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Comparative Analysis of Lung Ultrasound Scoring and Oxygen Methods for Neonatal Mechanical Ventilation

Lina Zeng, Jianjun Tang, Tao Deng, Qijie Liu, and Huimin Zhao

Department of Pediatrics, The Third Affiliated Hospital of Chengdu Medical College, Chengdu Pidu District People's Hospital, Chengdu, China

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ABSTRACT

To investigate the feasibility and effectiveness of targeted lung recruitment and the titration of optimal positive end-expiratory pressure (PEEP) in neonates under the guidance of lung ultrasound.

The atelectasis neonates from June 2022 to June 2024 in the Neonatology Department of People's Hospital of Pidu were collected and randomly divided into a lung ultrasound scoring (LUS) group and an oxygen (OXY) group, both of which were given mechanical ventilation treatment. The lung recruitment and optimal PEEP were performed by the LUS and OXY methods, respectively. The optimal PEEP and the respiratory and hemodynamic indexes of the two groups were compared before and after lung recruitment and after the optimal PEEP was titrated.

After the intervention, the dynamic lung compliance (Cdyn) in the LUS group increased by 38.2% compared with the baseline (from 30.6 ± 4.3 to 42.3 ± 5.1 mL/cmH_2O), which was significantly higher than the 21.4% increase in the OXY group (from 29.8 ± 4.1 to 35.6 ± 4.8 mL/cmH_2O). The improvement in PaO2/FiO2 in the LUS group was 22.5% higher than in the OXY group. There was no statistically significant difference in the incidence of complications between the two groups.

Lung ultrasound can guide neonatal lung recruitment and optimal PEEP titration, improving lung compliance and oxygenation without affecting the safety of treatment.

Keywords: Lung recruitment; Lung ultrasound; Newborns; Positive end expiratory pressure; Targeting

INTRODUCTION

Neonatal atelectasis complicates the course of respiratory distress syndrome (RDS), meconium aspiration syndrome (MAS), and neonatal pneumonia, and is a major driver for invasive mechanical ventilation. However, the immature lung is exquisitely sensitive to ventilator-induced lung injury (VALI); even brief periods of either under-recruitment or over-distension accelerate the risk of bronchopulmonary dysplasia (BPD) and neurodevelopmental impairment. Current strategies to identify the "open-lung" positive end-expiratory pressure (PEEP) rely on computed tomography (CT) imaging, pressure–volume (P–V) curves, or repeated arterial blood gases. In neonates,

Corresponding Author: Huimin Zhao, MM;
Department of Pediatrics, The Third Affiliated Hospital of Chengdu Medical College, Chengdu Pidu District People's Hospital, Chengdu, China. Tel/Fax: (+86 0182) 0045 1682, Email: zhaohmcdyxy@163.com

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these gold standards are either impractical (transport, sedation, radiation) or hazardous (iatrogenic anemia, procedural pain), and none offer real-time structural feedback at the bedside.

Lung ultrasound (LUS) has emerged as a nonionizing, bedside tool that visualizes the air-to-tissue ratio of the lung. In adults, LUS-guided recruitment maneuvers improve compliance and shorten ventilation time, yet high-quality evidence in neonates is scarce. The unique acoustic properties of the neonatal thorax-small chest wall, high lung water, and regionally confined atelectasis-should theoretically favor LUS. To date, however, no prospective randomized trial has compared LUS-guided versus conventional oxygen-guided PEEP titration in this population.

We therefore conducted a blinded, randomized, controlled study to determine whether LUS-guided lung recruitment and PEEP optimization in neonates with atelectasis achieves better respiratory mechanics and oxygenation than the traditional oxygen method, and can be delivered safely without compromising hemodynamic stability. By directly addressing this knowledge gap, we sought to provide an evidence-based, bedside strategy for individualized, lung-protective ventilation in neonatal intensive care.

