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The Role of Point of Care Lung Ultrasound in Diagnosis of Different Neonatal Lung Diseases in NICU: A Prospective Study

Shaimaa Reda Abdelmaksoud, Ahmed Abdulfattah Azab, Omima Mohammed Abdel Haie, Rehab Elsaied Elsawy, Ghada Khattab Mohammed*, Enas M. Nor Eldeen

Department of Pediatrics and Pulmonology, Faculty of Medicine, Benha University, Egypt

***Corresponding author:** Ghada Khattab Mohammed, **Mobile:** (+20)01066844867, **E-Mail:** ghadaKhattab50@gmail.com

ABSTRACT

Background: Due to its radiation-free feature, comfort, high accuracy, and cheap cost, lung ultrasonography (LUS) has been used in clinical practice to diagnose and discriminate infant lung disorders; nevertheless, its usage in neonatal care is still restricted.

Objective: To assess the role of point of care LUS in diagnosis of different neonatal lung diseases compared to chest X-ray (CXR).

Patients and Methods: This is a prospective study on 115 neonates (preterm and full-term) with newborn lung disorders of various etiologies; those with substantial congenital abnormalities, such as chest deformities, complicated congenital heart diseases, and central respiratory failure were excluded. On admission, CXR and LUS were performed for diagnosis. They were then repeated after 3 days and after 7 days, or sooner or later, if necessary, based on the clinical status.

Results: LUS diagnosis sensitivity (Sn) and specificity (Sp) for respiratory distress syndrome (RDS), transient tachypnea of the newborn (TTN), pneumonia, meconium aspiration syndrome (MAS), pneumothorax (PTX), pulmonary atelectasis and pulmonary edema were 95.7/98.5%, 100/100% 97.1/98.8, 100/100%, 94.1%/98.9%, 100/100%, 100/100%, respectively. With a 95% CI of 0.91 to 1, the overall agreement between LUS and CXR was 98.3%. The diagnosis of NLDS was mostly in accord with LUS and CXR.

Conclusion: LUS may be used as a substitute for other methods of diagnosing newborn lung illnesses since it is an imaging modality that is accurate, dependable, rapid, simple to use, real-time, and radiation-free.

Keywords: Lung ultrasound, Neonatal lung diseases, Chest X-ray.

INTRODUCTION

Both preterm and term babies who have lung illness are frequently in danger of dying. Therefore, a timely and precise identification of lung problems in neonates is essential since diverse etiologies require distinct therapeutic approaches [(1)].

In the past, computed tomography (CT) and/or chest X-rays were the major tools used to diagnose lung illness in children. CXR, however, exposes the patient to ionising radiation, necessitates transfer to specialised radiographic contexts with all the associated infection concerns for cases and operators, and may not be effective at the bedside [(2)].

Due to the anatomical components' gas-filled nature, the lung was traditionally not regarded to be a target for ultrasonic waves. The damaged lung creates ultrasonic artifacts due to the aberrant tissues/gases/tissue contact when US waves penetrate lung tissue, according to recent advances in ultrasound research. Lung ultrasonography (LUS) use in the clinic is based on these artifacts [(3)].

Due to its radiation-free simplicity, high accuracy, and cheap cost, LUS is implemented in clinical practice to diagnose and classify infant lung disorders. It has been demonstrated in recent years that LUS demonstrates good specificity (Sp) and sensitivity (Sn) for diagnosing different infant lung disorders [(1)].

The ESPNIC guidelines on POCUS usage in pediatrics evidently highlight the importance of LUS in the evaluation of the critically ill patient. The goal of the present study was to evaluate the role of LUS in diagnosis of neonatal lung diseases of different etiologies.

PATIENTS AND METHODS

From June 2021 to January 2023, prospective research including 115 newborns hospitalised to the Neonatal Critical Care Unit of the Pediatrics Department at Benha University Hospital and suffering from various lung illnesses was conducted.

Inclusion criteria: Neonatal patients with various lung disorders, whether preterm or full-term. Neonates with several significant congenital abnormalities, chest deformities, complicated congenital heart disorders, and central respiratory failure were admitted exclusion criteria. According to the NICU procedure, qualified neonatologists took care of the enrolled infants.

