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RESEARCH

Serial lung ultrasound in predicting the need for surfactant and respiratory course in preterm infants—multicentre observational study (SLURP)

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Abstract

Lung ultrasound (LUS) scores may predict surfactant need early and the progression of the respiratory course in preterm infants. The objective of this study is to report the diagnostic value of LUS scores performed by operators of varying levels of experience to predict the need for surfactant in preterm infants. A prospective observational study was conducted across 3 UK-based neonatal intensive care units. Preterm infants ≤ 34 weeks on non-invasive respiratory support within 3 h of birth were included. Ten lung zones were scored serially, first within the first 3 h of life, then at 12–24-h intervals (a total of four scans). All scans were performed by the local team members with formal training on LUS and varying levels of expertise. All the LUS videos were scored by an expert investigator who was blinded to clinical details. Written retrospective parental consents were obtained. We recruited 83 preterm infants ≤ 34 weeks (May 2023 to June 2024). A total of 325 LUS scans were performed by 27 clinical staff. The median birth gestational age and birth weight were 31 weeks and 1515 g, respectively. Twenty-eight (34%) babies received surfactants. The first LUS using a 6-zone method within 3 h of life predicted surfactant need and bronchopulmonary dysplasia with an AUC of 0.80 for both outcomes, offering sensitivity (79% and 73%) and specificity (75% and 76%), respectively.

Conclusions: LUS performed by operators of varying levels of experience within the first 3 h of life is a reliable tool for predicting surfactant need in preterm infants ≤ 34 weeks.

Trial registration: ClinicalTrials.gov (https://clinicaltrials.gov/): NCT05782569.

What is Known:

- *There are considerable variations in the selection criteria of preterm infants for surfactant administration.*
- *Lung ultrasound score has been shown to predict the need for surfactant early and the progression of respiratory course in preterm infants.*

What is New:

- *LUS performed within 3 h of life by operators of varying levels of experience and interpreted by expert predicted the need for surfactant deficiency in preterm infants.*
- *Our research with a structured training programme enabled novice operators to perform LUS and achieve reasonable competency.*

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Keywords Lung ultrasound · Surfactant · Bronchopulmonary dysplasia · Training

Abbreviations

BPD	Bronchopulmonary dysplasia (BPD)
CPAP	Continuous positive airway pressure
FiO_2	Fraction of inspired oxygen
HHHFNC	Heated humidified high-flow nasal cannula
LUS	Lung ultrasound
LUS Score	Lung ultrasound score
RCTs	Randomised controlled trials
RDS	Respiratory distress syndrome
SpO2	Oxygen saturation

Background

Early use of continuous positive airway pressure (CPAP) and early selective use of surfactant in preterm infants with respiratory distress syndrome (RDS) are recommended by international guidelines [1, 2]. This recommendation is based on systematic reviews which have shown that compared to the "intubation group", infants receiving CPAP at birth had reduced death and/or bronchopulmonary dysplasia (BPD) [3]. A Cochrane review has shown that prophylactic use of surfactant is associated with a higher risk of death/BPD [4], and the review suggested early selective use of surfactant rather than prophylactic surfactant use [5]. Early selective use of surfactant has been shown to have a significant reduction in neonatal morbidities [5]. Criteria for the selection of preterm infants for surfactant administration vary between neonatal units, agencies, and countries [6]. In clinical practice, varying levels of fraction of inspired oxygen (FiO2), along with other clinical factors, are used to select infants for surfactant administration. The reliance on FiO_2 thresholds lacks strong evidence [7, 8]. Infants could take variable time to reach this threshold, which could reduce the benefits of early surfactant administration [9].

Emerging evidence suggests that Lung ultrasound (LUS) score could predict the need for surfactant early and BPD in the preterm population [10–13]. LUS can be performed easily at the bedside, requires a very short period (3 min ± 2 [11]), is non-invasive, has no radiation hazard (unlike X-rays), has a steep learning curve, and has a good inter-rater reliability ($k = 0.89$) [11, 12].