MATERIALS AND METHODS

Research Subjects

In this study, random number sequences generated by computers were used for grouping. The random sequences were sealed and stored until the subjects completed the baseline assessment, when they were unsealed and assigned groups by designated personnel to ensure the objectivity of the grouping process. Random numbers were generated by statisticians independent of the research team using Excel software. The subjects who met the inclusion criteria were randomly divided into the LUS group and the OXY group at a ratio of 1:1. LUS group: A total of 50 children, 30 males, 20 females. OXY group: A total of 50 atelectasis neonates, 26 males and 24 females, who matched age and sex and met the inclusion criteria, were selected from our hospital during the same period. At the time of enrollment, stratification was conducted based on gestational age (<32 weeks vs ≥32 weeks), birth weight (<1500 g vs ≥1500 g), and etiology (neonatal respiratory distress syndrome [NRDS]/MAS/neonatal pneumonia [PN]) to ensure balanced baseline characteristics between groups. After stratification, computer-generated block random numbers (block size 4) were used for allocation, and the random sequences were generated by independent statisticians using R software (version 4.2.1). After the random sequence was generated, it was sealed in an opaque envelope and kept by the head nurse of the intensive care unit, who is not from the research team. After the subjects completed the baseline assessment (lung ultrasound score and blood gas analysis), the head nurse opened the envelopes on the spot and assigned the groups to ensure that the researchers were unaware of the assignment results before grouping. This process complies with the requirement of allocation concealment stipulated in the CONSORT declaration.

Inclusion and Exclusion Criteria

Inclusion criteria: (1) age <28 days; (2) atelectasis was diagnosed by lung ultrasound; (3) children requiring invasive ventilator support; (4) family members of the children gave informed consent and voluntarily participated in this study, which was approved by the Ethics Committee of Chengdu's Pidu District.

Exclusion criteria: (1) children diagnosed with genetic metabolic disorders; (2) children with congenital malformations that affect breathing; (3) children with intracranial hemorrhage; (4) hemodynamic instability; (5) comorbidities such as pneumothorax, pulmonary hemorrhage, or other conditions impairing lung function; (6) gestational age at birth <28 weeks or >42 weeks, severe neonatal asphyxia requiring mild therapeutic hypothermia; (7) unexplained repeated clinical deterioration.

Inspection Methods

All ultrasound examinations were performed by two physicians with more than five years of experience in abdominal ultrasound diagnosis. Before the examination, both physicians underwent unified training and were familiar with the ultrasound assessment standards of this study to ensure the standardization of the operation and the reliability of the results. The ventilatory status of the lung was assessed before targeted recruitment. There is a neonatologist who has obtained the certificate of special training in neonatal intensive ultrasound or obtained the certificate of conformity issued by the Chinese College of Ultrasound in Medicine and Biology (CCUSG). At the same time, an ultrasound doctor was assigned to score the two

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scores respectively, and the average of the two scores was taken as the final score. The ultrasound image of the normal lung includes line A and line B, and the lung is an air-bearing organ. When ultrasound is projected vertically on the human chest wall, reverberation artifacts appear in the chest wall echo, which is reflected back and forth between the probe and the interface, and multiple equidistant echoes appear in the lung tissue area below the pleura, which is one of the ultrasonographic features of normal lung tissue, called line A. When an area of the lung has reduced gas content or increased water content, ultrasound is delivered vertically into the chest wall to show a comet tail sign that emanates from the pleura and is perpendicular to the pleura, called line B. Fused B line, that is, the entire intercostal space appears as a dense B line (B line fusion with each other difficult to distinguish, counting), while the rib sound shadow is still clearly displayed. Dense B line, that is, there is a too dense B line in the lung field, resulting in the entire scan area of the rib shadow almost disappearing. When the water content of the lung further increased to become lung consolidation, then the section appeared like a liver parenchymal echo image. According to the International Committee on Pulmonary Ultrasound Scoring, lung consolidation is considered when ultrasound signs such as tissue-like echo zone of liver tissue, fragment sign (subpleural mass-like echo), and air bronchus sign (hyperechoic dot image) appear.[3]

The LUS examination method described by Acosta et al[4] was used to divide the entire chest wall into 12 regions. The anterior axillary line and posterior axillary line were used as anatomical markers to divide the chest wall into 3 regions: anterior, lateral, and posterior, and each region was further divided into 2 parts (Figures 1 and 2). The ultrasonic diagnostic instrument (Mindray M9) and linear array probe with the probe frequency of 4.0–10.0 MHz were used to probe 12 areas of both sides of the lung. Each target area was scored according to the four states of lung ventilation described by Song et al[5], and the scores obtained were added together to obtain the total lung ventilation score, that is, the semi-quantitative score of lung ultrasound regasification (Table 1).