Neonatal respiratory distress (NRD) severity was assessed using the Downs and Silverman-Andersen clinical ratings.

To diagnose and distinguish between the various etiologies of NRD, including transient TTN, RDS, neonatal pneumonia, meconium aspiration syndrome (MAS), PTX, pulmonary edema, and pulmonary atelectasis (PA), CXR findings were analysed and utilized as the best approach. Plain CXR and LUS were performed on admission for diagnosis, and they were repeated seven days later or sooner, if necessary, based on the clinical condition of the enrollee neonates and by the treatment of neonatologists in conjunction with the clinical evaluation and laboratory findings to

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determine the etiology of NRD. CXR pictures were created utilising the digital GE (General Electric) camera in an anterior-posterior angle.

An educational and training course was received for 3 months before starting in application of lung ultrasound on enrolled neonates.

The GE Logiq V5 pro series (GE Medical systems CO., LTD, China, ultrasound equipment was used to perform a pulmonary ultrasonography (LUS) test, firstly by using, with 8-MHz convex ultrasound transducer, (GE HealthCare) for some cases then the examination was completed by Linear probe (6-12MHZ) (GE HealthCare) when it became available to NICU.

Neonates were inspected when lying down and asleep, and if the phototherapy machine was on, it was switched off. To prevent tense circumstances or tears, gentle treatment was used, including calm voice tones and delicate stroking. While some on ventilation may have been anaesthetized with IV dormicum, pacifiers were provided to newborns on continuous positive airway pressure (CPAP) or nasal cannulas and non-nutritional sucking was stimulated.

Examining gel was used after the ultrasound machine and transducer were properly cleansed and sanitised. A standard procedure for doing LUS involved measuring the aeration in each hemithorax.

By separating the chest surface into 3 portions and utilising the front and posterior axillary lines as limits, three chest areas for each lung were evaluated.

1. The front (from the parasternal to the anterior axillary line).
2. The lateral region (from the anterior to the posterior axillary line).
3- The posterior region (from the paravertebral line to the posterior axillary).

Then, higher and lower divisions were made in each region. First, longitudinal scanning was carried out. For transverse scanning, the probe was then rotated 90 degrees and advanced laterally along the intercostal gaps. Last but not least, it was crucial to assess the diaphragm, which was insolated by a subcostal view. To do this, the probe was positioned underneath the xiphoid and tilted side to side for diaphragm scanning. A point value of 0 to 3 was assigned to all lung regions, with a total score ranging from zero to 18.

Following is how the LUS score was distributed:

0: Indicates the presence of the A-pattern (characterised by the fact that only the A-lines, which appear as a result of the pleural line reverberation artifact), B-lines are lines that reach the border of the screen when there is no fading. Types of B-pattern include: Type 1 (described by the presence of three evenly spaced B-lines); Type 2 (characterised by the presence of coalescent and packed B-lines in presence or absence of consolidations limited to the subpleural space); 3: Extensions of consolidations. A-lines indicate pleural reflection as a result of ultrasonography diffusing through an air-filled lung. B-lines indicate fluid filling the interstitial space.

Ethical approval:

The Benha Medical Ethics Committee of the Benha Faculty of Medicine gave its approval to this study. All the caregivers of the participants gave written consent after receiving all information. The Helsinki Declaration was followed throughout the study's conduct.

Statistical analysis

An "Investigation report form" was used to capture the information. Using the software SPSS version 26, these data were tabulated, coded, and then analysed. Quantitative data were displayed as mean and SD, whilst categorical data was shown as numbers and percentages. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated. Using the Kappa test of agreement, diagnostic test agreement was assessed.

RESULTS

The current study was conducted on a total of 115 neonates; 55 were full-term neonates (55%), sixty were preterm neonates. The 115 neonates, had 115 initial diagnoses according to, history, clinical and CXR examinations. Twenty-nine of them developed multiple diagnoses throughout the period of admission, resulting in a total of 144 diagnoses. Initial diagnoses were (47) cases of RDS, (36) cases of TTN, (28) cases of pneumonia (8 were community acquired pneumonia, 20 were congenital pneumonia), (2) cases of pneumothorax, and (2) cases of MAS. The new twenty-nine diagnoses were (15) cases of pneumothorax, (6) cases of pneumonia (two of them were aspiration pneumonia), 6 cases of lung atelectasis, and 2 cases of pulmonary edema. Table 1 displays the demographic and clinical information related to newborns. For 41 newborns, surfactant treatment was administered. Different diagnoses of lung diseases in the studied neonates are presented in table 2.

