

Utility of Lung Ultrasound in Diagnosis of Respiratory Distress Syndrome in Neonates: A Cross-sectional Study

SINCHANA BHAT¹, GN SHREEKRISHNA², G SHWETHA³

ABSTRACT

Introduction: Respiratory Distress Syndrome (RDS) is one of the most common conditions leading to significant morbidity and mortality. Early diagnosis with a non-invasive imaging tool such as ultrasound, with no radiation hazard will be beneficial for timely intervention in neonates.

Aim: To evaluate the utility of Lung Ultrasound (LUS) in diagnosing RDS in neonates and to compare it with chest X-ray (CXR).

Materials and Methods: A cross-sectional study was conducted at a tertiary care hospital in Department of Pediatrics, AJ Institute of Medical Sciences, Mangalore, Karnataka, India, from June 2017 to December 2018. Forty neonates (preterm and term) admitted to Neonatal Intensive Care Unit (NICU) with symptoms of respiratory distress within six hours of life and fulfilling clinical criteria of RDS were included in the study. CXR and LUS were performed and interpreted by the same radiologist. The disease was graded as mild and severe by LUS based on the indices like B (Beam like comet-tail pattern) lines, alveolar consolidation, air bronchogram and white lung and it was compared with CXR in

terms of sensitivity and specificity to diagnose RDS. Data were statistically analysed using Kendall's tau-b test.

Results: Eighteen (45%) neonates were <32 weeks, 19 (47%), between 32-34 weeks and 3 (7.5%) were >34 weeks of gestation. Twenty-six (65%) were males and 14 (35%) were females. Mean gestational age of the study cohort was 32±2 weeks. Mean birth weight in the study group was 1.7±0.5 kg. 14 out of the 40 neonates (65%) received steroids prior to delivery. LUS detected signs of RDS in all the 40 cases (100% sensitivity). Sixteen out of 40 (40%) neonates were graded as mild RDS and 24 out of 40 neonates (60%) as severe RDS. The sensitivity to detect severe cases was 100% when compared to CXR but specificity to detect mild cases was found to be 59%. The Positive Predictability Value (PPV) was found to be 54% and the Negative Predictable Value (NPV) was found to be 100%.

Conclusion: LUS can be used as a reliable, bed side screening tool for the early diagnosis of RDS in NICU without side-effects of radiation.

Keywords: Chest X-ray, New born, Prematurity, Respiratory disease

INTRODUCTION

The RDS is one of the commonest cause respiratory distresses in neonates [1]. It is more common in premature newborns due to deficiency of surfactant [2]. Approximately, 70% of cases occur in premature neonates (<28 weeks) and 30% occur in neonates of 32-36 weeks gestation [3]. Approximately, 6-7% of cases of RDS occur in term newborns [4].

Early diagnosis of this condition helps in treatment decisions and improves the prognosis. Traditionally, CXR along with clinical features was considered as the gold standard to diagnose this condition [5]. It is also done to evaluate the effectiveness of therapy. However, CXR poses a threat of ionising radiation on the neonate. Younger the child, more severe is the effect of ionising radiation [6]. The findings of consolidation, air-bronchograms and ground-glass appearance on CXR are not pathognomonic of this condition and may not appear early in the course of the illness [2].

LUS is one modality which has been used to diagnose many respiratory conditions [7]. The artefacts generated at the pleural/sub-pleural interface by the reflection of the ultrasound beam are evaluated by the LUS. These findings appear very early in the course of the disease and unlike a CXR, do not change immediately post-treatment [8]. It is non-invasive, easy-to-do radiological investigation readily available in all hospital settings. The imaging is performed in real-time with absolutely no radiation hazard.

There are studies, which have shown the utility of LUS to diagnose neonatal RDS [2,8-11], and hence, improved management, treatment planning of the condition [12,13], but the LUS findings in RDS were defined and correlated with clinical features in very few studies [2,8], also the literature recommending its routine diagnostic utility in respiratory distress instead of a CXR is lacking. Hence; present study was conducted to compare LUS with CXR to diagnose RDS in neonates and further validate its utility as imaging modality for early diagnosis of this condition.

MATERIALS AND METHODS

This cross-sectional study was conducted in a tertiary care hospital at Department of Pediatrics, AJ Institute of Medical Sciences, Mangalore, Karnataka, India, from June 2017 to December 2018. Study was approved by the Ethics Committee of the hospital (IEC No: AJEC/REV/176/20160). Informed consent of parents was taken prior to the inclusion of their newborn in the study.

