Lin et al. Respiratory Research (2024) 25:307
https://doi.org/10.1186/s12931-024-02944-6

Respiratory Research

RESEARCH

Open Access

Proportion of confluent B-Lines predicts respiratory support in term infants shortly after birth

Xinao Lin[1†], Hehua Zhang[2†], Xuefeng Wang[1], Ruijie Zhang[1], Lu Zhang[1], Xueqin You[1], Lingling Xiao[1], Chuyan Wu[3], Feng Jiang[1*] and Jimei Wang[1*]

Abstract

Objective To develop and evaluate the predictive value of a simplified lung ultrasound (LUS) method for forecasting respiratory support in term infants.

Methods This observational, prospective, diagnostic accuracy study was conducted in a tertiary academic hospital between June and December 2023. A total of 361 neonates underwent LUS examination within 1 h of birth. The proportion of each LUS sign was utilized to predict their respiratory outcomes and compared with the LUS score model. After identifying the best predictive LUS sign, simplified models were created based on different scan regions. The optimal simplified model was selected by comparing its accuracy with both the full model and the LUS score model.

Results After three days of follow-up, 91 infants required respiratory support, while 270 remained healthy. The proportion of confluent B-lines demonstrated high predictive accuracy for respiratory support, with an area under the curve (AUC) of 89.1% (95% confidence interval [CI]: 84.5-93.7%). The optimal simplified model involved scanning the R/L 1–4 region, yielding an AUC of 87.5% (95% CI: 82.6-92.3%). Both the full model and the optimal simplified model exhibited higher predictive accuracy compared to the LUS score model. The optimal cut-off value for the simplified model was determined to be 15.9%, with a sensitivity of 76.9% and specificity of 91.9%.

Conclusions The proportion of confluent B-lines in LUS can effectively predict the need for respiratory support in term infants shortly after birth and offers greater reliability than the LUS score model.

Keywords Lung ultrasound, Respiratory support, Term infant

†Xinao Lin and Hehua Zhang authors contributed equally.

*Correspondence:
Feng Jiang
dxyjiang@163.com
Jimei Wang
wjm821920@163.com

[1]Department of Neonatology, Obstetrics and Gynecology Hospital of Fudan University, No. 128, Shenyang Rd, Yangpu District, Shanghai 200082, China
[2]Department of Neonatology, Fuyang Women and Children's Hospital, Fuyang, China
[3]Department of Rehabilitation Medicine, The First Affiliated Hospital of Nanjing Medical University, Nanjing, China

Introduction

Neonatal respiratory disease significantly contributes to neonatal mortality, with dyspnea being the predominant symptom observed. Various forms of respiratory support, such as oxygen therapy via a head mask, high-flow nasal cannula (HFNC), continuous positive airway pressure (CPAP), and mechanical ventilation, are critical interventions for neonates experiencing respiratory distress. While the respiratory management of preterm infants has been thoroughly researched and standardized by neonatologists [1], similar issues in term infants have not received comparable scrutiny. Notably, recent data indicate a marked increase in the incidence of respiratory diseases among term infants [2]. The delayed recognition and treatment of dyspnea can lead to severe complications, including pulmonary hypertension. Furthermore, the absence of timely respiratory support can significantly worsen the prognosis [3]. It is, therefore, crucial to acknowledge the importance of early respiratory support for term infants.

Lung ultrasound (LUS) has emerged as a valuable diagnostic tool in neonatal medicine, offering advantages such as being free from radiation, cost-effective, and convenient. During an LUS examination, various pathological changes in the lungs manifest as distinct ultrasound artifacts. Utilizing these findings, experts have devised guidelines for the ultrasound diagnosis of lung diseases in neonates [4]. Numerous studies have validated the efficacy of LUS in predicting bronchopulmonary dysplasia (BPD) [5–7], respiratory distress syndrome (RDS), and the necessity for surfactant therapy [8–10], underscoring its capability to monitor pathological lung changes effectively.

We hypothesize that the presence of specific LUS signs correlates with neonatal respiratory outcomes. Our objective is to develop a reliable and practical LUS methodology to predict the necessity for respiratory support in term infants shortly after birth.

Materials and methods

Study design

This observational, prospective study assessed the diagnostic accuracy of LUS signs for predicting the need for respiratory support in term infants shortly after birth. The study was conducted at the Obstetrics and Gynecology Hospital of Fudan University, Shanghai, China. Neonates were examined using LUS within one hour of birth and monitored over a three-day period to determine the necessity for any form of respiratory support. Based on these observations, participants were categorized into either a respiratory support group or a control group. We compared the LUS signs between these groups to identify predictors of respiratory support. The LUS score served as a benchmark in our predictive modeling, with efforts to refine the model by selecting different scan regions (Fig. 1A and B).