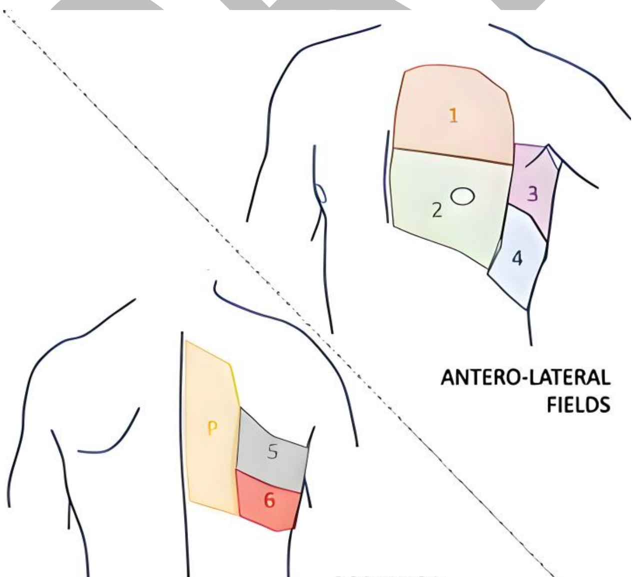

Figure 1. Lung ultrasonic scanning parts. (Taking the ANTERO-LATERAL and POSTERIOR axillary lines as anatomical landmarks, each side of the chest wall was divided into three regions: anterior, lateral, and posterior. Each region was further divided into two parts according to the intercostal space, with a total of 12 scanning areas (6 areas on each side). The scanning was conducted using the Mindray M9 ultrasound instrument with a linear array probe (4.0-10.0 MHz). After scoring each area based on the lung ventilation status, the total score of lung recruitment was summarized.)

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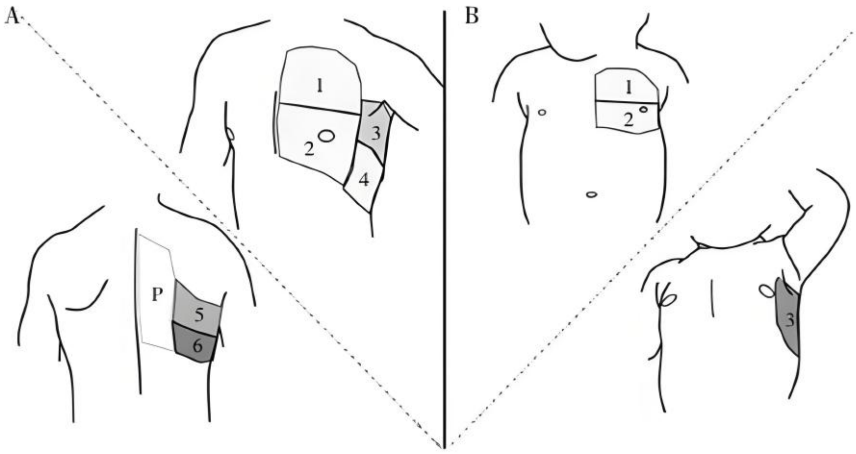

Figure 2. LUS scan area. Figure A is suitable for adults and children; Panel B is for neonates. (Figure A (for adults and children): Divided into 12 sections according to anatomical landmarks; Figure B (for newborns): Due to the smaller thorax, it was adjusted to anterior zone 4 (1-4), lateral zone 4 (5-8), and posterior zone 4 (9-12). During the scan, the body position was adjusted according to the location of atelectasis (supine position for anterior collapse and prone position for posterior collapse).