Objectives

The primary objective of our study was to assess the diagnostic value of LUS performed by operators of various levels of experience and to identify the best LUS score, using ten versus six zones, before 3 h of age to predict the need for surfactant in preterm infants ≤ 34 weeks on non-invasive respiratory support. The secondary objectives of our study were as follows: (1) to study the value of serial LUS until day 3 and to predict the need for repeated doses of surfactant, (2) to predict the development of BPD at 36 weeks, and (3) to report the correlation between chest X-ray and LUS, and between Silverman-Anderson score and LUS score.

Methods

We conducted a multi-centre observational prospective study in three level 3 neonatal intensive care units in the UK (Centre 1: James Cook University Hospital, Middlesbrough (JCUH); Centre 2: University Hospital Wishaw, Glasgow (UHW) and Centre 3: Oliver Fisher Neonatal unit, Kent (OFNU). We recruited inborn preterm infants with a birth gestational age of ≤ 34 weeks and receiving non-invasive respiratory support. Continuous positive airway pressure (CPAP) and heated humidified high-flow nasal cannula (HHHFNC) were considered non-invasive respiratory support. The decision to administer surfactant ("surfactant need") is based on each unit guidelines relying on European guidelines for respiratory distress syndrome [14].

We excluded infants receiving surfactant or delivery room intubation before the first LUS, infants with major congenital malformations, and infants with pneumothorax needing intervention.

For chest X-rays, we used scoring developed by Perri et al. [15] and the Silverman-Anderson score for the assessment of respiratory distress [16]. We defined BPD as oxygen or respiratory support needed at 36 weeks postmenstrual age for preterm infants < 32 weeks birth gestational age [17]. We also calculated the oxygen saturation (SpO2)/FiO2 ratio and the modified oxygenation index (CPAP pressure *FiO2/SpO2). We did not specify that these SpO2 measurements must be preductal and we did not clean the data for artifacts.

LUS training

We have organised one full-day LUS workshop independently at each of the centres. Following this, we also developed an online learning module. All scans were performed by the local team members who had completed one or more of the aforementioned formal LUS training sessions. Operators were divided into four experience levels: "Training only" (completed only online course and workshop); "Beginner" (performed 20 scans with 5–10 supervised scans); "Intermediate" (50 to 70 LUS scans of all pathologies) and "Advanced" (more than 70 LUS scans of all pathologies). For the operators "Training only" and "Beginner", we suggested performing at least the first five LUS scans under supervision.

Lung ultrasound

All of the recruited infants underwent LUS before surfactant administration within 3 h of life and subsequent serial LUS every 12–24 h until day 3 (total of 4 LUS). We chose 3 h cut-off as it aligns with the preferred timing for early surfactant administration [5]. For each of the scans, we assessed five lung zones on each side (a total of 10 lung zones): Upper anterior at the level of the mid-clavicular line, lower anterior at the level of the mid-clavicular line, lateral at the level of the mid-axillary line, upper posterior at the level of the posterior axillary line between the scapula and spine, and lower posterior at the same level. All recruited infants underwent LUS scanning using two methods: the classical 6-zone LUS scores and the extended 10-zone LUS scores [18]. For the 6-zone LUS scores, the scan focused on the non-dependent lung areas based on the infant's default position at least 30 min before the ultrasound. In infants who were scanned while in their default prone position, the 6 zones were as follows: right upper posterior, right lower posterior, right lateral, left upper posterior, left lower posterior, and left lateral. For the 10-zone LUS scores, the infants remained in the same default position but were tilted (not completely change their position) to allow scanning of four additional zones: right upper anterior, right lower anterior, left upper anterior, and left lower anterior; vice versa for infants who are supine at the time of LUS. This approach ensured that the dependent lung areas were not included in the 6-zone scan. We intentionally did not alter the infants' default positions specifically for the research, as both supine and prone positions were standard practices in the recruiting units. We performed sensitivity analysis excluding infants who were in a prone position at the time of the scan. We used the LUS scoring system adapted from Brat et al. [10] and assessed each area of interest (5 areas for each lung: 10 lung zones) for a score of 0 to 3 for each zone, based on the four different patterns.