The study protocol adhered to the Declaration of Helsinki and received approval from the Ethics Committee of the Obstetrics and Gynecology Hospital of Fudan

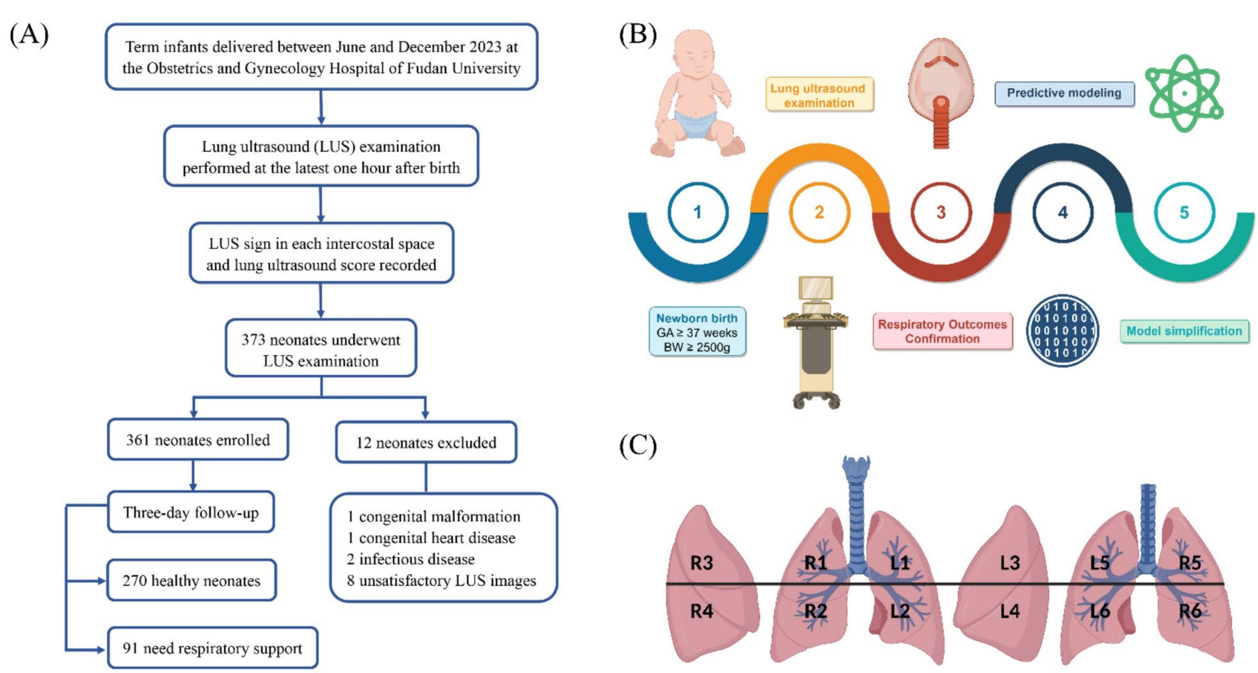

Fig. 1 Research flowchart, study design and twelve regions of lung ultrasound scanning .GA: gestational age; BW: birth weight

University (kyy2020-162). Participation in this study did not alter the neonates' routine clinical care.

Participants

Eligible participants were all neonates born between June and December 2023, with a gestational age (GA) of ≥37 weeks and a birth weight (BW) of ≥2500 g. We excluded neonates with chromosomal abnormalities, congenital malformations, congenital heart disease, sepsis or infectious shock, pneumothorax, and those with incomplete clinical data or unsatisfactory LUS images. Using GPower (version 3.1.9.7, Heinrich-Heine-University Düsseldorf, North Rhine-Westphalia, Germany) for sample size calculation, the study required at least 60 participants in the respiratory support group and 178 in the control group to achieve sufficient power. This calculation was based on a two-tailed test with an effect size (d) of 0.5, an alpha (α) of 0.05, and a power (1-β) of 0.9.

LUS examination

LUS was performed using a CX50 device (Philips Healthcare, Eindhoven, The Netherlands) equipped with a 10–13 MHz linear array probe, within one hour of birth. The LUS operators were certified by the Neonatal Lung Ultrasound Training Center of China and had a minimum of six months' experience under senior supervision. Neonates were positioned as required—supine, lateral, or prone. Scanning encompassed a total of 12 regions, with each lung divided into three zones along the anterior and posterior axillary lines, and further segmented into two by the mammillary line. These regions were designated as R/L 1–6 (Fig. 1C). In each region, LUS signs were recorded for each intercostal space, along with the total number of intercostal spaces and the LUS score. The proportion of each LUS sign was calculated as the number of intercostal spaces showing the specific LUS sign divided by the total number of intercostal spaces (Figure S1).

Data collection

Data collected in this study included both clinical and ultrasound information. Clinical data encompassed GA, BW, sex, mode of delivery (cesarean section), 5-minute Apgar score, presence of premature rupture of membranes (PROM), and the need for any form of respiratory support. Ultrasound data comprised the total number of intercostal spaces, those within each of the R/L 1–6 regions, the LUS signs in each intercostal space, and the participant's LUS score.

Blinding

Several measures were implemented to minimize bias in the study. LUS examinations and clinical data collection were conducted by different personnel, with results correlated via the neonate's hospitalization number. LUS image assessments were independently verified by a physician from the ultrasound department. The determination of a neonate's need for respiratory support was made by a clinician blinded to the LUS results. Furthermore, statistical analyses were executed by a department secretary who was not familiar with either clinical medicine or the LUS methodology, based on the established protocols. These steps were taken to minimize diagnostic suspicion bias and ensure clinical decision-making was unaffected by study data, maintaining a strict blinding process throughout the research.

Reference assessment

In the field of neonatology, the LUS score was initially proposed by Brat et al. [11] as a semi-quantitative method to assess the physiological status of the lung. This method involves assigning scores to specific LUS signs within each lung region, thereby allowing the aggregated score to reflect the lung's overall physiological condition. Given the robust validation of the LUS score's predictive capability in diagnosing [12, 13] and managing [14, 15] neonatal pulmonary diseases, it is acknowledged as a suitable biomarker for evaluating lung status in LUS examinations. Consequently, we have adopted the LUS scoring system proposed by Brat et al. [11] as the reference standard in our diagnostic prediction model, enabling comparisons with both our primary model and the simplified version.

