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Research Article

Medical Image Enhancement Algorithm for B-Mode Ultrasound Image Analysis of Neonatal Respiratory Distress Syndrome

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The aim of this paper was to explore the imaging characteristics of lung B-ultrasound images under image enhancement algorithm for neonatal respiratory distress syndrome (NRDS) and the therapeutic effect of vitamin A (VA) on NDRS. 30 newborn babies with NRDS in hospital were selected as the experimental group and 30 healthy newborn babies were selected as the control group. All of them received the lung B-ultrasound based on the image enhancement algorithm under the partial differential equation (PDE). The subjects of the control group were given formula milk every day. On the basis of formula milk, the subjects of the experimental group took VA soft capsule orally once a day at noon. Oxidative stress indexes, blood gas indexes, and mechanical ventilation parameters were recorded in the subjects of the two groups. The results of 30 newborn babies with NRDS in the experimental group indicated that the images of 12 cases presented the disappearance of line A and dense or discontinuous distribution of line B; the abnormal pleural line was found in the images of 8 cases; there was lung consolidation under the pleural line, patchy hypoecho, and point-strip hyperecho in the images of 5 cases; the images of 2 cases showed alveolar edema and alveolar interstitial syndrome. Compared with before treatment, the arterial partial pressure of oxygen (PaO_2) of subjects in the experimental group (87.61 ± 5.79) increased dramatically, but their arterial partial pressure of carbon dioxide ($PaCO_2$) decreased sharply after treatment (40.07 ± 6.12), with statistically huge differences ($P < 0.05$). The respiratory rate (RR) and positive end expiratory pressure (PEEP) after treatment were greatly less than those before treatment of subjects in the experimental group ($P < 0.05$), and the difference was statistically obvious ($P < 0.05$). By comparing with before treatment, malondialdehyde (MDA) of subjects in the experimental group decreased after treatment while superoxide dismutase (SOD) and glutathione peroxidase (GSH-Px) increased considerably, with statistically marked differences ($P < 0.05$). In conclusion, lung B-ultrasound based on partial image enhancement algorithm could clearly display the imaging characteristics of NRDS, such as pleural abnormalities and alveolar stroma. Besides, VA could effectively improve the neonatal shortness of breath, which had a good clinical effect.

1. Introduction

Caused by a lack of pulmonary surfactant (PS), NRDS is the most common neonatal respiratory system disease and one of the important reasons for the neonatal premature death [1]. In recent years, ultrasonic diagnosis has been more and more widely applied in lung diseases [2]. Lung field is a consistent, uniform, and transparent area of two lungs filled with gas on chest radiograph. Under normal conditions, the transparency of lung fields on both sides is basically the same, and its transparency is directly proportional to the amount of gas contained in the lungs [3]. Therefore, the early diagnosis and treatment of NRDS can effectively reduce the neonatal mortality, and the diagnosis of NRDS relies on ultrasonic imaging findings and clinical manifestations [4].

The image enhancement algorithm can not only improve the contrast sharpness of the overall and local ultrasound images but also highlight the details of the images. The imaging characteristics of the lung ultrasound images are more prominent on this basis [5]. PDE is a kind of differential equation. When multiple partial derivatives occur in the differential equation, this kind of differential equation is called PDE. The image enhancement algorithm was applied in this study based on PDE. VA is a kind of unsaturated monoalcohol with a lipid ring, which has various physiological functions such as maintaining normal secretion of bone, epithelial tissue, vision, and mucosal epithelium [6]. Besides, it can promote the lung development by alveolarization and facilitate the synthesis of PSs, mainly acting on the synthesis of lung surfactant protein (SP) [7]. VA can be transformed into retinoic acid (RA) in cells and combined with the RA receptor (RAR) of the lungs [8], so as to improve the transcription and expression of SP-B gene to enhance the synthesis of PS. Studies have shown that clinical administration of VA can improve NRDS in recent years and VA also has a critical effect in the treatment of pneumonia [9].

The newborn babies with NRDS received the ultrasonic examination in this study. The PDE image enhancement algorithm was used for the improvement of ultrasonic image definition, and the imaging characteristics were analyzed. The subjects of the experimental group were treated with VA and the therapeutic effect was analyzed.

2. Materials and Methods

2.1. Research Objects. The newborn babies with NRDS were selected to receive the lung ultrasound diagnosis and were admitted in hospital from October 2015 to August 2020. Finally, 30 of those met the diagnostic criteria. Another 30 healthy newborn babies were selected as the control group. This experiment had been approved by the Medical Ethics Committee of the hospital. The family members of the newborn babies had known about this experiment and signed the informed consent.

The criteria for inclusion were defined to include subjects who suffered from clinical manifestations and pulmonary ultrasound diagnosis consistent with NRDS symptoms, had gestational age of 26–40 weeks, were 1200–4200 g at birth, were from 3 to 15-day old, and did not suffer from other respiratory diseases.

The criteria for exclusion were defined to include subjects who had other respiratory diseases, were malformed from birth, and received PS treatment.

2.2. Observation Indexes of Clinical Therapeutic Effect. The clinical manifestations of respiratory distress syndrome were as follows. The newborn babies suffered from respiratory distress, respiratory sound, hypoxemia, and nasal alar agitation after the birth of half an hour. The symptoms gradually became more severe over time with the clinical manifestations of respiratory distress. The blood gas indexes should be recorded before and after treatment, including PaO_2, $PaCO_2$, and Pondus Hydrogenii (PH) value. Moreover, the mechanical ventilation parameters were recorded before and after treatment, such as RR and PEEP. The oxidative stress indexes before and after treatment were collected, including MDA, SOD, and GSH-Px.