Each unit had its guidelines for respiratory management, and the decision to intubate was under the clinical discretion of the attending team [2]. For the recruited infants, members of the clinical team who underwent training performed LUS and calculated their scores. They also completed the case report form (workbook) for each of the LUS (Appendix_1). The LUS findings were not shared with the clinical team (except in cases of pneumothorax), who pragmatically treated those babies according to their local guidelines. We collected infant and maternal demographics and clinical data from the neonatal database. Only non-identifying study data were entered and managed using REDCap (Research Electronic Data Capture), a secure online research database [19] by the research team. Video files of the LUS were downloaded without any patient information and securely transferred to one of the expert study investigators (VMP), who was blinded to the clinical history and LUS scores calculated by the person who performed the LUS at the bedside. We used the scores of the expert (VMP) for all our primary analyses. An expert (VMP) labelled a LUS as "uninterpretable" if the quality of the scans was too poor (e.g., too dark) and, as a result, unable to score. Details of the study protocol are provided in Appendix_2.

Descriptive statistics were used for population characteristics. Categorical variables were presented as proportions, while numerical variables were presented as mean with standard deviation (SD) or median with interquartile range (IQR) as appropriate. We calculated sensitivity, specificity, and predictive values for LUS scores for the need for surfactant and BPD at 36 weeks. Receiver operator characteristic (ROC) curves were constructed, and the corresponding areas under the curve (AUCs) were reported. Comparisons between AUCs were performed using the DeLong method for ROC curves. We specifically reported diagnostic values for the LUS scores cut-off of 8 and 9 as these scores were commonly reported to have higher diagnostic values in previous studies [11, 13].

For assessing the correlations between two sets of continuous variables, we used Spearman's rank correlation coefficient, and the strengths of correlation were reported as described by Schober et al. [20]. For all statistical analyses, a p-value of <0.05 was considered significant. All the analyses were performed using StataNow/SE 18.5 (StataCorp LLC). We used Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement guidelines for reporting the study (Appendix 3) [21].

Currently, chest X-ray is the standard diagnostic tool for imaging infants with respiratory distress. The sensitivity of chest X-ray in predicting the need for surfactant was 38% [12]; to improve the sensitivity to approximately 60% by LUS, we needed 39 infants to show this difference with a power of 90% and an alpha error of 5% [22]. With the expected loss of poor-quality images, we aimed to recruit at least 50 infants with at least half of the population (25 babies) in the gestation ≤ 29 weeks. We obtained retrospective consent from the mothers of the recruited infants. This study was registered with clinictrials.org (NCT05782569). Research and ethical approval were obtained from the health research authority and Health and Care Research Wales (REC reference 22/WM/0276 and IRAS 291372). Research was conducted in accordance to UK Policy Framework for Health and Social Care Research.

Results

We recruited 83 preterm infants with a birth gestational age ≤ 34 weeks (May 2023 to June 2024). Infant and maternal demographics are provided in Table 1. Thirty-two infants

Table 1 Demographics and respiratory support data ($n = 83$)

Infant demographics	
	Characteristics
Male sex, *N* (%)	53 (64%)
Median birth weight in grams (IQR*)	1515 (1185–1950)
Median birth gestational age in weeks (IQR*)	31 (29–32)
Caesarean section, *N* (%)	64 (77%)
Median admission temperature in degree Celsius (IQR*)	36.9 (36.6–37.1)
Median Clinical risk index for babies II score (IQR*)	3 (2–7)
Maternal demographics	
Any antenatal steroids, *N* (%)	76 (91.5%)
Maternal diabetes, *N* (%)	15 (18%)
Multiple pregnancy, *N* (%)	19 (23%)

*IQR; Inter-quartile range

were born ≤ 29 weeks. Recruitment in each centre is as follows: JCUH = 37, UHW = 9, and OFNU = 37. Two common reasons for not recruiting infants were "intubation in the delivery room" and "non-availability of trained personnel to perform LUS". Twenty-eight (34%) babies received surfactant, with 19 infants by LISA and nine infants after intubation. Only two infants received more than one dose of surfactant. The median age for receiving surfactant from birth was 3.58 (IQR 3.12–7.35) h.