Statistical analysis

All data were analyzed using RStudio version 2023.09.1–494 (RStudio Corporation, Massachusetts, USA), based on R version 4.3.2 (The R Foundation, Vienna, Austria). Continuous variables were tested for normality with the Shapiro–Wilk test and presented as mean (standard deviation) or median (interquartile range), depending on their distribution. Categorical variables were expressed as frequency distributions. Baseline population data and LUS examination results were compared between the two groups using Student's t-test, Mann-Whitney U test, Chi-square test, or Fisher's exact test as appropriate. The relationship between LUS sign proportions, LUS scores, and the necessity for respiratory support was examined through one-way logistic regression, calculating odds ratios (OR) and 95% confidence intervals (CI). Receiver operating characteristic (ROC) curves were utilized to evaluate the sensitivity, specificity, and area under the curve (AUC) of each predictive model. The DeLong test was applied to assess differences between ROC curves. The best predictive model was determined by comparing positive likelihood ratio (+LR), negative likelihood ratio (-LR), positive predictive value (PPV), and negative predictive value (NPV).

Table 1 Baseline characteristics result of the lung ultrasound examination

	Total (n = 361)	Respiratory support (n = 91)	Control group (n = 270)	P
Baseline characteristics				
GA, day	273 (269, 278)	271.5 (265.5, 277.5)	274 (270, 278)	0.08
BW, g	3324.2 (416.8)	3278.0 (444.5)	3339.8 (406.7)	0.24
Male sex	179 (49.6%)	40 (44.0%)	139 (51.5%)	0.26
Cesarean delivery	156 (43.2%)	43 (47.3%)	113 (41.9%)	0.40
PROM	31 (8.6%)	6 (6.6%)	25 (9.3%)	0.57
5'Apgar score	9 (9–9)	9 (9–9)	9 (9–9)	0.09
Result of the lung ultrasound examination				
Total intercostal space	48 (35, 52)	48 (37, 52)	48 (35, 52)	0.22
Proportion of A-lines, %	68.6 (55.8, 80.0)	46.3 (36.3, 59.7)	73.6 (63.9, 82.9)	< 0.01
Proportion of B-lines, %	22.4 (16.1, 28.8)	24.2 (19.5, 30.6)	21.7 (14.3, 27.8)	0.01
Proportion of confluent B-lines, %	5.7 (0.0, 16.7)	27.0 (17.7, 32.6)	2.3 (0.0, 8.8)	< 0.01
Consolidation	23 (6.4%)	16 (17.6%)	7 (2.6%)	< 0.01

BW: birth weight; GA: gestational age; PROM: premature rupture of membranes

Definition of respiratory support

Transcutaneous oxygen saturation ($TcSO_2$) is routinely monitored in our clinical practice. In this study, respiratory support was defined as the administration of oxygen via a hood, HFNC, CPAP, or mechanical ventilation. Initially, infants with a $TcSO_2$ consistently below 95% received approximately 30% oxygen at a flow rate of 1.0–1.5 L/min under a hood covering the head. If $TcSO_2$ could not be stabilized with hood oxygen, or if specific respiratory issues were confirmed via X-ray, HFNC or CPAP was considered. HFNC settings included a flow of 5 L/min and an approximate 25% fraction of inspired oxygen (FiO_2). CPAP was initiated at a pressure of about 5 cm H_2O. Mechanical ventilation was reserved as a last resort when other methods failed, with parameters tailored to the individual clinical condition of the infants.

Results

In this study, 373 neonates underwent LUS examinations and had their clinical data collected. Twelve neonates were excluded based on the exclusion criteria: one had a congenital malformation, one had congenital heart disease, two were admitted to the NICU for infectious diseases, and eight had unsatisfactory LUS images. Consequently, a total of 361 neonates were included in the study. Based on their respiratory outcomes, 91 were assigned to the respiratory support group, and 270 to the control group.

Baseline characteristics

The baseline characteristics of the participants are summarized in Table 1. All 361 neonates underwent LUS examinations within one hour of birth. The GA and BW ranged from 259 to 290 days (37 to 41^{+3} weeks) and 2500 to 4860 g, respectively. No statistically significant differences were observed between the respiratory support and control groups regarding GA, BW, sex, mode of cesarean delivery, presence of PROM, and 5-minute Apgar scores. Although the respiratory support group tended to have lower GA and BW, these differences did not reach statistical significance.

Table 2 Logistic regression analysis for LUS signs and LUS score to predict respiratory supports

	OR	95% CI	z	P
Proportion of A-lines	0.91	0.89–0.93	-8.75	< 0.01
Proportion of B-lines	1.03	1.01–1.06	2.66	0.01
Proportion of confluent B-lines	1.18	1.14–1.22	9.56	< 0.01
Proportion of consolidation	1.56	1.27–2.07	2.57	< 0.01
LUS score	1.82	1.61–2.10	8.84	< 0.01

CI: confidence interval; LUS: lung ultrasound; OR: odds ratio

Predictive models and their accuracy

Differences in the proportion of LUS signs between the respiratory support and control groups were analyzed using logistic regression to calculate ORs and 95% CIs (Table 2). The proportion of A-lines was associated with a lower risk of requiring respiratory support ($OR = 0.91$, 95% CI: 0.89–0.93, $p < 0.01$). In contrast, higher proportions of confluent B-lines ($OR = 1.18$, 95% CI: 1.14–1.22, $p < 0.01$), consolidation ($OR = 1.56$, 95% CI: 1.27–2.07, $p < 0.01$), and the overall LUS score ($OR = 1.82$, 95% CI: 1.61–2.10, $p < 0.01$) were indicative of an increased risk of respiratory support. The OR for the proportion of B-lines was marginally above 1 ($OR = 1.03$, 95% CI: 1.01–1.06, $p = 0.01$), suggesting a slight increase in risk.