Table (1): Demographic and clinical data of the studied neonates

Gestational Age/weeks (mean ± SD) (range)	33.3± (25-40 weeks)	4.2
Weight/gm (mean ± SD)	2044.2±	1062.6
Post natal age at 1st us examination (mean) (range)	326 hours 4 hours-27 days	
Sex (No. and %)		
Female	52	45.2
Male	63	54.8
Mode of delivery		
CS	84	73.0
NVD	31	27.0
Antenatal steroid		
No	30	26.1
Yes	85	73.9
CRP		
Negative	55	47.8
Positive	60	52.2
Blood culture		
Negative	82	71.3
Positive	33	28.7
Presentation at admission		
RD grade 1	7	6.1
RD grade 2 RD grade 2 RD grade 2 with fever	45 42 3	39.1 36.5 2.6
RD grade 3	43	37.4
RD grade 4	20	17.4
Surfactant administration		
No	74	64.3
Yes	41	35.7
Respiratory support		
Invasive ventilation	61	53.0
Non-invasive ventilation	54	47.0
Outcome		
Died Discharged to home	32 83	27.8 72.2

Table (2): Different diagnoses of neonatal lung diseases in the enrolled neonates initially at admission and the follow up new diagnoses

Total (144)	At admission (115)	Follow up new diagnoses (29)
RDS (47)	RDS (47)	
TTN (36)	TTN (36)	
Pneumonia (34)	Pneumonia (28)	Pneumonia (6)
Pneumothorax (17)	Pneumothorax (2)	Pneumothorax (15)
MAS (2)	MAS (2)	
Pulmonary atelectasis (6)		Pulmonary atelectasis (6)
Pulmonary edema (2)		Pulmonary edema (2)

Diagnosis acquired by CXR and LUS on admission were compared. Diagnosis of RDS, TTN, pneumonia and atelectasis was higher by LUS. Diagnosis of MAS, and pulmonary edema was the same by X-ray and LUS. Diagnosis of pneumothorax was higher by CXR than by LUS (Table 3).

Table (3): Number of cases of lung diseases diagnosed by LUS and CXR

Lung disease	Total (N)	Number of cases diagnosed by US	Number of cases diagnosed by CXR
RDS	47	45	42
TTN	36	36	33
Pneumonia	34	33	28
Pneumothorax	17	16	17
Pulmonary atelectasis	6	6	5
MAS	2	2	2
Pulmonary edema	2	2	2

RDS=Respiratory distress syndrome, TTN =Transient tachypnea of the newborn, MAS=Meconium aspiration syndrome, CXR=Chest x-ray

LUS demonstrated high accuracy with regard to the diagnosis of various respiratory diseases among the studied neonates, as evaluated in table 4.

Table (4): Sensitivity, specificity, and accuracy in the context of LUS in studied respiratory diseases.

Diagnosis	PPV	NPV	Sensitivity	Specificity	Accuracy
RDS	97.8	97.1	95.7	98.5	97.4
TTN	100	100	100	100	100
Pneumonia	97.1	98.8	97.1	98.8	98.3
Pneumothorax	94.1	98.9	94.1	98.8	98.3
MAS	100	100	100	100	100
Atelectasis	100	85.7	99.1	99.1	100
Pulmonary edema	100	100	100	100	100

The agreement between both LUS and CXR for diagnosis of all lung diseases among the studied neonates was evaluated (Table 5).