Operators and LUS

Forty-nine percent of the LUS were performed by the operators in the "Training only" group, and 17% by the "Beginner" operators. Twenty-seven clinical staff members performed all of the LUS in total: 16 trainees, two advanced nurse practitioners, and 9 consultants. Details of lung ultrasound at the time of each lung ultrasound are provided in Table 2, and other respiratory parameters are provided in Supplementary Table 1. A total of 325 LUS scans were performed: 83 first LUS, 81 s LUS, 81 third LUS, and 80 fourth LUS. Of the 325 LUSs performed, 37 scans (11%) were uninterpretable, with 288 LUS scans available for analysis. Six and 10 zone LUS scores by time interval were provided as a box-whisker plot in Fig. 1 (Fig. 1A: 6 zone LUS scores and Fig. 1B: 10 zone LUS scores). The number of available video clips and uninterpretable video clips in each centre are provided in Supplementary Fig. 1.

Surfactant

We got best the diagnostic value for LUS score cut-off ≥ 9. With 10 zones, LUS score cut-offs of ≥ 9, the sensitivity was higher, with low specificity for predicting "surfactant need"

Table 2 Details of LUS at the time of each lung ultrasound

	First LUS ($n = 83$)	Second LUS ($n = 81$)	Third LUS ($n = 81$)	Fourth LUS ($n = 80$)
Self-reporting experience with performing lung Ultrasound	Training only: 38 Beginner: 11 Intermediate: 25 Advanced: 9	Training only: 34 Beginner: 16 Intermediate: 20 Advanced: 11	Training only: 34 Beginner: 16 Intermediate: 16 Advanced: 15	Training only: 47 Beginner: 11 Intermediate: 11 Advanced: 11
Median age in hours for performing lung ultrasound scans from birth (IQR*)	1.93 (1.4–2.4)	20.3 (17–23)	40.4 (37–45)	61 (53–67)
Median age in hours for performing lung ultrasound scans from the previous scan (IQR*)	NA	18.5 (14.5–20.1)	22.5 (16–23.7)	21.5 (15.5–23.4)
Position of the infant prior to the LUS	Supine: 65 Prone: 17	Supine: 58 Prone: 23	Supine: 60 Prone: 21	Supine: 61 Prone: 19
Chest X-ray score, N	Zero: 3 One: 43 Two: 20 Three: 15	Not available at the time of scan	Not available at the time of scan	Not available at the time of scan

*IQR; Inter-quartile range, *CPAP*; continuous positive airway pressure, *HFOV*; high frequency oscillatory ventilation