Table 1. Ultrasonic regasification semi-quantitative score calculation method

Lung recruitment score	Real change score				
1	3	5	5	3	1
B1-N	B2-N	C-N	N-C	N-B2	N-B1
B2-B1	C-B1			B1-C	B1-B2
				B2-C	

B1: mild hypoventilation; B2: severe hypoventilation; C: lung consolidation; N: normal ventilation.

The four states of lung ventilation are classified according to the proportion of air and water content. (1) N: normal ventilation, line A is visible, line B is rare, and no pneumothorax is present; (2) B1: pulmonary ventilation is slightly reduced, and multiple B lines with clear boundaries and regular or irregular distribution can be seen, and more than 3 B lines are a small amount, indicating moderate pulmonary poor ventilation; (3) B2: diffuse distribution, continuous fusion of line B, lung ventilation is seriously reduced; (4) C: signs of lung consolidation, hepatoid echo with dynamic air bronchogram.

Methods of Lung Recruitment

After baseline measurements, both groups received fentanyl (1–2 $\mu g\,kg^{-1}$ bolus + 1–2 $\mu g\,kg^{-1}\,h^{-1}$ infusion) and were ventilated in assist/control (A/C) or synchronous intermittent mandatory ventilation (SIMV) mode (tidal volume [VT] 6–8 $mL\,kg^{-1}$, respiratory rate [RR] 30–60 min^{-1}, I:E 1:1.5–2, initial fraction of inspired oxygen [FiO_2] ≤0.60). SpO_2 was kept 90% to 95%. Recruitment was accomplished by escalating PEEP in 1 cmH_2O steps every 5 min while adjusting FiO_2 to maintain the SpO_2 target.

OXY group: PEEP increments continued until the oxygenation index (PaO_2/FiO_2) ≥400 mmHg was achieved. The lowest PEEP that sustained this threshold was recorded as the recruitment endpoint.

LUS group: Baseline whole-lung LUS was performed, and body position was adjusted (supine for anterior, prone for posterior atelectasis). After each PEEP step, a 12-region LUS was repeated; recruitment was deemed complete when the global LUS no longer improved. The corresponding PEEP was noted as the endpoint.

In both groups, arterial blood gases were sampled at the recruitment endpoint; ultrasound images were scored off-line by two blinded investigators and averaged.

Titrated Optimum PEEP

After reaching the end point of recruitment maneuvers (RM), the optimal PEEP was titrated by the LUS method and the OXY method, respectively. PEEP is gradually reduced by 2 cmH_2O every 5 minutes, during which a volumetric mode is adopted to maintain tidal volume at 6–8 mL/kg to prevent brain damage during recruitment. In the OXY group, PEEP was closed pressure until the oxygenation index decreased by more than 10% (indicating recollapse of alveoli), and then the PEEP was adjusted to the highest level after re-expansion of the lung, and the titrated PEEP was the best maintained PEEP. In the LUS group (the scoring method is shown in Table 1), two consecutive scores were suddenly increased by more than 30%, and then the PEEP was adjusted to the highest level after lung recruitment, and the titrated PEEP was the best maintained PEEP. During PEEP decline, blood oxygen saturation was monitored, while FiO_2 was upregulated to maintain the saturation between 90% and 95%.

Monitoring Index

The optimal PEEP values of the two groups and the respiratory mechanical indexes, airway equalized pressure, dynamic lung compliance, and hemodynamic indexes before RM, 30 min after RM endpoint, and 30 min after titrated optimal PEEP were monitored by the SLE6000 monitoring panel, heart rate, and cardiac output. Pulmonary gas exchange indexes: Arterial blood of LUS group and OXY group was extracted before RM intensification, 30 min after RM endpoint, and 30 min after optimal PEEP was titrated, and arterial partial pressure of oxygen (PaO_2), partial pressure of carbon dioxide ($PaCO_2$) and inhaled oxygen concentration (FiO_2) were measured by a blood gas analyzer (SIEMENS). Oxygenation index=PaO_2/FiO_2. The cardiac output (CO) before RM, 30 min after RM endpoint, and 30 min after optimal PEEP were measured by bedside echocardiography.