Inclusion criteria: All premature newborns (born <37 weeks) admitted to NICU with respiratory distress within first six hours of life and having clinical features of RDS such as: Progressive respiratory distress occurring shortly after birth presenting with expiratory grunting, tachypnoea, subcostal retractions, nasal flaring, cyanosis, reduced or absent breath sounds, typical CXR findings of RDS such as hypo-expansion, diffuse, reticulo-granular pattern, air bronchograms, ground-glass opacities, blurred cardiac borders,

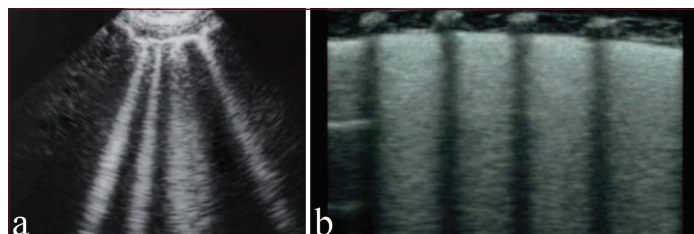
or white lungs ("white-out" appearance), arterial blood gas analysis showing hypoxia or hypercapnia [9] were included in the study.

Exclusion criteria: Neonates with onset of respiratory distress after six hours of life and those with major congenital anomalies were excluded.

Sample size: Universal sampling method was used i.e., all the 40 neonates who were admitted during the specified study period with clinical features suggestive of RDS were enrolled in the study.

Data collection: The demographic details of the mother such as the age, parity, the last menstrual period and the expected date of delivery, the mode of delivery, the timing and number of doses of antenatal steroids received prior to delivery and mode of delivery were noted. Gestational age assessment of the newborn was done by New Ballard's Scoring [13]. Physical examination was done on all the neonates to rule out major congenital anomalies.

Lung Ultrasound (LUS): LUS was done at the bedside immediately by a radiologist. A high-resolution linear probe (7.5 MHz) was used to visualise the anterior, posterior and lateral lung areas by the transthoracic approach. A 5 MHz convex probe was used for the trans-abdominal approach for trans-hepatic and trans-splenic view [Table/Fig-1a,b].



[Table/Fig-1]: Lung Ultrasound (LUS) finding in Respiratory Distress Syndrome (RDS). a) Presence of B lines seen in Stage-I of Respiratory Distress Syndrome (RDS). b) B line merging to form a white out lung Stage-II.

Lung Ultrasound (LUS) indices used in the study [2,3,9]:

- **Pleural line:** It is a regular echogenic line which moves continuously during respiration present under the superficial layers of the thorax. Abnormal pleural lines refer to pleural lines disappearance, indistinct or thicker in width more than 0.5 cm.
- **B-lines:** These lines are seen when the air content in the lung reduces due to sub-pleural interstitial oedema. An acoustic mismatch is generated between the fluid interfaces which are surrounded by air creating vertical reverberation artifacts called B-lines. They are also known as "ultrasound lung comets" because they are hyperechoic narrow based artifacts which spread like laser rays from the pleural line to the edge of the screen and move with respiration.
- **Lung consolidation:** They are defined as hypoechoic areas with poorly defined or wedge-shaped borders of hepatisation (tissue pattern) with presence of air bronchograms or fluid bronchograms.
- **Pleural effusion:** Defined as anechoic-dependent collections limited by the diaphragm and the pleura.
- **Interstitial syndrome:** It is defined as the presence of more than 3 B-lines or the presence of areas of 'white lung' in every examined area.
- **Bilateral white lung:** It is defined as the presence of compact B-line in the 6 areas without horizontal reverberation.

- **Lung pulse:** Lung sliding is replaced by a kind of pulsation, synchronised with heart activity. It is an early specific sign of complete atelectasis on LUS.

Staging of Respiratory Distress Syndrome (RDS) on Lung Ultrasound (LUS) [14]:

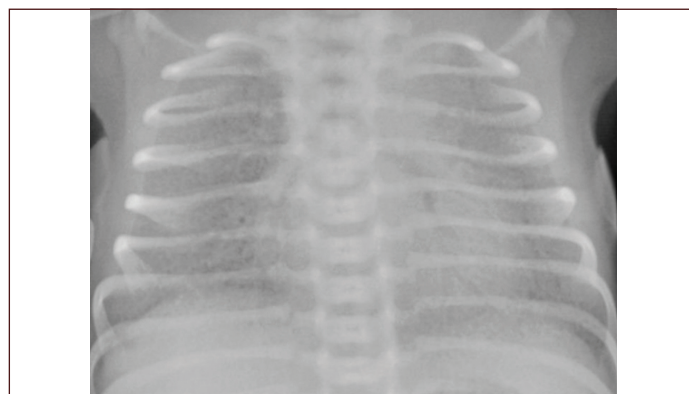
Stage-I: B lines observed only on expiration, normal lung on inspiration

Stage-II: B lines observed on inspiration, also merging together into areas of homogenous echo enhancement (white lung) on expiration with or without consolidations

Stage-III: Homogenous hyper echogenicity (white lung) observed irrespective of respiratory phase with consolidations, air bronchograms

Stage-I: was considered mild RDS and Stage-II and Stage-III were considered severe.