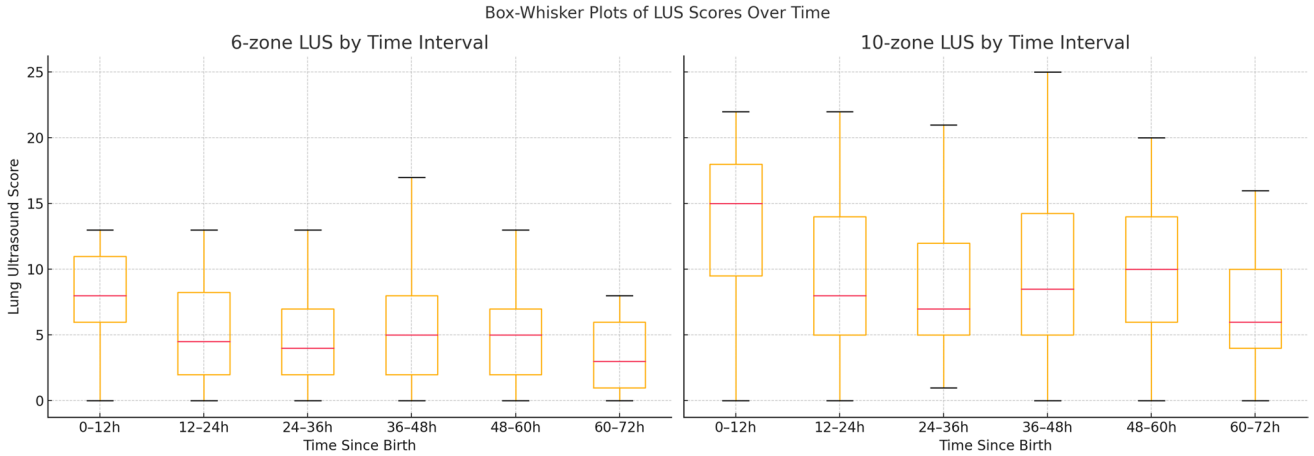

Fig. 1 Box-whisker plot for 6 and 10 zone LUS by time interval

(Table 3). With six zones LUS scores, the optimal threshold is 9, with Youden index of 0.55 and sensitivity and specificity of 79% and 75%, respectively. Figure 2 shows the receiver operator curve analysis and associated area under the curve (AUC) for 6 and 10 zones in the 1 st LUS score for "surfactant need". There was no statistically significant difference between 6 and 10 zone AUC for "surfactant need" (DeLong test, "p" value 0.24).The optimal cut-off for the 10-zone LUS scores is 16, with Youden index of 0.54 and sensitivity and specificity of 79% and 76%, respectively.

BPD

Seventeen (20%) infants had the diagnosis of BPD at 36 weeks, with 4 infants on HHHFNC and the rest on low flow oxygen. For "prediction of BPD", six zones LUS score cut-off of ≥ 9 in the first LUS provided higher sensitivity and specificity as compared to 10 zones in the first LUS and 4 th LUS (Table 3). The AUC for 6 and 10 zones in the 1 st LUS scores for BPD were higher than the subsequent LUS scores for BPD prediction (Fig. 2). For the first LUS, there was no statistically significant difference between 6 and 10 zone AUC for BPD prediction (DeLong test, "p" value 0.76). Details of AUC for BPD prediction for each LUS were provided in supplementary Table 2.

Sensitivity analysis

For sensitivity analysis, we used the LUS of the first and excluded all the infants who had a default prone position. We had a total of 65 infants. The cut-off score that provided the best Youden index for 6 zones was 9 (sensitivity 75.8%, specificity 78.3%, Youden index 0.49). These results were similar with our primary analysis (including babies in prone and supine) making 6-zone cut-off of 9 potentially the best all-round predictor.

Subgroup analysis for LUS predicting "surfactant need" and BPD in preterm infants ≤ 29 weeks were provided in Supplementary Table 3.

Table 3 Predictive value of 6 and 10 regions LUS for cut-off ≥ 9 for the need of surfactant and prediction of BPD

	1 st LUS for surfactant		1 st LUS for BPD		4 th LUS for BPD	
	10 zones ($n = 73$)	6 zones ($n = 74$)	10 zones ($n = 73$)	6 zones ($n = 74$)	10 zones ($n = 70$)	6 zones ($n = 70$)
LUS score cut-off ≥ 9						
Sensitivity (95% CI)	96 (82–100) %	79 (59–92) %	100 (78–100) %	73.3 (44.9–92) %	75 (43–94) %	16.7 (2–48) %
Specificity (95% CI)	28 (16–44) %	75 (60–87) %	29 (18–42.7) %	76.3 (63.4–86.4) %	65 (52–78) %	96.5 (88–99) %
PLR (95% CI)	1.36 (1.11–1.66)	3.21 (1.86–5.6)	1.41 (0.12–1.67)	3.1 (1.78–5.4)	2.17 (1.34–3.5)	4.8 (0.75–31) %
NLR (95% CI)	0.12 (0.02–0.89)	0.28 (0.14–0.59)	0.0	0.35 (0.15–0.8)	0.38 (0.14–1.03)	0.86 (0.67–1.12) %

LUS scores; lung ultrasound scores, *PLR*; positive likelihood ratio, *NLR*; negative likelihood ratio, *BPD*; bronchopulmonary dysplasia