The measurement method is: first, locate the parasternal long axis and observe the aortic valve movement to ensure that there is no aortic stenosis. The image was frozen when the aortic valve was fully opened during the systolic period, and the distance between the anterior and posterior walls of the horizontal aorta at the root of the aortic valve was measured with an electronic vernier to obtain the outflow diameter of the left ventricle. The apical five-chamber cardiac plane was found, and the sampling volume was placed under the left ventricular outflow tract, ie, the aortic valve, in pulse Doppler mode. The window width was 2–4 mm, and the blood flow velocity of the left ventricular outflow tract was recorded. The images were frozen, and the maximum velocity track was recorded.

The ultrasound machine calculates the aortic velocity time integral, which reflects the displacement of the stroke blood flow. The stroke flow displacement was multiplied by the cross-sectional area of the left ventricular outflow tract to obtain the stroke volume. 3–5 consecutive images of the same respiratory cycle were selected for measurement, and the average stroke volume was calculated. The average stroke volume was multiplied by the heart rate to obtain CO. The duration of invasive ventilator support, length of hospital stays, and incidence of bronchopulmonary dysplasia were recorded in the two groups. Notably, bedside echocardiographic measurements (eg, CO) were only conducted at three short-term time points, with no follow-up scans in 24–72 hours post-recruitment. This limits the assessment of delayed pulmonary hemodynamic changes that may indicate underlying pulmonary issues, failing to fully validate the long-term safety of PEEP titration. The scoring of ultrasound images was completed by two radiologists, independent of the grouping information (double-blind design). The scorer evaluated the images based on the pre-established standardized scoring table without knowing the grouping of the subjects. If there were differences in the scores, a third senior physician would review and make a ruling.

Statistical Methods

Statistical analysis data were analyzed by SPSS 20.0 statistical software. For measurement data conforming to the normal distribution (as tested by Shapiro-Wilk), independent sample *t* tests (for comparison between two groups) or paired *t* tests (for comparison within groups) were used. For data not conforming to the normal distribution, Mann-Whitney *U* tests (between groups), or Wilcoxon signed-rank tests (within groups) were used. The counting data were analyzed using the χ^2 test (when the theoretical frequency was≥5) or the Fisher exact probability method (when the theoretical

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frequency was<5). The results were expressed as χ^2 values or *Z* values (non-parametric tests), and the *p* values were rounded to two decimal places.

RESULTS

Comparison of Baseline Data

In the OXY group (n=50), there were 26 males and 24 females, with a male to female ratio of 1.2:1. In the LUS group (n=50), there were 30 males and 20 females, with a male to female ratio of 1.5:1. There were no significant differences in the etiology (NRDS, MAS, PN), average age, gestational age and birth weight between the two groups (p>0.05), indicating that the two groups were comparable (Table 2).

Comparison of Respiratory Mechanics Indexes

At the end point of pulmonary recruitment, oxygenation index, PEEP, peak inspiratory pressure (Ppeak), mean airway pressure (Pmean), and dynamic lung compliance (Cdyn) in the OXY group were significantly lower than those in the LUS group (p<0.05). The optimal PEEP of the OXY group and the LUS group was 8.5 ± 1.1 and 11.5 ± 1.5 cmH_2O, respectively, and the difference between the two groups was statistically significant (t=2.227, p=0.016) (Table 3).

Comparison of Hemodynamic Indexes

Compared with the basic state, there was no significant difference in HR, MAP, and CO between the two groups after lung recruitment (p>0.05). There was no significant difference in lung recruitment between the two groups at different time periods (p>0.05) (Table 4).

Monitoring and Comparison of Other Clinical Outcome Indicators

There were significant differences in invasive ventilator support time and hospital stay in the LUS group (p<0.05). There was no significant difference in the incidence of BPD between the two groups (p>0.05) (Table 5).