ROC analysis was employed to evaluate the accuracy of the predictive models (Fig. 2; Table 3). Among all LUS signs, A-line (AUC = 85.9%) and confluent B-line (AUC = 89.1%) demonstrated higher AUC values compared to B-line (AUC = 59.9%) and consolidation (AUC = 57.6%). The LUS score, a common biomarker, also displayed high accuracy in predicting respiratory support (AUC = 85.4%). According to the results of the DeLong

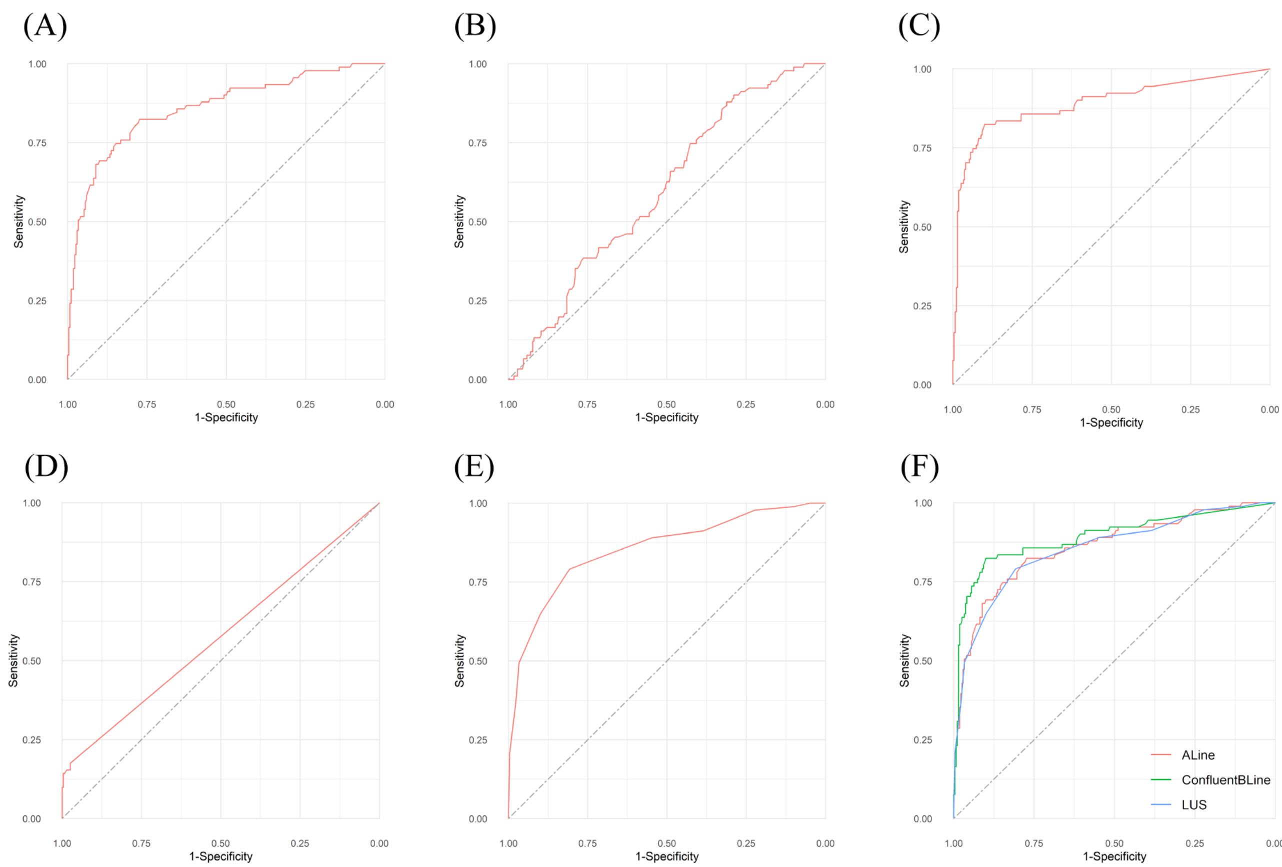

Fig. 2 Receiver operating characteristic analysis of A-lines, B-lines, confluent B-lines, consolidation, and lung ultrasound score. **(A)** A-lines, with a cut-off of 63.0%, sensitivity of 82.4%, specificity of 77.4%, and area under the curve of 85.9%. **(B)** B-lines, with a cut-off of 16.3%, sensitivity of 87.9%, specificity of 31.1%, and area under the curve of 59.9**%. C)** Confluent B-lines, with a cut-off of 15.3%, sensitivity of 82.4%, specificity of 90.0%, and area under the curve of 89.1%. **(D)** Consolidation, with a cut-off of 0.9%, sensitivity of 17.6%, specificity of 97.4%, and area under the curve of 57.6%. **(E)** Lung ultrasound score, with a cut-off of 7.5, sensitivity of 79.1%, specificity of 80.7%, and area under the curve of 85.4%. **(F)** ROC curve of A-line, confluent B-line and lung ultrasound score