Chest X-ray: CXR was done after the LUS, within six hours of life and reported by a different radiologist who was not aware of this study [Table/Fig-2].



[Table/Fig-2]: Chest X-ray (CXR) of a neonate with ground glass appearance and air bronchograms (Stage-II).

Staging of Respiratory Distress Syndrome (RDS) on Chest X-ray (CXR) [14]:

Stage-I: Fine homogenous ground glass shadowing

Stage-II: Bilateral widespread air bronchogram

Stage-III: Confluent alveolar shadowing

Stage-IV: Alveolar shadowing obscuring cardiac border

STATISTICAL ANALYSIS

Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) version 21.0 software. LUS findings were compared with chest radiographic findings using Kendall's tau-b test.

RESULTS

In the present study, out of total 40 neonates, 18 (45%) neonates were <32 weeks, 19 (47.5%) between 32-34 weeks and 3 (7.5%) >34 weeks of gestation. Mean gestational age of the study cohort was 32±2 weeks. Mean birth weight in the study group was 1.7±0.5 kg. Antenatal steroids were administered to the mothers of 14 out of the 40 neonates (35%) 27 (67%) neonates were born by LSCS [Table/Fig-3]. The LUS showed features of RDS in all 40 neonates. Sixteen (40%) out of 40 neonates were having mild RDS and 24 (60%) out of 40 neonates were having severe RDS according to LUS [Table/Fig-4].

On comparing LUS with CXR, out of 13 cases diagnosed as severe on CXR, all the 13 patients (100%) were diagnosed as severe by the

Parameter	Number	Percentage
Gestational age		
< 32 weeks	18	45%
32-34 weeks	19	47.5%
>34 weeks	3	7.5%
Sex		
Male	26	65%
Female	14	35%
Birth weight		
<1 kg	5	12.5%
1-1.5 kg	10	25%
1.5-2 kg	12	30%
2-2.5 kg	11	27.5%
>2.5 kg	2	5%
Mode of delivery		
LSCS	27	67.5%
NVD	13	32.5%
Antenatal steroids		
Received	14	35%
<24 hours prior delivery (1 dose)	9	22.5%
>24 hours prior delivery (2 doses)	5	12.5%
Not received	26	65%
Investigation		
X-ray	40	100%
Lung Ultrasound (LUS)	40	100%
Intervention		
Continuous Positive Airway Pressure (CPAP)	27	67.5%
Mechanical ventilation	13	32.5%
Surfactant given	6	15%

[Table/Fig-3]: Demographic characteristics of the study group. LSCS: Lower section caesarean surgery; NVD: Normal vaginal delivery

Grade	Frequency	Percentage
Mild	16	40%
Severe	24	60%
Total	40	100%

[Table/Fig-4]: Lung Ultrasound (LUS) grading of Respiratory Distress Syndrome (RDS).

LUS as well. However, 16 out of the 27 cases diagnosed as mild RDS on CXR were reported as mild on LUS [Table/Fig-5].

Lung Ultrasound (LUS)	Chest X-ray (CXR)			p-value
	Severe (Stage-III & IV)	Mild (Stage I & II)	Total	
Severe	13	11	24 (60%)	<0.001
Mild	0	16	16 (40%)	<0.001
Total	13	27	40 (100%)	<0.001

[Table/Fig-5]: Comparison of Lung Ultrasound (LUS) with Chest X-ray (CXR).

Hence, the sensitivity of LUS to diagnose RDS was 100%. The specificity of LUS was 59% as compared to CXR. The PPV was 54% and NPV was found to be 100% [Table/Fig-6].

	Sensitivity	Specificity	PPV	NPV
LUS	100%	59%	54%	100%

[Table/Fig-6]: Sensitivity, Specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV) of Lung Ultrasound (LUS).