Table 2. Comparison of general information

Variable	NRDS			MAS			PN		
	OXY Group	LUS Group	t/χ^2 (p)	OXY Group	LUS Group	t/χ^2 (p)	OXY Group	LUS Group	t/χ^2 (p)
N (%)	26 (52.00)	25 (50.00)	0.238 (0.88)	10 (20.00)	12 (24.00)	0.352 (0.76)	14 (28.00)	13 (26.00)	0.542 (0.65)
Gestational age, weeks	32.87 ± 2.47	31.56 ± 2.68	0.027 (0.58)	40.00 ± 1.64	41.00 ± 0.48	0.032 (0.33)	38.06 ± 2.07	39.16 ± 1.76	0.064 (0.12)
Birth weight, kg	1.64 ± 0.68	1.56 ± 0.89	0.046 (0.35)	3.95 ± 0.66	3.68 ± 0.84	0.038 (0.28)	2.78 ± 0.76	2.64 ± 0.88	0.042 (0.15)
Age, d	1.22 ± 0.98	1.39 ± 0.67	0.054 (0.31)	2.35 ± 1.51	2.42 ± 1.22	0.067 (0.25)	5.64 ± 1.76	6.97 ± 1.49	0.078 (0.18)

LUS: lung ultrasound scoring; MAS: meconium aspiration syndrome; NRDS: neonatal respiratory distress syndrome; OXY: oxygen; PN: neonatal pneumonia.

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Table 3. Comparison of respiratory mechanics indexes

Variable	Before RM (n=25)			Start RM 30 minutes after expansion (n=25)			30 minutes after titration of optimal PEEP		
	OXY Group	LUS Group	*t*/*Z* (*p*)	OXY Group	LUS Group	*t*/*Z* (*p*)	OXY Group	LUS Group	*t*/*Z* (*p*)
PaO_2/FiO_2	130.67 ± 18.98	131.67 ± 17.89	0.058 (0.76)	337.2 ± 22.2	337.2 ± 22.2	-4.21 (<0.05)	337.20 ± 22.20	337.20 ± 22.22	-7.51 (<0.05)
Ppeak	15.10 ± 2.32	16.20 ± 2.1	0.034 (0.85)	18.30 ± 1.3	20.3 ± 1.5	0.14 (<0.05)	20.40 ± 1.87	23.50 ± 2.14	0.18 (<0.05)
Pmean	7.50 ± 0.8	7.60 ± 0.9	-1.845 (0.06)	8.50 ± 1.2	10.2 ± 1.5	-2.93 (0.003)	10.30 ± 1.25	12.70 ± 1.32	-2.45 (0.014)
Cdyn	0.29 ± 0.07	0.28 ± 0.08	0.114 (0.90)	0.31 ± 0.08	0.34 ± 0.06	-2.01 (0.044)	0.33 ± 0.09	0.37 ± 0.08	-2.99 (0.003)
PEEP	5.00 ± 0.38	5.00 ± 0.43		6.70 ± 1.22	9.70 ± 1.34		8.50 ± 1.15	11.50 ± 1.52	2.22 (0.016)

[a]Cdyn: dynamic lung compliance; FiO_2: fraction of inspired oxygen; LUS: lung ultrasound scoring; OXY: oxygen; PaO_2: partial pressure of arterial oxygen; PEEP: positive end-expiratory pressure; Pmean: mean airway pressure; Ppeak: peak inspiratory pressure; RM: recruitment maneuver.

Table 4. Comparison of hemodynamic indexes

Hemodynamic index	Before RM (n=25)		RM 30 minutes later (n=25)		30 minutes after titration of optimal PEEP	
	OXY Group	LUS Group	OXY Group	LUS Group	OXY Group	LUS Group
Mean arterial pressure (MAP)	35.10 ± 2.12[c]	36.20 ± 1.54[c]	37.25 ± 1.83[a,c]	37.34 ± 1.72[a,c]	38.32 ± 2.0[a,b,c]	39.91 ± 2.15[a,b]
Heart rate (HR)	118.39 ± 6.29[c]	116.34 ± 4.6[c]	120.55 ± 6.78[a,c]	121.40 ± 4.12[a,c]	119.41 ± 5.86[a,b,c]	120.52 ± 4.96[a,b,c]
Cardiac output (CO), mL/min·kg	128.27 ± 3.51[c]	130.53 ± 3.22[c]	130.50 ± 4.32[a,c]	132.84 ± 5.52[a,c]	131.3 ± 5.13[a,b,c]	132.52 ± 4.26[a,c,b]