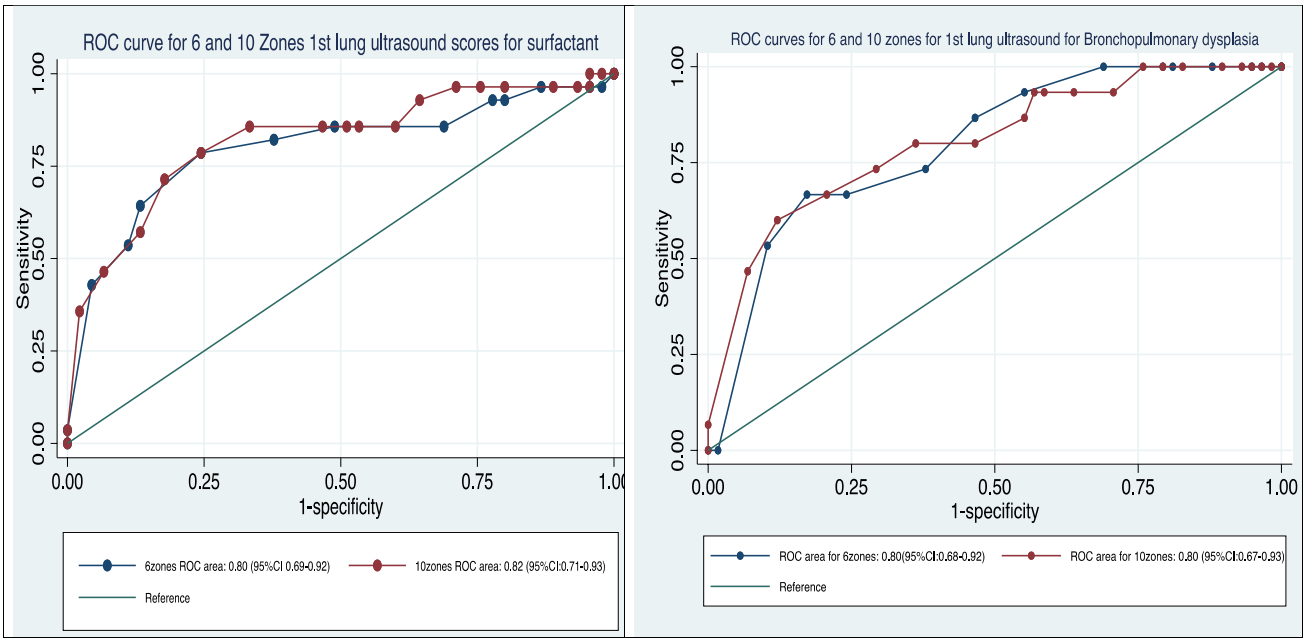

Fig. 2 ROC curves for 6 and 10 zones for 1 st lung ultrasound scores for outcomes of surfactant need and bronchopulmonary dysplasia

Correlation and agreement

Correlation between first LUS scores and chest X-ray score (10 zones: rho: 0.53; 6 zones: rho: 0.51) was better than Silverman Anderson score (10 zones: rho: 0.32; 6 zones: rho: 0.30). Correlation between first LUSS and S/F ratio was 10 zones: rho: −0.62; 6 zones: rho: −0.59, and oxygenation/modified oxygenation index was 10 zones: rho: 0.60; 6 zones: rho: 0.54. Kappa inter-rater agreement for LUS cut-off score of 9 and above for both 10 and 6 zones between the expert and other operators for all four LU was either moderate or substantial (Supplementary Table 4). All the short-term hospital outcomes were provided in Supplementary Table 5. Retrospective consents were obtained at a median (IQR) 2 (1–7) days after birth.

Discussions

Our multi-centre observational study demonstrates that LUS, performed by operators with varying expertise levels, can reliably predict the need for surfactant and progression to BPD. Similar to our study, a systematic review has been published with seven studies ($n = 697$) involving preterm infants ≤34 weeks and on non-invasive respiratory support [6]. In this review, 3 out of 7 included studies have used LUS score cut-off of >8, and other studies used variable cut-offs. Using all the LUS score cut-offs, the summary receiver operator characteristic (sROC) curve for LUS predicting the first surfactant dose showed an area under the curve (AUC) of 0.88 with a cut-off of LUS score at 8, providing specificity and sensitivity of 0.83 and 0.81, respectively [6].

