promote LUS. In addition, because of its easy operation and its commercially automated and non-invasive software, it is worthy and necessary to extend the clinical applications of LUS in neonatal lung diseases further.

Sources of funding

This research did not receive any specific grant from funding agencies in the public, commercial, or non-profit sectors.

Author contribution

Authors contributed equally to the study.

Conflicts of interest

No conflicts of interest

References

1. Sefic Pasic I, Riera Soler L, Vazquez Mendez E, Castillo Salinas F. Comparison between lung ultrasonography and chest X-ray in the evaluation of neonatal respiratory distress syndrome. *J Ultrasound*. 2023;26(2):435–48.
2. Capasso L, Pacella D, Migliaro F, Salomè S, Grasso F, Corsini I, et al. Can lung ultrasound score accurately predict surfactant replacement? A systematic review and meta-analysis of diagnostic test studies. *Pediatr Pulmonol*. 2023;58(5):1427–37.
3. Louis D, Belen K, Farooqui M, Idiong N, Amer R, Hussain A, et al. Prone versus supine position for lung ultrasound in neonates with respiratory distress. *Am J Perinatol*. 2021;38(02):176–81.
4. Hooven TA, Randis TM, Polin RA. Pneumonia in the Newborn Infant. *Man Neonatal Respir Care*. 2022;651–73.
5. Liu J, Qiu RX, Liu Y. Case Report: Neonatal Massive Pneumothorax Resulting in Compression Atelectasis Treated by Ultrasound-Guided Pleural Puncture Therapy: A Typical Case Based on Lung Ultrasound Finding. *Front Pediatr*. 2021;9:779615.
6. Patrinos ME, Martin RJ. Pulmonary Hemorrhage, Transient Tachypnea, and Neonatal Pneumonia. *Neonatology*. 2018;865.
7. Hooven TA, Polin RA. Pneumonia. *Semin Fetal Neonatal Med*. 2017 Aug;22(4):206–13.
8. Liu J, Chen SW, Liu F, Li QP, Kong XY, Feng ZC. The diagnosis of neonatal pulmonary atelectasis using lung ultrasonography. *Chest*. 2015;147(4):1013–9.
9. Gezmu AM, Tefera E, Mochankana K, Imran F, Joel D, Pelaelo I, et al. Pulmonary hemorrhage and associated risk factors among newborns admitted to a tertiary level neonatal unit in Botswana. *Front Pediatr*. 2023;11:1171223.
10. Singh Y, Dauengauer-Kirliene S, Yousef N. Setting the Standards: Neonatal Lung Ultrasound in Clinical Practice. *Diagnostics*. 2024;14(13):1413.
11. Demi M, Soldati G. Lung Ultrasound: A Leading Diagnostic Tool. Vol. 13, *Diagnostics*. MDPI; 2023. p. 1710.
12. Liu J, Liu F, Liu Y, Wang HW, Feng ZC. Lung ultrasonography for the diagnosis of severe neonatal pneumonia. *Chest*. 2014;146(2):383–8.

13. Verma A, Paul A, Tekleab AM, Lodha A, Lui K, Maheshwari A, et al. Lung ultrasound in neonates: an emerging tool for monitoring critically ill infants. *Lung*. 2023;2(1).
14. Chichra A, Makaryus M, Chaudhri P, Narasimhan M. Ultrasound for the pulmonary consultant. *Clin Med Insights Circ Respir Pulm Med*. 2016;10:CCRPM-S33382.
15. Rea G, Sperandeo M, Di Serafino M, Vallone G, Tomà P. Neonatal and pediatric thoracic ultrasonography. *J Ultrasound*. 2019;22:121–30.
16. Liu J, Chi JH, Lu ZL, Fu W. The specific signs of lung ultrasound to diagnose pulmonary hemorrhage of the newborns: Evidence from a multicenter retrospective case-control study. *Front Pediatr*. 2023;11:1090332.
17. Ren XL, Fu W, Liu J, Liu Y, Xia RM. Lung ultrasonography to diagnose pulmonary hemorrhage of the newborn. *J Matern Neonatal Med*. 2017;30(21):2601–6.
18. Soldati G, Smargiassi A, Demi L, Inchingolo R. Artifactual lung ultrasonography: it is a matter of traps, order, and disorder. *Appl Sci*. 2020;10(5):1570.
19. Miller DL, Dou C, Raghavendran K, Dong Z. Variation of diagnostic ultrasound-induced pulmonary capillary hemorrhage with fraction of inspired oxygen. *Ultrasound Med Biol*. 2020;46(8):1978–85.
20. Esposito S, Papa SS, Borzani I, Pinzani R, Giannitto C, Consonni D, et al. Performance of lung ultrasonography in children with community-acquired pneumonia. *Ital J Pediatr*. 2014;40(1):37.
21. Urbankowska E, Krenke K, Drobczyński Ł, Korczyński P, Urbankowski T, Krawiec M, et al. Lung ultrasound in the diagnosis and monitoring of community acquired pneumonia in children. *Respir Med*. 2015;109(9):1207–12.
22. Pereda MA, Chavez MA, Hooper-Miele CC, Gilman RH, Steinhoff MC, Ellington LE, et al. Lung ultrasound for the diagnosis of pneumonia in children: a meta-analysis. *Pediatrics*. 2015;135(4):714–22.
23. Liu J, Ren XL, Fu W, Liu Y, Xia RM. Bronchoalveolar lavage for the treatment of neonatal pulmonary atelectasis under lung ultrasound monitoring. *J Matern Neonatal Med*. 2017;30(19):2362–6.
24. Ruoss JL, Bazaciu C, Cacho N, De Luca D. Lung Ultrasound in the Neonatal Intensive Care Unit: Does It Impact Clinical Care? *Children*. 2021;8(12):1098.

To cite this article: Mohamed M. Elbakry, Samar N. Ahmed, Nesma F. Elazab, Rania I. Abdelatty. Lung Ultrasound as an Emerging Tool for Monitoring Critically Ill Infants among Neonates. *BMFJ* XXX, DOI: 10.21608/bmfj.2025.404137.2543.