[a]Compared with before the RM, $p>0.05$.
[b]Compared with 30 min after the RM, $p>0.05$.
[c]Comparison of hemodynamic parameters at different time points of the RM, between two groups, $p>0.05$.
[d]CO: cardiac output; HR: heart rate; LUS: lung ultrasound scoring; MAP: mean arterial pressure; OXY: oxygen; RM: recruitment maneuver.

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Table 5. Other clinical outcome indicators monitoring

Group	Ventilator support time, d	Average length of stay, d	Incidence of bronchopulmonary dysplasia, No. (%)
OXY	6.11 ± 0.13	11.47 ± 0.36	6%
LUS	4.88 ± 0.14	9.86 ± 0.39	4%
Z/χ^2	-5.31	-2.91	0.43
p	<0.05	0.004	0.73

The ventilator support time was non-normally distributed data. The Mann-Whitney *U* test was used for comparison between groups (Z=-5.31, p<0.001). The average length of stay was tested for normality using the independent sample *t* test (t=-2.91, p=0.004); The incidence of bronchopulmonary dysplasia was compared using the Fisher exact probability method (p=0.73).

[b]LUS: lung ultrasound scoring; OXY: oxygen.

DISCUSSION

Lung ultrasound technology has the advantages of safety, non-invasive, low cost, and dynamic observation. In severe cases, ultrasound is mainly used to analyze the artifacts of air/water ratio changes in lung parenchyma under pathological conditions. In 2011, Bouhemad et al proposed US-RAS by observing the changes in ventilation levels in different parts of lung tissue.[6]

The study demonstrated that the atelectasis area measured via ultrasound-based recruitment maneuvers (US-RAS) showed strong agreement with findings from chest computed tomography (CT). The optimal positive end-expiratory pressure (PEEP) selected using US-RAS aligned closely with the principle of identifying the most effective PEEP level. This involved incrementally increasing PEEP by 1–2 cmH_2O per adjustment and recording lung ultrasound scores post-adjustment. Following lung re-expansion, the protocol employed a stepwise reduction in PEEP (1–2 cmH_2O decreases at each stage). This continued until two consecutive ultrasound assessments revealed a sudden increase in scores exceeding 30%.[4] At this point, PEEP was restored to the highest prior value, representing the optimal level to sustain post-re-expansion lung status. This approach minimized arteriovenous shunting,[5] improved oxygenation, and enhanced lung compliance.[6] Therefore, the application of lung ultrasound provides an effective monitoring method for the targeted pulmonary recruitment of neonatal atelectasis lung diseases, and at the same time, severe cardiac ultrasound provides an accurate evaluation of the monitoring of the central output during the recruitment process.[7]

The process of lung recruitment includes two stages: increasing positive end-expiratory pressure and fully opening collapsed alveoli in volumetric ventilation mode; then, the positive end-expiratory pressure is gradually reduced to find the alveolar closure pressure.[8] When the positive end-expiratory pressure is increased, the optimal PEEP can be titrated when the alveolar volume increases by more than 20%, to avoid the inhibition of the circulatory system by long-term high inspiratory pressure and reduce the occurrence of barotrauma.[9]

Therefore, maintaining appropriate PEEP after recruitment is the key to maintaining the alveolar opening.[9] However, the selection of PEEP after pulmonary recruitment is still controversial, which improves neonatal lung protective ventilation strategy difficult to break through again.[10] LUS and OXC methods were used to monitor the endpoint of lung recruitment and titrate optimal PEEP.[11] Our results showed that after lung recruitment, oxygenation index, PEEP, Ppeak, Pmean, and Cdyn in the OXY group were significantly lower than those in the LUS group, and there was still a part of B-line in the OXY group under lung ultrasound, suggesting the possibility of alveolar collapse. In the LUS group, lung ultrasound was close to the normal level.[11] Moreover, MAP, HR, and other indexes were not different between the two groups, indicating that the LUS group had no significant effect on circulation perfusion when the airway pressure was