We recruited more infants than our intended sample size to compensate for the data loss and also to have at least 25 babies with a birth gestational age ≤29 weeks. In our study, adding additional regions of LUS increased only the sensitivity without increasing specificity. This reinforces that a reliable diagnosis of surfactant deficiency could be made by scanning only six zones without changing the infant's position, as the RDS should be a homogenous pathology. Similar to our study, a recent study with 242 patients compared the diagnostic value of standard LUS scores versus extended LUS scores (eLUS) involving additional posterior regions [18]. There was no statistical difference between the two LUS scores, with an AUC for standard LUS scores of 0.84 and an AUC of 0.83 for eLUS scores.

We performed serial scans to predict the need for repeated doses of surfactant. However, only two infants in our study cohort received the second dose of surfactant. So, there were not enough patients to perform multiple ROC curve to predict repeated doses of surfactant.

In a previous physiological crossover study, patients underwent lung ultrasound 6 h after changing positions (from supine to prone and vice versa) [23]. The study concluded that 6 h of prone positioning improved gas exchange and lung aeration in infants recovering from respiratory distress syndrome and those with evolving BPD. In contrast, our findings differ, likely due to several key differences. First, we considered a position as the infant's default if they remained in it for at least 30 min, unlike the 6-h duration

used in the previous study. Second, we did not have data on how long each infant remained in a given position, which may have influenced outcomes. Additionally, our study included infants before they received surfactant, whereas the previous study focused on infants in the recovery phase of RDS who had already been treated with surfactant. Lastly, we did not score dependent lung regions based on position (supine vs. prone) when applying the 6-zone scoring method. The study by Louis et al. concluded that LUS scores were higher immediately after a change in position but were similar to baseline 1 h after the change in position [24].

Similar to our study, few studies have shown that LUS scores could predict BPD in preterm infants [25–27]. In a study of preterm infants < 32 weeks ($n = 190$), serial LUS were performed on days 3, 7, 14, and 21 [25]. In this study, the LUS scores cut-off on day 7 had the highest AUC of 0.78 to predict moderate-severe BPD. In another similar study, serial LUS performed on days 3, 7, and 14 showed a higher area under the receiver operating characteristic (AUROC) at > 0.90 at all the time points, with a cut-off score of > 10, providing the highest sensitivity and specificity [28]. In our study, the first LUS performed within 3 h had the highest AUROC (0.80) and a cut-off score of ≥ 9, providing the highest sensitivity and specificity for the prediction of BPD. The results of 10 zones and 6 zone LUS scores were similar for the prediction of BPD, and this was similar to the results published in the meta-analysis [29]. Our study was limited by a relatively smaller number of infants with BPD than the published studies, and we did not perform LUS after 3 days of life. Our study has shown that the prediction of BPD is possible as early as 3 h of life, which could probably help in early targeted intervention for high-risk infants (e.g. Hydrocortisone). This would need a further study with a larger cohort.

One centre had a higher rate of uninterpretable LUS video clips compared to others. This could be due to a few reasons. Centre-1 started using LUS for the first time as a part of this research as compared to the other two centres. There were more expert-level operators in the other centres as compared to centre-1, which would play a role in ongoing training and supervision. There were regular meetings with the expert to address and improve the quality of video clips, which resulted in significant improvement in the quality of scans. Inter-rater agreement in our study between the expert-blinded scorer and the operators at each unit was moderate to substantial. This is slightly lower than reported. This probably could be due to a few reasons. Operators at each unit had varying levels of experience. Operators based their score on real-time scanning with clinical pictures at the bedside, whereas the expert was blinded to clinical data. A prospective multi-centre study reported much higher Inter-rater agreement with Cohen's kappa of 0.89 to 0.93 [30]. In this study, 47% of LUS were performed by experts as compared to our study, where more than 60% of LUS were performed by operators with much less experience. While most previous studies on LUS scoring for surfactant prediction have been conducted in Europe, this is the first study to examine its application within a UK clinical setting [13]. We deliberately included data interpreted by learners to assess concordance with expert evaluations, thereby reflecting the realities of current UK-based training practices. Our objective was to evaluate the effectiveness of existing educational programs in equipping clinicians to apply LUS scoring for clinical decision-making.