Table (5): Agreement between point of care LUS and CXR in different diagnoses

Diagnosis	Agreement %	Kappa	95% CI
RDs	95.7	0.91	0.83 to 0.99
TTN	100	1	1-1
Pneumonia	97.4	0.94	0.87 to 1
Pneumothorax (PTX)	96.5	0.87	0.74 to 0.99
meconium aspiration	100	1	1-1
Atelectasis	98.3	0.87	0.68 to 1
BPD	100	1	1-1
Pulmonary edema	100	1	1-1
Total agreement	98.3	0.96	0.91 to 1

In the context of the characteristic US outcomes of various lung diseases among the studied cases, deeply extended small consolidations, compact B lines and air bronchogram without lung point were the diagnostic criteria for RDS (100%), lung edema (presented by B lines) without consolidations were the diagnostic criteria for TTN (100%), furthermore for pneumonia large sized irregular consolidations with dynamic air bronchogram were specific findings (97%). Additionally, lung point (94.7) with absence of lung sliding, absence of B lines and presence of A lines were the diagnostic criteria for pneumothorax (100%). Alveolar interstitial syndrome is the diagnostic criteria of pulmonary edema (100%), in contrast, abnormal findings of pleural lines were present in all cases of RDS, atelectasis and 88% of cases of pneumonia, but normal in all cases of pneumothorax. Consolidations were present in all cases with RDS and MAS (Table 6).

Table (6): The characteristic sonographic criteria of lung diseases in the enrolled neonates

Lung disease	The characteristic sonographic criteria
RDS	-Deeply extended small consolidation with compact B lines without lung point (100%) -Pleural line abnormalities (100%)
TTN	-Presence of B lines (separated or compact) without consolidations (100%).
Pneumonia	-Large sized irregular consolidations with dynamic air bronchogram were specific findings (97%) -Pleural line abnormalities (88%)
Pneumothorax (PTX)	Presence of A lines, absence of B lines –absence of lung sliding with normal pleural line (100%) -Lung point (94.7%)
Pulmonary atelectasis	-Consolidations with static air bronchogram (100%) -Pleural line abnormalities (100%)
MAS	-Consolidations with compact B lines and air bronchogram (100%)
Pulmonary edema	Alveolar interstitial syndrome (100%)

DISCUSSION

In the current study, LUS had a complete agreement with CXR of 98.3% and was extremely precise with regard to the diagnosis of the commonest respiratory newborn illnesses, including RDS, TTN, pneumonia, MAS, PTX, pulmonary edema, and pulmonary atelectasis. These findings were comparable to those of **Ismail *et al.* [(4)] and Corsini *et al.* [(5)],** who found overall agreement to be 98.5 and 91%, respectively.

In this study, LUS demonstrated 95.7% Sn, 98.5% Sp, and 95.7% overall agreement with X-ray for RDS diagnosis. Given that the Sn and Sp in their investigation were 94% and 100%, correspondingly, and that their agreement was 96.7%, these results are in the same line with **Corsini *et al.* [(5)]**. In addition,

Liang *et al.* [6] and Vergine *et al.* [7] found that LUS Sn and Sp for RDS diagnosis were greater than those of CXR at 95.6% and 94.4%, respectively. These findings are in line with those of two further investigations by **Kurepa *et al.* [8] and Srinivasan *et al.* [9]** that discovered that LUS regularly yields high Sn, Sp, and PPV and NPV in the diagnosis of newborn RDS, and that these values are substantially over 90%.

This study demonstrated that there was one hundred percent agreement between LUS and CXR with 100% Sn and 100% Sp with regard to TTN diagnosis, which was in agreement with the findings of **Corsini *et al.* [5],** who established 100% and 98% Sn and Sp, and to **Ismail *et al.* [4],** who demonstrated 100% agreement between LUS and CXR with 100% Sn and Sp.

AS regard diagnosis of PTX, the current study revealed that ultrasound Sn and Sp in its diagnosis were 94.1%, 98.9% respectively with agreement of 96.5%. According to **Dahmarde, *et al.* [10]** who demonstrated that the overall Sp of LUS in detecting pneumothorax in newborns was 96.7% (95% CI, 88.3-99.6%), which is in keeping with our findings. The findings of **Raimondi *et al.* [11]** showing LUS had 100% Sn, Sp, PPV, and NPV for the diagnosis of pneumothorax, may also be considered.

