Comprehensive Quantitative Assessment of Lung Liquid Clearance by Lung Ultrasound Score in Neonates with No Lung Disease during the First 24 Hours

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Objectives. To comprehensively and quantitatively assess the process of lung liquid clearance using the lung ultrasound score. This study is to evaluate the whole healthy lungs of neonates during the first 24 h. Methods. Lung ultrasound was performed in neonates with no respiratory symptoms within 3 h after birth, and scans were then repeated at 6 hours and 24 hours, respectively. The entire chest wall was divided into 12 regions. The lung ultrasound scores of the anterior, posterior, upper, and lower regions and sum of all regions were calculated according to the ultrasound pattern of each region examined. Results. The total lung ultrasound score decreased gradually during the first 24 h, with the total lung ultrasound score at 6 h being significantly lower than that at <3 h (P<0.05). At <3 h, B-lines were more abundant in the posterior chest than in the anterior chest (P<0.001), and more B-lines were observed in the lower chest than in the upper chest (P<0.001). At 6 h and 24 h, there were no significant differences among the regions. Conclusion. Changes in the lung ultrasound score may quantitatively reflect the characteristics of different regions and processes of lung liquid clearance during the first 24 h.

1. Introduction

The lungs are vital and vulnerable organs in neonates; therefore, assessment of the lungs is a major concern of neonatologists [1]. Traditional tools include computed tomography (CT) and chest radiographs, which both expose neonates to potentially harmful radiation [2, 3]. Compared with these modalities, lung ultrasound (LUS) is non-irradiating and easily repeatable with no side effects and provides accurate diagnostic information in real time [4, 5]. Lung ultrasound has been increasingly used to differentiate and diagnose neonatal diseases causing respiratory symptoms as a useful bedside diagnostic tool [6–16]. However, few studies have addressed the ultrasound findings of normal lungs in neonates; in the most cases, these findings have only been described qualitatively [17, 18]. To the best of our knowledge, only one study has quantitatively monitored lung liquid clearance in healthy neonates [19], but the results may not be sufficiently comprehensive. The aim of this study was to comprehensively and quantitatively assess lung liquid clearance using the lung ultrasound score in neonates with no lung disease during the first 24 h.

After birth, the neonate gas exchange transitions from dependency on the placenta to dependency on the lungs, and the process must involve airway liquid clearance and air entry into the lungs [17, 18], which results in fluid accumulation in the alveolar interstitial space and then generates lung ultrasound vertical artifacts called B-lines [18, 20]. One animal study showed a good correlation between lung liquid evaluated using gravimetry and that evaluated using B-lines by lung ultrasound [21], and another one noted that the B-line score determined by LUS was quite valuable as a semiquantitative index [22]. In addition, B-lines have been found in both pathological and normal conditions at the

2. Methoden

2.1. Studiendesign. Es war eine prospektive Studie von Neugeborenen. Die Studie wurde von der First Affiliated Hospital of Harbin Medical University Human Research Ethics Committee genehmigt.


2.3. Statistical Analysis. Alle statistischen Analysen wurden mit SAS 9.3 international standard statistical programming software durchgeführt. Die Daten wurden durch den Median und die obere und untere Quartile sowie den Wilcoxon rank-sum test berechnet. Ein Intraclass Korrelationskoeffizient wurde verwendet, um die Interrater Reliability zu berechnen. Der statistische signifikanz wurde als P < 0.05 definiert.

3. Ergebnisse


3.2. Total Scores. Der Gesamtlung Ultra Sound Score in den ersten 24 Stunden (Tabelle 2).

3.3. Regional Scores. Auf <3 Stunden, gab es signifikante Unterschiede in der Anzahl von B-Linien zwischen den Regionen. B-Linien waren mehr in der hinteren Brust (P < 0.001; Bild 3(a)). Es gab signifikant mehr B-Linien in der unteren Brust als in der oberen Brust (P < 0.001; Bild 3(b)).

In den ersten 24 Stunden, gab es keinen signifikanten Unterschied zwischen der hinteren und vorderen Brust und zwischen der Brust und der unteren Brust (Bild 3).

