**ORIGINAL RESEARCH ARTICLE**

# Diagnostic significance of pulmonary ultrasound in neonatal respiratory distress syndrome and its correlation with the severity of the disease

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## Abstract

This study explored the diagnostic significance of lung ultrasound scan in neonatal respiratory distress syndrome. Sixty children with neonatal respiratory distress syndrome admitted in the Harbin Red Cross Central Hospital from January 2022 to January 2023 were included, and all neonatal respiratory distress syndrome children completed lung ultrasound examination within 24 h after admission. Relative to healthy newborns, children with neonatal respiratory distress syndrome had higher detection rate of lung consolidation, air bronchogram, aberrant pleural line, disappearance of A line, white lung along with pleural effusion. The detection rates of the above signs were higher in severe children than mild and moderate children. Relative to healthy newborns, neonatal respiratory distress syndrome children presented higher lung ultrasound score, higher arterial carbon dioxide partial pressure values and lower partial pressure of arterial oxygen values. Relative to mild to moderate neonatal children, the above indexes changed more significantly in severe children. The area under curve of lung ultrasound score for diagnosing neonatal respiratory distress syndrome, mild and moderate and severe was 0.8, 0.9, and 0.9, respectively. We conclude that lung ultrasound has a good diagnostic value for neonatal respiratory distress syndrome and the severity of disease. *(Afr J Reprod Health 2025; 29 [5s]: 65-73).*

**Keywords:** Neonatal respiratory distress syndrome; lung ultrasound; diagnostic value; severity; blood gas indexes

## Résumé

Cette étude a exploré l'importance diagnostique de l'échographie pulmonaire dans le syndrome de détresse respiratoire néonatal. Soixante enfants atteints de ce syndrome, admis à l'hôpital central de la Croix-Rouge de Harbin entre janvier 2022 et janvier 2023, ont été inclus. Tous ont subi une échographie pulmonaire dans les 24 heures suivant leur admission. Comparativement aux nouveau-nés en bonne santé, les enfants atteints de ce syndrome présentaient un taux de détection plus élevé de consolidation pulmonaire, de bronchogramme aérien, d'anomalie de la ligne pleurale, de disparition de la ligne A, de poumon blanc et d'épanchement pleural. Les taux de détection de ces signes étaient plus élevés chez les enfants atteints d'une forme grave que chez les enfants atteints d'une forme légère ou modérée. Comparativement aux nouveau-nés en bonne santé, les enfants atteints de ce syndrome présentaient un score d'échographie pulmonaire plus élevé, des valeurs de pression partielle de dioxyde de carbone artérielle plus élevées et des valeurs de pression partielle d'oxygène artérielle plus faibles. Comparativement aux nouveau-nés en bonne santé, les indices ci-dessus variaient plus significativement chez les enfants atteints d'une forme grave. L'aire sous la courbe du score d'échographie pulmonaire pour le diagnostic du syndrome de détresse respiratoire néonatal (SDR) léger, modéré et sévère était respectivement de 0,8, 0,9 et 0,9. Nous concluons que l'échographie pulmonaire a une bonne valeur diagnostique pour le SDR et la gravité de la maladie. *(Afr J Reprod Health 2025; 29 [5s]: 65-73).*

**Mots-clés**: SDR, échographie pulmonaire, valeur diagnostique, gravité, indices des gaz du sang

## Introduction

Neonatal respiratory distress syndrome (NRDS) which is triggered by a deficiency of surfactants in the lungs, mostly occurs in newborns 4-12 h after birth[1]. It is one of the most frequent causes of neonatal pneumothorax, pulmonary hemorrhage along with persistent pulmonary hypertension.[2] The occurrence of this series of complications increases the case fatality rate of NRDS, even as high as

43.6%.[3] The 2019 European NRDS Guidelines indicate that the occurrence of NRDS in newborns delivered at 28 weeks of pregnancy is up to 80%, and that it seriously harms the health of children.[4] Hence, timely and accurately diagnosis of NRDS is essential to promote the health of the newborn infant.