A recent survey of 560 NICUs from 24 countries has shown a considerable variation in the uptake, ranging from 20 to 98% NICU [13]. In this survey, LUS use in NICU, UK was < 10% as compared to 83% uptake in Italian NICUS [13]. Similar results were shown in the UK survey 2022 that only 6% of the responders routinely used LUS in their neonatal unit [31]. One of the reasons for this could be due to limited evidence to show that the early LUS-based surfactant replacement would improve outcomes such as BPD. Currently, a European multi-centre RCT on early LUS-based surfactant treatment is ongoing to recruit more than 600 preterm infants (< 29 weeks) with BPD or death as the primary outcome [32]. Lack of training is another reason for the limited uptake of LUS. Our study has shown that research with a proper structured training programme could help in the implementation and upskilling of LUS in the NICU and could empower other staff to perform LUS.

Our study had a few strengths. A large number of LUS scans were performed by operators with varying levels of experience using a standardised protocol for lung ultrasound scanning. Through our study, many operators who had never performed LUS before the study were able to achieve a reasonable level of competency and were able to accurately diagnose more lung pathologies and perform scans in much less time. Our study also had a few limitations. We had a relatively smaller number of extremely preterm infants. Our study had 11% uninterpretable LUS scans, and this is due to the learning process by various operators.

In our study, 40% of infants received HHHFNC for respiratory distress prior to undergoing their first LUS. While HHHFNC is commonly used as a primary mode of respiratory support in cases of RDS, it is not considered the gold standard for RDS management, and its specific impact on LUS findings remains unclear. Participating units adhered to European guidelines for surfactant administration in RDS; however, it is important to note that these guidelines are based on limited evidence, and a definitive gold standard for clinically identifying surfactant deficiency has yet to be established.

LUS, apart from providing earlier target therapy, could potentially decrease the need for performing additional investigations such as X-rays and associated handling. In an

international survey, 20% of the units use LUS as a stand-alone imaging technique, and 36% use LUS as the primary diagnostic tool for neonatal lung disease [13]. Our study has shown that LUS enables clinicians to offer early targeted therapy for surfactant and provide early prediction of BPD.

Conclusions

LUS performed within 3 h of life by operators of varying levels of experience and interpreted by experts could predict the need for surfactant deficiency and BPD in preterm infants with better diagnostic value than currently used methods. Our study has demonstrated that research with a structured training programme could enable novice operators to perform LUS and achieve reasonable competency.

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Authors' contributions P K Loganathan: conceptualised and designed the study, performed data collection, planned and performed the analysis, drafted the initial manuscript, and reviewed and revised the manuscript. V. Meau-Petit conceptualised and designed the study and reviewed and revised the manuscript. Planned and delivered LU training package and supported the participating centres for training issues. Was the expert to score all scans B. Bhojnagarwala conceptualised and designed the study, performed data collection, and reviewed and revised the manuscript. Planned and delivered LU training package and supported the participating centres for training issues. V Nair conceptualised and designed the study, performed data collection, and reviewed and revised the manuscript. J Holmes: planned and performed the analysis, reviewed, and revised the manuscript. A Occhipinti: planned and performed the analysis, reviewed, and revised the manuscript. M. Montasser conceptualised and designed the study, performed data collection, and reviewed and revised the manuscript. Planned and delivered LU training package and supported the participating centres for training issues. All authors approved the final manuscript as submitted and agreed to be accountable for all aspects of the work.

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Data availability No datasets were generated or analysed during the current study.

Code availability Not Applicable.

Declarations

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Consent to participate Written informed consent was obtained from participants.

Consent for publication Yes.

Competing interests The authors declare no competing interests.

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