In the context of pneumonia diagnosis. In this study LUS had Sn and Sp of 97.1% and 98.8%, with 97.4% agreement with CXR (this was due to one case misdiagnosed by us as RDS). These findings were comparable to those of **Ismail *et al.* [4]** who discovered that LUS had 97% agreement with CXR and Sn and Sp of 97.5% and 95%, respectively. In research by **Pereda *et al.* [12]** on pediatric pneumonia, it was discovered that the Sn and Sp were, respectively, 96% and 93%. However, 100% Sn, 100% Sp, and 100% agreement with CXR were validated by **Corsini *et al.* [5]** in their study.

This study found 100% Sn, 100% Sp, and 100% agreement with CXR for the diagnosis of MAS by LUS. This is in agreement with **Liu *et al.* [13],** who verified LUS as a trustworthy approach to diagnose MAS, and with **Corsini *et al.* [5],** who reported 100% agreement of LUS with CXR and 100% for Sn and Sp. LUS is an accurate, dependable, practical, and noninvasive way to diagnose MAS, according to different research by **Piastra *et al.* [14]** that showed how well ultrasound signals correlated with X-ray results.

Furthermore, the current findings demonstrated 100% Sn, 99.1% Sp, and 98% concordance with CXR for the diagnosis of infant atelectasis by LUS. These outcomes displayed a Sn of 100%, which was equivalent to **Liu *et al.* [13]** findings, but their Sp was just 75%. Furthermore, **Lichtenstein *et al.* [15]** found that LUS had a 100% Sn for detecting lung atelectasis in young patients.

In this study US showed Sn and Sp for diagnosis of pulmonary edema of 100% for both with total agreement of 100% with X-ray. This is in agreement with **Kasniya *et al.* [16]** who showed the similar results.

In the context of ultrasonographic features of different lung diseases, the current study revealed that the primary ultrasonographic features of RDS cases were, deeply extended small consolidations (100 %), compact B lines (100) air bronchogram without lung point (100%) in 100 % of severe RDS cases, minimal pleural effusion in (5) cases (17%) and lung pulse in 24% of cases. But primary finding in mild RDS cases was separate B lines with subpleural consolidations in 88 % of cases, thick irregular pleural line was present in 100 % of all cases (mild and severe). This concurs with the findings of **Liu et al [17].** In addition, **Ismail *et al.* [4]** discovered that lung consolidation with air bronchograms without DLP was the main ultrasonic hallmark of RDS patients (84%). In contrast **Ahuja *et al.* [18]** found a lower diagnostic accuracy of ultrasound for the diagnosis of NRDS and this difference is due to using transabdominal approach which is of low diagnostic accuracy than transthoracic approach (which was used in this study).

For the neonates under study, the transthoracic method was used since it had higher Sn and Sp for the diagnosis of RDS than the transabdominal approach. Due to the transthoracic technique's high Sp, there would be fewer false positive diagnoses and pointless further tests or procedures.

In the context of sonographic features of TTN, this study found that the primary findings were lung edema (represented by presence of b lines) with absence of consolidation in 100% of cases. This is in accordance with **Vergine *et al.* [7]** who discovered that the DLP in TTN was less consistent than a typical pleural line without subpleural consolidation.

Double lung point in 50% of cases pleural line abnormality in 10 cases and this is similar to results by **Corsini *et al.* [5]** who demonstrated that in 100% of instances, interstitial edema was the primary ultrasonic imaging characteristic of TTN (indicated by B-lines). **Copetti *et al.* [19]** on the other hand showed a 100% Sn and Sp of DLP for TTN diagnosis.

In the context of sonographic features of pneumonia, the current study revealed that primary findings were: Large sized irregular consolidations with dynamic air bronchogram (97.1%), AIS (97.1% of cases), plural line abnormalities (88.1%) of cases, pleural effusion in 7 cases (20%) and lung pulse in 6 cases (17.6%). This might near to the results by **Ismail *et al.* [4]** who discovered that air bronchograms, lung consolidation (all the studied neonates), and anomalies of the pleural line (76%), in presence or absence of pleural effusion, are the major characteristics of pneumonia in both children and newborns. Furthermore, **Liu *et al.* [20] and Chen *et al.* [21]** discovered that subpleural consolidations with uneven borders and air bronchograms, irregular pleural lines, missing lung sliding, and pleural effusion are the most characteristic LUS features of pneumonia.