The diagnosis and curative effects of NRDS in clinical work mainly rely on chest X-ray examination.[5] Chest X-ray examination has high reliability in diagnosing NRDS, and it has more characteristic manifestations shortly after birth, including significant reduction in the opacity of both lungs, ground-glass changes and air bronchogram.[6] However, due to the limitations of environmental site and neonatal position, X-ray examination is difficult to carry out near the bed in time. In addition, seriously ill children are at great risk of exposure to radiation.[7]

In recent years, in response to people's concern about chest X-ray radiation injury, people began to pay attention to the exploration and application of lung ultrasound (LUS), and tried to replace chest X-ray as the main examination means to diagnose lung diseases.[8] LUS has been extensively utilized in diagnosing pulmonary diseases including atelectasis, bronchopulmonary dysplasia, pulmonary edema, acute respiratory distress syndrome and acute lung injury, pneumothorax, and infectious pneumonia.[9-11] Ultrasound has the advantages of maturity, safety, non-invasiveness, repeatable examination, limited environmental site restrictions, and less requirement to carry children. As such LUS technology is being gradually accepted and recognized by neonatologists and sonographers.[12] Due to its high accuracy and reliability, in some advanced neonatal intensive care unit (NICU) wards, LUS has replaced chest X-ray as the main imaging diagnostic means for lung diseases.[13]

In addition, in clinical diagnosis and treatment, blood gas score and neonatal respiratory distress score are used to assess the severity of NRDS, while LUS can better reflect pulmonary ventilation, and LUS score can be adopted to quantify pulmonary ventilation, which has been extensively reported in adults.[14, 15] This study was designed to evaluate the diagnostic significance of LUS in NRDS and to determine its correlation with LUS score and NRDS's severity.

# Methods

Sixty children with NRDS accepted therapy in the Department of Pediatrics of the Harbin Red Cross Central Hospital from January 2022 to January 2023 were chosen to be the study group. The inclusion criteria were: (1) diagnosis of NRDS in line with the diagnostic criteria in the Montreux Criteria for Neonatal acute Respiratory Distress Syndrome (2017 edition);[16] (2) LUS examination was completed within 24 h after admission; (3) All were single births.

The exclusion criteria were: (1) children who had received pulmonary surfactant treatment before LUS examination; (2) those with severe inflammatory diseases such as sepsis; (3) children with congenital developmental abnormalities such as congenital lung dysplasia.

Sixty healthy newborns born in the hospital during the same period were chosen as the control group. All families of newborns signed informed consent.

## *Method of LUS examination*

The Mindray M9 portable ultrasonic diagnostic instrument was used for LUS examination with the linear array probe frequency of 5 ~ 20 Hz. The newborn was in the supine position. The ultrasound examination was performed by two ultrasound doctors with over 15 years of work experience. The films were read independently. The bilateral lungs were separated into anterior and lateral areas by the parasternal, anterior axillary and posterior axillary lines, and then into upper and lower regions by the nipple line, with together 12 regions. The scanning was implemented starting from the second intercostal space, from top to bottom and from inside to outside. The scanning sequence was first conducted perpendicular to the intercostal space, and then parallel to the intercostal space. The detection rates of lung consolidation, air bronchogram, abnormal pleural line, disappearance of A line, white lung as well as pleural effusion were analyzed. The LUS score was calculated, and

the two physicians reached an agreement on the score after discussion.

### *LUS score*

The criterion of LUS score was as follows: 0 point: lung ventilation was normal, lung volume was normal, line A or < 2 isolated line B were clearly shown, lung slip could be seen; 1 point: pulmonary ventilation was moderately reduced and pulmonary interstitial syndrome could appear. Multiple isolated B-lines were found on ultrasound imaging, and focal pulmonary edema appeared. Subpleural consolidation was found when the B-line was fused during vertical scanning < 50% of the intercostal space. 2 points: lung ventilation and lung gas content were largely reduced, edema in the lungs could be found, and multiple groups of mutually fused B-line were detected; 3 points: lung consolidation, the lungs showed hepatoid changes, may or may not be accompanied by air bronchial sign. The LUS consisted of 12 regions, each with a score of 0-3 points, and the total score ranged from 0 to 36 points.

### *Neonatal respiratory distress score*

The neonatal respiratory distress score was based on the respiratory rate, oxygen concentration, three concave signs during inhalation, moaning manifestations, gestational age, etc. The score range of each item was 0 points, 1 point along with 2 points, with a total score of 12 points, among which < 5 was classified as mild respiratory distress, 5-8 as moderate respiratory distress, and > 8 as severe respiratory distress.