Table 3 ROC curve of LUS signs and LUS score models

	Cut-off	Sensitivity, % (95% CI)	Specificity, % (95% CI)	AUC, % (95% CI)	*P*
A-lines	63.0%	82.4 (74.7, 90.1)	77.4 (72.2, 82.2)	85.9 (81.0, 90.7)	0.01
B-lines	16.3%	87.9 (81.3, 94.5)	31.1 (75.0, 91.7)	59.9 (25.6, 36.7)	< 0.01
Confluent B-lines	15.3%	82.4 (74.7, 90.1)	90.0 (86.3, 93.3)	89.1 (84.5, 93.7)	< 0.01
consolidation	0.9%	17.6 (9.9, 25.3)	97.4 (95.2, 99.3)	57.6 (53.6, 61.7)	< 0.01
LUS score	7.5	79.1 (70.8, 87.5)	80.7 (76.0, 85.4)	85.4 (80.5, 90.3)	< 0.01

AUC: area under curve; CI: confidence interval; LUS: lung ultrasound

test, there was a statistically significant difference between the confluent B-line and the LUS score, with a *p*-value of 0.01, and between the A-line and confluent B-line, with a *p*-value of 0.02. The confluent B-line's AUC was significantly higher than that of the LUS score, suggesting it may be a more accurate predictor of respiratory support in this population.

The accuracy metrics for the confluent B-line and LUS score in predicting respiratory support are summarized in Table 4. The confluent B-line model exhibited a higher NPV, PPV, +LR, and a lower -LR compared to the LUS score. Thus, the confluent B-line emerges as an ideal predictor. The optimal cut-off value for the proportion of confluent B-lines to predict respiratory support was 15.3%, with a sensitivity of 82.4% (95% *CI*: 74.4-90.1%) and a specificity of 90.0% (95% *CI*: 86.3-93.3%).

Simplified models and their accuracy

Initially, the LUS scan regions were designated according to the R/L 1–6 labeling method, and a single region was selected, resulting in a total of 6 regions for R/L 1–6. Further simplification of the model involved dividing the lung into anterior, lateral, and posterior surfaces, creating three simplified models: R/L 1+2, R/L 3+4, and R/L 5+6. Additionally, selecting any two sides of the lung

Table 4 Reliability of LUS score and confluent B-lines models to predict respiratory supports

	NPV, (95% CI)	PPV, (95% CI)	+LR (95% CI)	-LR (95% CI)
Confluent B-lines	0.94 (0.91, 0.97)	0.74 (0.65, 0.82)	8.24 (5.69, 11.93)	0.20 (0.13, 0.31)
LUS score	0.92 (0.89, 0.95)	0.58 (0.49, 0.67)	4.11 (3.15, 5.36)	0.26 (0.17, 0.39)
Simplified models				
R/L 3+4	0.91 (0.88, 0.95)	0.72 (0.63, 0.81)	7.76 (5.28, 11.40)	0.28 (0.20, 0.40)
R/L 1–4	0.92 (0.89, 0.95)	0.76 (0.67, 0.85)	9.44 (6.23, 14.31)	0.25 (0.17, 0.37)
R/L 3–6	0.93 (0.90, 0.96)	0.67 (0.58, 0.75)	5.93 (4.33, 8.13)	0.22 (0.14, 0.33)

LR: likelihood ratio; LUS: lung ultrasound; NPV: negative predictive value; PPV: positive predictive value

resulted in three simplified predictive models: R/L 1–4, R/L 1+2+5+6, and R/L 3–6.

ROC analysis of these simplified models (Figures S2-S4) showed similar AUC values for R/L 3+4 (87.3%), R/L 1–4 (87.5%), and R/L 3–6 (88.0%). According to the DeLong test, there were no statistically significant differences among the AUC values of these models. The accuracy data for simplified models is detailed in Table 4. The R/L 1–4 simplified model displayed higher NPV, PPV, and +LR, surpassing those of the LUS score model. Although the -LR for R/L 1–4 was not the lowest among the simplified models, it was still lower than that of the LUS score model, making R/L 1–4 an ideal simplified model. The optimal cut-off value for this model was 15.9%, with a sensitivity of 76.9% (95% *CI*: 67.0-85.7%) and a specificity of 91.9% (95% *CI*: 88.5-94.8%). With an average total intercostal space count of 48 in LUS examinations, a threshold of 15.3%, or about 7 intercostal spaces showing confluent B lines, suggests a higher likelihood of respiratory support.

Discussion

Dyspnea typically manifests within the first six hours post-birth. In several developing countries, the decision to initiate respiratory support for neonates is based predominantly on clinical symptoms and physician experience, which can be subjective and imprecise. Such delayed recognition and intervention may result in adverse outcomes. LUS offers an objective method to evaluate the physiological status of the lungs. Despite this, the semi-quantitative LUS score, recognized for its predictive value in diagnosing and managing neonatal respiratory diseases [16, 17], has recently faced scrutiny regarding its accuracy [18, 19]. Furthermore, modifications to the LUS scoring system in various studies [12, 13, 15, 20, 21] have demonstrated the effectiveness of alternative scoring methods, albeit with a steep learning curve.