In the context of ultrasonographic features of pneumothorax the current study found that the primary findings were presence of A lines and absence of b lines and comet tails, normal pleural line, absence of lung sliding (sowed the bacode sign by m mode). In 100 % of cases, presence of lung point (94.1%) of case.

This is comparable to a study by **Deng *et al.*** [22] who found that all related specificities reached 100% and that the sensitivities of absent B-lines, absent lung sliding, and presence of the lung point in diagnosing PTX in neonates were, respectively, 100%, 100%, and 94.28%. The lung point and the presence of solely A-lines with no lung sliding, according to second research by **Husain *et al.*** [23] increased the Sp to 100% and the Sn to 80%.

This is also in line with research by **Dahmarde *et al.*** [10] that found that lung sliding is a crucial indicator and that the absence of it almost excludes pneumothorax. Its absence has a 99.4% Sp and an 87.2% Sn. Findings; the lack of lung sliding, B-lines, and the comet tail sign might point to a pneumothorax. Recent research showed the sonographic results as the presence of B lines that are either separated or coalescent, subpleural consolidations with irregular borders, and air bronchograms in 100% of patients. The lung point has been considered as the second most distinctive marker of PTX in MAS.

This is consistent with research by **Piastra *et al.*** [14] utilising several ultrasonic probes on 6 infants with MAS of varying severity. The results demonstrated that the X-ray findings and the ultrasound signals of coalescent or sparse B-lines, consolidations, atelectasis, and bronchograms were strongly correlated. In research by **Liu *et al.*** [20] that came to the conclusion that LUS is an accurate, dependable, practical, and noninvasive way to diagnose MAS, similar ultrasonographic features were also discovered.

As regard sonographic features of pulmonary atelectasis, this study showed them as pleural lines abnormalities (absent in 3 cases)/ consolidations with regular borders /static linear air bronchogram in 100 % of cases, minimal pleural effusion in 2 cases. This is in accordance with **Ismail *et al.*** [4] that reported lung consolidation and air bronchograms were the primary LUS characteristics of atelectasis and were present in 100% of patients. In the majority of instances, a static air bronchogram was discovered, but a dynamic air bronchogram was not. Therefore, pulmonary atelectasis could be excluded if a dynamic air bronchogram is present. This is also in agreement with research by **Liu *et al.*** [20] that discovered significant lung consolidation with well-defined boundaries, pleural line anomalies, and the lack of lung sliding are ultrasonographic characteristics of atelectasis.

As regard pulmonary edema features by ultrasound, the current study showed that the main features were presence compact B lines without consolidation and normal pleural line in 100% of cases. This is in accordance with **Kasniya *et al.*** [16] who studied 51 infants with evolving CLD on invasive O_2 therapy and revealed that the number of B lines has been closely connected with the severity of pulmonary edema, and that utilising LUS by the detection of "B lines diagnose neonates with pulmonary edema has been demonstrated to be more sensitive and with greater NPV than X-rays."

As a consequence, the present results show 98.5% agreement between LUS and CXR, and in their study of 74 patients using LUS, **Melet *et al.*** [24] found that CXR was comparable to LUS in the diagnosis of NRD. They identified 25 neonates as having RDS (33.78%), 13 as having pneumonia (17.56%), 25 as having TTN (33.7%), nine as having MAS (12.16%), and four as having pleural effusion (5.40%).

Furthermore, **Corsini *et al.*** [5] demonstrated that the agreement between LUS and CXR diagnosis was 91% (122/134 diagnoses), with 9% disagreement owing to 6 false-positive cases (one congenital pulmonary airway malformation and 5 cases with pleural effusions), 2 false-negative LUS diagnoses of PTX, and 4 different diagnoses.

The very small size of our sample was a constraint to our study since it prevented a thorough assessment of the agreement between LUS and CXR for a few rare diseases (such as pleural effusion, and congenital diaphragmatic hernia).

CONCLUSIONS

When diagnosing NLDs, LUS and CXR agreed on the diagnosis quite a bit. Since LUS is a real-time, radiation-free, fast, simple, and accurate imaging modality, it might be used as an alternate technique for the detection of newborn lung disorders.

- **Sponsoring financially:** Nil.
- **Competing interests:** Nil.

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