3.4. Scores by Delivery Mode. Wir verglichen auch den B-Linien Score zwischen Neugeborenen, die vaginal oder durch Kaiserschnitt geboren wurden. Es gab keine signifikanten Unterschiede in der postnatalen Altersmessung, demographischen...
data, and clinical characteristics between the two groups (\(P > 0.05\)). At <3 h, there were significantly more B-lines in neonates delivered by cesarean section than in those delivered vaginally (\(P < 0.001\); Figure 4). At 6 h and 24 h, there were no significant differences in the amounts of B-lines between the two groups.

### 3.5. Interrater Consistency

There was a good correlation between the measurements of the two observers. \(r = 0.833\) at <3 h, \(r = 0.816\) at 6 h, and \(r = 0.829\) at 24 h.

### 4. Discussion

In this study, we show a comprehensive quantitative assessment of lung liquid clearance by the lung ultrasound score in neonates without lung disease during the first 24 h. Compared with another quantitative trial of healthy neonates [19], our study examined the whole lungs, including not only the anterior and lateral chest but also the posterior chest. Moreover, our results show that B-lines were more abundant in the posterior chest than in the anterior chest at <3 h. Although there were less significant differences at 6 h and 24 h, the B-line scores of the posterior chest were still higher than those of the anterior chest. We consider that the distribution of redundant liquid may be attributed to gravity. Although our findings support the premise that the neonates had healthy lungs, whether these results apply to newborns with injured lungs remains to be studied. In fact, one study has shown that ventilation in the prone position can result in a gradient decrease in the gravity distribution of intrathoracic pressure [28], and a review has shown that the prone position can improve oxygenation in neonates undergoing mechanical ventilation compared to the supine position [29]. The results of current and previous studies suggest that the posterior chest is an important part to study in airway liquid clearance, the process of which requires comprehensive assessment.

We observed that the total lung ultrasound score, as expected, decreased gradually in neonates without lung disease during the first 24 h. These results suggest that changes in B-lines are consistent with the physiological process of airway liquid clearance, the process of which requires comprehensive assessment.

In the current study, more B-lines were observed in the lower chest than in the upper chest at <3 h. A similar observation was reported by Laura Martelius, who suggested that airway liquid clearance may occur later in the lower lobes than in the upper lobes [19]. Others have shown that in preterm rabbit pups, initiating ventilation at birth with 0 PEEP could result in the unequal distribution of air between the upper and lower lobes, with a significantly greater distribution of air toward the upper than the lower lobes at functional residual capacity [30].

We found at <3 h, there were more B-lines in neonates born by cesarean section than in those born vaginally. A similar observation was reported by Laura et al. [31], who demonstrated that vaginal delivery was associated with a significantly lower lung liquid content than cesarean section at 3 h after birth.

Our study had several limitations. First, the subjects of our study were term infants and late preterm infants, so it is
not known whether our results are applicable to other gestational ages. In fact, most early preterm infants are treated prophylactically with pulmonary surfactant after birth, which makes it impossible to objectively observe the process of airway liquid clearance. Second, although the accuracy of the results increases with the inclusion of more sectors, the analysis of more sectors is also more time consuming and not quite suitable for clinical application. Thus, we will seek a comprehensive and efficient method for assessing lung liquid clearance. Third, in this study, the examination time interval was slightly long, which may have resulted in the exact cut-off time when lung liquid clearance is achieved being missed. In future studies, we will increase the examination frequency appropriately.

5. Conclusion

This was a comprehensive study using a 12-sector LUS approach, to evaluate the airway liquid clearance of neonates. Our results indicate that the lung ultrasound score may be used to comprehensively and quantitatively characterize different lung regions and the process of lung liquid clearance of neonates in the first 24 h after birth. Our study also creates a quantitative comparison for future studies of predicting lung diseases such as neonatal respiratory distress syndrome and transient tachypnea of newborn. Lung ultrasound is a valuable tool for use in neonates.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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