In our study, we analyzed the proportion of LUS signs in term infants with different respiratory outcomes. Predictive models based on LUS sign differences were developed to ascertain the need for respiratory support. Upon identifying the high predictive accuracy of the proportion of confluent B-lines, we explored simplified models by focusing on this particular LUS sign across different scanning regions. We used the LUS score developed by Brat et al. [11] as a benchmark to determine the most effective predictive LUS sign and simplified model.

Findings and interpretation (a) The proportion of confluent B-lines, which indicate fluid-filled alveoli [22, 23], can accurately predict the need for respiratory support shortly after birth, surpassing the accuracy of the traditional LUS score. Confluent B-lines are commonly observed in conditions such as transient tachypnea of the newborn [24, 25] and non-consolidated areas of BPD, RDS, and pneumonia. The superior predictive capabilities of confluent B-lines, evidenced by higher NPV, PPV, positive+LR, and lower negative -LR, can be attributed to the more extensive utilization of data derived from LUS examinations. (b) The analysis of three simplified models (scanning R/L 3+4, R/L 1–4, and R/L 3–6) demonstrated similar AUCs, yet the R/L 1–4 model exhibited the highest accuracy. Compared to the LUS score, the R/L 1–4 model leveraged information from each intercostal space, potentially offering a more comprehensive assessment and thus, higher accuracy. This enhanced methodological approach could provide a more precise and reliable tool for clinical decision-making regarding respiratory support in neonates.

Strengths and limitations (a) We introduced a new semi-quantitative method using the proportion of confluent B-lines to predict respiratory support in term infants. This approach leverages the information from each intercostal space for a thorough assessment, offering an advantage over the traditional LUS score. (b) Our study utilized "any form of respiratory support" as the primary outcome, rather than targeting a specific neonatal respiratory disease. This outcome is more objective as it is based on measurable oxygen saturation levels in neonates and does not rely on X-rays or other diagnostic tests, thereby minimizing external test biases. Moreover, since respiratory support is a fundamental treatment for many neonatal respiratory diseases [26–28], our model facilitates early detection of respiratory issues, potentially improving patient outcomes. (c) We simplified the predictive model by selecting high-quality LUS images, which streamlined the LUS examination process and enhanced the reliability of the results. (d) Although our scanning regions aligned with those used in the LUS score system, our method did not strictly require calculating the proportion of confluent B-lines. Typically, 6–8 intercostal spaces showing confluent B-lines indicate a higher likelihood of needing respiratory support, which simplifies clinical assessments.

Our study, while informative, is not without limitations. Being a single-center study, potential bias in participant recruitment cannot be overlooked. In our clinical setting, the use of oxygen in the hood serves as a basic method for supporting the transition from intrauterine to extrauterine life; however, its routine use in treating respiratory failure is uncommon, which may introduce bias in our findings. Furthermore, our focus was primarily on term infants, thus not addressing the respiratory issues that may affect near-term or late preterm neonates. The timing of the LUS examination—conducted within one hour of birth—could miss later-developing signs, making our conclusions most applicable to early neonates. The efficacy of our model in identifying late-onset respiratory diseases remains uncertain and warrants further investigation. Additionally, our study did not distinguish between different forms of respiratory support, highlighting a need for future research to explore whether our model can specifically predict the type of support required.

Comparison with other studies LUS in neonates has predominantly been applied to diagnose and manage conditions such as bronchopulmonary dysplasia (BPD) [5, 20] and RDS [29–31], focusing on lung ultrasound scores to forecast interventions in preterm infants. Recent research [32, 33] has also tried employing LUS scores to anticipate respiratory support needs, albeit still centered on preterm infants. Our study diverges by concentrating on term infants, who are more frequently encountered in clinical practice and are experiencing a rising incidence of respiratory issues [2]. We adopted a new semiquantitative method that evaluates the proportion of confluent B-lines within a specific region (R/L 1–4), which simplifies the examination process and enhances its practicality for clinical application. This differs from other studies that have explored specific LUS signs [3, 34, 35], with some like our earlier work [3] evaluating the predictive value of LUS signs against symptom-based assessments such as the ACoRN score, and others not differentiating between B-lines and confluent B-lines.

Utility of our findings The utility of our findings is significant, especially given the low cost of equipment and the convenience of bedside LUS, which features immediate image acquisition. Our simplified model is ideally suited for rapid screening of respiratory support needs in term infants, allowing clinicians to perform an LUS examination and, based on the proportion of confluent B-lines observed, make informed predictions about the necessity for respiratory support. This approach facilitates quick decision-making in clinical settings, potentially improving outcomes for newborns requiring immediate care.

Conclusions

Our study demonstrates that semi-quantitative analysis of lung ultrasound (LUS) can effectively identify neonates who require respiratory support shortly after birth. Specifically, the proportion of confluent B-lines within the LUS scan exhibits good accuracy in predicting the need for respiratory support among term infants. We found that the predictive capability of the simplified model closely matches that of the full model, and both outperform the traditional LUS score model in terms of accuracy. These findings underscore the utility of our approach in enabling the early detection of respiratory issues, which could potentially improve clinical outcomes for affected neonates.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12931-024-02944-6.

Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

Supplementary Material 4

Acknowledgements

Yunlei Bao and Jun Yin, the secretaries of our department, should be appreciated for their efforts to this study.