### *Detection of blood gas parameters*

1.5 ml of neonatal arterial blood was gathered from children, and the partial pressure of arterial oxygen ($PaO_2$) together with arterial carbon dioxide partial pressure ($PaCO_2$) was measured by BG-800A blood gas analyzer.

### *Observed indicators*

(1) General data including newborn sex, gestational age, birth weight, as well as delivery mode were compared in 2 groups.
(2) LUS characteristics including lung consolidation, air bronchogram, abnormal pleural line, disappearance of A line, white lung as well as pleural effusion were compared between 2 groups.
(3) The LUS score along with blood gas parameters were compared in 2 groups.
(4) Utilizing Pearson linear correlation analysis, the correlation between LUS score and $PaO_2$ and $PaCO_2$ in children with NRDS was analyzed.
(5) Utilizing receiver operator characteristic (ROC) curve, the clinical value of LUS score in diagnosing of NRDS along with the severity of the disease was analyzed.

### *Statistical analysis*

SPSS 24.0 statistical software was adopted for data analysis. Measurement data exhibited as (x±s) were compared using t-test. Count data exhibited as [n (%)] were compared using $\chi^2$ test. Utilizing Pearson linear correlation analysis, the correlation between LUS score and $PaO_2$ and $PaCO_2$ in children with NRDS was analyzed. Utilizing ROC curve, the clinical value of LUS score in diagnosing NRDS as well as the severity of the disease was analyzed. $P<0.05$ meant the difference was significance.

### *Ethical clearance*

This study was consistent with the ethical standards of the 1964 Declaration of Helsinki and its later amendments, and was approved by the Ethics Committee of Harbin Red Cross Central Hospital, and the Ethics approval number was Harbin Center Hospital Ethics 2022 [018].

## Results

### *General data of children in 2 groups*

As Table 1 displayed, no difference was observed in sex, gestational age, birth weight and delivery mode between the two groups ($P>0.05$), implying comparability.

### *LUS characteristics in 2 groups*

As shown in Table 2-1 and Table 2-2, relative to the control group, the study group exhibited higher detection rates of lung consolidation, air

**Table 1:** General data of children in 2 groups

| Items | Control group (n=60) | Study group (n=60) | $t/\chi^2$ | P |
|---|---|---|---|---|
| **Sex (male/female)** | 32/28 | 33/27 | 0.0 | 0.6 |
| **Gestational age (weeks)** | 34.2±1.8 | 34.4±1.8 | 0.4 | 0.7 |
| **Birth weight (g)** | 2205.8±188.3 | 2210.6±182.7 | 0.1 | 0.9 |
| **Delivery mode (vaginal delivery/ cesarean section)** | 21/39 | 23/37 | 0.1 | 0.7 |

**Table 2-1:** LUS characteristics in 2 groups

| Groups | N | Lung consolidation | | Air bronchogram | | Abnormal pleural line | |
|---|---|---|---|---|---|---|---|
| | | Yes | No | Yes | No | Yes | No |
| **Study group** | 60 | 31 (51.7) | 29 (48.3) | 21 (35.0) | 39 (65.0) | 39 (65.0) | 21 (35.0) |
| **Control group** | 60 | 0 (0.0) | 60 (100.0) | 6 (10.0) | 54 (90.0) | 4 (6.7) | 56 (93.3) |
| $\chi^2$ | | 41.8 | | 10.8 | | 44.4 | |
| **P** | | <0.001 | | 0.0 | | <0.001 | |

**Table 2-2:** LUS characteristics in 2 groups

| Groups | N | Disappearance of A line | | White lung | | Pleural effusion | |
|---|---|---|---|---|---|---|---|
| | | Yes | No | Yes | No | Yes | No |
| **Study group** | 60 | 34 (56.7) | 26 (43.3) | 15 (25.0) | 45 (75.0) | 20 (33.3) | 40 (66.7) |
| **Control group** | 60 | 5 (8.3) | 55 (91.7) | 0 (0.0) | 60 (100.0) | 1 (1.7) | 59 (98.3) |
| $\chi^2$ | | 32.0 | | 17.1 | | 20.8 | |
| **P** | | <0.001 | | <0.001 | | <0.001 | |