DISCUSSION

The present study aims to study the utility of LUS in diagnosing RDS and also comparing it with the gold standard i.e., the CXR. Forty neonates with clinical features of RDS were enrolled, 19 of them (47%) were between the gestational age of 32-34 weeks. RDS was graded as mild (Stage-I) and severe (Stage-II and III) and a four-stage grading was done on CXR (Grade-I & II considered as mild, Grade-III & IV as severe). Copetti R et al., in their study, have found that compact B Lines with an echographic white lung appearance, the presence of a thickened and irregular pleural line, and multiple subpleural lung consolidations indicating alveolar collapse have sensitivity and specificity of 100% for the diagnosis of RDS [2].

Liu J et al., in their study observed that lung consolidations, air bronchograms, pleural line abnormalities and white lung abnormalities were seen in 100% of patients with RDS compared to the control group [9]. They also concluded that consolidations are small in size and found in the sub-pleural region in mild RDS whereas they enlarge and merge with the deeper tissues and air bronchograms also are better visualised in severe RDS [9].

This study graded RDS based on the same criteria and the sensitivity and specificity of LUS was found to be 100% and 59%. The sensitivity of LUS to diagnose RDS is high in the present study since 100% of the cases had signs of RDS (B lines, white lung, consolidation and air bronchograms) but the specificity to grade the disease as mild or severe is not very high and hence the actual specificity seen in the present study is 59%.

A study done in China which enrolled 3405 neonates, 2658 was detected to have lung disease on LUS. A total of 657 (19%) patients were diagnosed as RDS on LUS based on findings of abnormal pleural lines, absence of A lines, interstitial syndrome, lung consolidation and air bronchograms and concluded that LUS has a good utility to diagnose RDS [10].

They also concluded that signs of RDS on LUS are not same as that on CXR and some signs of RDS can also be found in other lung diseases like pneumonia, transient tachypnoea of newborn [6]. The low specificity of the present study could also be explained based on this since some of the neonates who had mild disease on CXR were diagnosed as severe due to presence of lung consolidation which is also seen in congenital pneumonia [10].

Vergine M et al., in their study also reported the sensitivity of LUS was 95% and specificity of 94% in diagnosing RDS and concluded that signs of RDS on LUS appear earlier than CXR helping in timely diagnosis and intervention [8]. Presence of B lines was considered as a sign of RDS in the present study similar to previous study. B lines can be present on LUS in normal neonates but their presence in neonates with symptoms is taken as significant. A total of 100% of the study population in the present study had clinical features of RDS and presence of B lines on LUS and hence this sign can be considered as mild RDS.

In an Indian study done by Rachuri H et al., Point of Care LUS (PoC-USG) done for newborns with respiratory distress showed a sensitivity of 98% and specificity of 100% in detection of RDS. The criteria of white lung and thickening of pleural line were considered in this study [15]. A systematic review done by Hiles M et al., has shown the pooled sensitivity and specificity of LUS in diagnosing RDS to be 97% and 91%, respectively [16]. They concluded that LUS is comparable CXR in diagnosis of RDS. However, LUS cannot detect air leak syndromes like pneumothorax and pneumomediastinum.

However, it was concluded that LUS can be used to exclude complication of RDS such as pneumothorax with a PPV of 100% thereby avoiding repeated exposures of CXR [16]. The utility of LUS for confirmation of the position of Endotracheal Tube (ETT) in newborns who need mechanical ventilation has not been evaluated for which CXR would be still be the modality of choice until further research is done in this area. Hence, LUS can be utilised for early diagnosis of RDS but cannot completely replace CXR. It can be used complementary to the CXR.

Limitation(s)

The sample size of this study is small. To validate the use of this investigation, a larger sample size is needed.

CONCLUSION(S)

The present study concludes that LUS has a sensitivity and NPV of 100% in diagnosis of neonatal RDS when compared to CXR which is the gold standard diagnostic tool. Hence, it can be used as a screening tool for early diagnosis RDS in neonates. This will facilitate early intervention and reduce the morbidity and mortality. This will also help to avoid radiation exposure in neonates. However, CXR may be needed to diagnose complications of RDS. However, since the sample size of this study is small, further studies are recommended so that this modality can be routinely used as a screening tool for neonates suspected to have RDS.

Authors contribution: Dr. Sinchana Bhat helped in conceptualising the study design, data analysis and interpretation, drafted manuscript. Dr. Shreekrishna G.N helped with reviewing the study design, editing and finalising the manuscript and Dr. Shwetha G helped with data collection and analysis.