Author contributions

Conceptualization: Xinao Lin and Jimei Wang; Methodology: Xinao Lin and Feng Jiang; Software: Xinao Lin, Xuefeng Wang and Ruijie Zhang; Validation: Lu Zhang and Xueqin You; Formal analysis: Xinao Lin; Investigation: Xinao Lin and Xuefeng Wang; Resource: Jimei Wang; Data curation: Xinao Lin, Xuefeng Wang, Ruijie Zhang and Lu Zhang; Writing – original draft preparation: Xinao Lin; Writing –review and editing: Jimei Wang, Feng Jiang, Hehua Zhang and Chuyan Wu; Visualization: Xinao Lin and Lingling Xiao; Supervision: Jimei Wang, Feng Jiang, and Hehua Zhang; Project administration: Jimei Wang; Funding acquisition: Jiemi Wang and Hehua Zhang. All the authors have read and agree to the published version of the manuscript.

Funding

This study was supported by the Shanghai Municipal Health Commission (202040402) and Science and Technology Innovation Program of Shanghai (21Y21900802).

Data availability

No datasets were generated or analysed during the current study.

Declarations

Informed consent statement

Oral informed consent was obtained from the parents of the infants to use the lung ultrasound images and clinical data for analysis. The study adhered to the Declaration of Helsinki and the protocol was approved by the Ethics Committee of the Obstetrics and Gynecology Hospital of Fudan University (kyy2020-162).

Consent for publication

Not Applicable.

Competing interests
The authors declare no competing interests.

Conflict of interest
All authors declare no conflict of interest.