**Table 3-1:** LUS characteristics in children with different severity of NRDS

| Groups | N | Lung consolidation | | Air bronchogram | | Abnormal pleural line | |
|---|---|---|---|---|---|---|---|
| | | Yes | No | Yes | No | Yes | No |
| **Mild to moderate group** | 40 | 16 (40.0) | 24 (60.0) | 7 (17.5) | 33 (82.5) | 22 (55.0) | 18 (45.0) |
| **Severe group** | 20 | 15 (75.0) | 5 (25.0) | 14 (70.0) | 6 (30.0) | 17 (85.0) | 3 (15.0) |
| $\chi^2$ | | 6.5 | | 16.2 | | 5.3 | |
| **P** | | 0.0 | | <0.001 | | 0.0 | |

**Table 3-2:** LUS characteristics in children with different severity of NRDS

| Groups | N | Disappearance of A line | | White lung | | Pleural effusion | |
|---|---|---|---|---|---|---|---|
| | | Yes | No | Yes | No | Yes | No |
| **Mild to moderate group** | 40 | 17 (42.5) | 23 (57.5) | 3 (7.5) | 37 (92.5) | 2 (5.0) | 38 (95.0) |
| **Severe group** | 20 | 17 (85.0) | 3 (15.0) | 12 (60.0) | 8 (40.0) | 18 (90.0) | 2 (10.0) |
| $\chi^2$ | | 9.8 | | 19.6 | | 43.4 | |
| **P** | | 0.0 | | <0.001 | | <0.001 | |

bronchogram, abnormal pleural line, disappearance of A line, white lung as well as pleural effusion (P<0.05).

### *LUS score and blood gas parameters in 2 groups*

Relative to the control group, the study group presented higher LUS score and $PaCO_2$ value, as well as lower $PaO_2$ value (P<0.01, Figure 1).

### *LUS characteristics in children with different severity of NRDS*

According to neonatal respiratory distress scoring method, 60 children in NRDS group were separated into mild to moderate group (40 cases) and severe group (20 cases). As Table 3-1 and Table 3-2 displayed, relative to mild to moderate group, the detection percentages of lung consolidation, air