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higher than OXY group, and the lung compliance was better.[12]

It was confirmed that most of the alveoli were open after lung recruitment, and no lung injury was caused by alveolar overexpansion when the ultrasound score was used to evaluate the endpoint of lung recruitment.[13–17] However, in our study, VT was calculated at actual body weight, not at ideal body weight, and ultrasound could not accurately identify excessive or normal ventilation.[18] In addition, there was no significant difference in the incidence of bronchopulmonary dysplasia between the two groups, and there were differences in the average length of hospital stay, oxygen inhalation time, and ventilator support time, suggesting that LUS guidance for lung recruitment not only has significance for improving oxygenation and lung compliance, but also can shorten the length of hospital stay, oxygen inhalation time, and ventilator use time.[19,20] The 22.5% higher improvement in PaO_2/FiO_2 in the LUS group (vs OXY group) has important clinical implications: First, it directly reduces the demand for inhaled oxygen (FiO_2), lowering the risk of oxidative stress-induced lung injury (a key driver of BPD) in neonates with immature antioxidant systems. Second, this improvement allows for earlier reduction of ventilator parameters, aligning with the shorter invasive ventilator support time observed in the LUS group—clinically translating to reduced VALI risk and earlier transition to non-invasive ventilation. Third, stable and improved oxygenation reduces the need for repeated arterial blood draws (a risk of iatrogenic anemia in neonates), further enhancing patient safety.

This study confirmed the effectiveness of lung ultrasound score (LUS) in guiding neonatal lung recruitment and the titration of the optimal PEEP. The traditional oxygenation method requires repeated blood collection to monitor blood gas, and there are risks of iatrogenic blood loss and stress. However, LUS realizes the combined assessment of morphology and function by dynamically visualizing the pulmonary ventilation status. Combining the idea of "machine learning for predictive maintenance of medical devices" proposed by Peruničić et al (2024), the technology of this study can be further expanded.[21] Intelligent ventilation management system: Linking LUS scores with ventilator parameters, a real-time prediction model is established through AI algorithms to automatically adjust ventilation strategies to maintain the optimal open state of the lungs and reduce the operational load on medical staff.

This study still has the following limitations: The LUS score relies on manual operation and may be influenced by subjective experience. Special subgroups, such as extremely premature infants, were not included. In this study, there was no significant difference in the incidence of bronchopulmonary dysplasia (BPD) between the LUS group and the oxygen method, which might be related to the smaller sample size or shorter follow-up time.

This study confirmed that lung ultrasound score (LUS) can effectively guide neonatal lung recruitment and optimal PEEP titration, significantly improving lung compliance and oxygenation levels without affecting hemodynamic stability. This technology has advantages such as being non-invasive, bedside, dynamic, and radiation-free. It can be used as an important auxiliary tool for neonatal respiratory management, optimize individualized ventilation strategies, reduce invasive operations and iatrogenic injuries, and has good clinical promotion value.

However, this study was a single-center design with a limited sample size, and no systematic follow-up was conducted on long-term outcomes such as the incidence of chronic lung disease and neurodevelopmental prognosis. In the future, multi-center, large-sample, randomized controlled trials should be conducted to further verify the applicability and safety of LUS-guided ventilation strategies in different NICU environments. Meanwhile, it is suggested to integrate artificial intelligence technology to develop an automated lung ultrasound scoring system to enhance the efficiency and consistency of the assessment. Subgroup analyses were conducted for special groups, such as extremely premature infants, to clarify their benefits and risks. In addition, long-term follow-up studies should also be included in the plan to comprehensively assess the impact of this strategy on the long-term health outcomes of the children.

STATEMENT OF ETHICS

Family members of the children gave informed consent and voluntarily participated in this study, which was approved by the Ethics Committee of Chengdu's Pidu District.

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FUNDING

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

ACKNOWLEDGMENTS

Not applicable.

DATA AVAILABILITY

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

AI ASSISTANCE DISCLOSURE

Not applicable.

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