Received: 17 May 2024 / Accepted: 6 August 2024
Published online: 13 August 2024

References

1. Polin RA, Carlo WA, Comm Fetus N. Surfactant replacement therapy for Preterm and Term neonates with respiratory distress. Pediatrics. 2014;133(1):156–63.
2. Bulut O, Buyukkayhan D. Early term delivery is associated with increased neonatal respiratory morbidity. Pediatr Int. 2021;63(1):60–4.
3. Xi GN, Dai JL, Wang XF, Luo F, Lu CQ, Yang Y, Wang JM. Ultrasound performed shortly after birth can predict the respiratory support needs of late preterm and term infants: a diagnostic accuracy study. Pediatr Pulmonol. 2021;56(7):2155–63.
4. Singh Y, Tissot C, Fraga MV, Yousef N, Cortes RG, Lopez J, et al. International evidence-based guidelines on point of Care Ultrasound (POCUS) for critically ill neonates and children issued by the POCUS Working Group of the European Society of Paediatric and neonatal intensive care (ESPNIC). Crit Care. 2020;24(1):65.
5. Zong HF, Huang ZF, Fu YP, Chen XY, Yu YL, Huang YS, et al. Lung ultrasound score as a tool to predict severity of bronchopulmonary dysplasia in neonates born ≤ 25 weeks of gestational age. J Perinatol. 2024;44(2):273–9.
6. Loi B, Vigo G, Baraldi E, Raimondi F, Carnielli VP, Mosca F, et al. Lung Ultrasound to monitor extremely Preterm infants and predict bronchopulmonary dysplasia a Multicenter Longitudinal Cohort Study. Am J Respir Crit Care Med. 2021;203(11):1398–409.
7. Pezza L, Alonso-Ojembarrena A, Elsayed Y, Yousef N, Vedovelli L, Raimondi F, De Luca D. Meta-analysis of lung ultrasound scores for early prediction of Bronchopulmonary Dysplasia. Ann Am Thorac Soc. 2022;19(4):659–67.
8. Pezza L, Sartorius V, Loi B, Regiroli G, Centorrino R, Lanciotti L, et al. Evolution of Ultrasound-assessed lung aeration and Gas Exchange in Respiratory Distress Syndrome and transient tachypnea of the Neonate. J Pediatr. 2023;256:44–52.e2.
9. De Luca D, Autilio C, Pezza L, Shankar-Aguilera S, Tingay DG, Carnielli VP. Personalized medicine for the management of RDS in Preterm neonates. Neonatology. 2021;118(2):127–38.
10. De Luca D, Loi B, Tingay D, Fiori H, Kingma P, Dellacà R, Autilio C. Surfactant status assessment and personalized therapy for surfactant deficiency or dysfunction. Semin Fetal Neonatal Med. 2023;28(6):101494.
11. Brat R, Yousef N, Klifa R, Reynaud S, Aguilera SS, De Luca D. Lung Ultrasonography score to evaluate oxygenation and surfactant need in neonates treated with continuous positive Airway pressure. JAMA Pediatr. 2015;169(8):e151797.
12. Oulego-Erroz I, Alonso-Quintela P, Terroba-Seara S, Jiménez-González A, Rodríguez-Blanco S. Early assessment of lung aeration using an ultrasound score as a biomarker of developing bronchopulmonary dysplasia: a prospective observational study. J Perinatol. 2021;41(1):62–8.
13. Raimondi F, Migliaro F, Corsini I, Meneghin F, Dolce P, Pierri L, et al. Lung ultrasound score progress in neonatal respiratory distress syndrome. Pediatrics. 2021;147(4):e2020030528.
14. Rodriguez-Fanjul J, Jordan I, Balaguer M, Batista-Muñoz A, Ramon M, Bobillo-Perez S. Early surfactant replacement guided by lung ultrasound in preterm newborns with RDS: the ULTRASURF randomised controlled trial. Eur J Pediatr. 2020;179(12):1913–20.
15. Szymanski P, Kruczek P, Hozejowski R, Wais P. Modified lung ultrasound score predicts ventilation requirements in neonatal respiratory distress syndrome. BMC Pediatr. 2021;21(1):17.
16. Corsini I, Lenzi MB, Ciarcià M, Matina F, Petoello E, Flore AI, et al. Comparison among three lung ultrasound scores used to predict the need for surfactant replacement therapy: a retrospective diagnostic accuracy study in a cohort of preterm infants. Eur J Pediatr. 2023;182(12):5375–83.
17. Roy T, Pal S, Sardar S, Mukherjee S, Ghosh M. Prediction of surfactant requirement in Indian preterm infants by lung ultrasound scores: a diagnostic accuracy study from a developing country. Eur J Pediatr. 2023;182(2):625–32.
18. Liu J. The lung ultrasound score cannot accurately evaluate the severity of neonatal lung disease. J Ultrasound Med. 2020;39(5):1015–20.
19. Louis D, Belen K, Farooqui M, Idiong N, Amer R, Hussain A, ElSayed Y. Prone versus supine position for lung ultrasound in neonates with respiratory distress. Am J Perinatol. 2021;38(2):176–81.
20. Shen JR, Du Y, Sun YH, Huang XY, Zhou JG, Chen C. Modified lung ultrasound score for bronchopulmonary dysplasia predicts late respiratory outcomes in preterm infants. Pediatr Pulmonol. 2023;58(9):2551–8.
21. Sun YH, Du Y, Shen JR, Ai DY, Huang XY, Diao SH, et al. A modified lung ultrasound score to evaluate short-term clinical outcomes of bronchopulmonary dysplasia. BMC Pulm Med. 2022;22(1):95.
22. Hooper SB, te Pas AB, Kitchen MJ. Respiratory transition in the newborn: a three-phase process. Arch Dis Child-Fetal Neonatal Ed. 2016;101(3):F266–71.
23. Zong HF, Guo G, Liu J, Bao LL, Yang CZ. Using lung ultrasound to quantitatively evaluate pulmonary water content. Pediatr Pulmonol. 2020;55(3):729–39.
24. Raimondi F, Yousef N, Fanjul JR, De Luca D, Corsini I, Shankar-Aguilera S, et al. A Multicenter Lung Ultrasound Study on transient tachypnea of the Neonate. Neonatology. 2019;115(3):263–8.
25. Srinivasan S, Aggarwal N, Makhaik S, Jhobta A, Kapila S, Bhoil R. Role of lung ultrasound in diagnosing and differentiating transient tachypnea of the newborn and respiratory distress syndrome in preterm neonates. J Ultrason. 2022;22(88):e1–5.
26. Yang G, Qiao YX, Sun XX, Yang TD, Lv AY, Deng M. The clinical effects of high-frequency oscillatory ventilation in the treatment of neonatal severe meconium aspiration syndrome complicated with severe acute respiratory distress syndrome. BMC Pediatr. 2021;21(1):560.
27. Baldan E, Varal IG, Dogan P, Cizmeci MN. The effect of non-invasive high-frequency oscillatory ventilation on the duration of non-invasive respiratory support in late preterm and term infants with transient tachypnea of the newborn: a randomized controlled trial. Eur J Pediatr. 2023;182(10):4499–507.
28. Iranpour R, Armanian AM, Abedi AR, Farajzadegan Z. Nasal high-frequency oscillatory ventilation (nHFOV) versus nasal continuous positive airway pressure (NCPAP) as an initial therapy for respiratory distress syndrome (RDS) in preterm and near-term infants. BMJ Paediatr Open. 2019;3(1):e000443.
29. Wu HL, Zhou SJ, Chen XH, Cao H, Zheng YR, Chen Q. Lung ultrasound score for monitoring the withdrawal of extracorporeal membrane oxygenation on neonatal acute respiratory distress syndrome. Heart Lung. 2024;63:9–12.
30. Szymanski P, Puskarz-Gasowska J, Hozejowski R, Stefanska M, Blaz W, Sadowska-Krawczenko I, et al. Prognostic relevance of the lung ultrasound score: a Multioutcome Study in infants with respiratory distress syndrome. Am J Perinatol. 2024;41(S 01):e2862–9.
31. Nosrati M, Akhoundi N, Nanva AHA, Siami A, Shariati MK, Rezazadeh E, Pouya EK. The role of lung Ultrasonography Scoring in Predicting the need for surfactant therapy in neonates, with respiratory distress syndrome. J Diagn Med Sonog. 2023;39(4):348–54.
32. Zhang LH, Feng JN, Jin D, Yu ZK, Qu YM, Zheng MY, Wu H. Lung ultrasound score as a predictor of ventilator use in preterm infants with dyspnea within 24 h after dhospitalization. Pediatr Neonatol. 2023;64(4):420–7.
33. Perri A, Sbordone A, Patti ML, Nobile S, Tirone C, Giordano L, et al. Early lung ultrasound score to predict noninvasive ventilation needing in neonates from 33 weeks of gestational age: a multicentric study. Pediatr Pulmonol. 2022;57(9):2227–36.
34. Raimondi F, Migliaro F, Sodano A, Umbaldo A, Romano A, Vallone G, Capasso L. Can neonatal lung ultrasound monitor fluid clearance and predict the need of respiratory support? Crit Care. 2012;16(6):R220.
35. Martelius L, Süvari L, Janér C, Helve O, Kaskinen A, Kirjavainen T, et al. Lung ultrasound and static lung compliance during postnatal adaptation in healthy term infants. Neonatology. 2015;108(4):287–92.

Publisher's Note