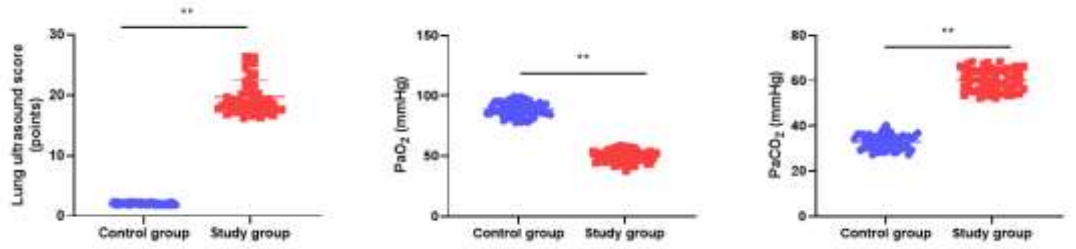


**Figure 1:** LUS score and blood gas parameters in 2 groups. **P<001

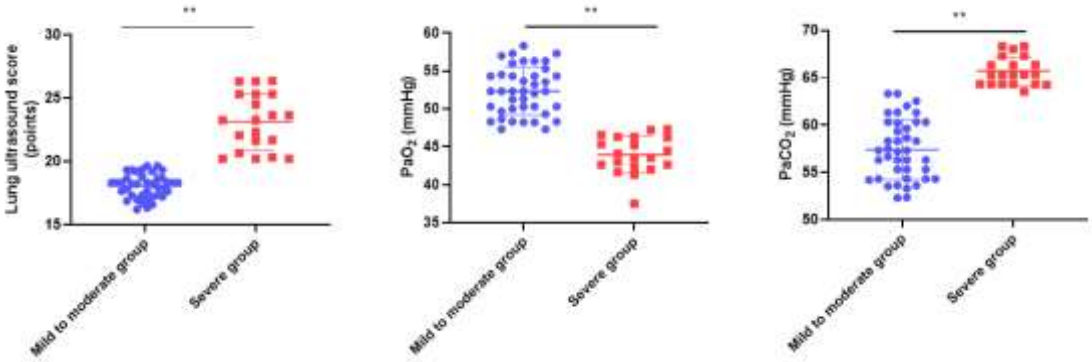


**Figure 2:** LUS score and blood gas parameters in different severity of NRDS. **P<001

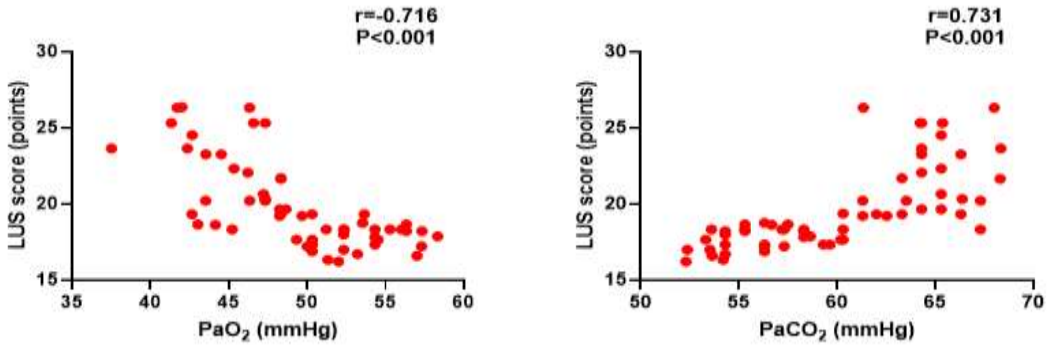


**Figure 3:** Correlation of LUS score with $PaO_2$ and $PaCO_2$ in NRDS

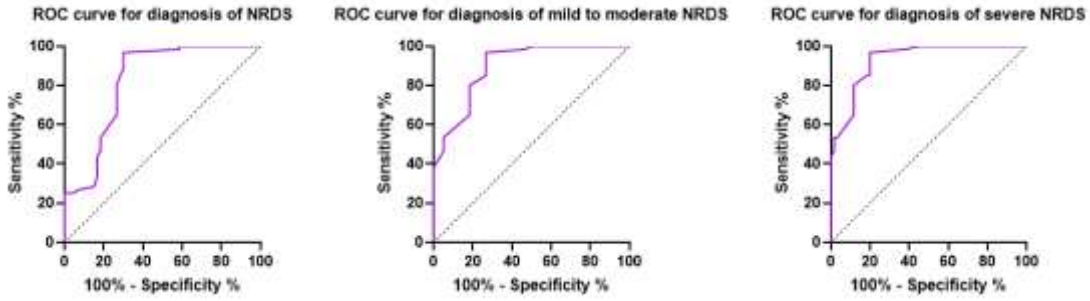


**Figure 4:** Clinical value of LUS score in diagnosing NRDS along with severity of disease

bronchogram, abnormal pleural line, disappearance of A line, white lung as well as pleural effusion in severe group was higher (P<0.05).

### *LUS score and blood gas parameters in different severity of NRDS*

Compared with the mild to moderate group, the severe group had higher LUS score and $PaCO_2$ value, as well as lower $PaO_2$ value (P<0.01, Figure 2).

### *Correlation of LUS score with $PaO_2$ and $PaCO_2$ in NRDS*

As Figure 3 displayed, LUS score was negatively correlated to $PaO_2$ and had positive correlation with $PaCO_2$ in children with NRDS (P<0.001).

### *Clinical value of LUS score in diagnosing NRDS and severity of disease*

As Figure 4 revealed, the area under curve (AUC) for diagnosing NRDS by LUS score was 0.822, and the 95% CI was 0.745-0.900. The AUC for diagnosing mild and moderate NRDS by LUS score was 0.896, and the 95% CI was 0.842-0.950. The AUC for diagnosing severe NRDS by LUS score was 0.929, and the 95% CI was 0.886-0.972. All these findings implied that LUS score possessed high clinical value in diagnosing NRDS along with severity of disease.