REFERENCES

- [1] Gallacher DJ, Hart K, Kotecha S. Common respiratory conditions of the newborn. . 2016;12(1):30-42.
- [2] Copetti R, Cattarossi L, Macagno F, Violino M, Furlan R. Lung ultrasound in respiratory distress syndrome: a useful tool for early diagnosis. *Neonatology*. 2008;94(1):52-59.
- [3] Liang HY, Liang XW, Chen ZY, Tan XH, Yang HH, Liao JY. Ultrasound in neonatal lung disease. *Quant Imaging Med Surg*. 2018;8(5):535-46.
- [4] Bouziri A, Ben Slima S, Hamdi A, Menif K, Belhadj S, Khaldi A, et al. Acute respiratory distress syndrome in infants at term and near term about 23 cases. 2007;85(10):874-79.
- [5] Ahuja CK, Saxena AK, Sodhi KS, Kumar P, Khandelwal N. Role of transabdominal ultrasound of lung bases and follow-up in premature neonates with respiratory distress soon after birth. *Indian J Radiol Imag*. 2013;4:279-83.
- [6] Lovrenski J. Lung ultrasonography of pulmonary complications in preterm infants with respiratory distress syndrome. *Ups J Med Sci*. 2012;117(1):10-17.
- [7] Barillari A, Fioretti M. Lung ultrasound: a new tool for the emergency physician. *Intern Emerg Med*. 2010;5(4):335-40.
- [8] Vergine M, Copetti R, Brusa G, Cattarossi L. Lung ultrasound accuracy in respiratory distress syndrome and transient tachypnea of the newborn. *Neonatology*. 2014;106(2):87-93.
- [9] Liu J, Cao HY, Wang HW, Kong XY. The role of lung ultrasound in diagnosis of respiratory distress syndrome in newborn infants. *Iranian Journal of Pediatrics*. 2014;24(2):147-54.
- [10] Chen SW, Fu W, Liu J, Wang Y. Routine application of lung ultrasonography in the neonatal intensive care unit. . 2017;96(2):e5826.
- [11] Wu J, Wang Y, Zhao A, Wang Z. Lung ultrasound for the diagnosis of neonatal respiratory distress syndrome: a meta-analysis. . 2020;36(2):102-10.
- [12] Sweet DG, Carnielli V, Greisen G, Hallman M, Ozek E, Plavka R, et al. European Association of Perinatal Medicine. European consensus guidelines on the management of neonatal respiratory distress syndrome in preterm infants-2013 update. *Neonatology*. 2013;103(4):353-68. Doi: 10.1159/000349928.
- [13] Ballard JL, Khoury JC, Wedig K, Wang L, Eilers-Walsman BL, Lipp R. New Ballard Score, expanded to include extremely premature infants. *J Pediatr*. 1991;119(3):417-23.
- [14] El-Malah H-EDGM, Hany S, Mahmoud MK, Ali AM. Lung ultrasonography in evaluation of neonatal respiratory distress syndrome. *The Egyptian Journal of Radiology and Nuclear Medicine*. 2015;46(2):469-74.
- [15] Rachuri H, Oleti TP, Murki S, Subramanian S, Nethagani J. Diagnostic performance of point of care ultrasonography in identifying the etiology of respiratory distress in neonates. *Indian J Pediatr*. 2017;84(4):267-70.
- [16] Hiles M, Culpam AM, Watts C, Munyombwe T, Wolstenhulme S. Neonatal respiratory distress syndrome: Chest X-ray or lung ultrasound? A systematic review. *Ultrasound*. 2017;25(2):80-91.

PARTICULARS OF CONTRIBUTORS:

1. Assistant Professor, Department of Pediatrics, AJ Institute of Medical Sciences, Mangalore, Karnataka, India.
2. Associate Professor, Department of Pediatrics, AJ Institute of Medical Sciences, Mangalore, Karnataka, India.
3. Junior Resident, Rainbow Childrens Hospital, Marthahalli, Bengaluru, Karnataka, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:

GN Shreekrishna,
3-136/3, Shreenivasa, Jyotnagara, P.O. Kavoor, Mangalore-575015,
Karnataka, India.
E-mail: shreekrishna_gn@yahoo.co.in

AUTHOR DECLARATION:

- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes (from parents)
- For any images presented appropriate consent has been obtained from the subjects. Yes

PLAGIARISM CHECKING METHODS: [Lain H et al.]

- Plagiarism X-checker: Aug 24, 2022
- Manual Googling: Feb 06, 2023
- iThenticate Software: Feb 09, 2023 (12%)

ETYMOLOGY: Author Origin

Date of Submission: **Aug 16, 2022**
Date of Peer Review: **Dec 07, 2022**
Date of Acceptance: **Feb 10, 2023**
Date of Publishing: **Jun 30, 2023**