## Discussion

NRDS mostly happen in the hours after birth with progressive dyspnea, cyanosis along with respiratory failure in a few hours following birth, which is regarded as one of the most common causes of neonatal deaths.[17] With increasing rates of cesarean section, the occurrence of NRDS is increasing, which not only harms children's lives, but also causes a heavy economic pressure to families and the society.[18] Therefore, early diagnosis of NRDS and assessment of the disease severity are of great importance.[19]

At present, the main imaging technology for diagnosing NRDS is X-ray examination, which is diagnosed by observing uniform ground-glass changes or "white lungs" without double lungs.[20] However, its specificity is poor, and the morphological distribution of lung lesions is difficult to diagnose.[21] Additionally, X-ray has radiation, which may influence children's growth and development. Consequently, exploring a safe, fast, as well as dynamic diagnosis method has emerged to be the focal point of medical scholars.[22]

With the advancement of ultrasonic diagnosis technology, LUS exhibits a high application value in diagnosing lung diseases.[23] Simultaneously, due to the small lung capacity together with thin chest wall of the newborn, the visualization of LUS is relatively simple, which has definite strengths in diagnosing neonatal diseases.[24]

In this paper, we discovered that relative to control group, the detection rates of lung consolidation, air bronchogram, aberrant pleural line, disappearance of A line, white lung as well as pleural effusion in study group were higher in the group diagnosed with ultrasound. The detection rate of the above signs in severe children was higher than that in mild to moderate NRDS. These data suggest that LUS is useful in diagnosing NRDS and assessing its severity. The A-line usually appears in gas-filled lung tissue, and when the ultrasound penetrates further and forms A strong reflection at the pleural and lung interface, a series of artifacts parallel to the pleural line appear at equal distances.[25] The disappearance of line A indicates the absence of a large gas interface under the parietal pleura, indicating a lack of gas in the chest cavity that should be inflated, a sign of abnormal lung function.[26] Consistent with our findings, Wu *et al.* also believe that LUS is a valuable diagnostic method and that it can exert a crucial function in the diagnosis along with follow-up monitoring of NRDS.[27]

LUS score can be used to assess lung lesions' severity through the change of lung water content, and has emerged as a quantitative indicator for assessing the severity of lung lesions.[28] Many scholars believe that the severity of NRDS in children can be evaluated by LUS score.[26] Furthermore, the most important pathological mechanism of NRDS is the deficiency of alveolar surfactant, which has the effect of reducing alveolar surface tension.[29] In children with NRDS, the

production of alveolar surfactant is lost, resulting in changes in the physiological structure of the alveolar, which is prone to collapse, resulting in hypoxia and carbon dioxide retention.[30] In this state, the anaerobic ergolysis of pulmonary blood vessels increases, resulting in the increase of $PaCO_2$ and the decrease of $PaO_2$.[31]

The results of this study indicate that relative to the control group, the study group had higher LUS scores, $PaCO_2$ values, and lower $PaO_2$ value. Relative to mild to moderate NRDS, the changes in the above markers were more obvious in children with severe NRDS. Additionally, our paper suggested that LUS score was negatively correlated with $PaO_2$ and had positive correlation with $PaCO_2$ in NRDS children. The above results imply that the combination of LUS score and blood gas indices would be better at predicting NRDS in babies, which is consistent with a study proposed by Huang *et al.*[32]

Studies have reported that LUS score can predict the severity of NRDS in children, and possesses high clinical value in assessing NRDS.[33] The reason may be that the alveolar changes in children with severe NRDS were relatively obvious, and the alveolar damage and atrophy were higher, so the ultrasound findings were more prominent.[34] Our study demonstrate that LUS score possessed high clinical value in diagnosing NRDS along with the severity of NRDS, which is similar to a previous report.[35]

## Strengths and limitations

The main strength of our study was that we used LUS to quantitatively evaluate the changes of NRDS, which has certain value in differentiating NRDS and has the advantages of non-radiation, rapid, and real-time dynamic observation. There are also shortcomings in this study. The number of included cases is small, and the test results may be biased, so it is indispensable to increase the sample size for further exploration.

## Conclusion

LUS has a good diagnostic value for NRDS and the severity of disease, and is worthy of being widely used in clinic.

## Competing interests

The authors report no actual or potential conflicts of interest.

## Authors contribution

Shen QX and Zhao X: conceived and designed the study. Wei XD and Su H: collected and analysed the data. Xiang D and Guo BB: prepared the manuscript. All authors mentioned in the article approved the manuscript.

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