2.3. Partial Differential Equation Image Enhancement Algorithm. The digital images of PDE could be regarded as pixel coordinates, as independent variables of binary function $f(a, b)$. The partial derivative at pixel was defined as follows:

$$F_x = \frac{\partial f(a,b)}{\partial f(a)} = f(a+1,b) - f(a,b), \tag{1}$$

$$F_y = \frac{\partial f(a,b)}{\partial f(b)} = f(a,b+1) - f(a,b). \tag{2}$$

In equations (1) and (2), x and y referred to the vertical and horizontal coordinate, respectively. $(a, b) \in \Omega$, and (a, b) represented the partial derivative in the pixel point. The gradient of point q $(q \in \Omega)$ was formed by its two sets of partial derivative, which could be expressed with the vector $V_I(p) = [F_a F_b]^T$. The set, composed of all the gradients, was employed to form a two-dimensional gradient field that was called contrast field. It could reflect the change of contrast in any range of the image. The speed of contrast change was represented by the range of gradient size, and the direction of contrast change was also expressed by the direction of gradient. By magnifying the contrast field, the image could be enhanced.

2.4. Research Methods and Process of Lung Ultrasound. A newborn baby was diagnosed with lung ultrasound through GE Voluson color Doppler ultrasonography with a 5.0–10.0 mHz linear array needle directly next to the ward bed. The newborn baby was placed in the supine position. The examination area contained the anterior, lateral, and posterior parts of the lung based on the anterior and posterior axillary lines, and the anterior and lateral parts of the lung were further divided into upper and lower parts. The left and right lung bottoms were under the bilateral costal margin, and a total of 10 areas were scanned and the ultrasonic images were saved. The ultrasound examination included pleural line, line A, line B, alveolar interstitial syndrome, and lung consolidation.

The parietal pleura and visceral pleura had smooth, regular, and linear hyperechoic patterns. The pleural line could be evidently found between the ribs, which were moved following respiration. Line A was located below and parallel to the pleural line with equal distance, showing a linear hyperecho. Line B was sent out from the pleura line perpendicularly and extended radially to the deep of the lungs. Alveolar interstitial syndrome meant that there were more than 3 strips of line B in the lung field. Lung consolidation could be confirmed that the ultrasound image showed the emerging of the alveolar tissue with "hepatization" pattern and air bronchogram.

Ultrasound diagnostic criteria were shown as follows. The normal lung ultrasound image indicated that pleural line was parallel to line A, they were smooth and clearly visible, and there was no line B. NRDS ultrasound diagnostic images presented pleural abnormalities, disappearance of line A, and aeration of bronchus and local lung consolidation of line B.

2.5. Collection, Detection, and Therapeutic Method of Vitamin A. Within 24 hours after birth, 1 mL of venous blood was taken from each subject, and the sample blood was placed in a heparin anticoagulant tube for numbering. The tube was sent to a biochemical instrument room in the hospital for centrifugation. The supernatant was extracted for testing. The content of VA in serum was determined by high performance liquid chromatography (HPLC). The VA deficiency was determined by the 2011 World Health Organization (WHO) recommended indicators, namely, subclinical VA deficiency and VA deficiency meant VA < 0.70 mol/L and VA < 0.35 mol/L in blood, respectively.

Among the 30 newborn babies with NRDS, VA of 13 subjects was less than 0.35 mol/L, VA of 16 subjects was from 0.36 to 0.7 mol/L, and VA of 1 subject was more than or equaled to 0.7 mol/L. On the contrary, VA of 30 healthy newborn babies was maintained at the normal level.

The therapeutic method was that each newborn baby with NRDS was given one VA capsule once a day at noon on the basis of formula milk and was observed for a week.

2.6. Statistical Methods. SPSS 21.0 statistical analysis software was used for data statistics and analysis, and the data information was expressed as the average ± standard deviation ($\overline{x} \pm s$). There was data comparison analysis on mechanical ventilation parameters (RR and PEEP), oxidative stress indexes (MDA, SOD, and GSH-Px), and the changes of PaO_2, $PaCO_2$, and PH before and after treatment. $P < 0.05$ meant the difference was statistically significant.

3. Results

3.1. Results of Lung Ultrasound Diagnosis in the Newborn Babies with NRDS. Among 30 newborn babies with NRDS, there were 9 mild cases, 14 moderate cases, and 7 severe cases based on their clinical manifestations. On the basis of lung ultrasound diagnosis, there were 3 cases of false positive. In addition, the sensitivity of lung ultrasound diagnosis was 90%.

3.2. Imaging Characteristics of Ultrasound Diagnosis. The ultrasound image of one healthy newborn baby from the control group showed smooth and clear line A in both lungs, their smooth pleural line was equidistantly parallel to line A and normal alveolar tissue (Figure 1).

Figure 2 indicated that the water content increased between the interstitial lung and alveolar tissue, line A disappeared, and the formed line B was radially perpendicular to the pleural line and extended to the deep lung field with a diffuse and dense distribution overall. In addition, the images of 8 newborn babies with NRDS were observed that the abnormal pleural line thickened and was irregular. The images of 5 newborn babies with NRDS presented a small area of hypoecho below the pleural line with a dotted strip of hyperecho inside, which was obvious characteristic lung consolidation. The images of 2 cases found that there was severe alveolar edema, severe dense distribution of line B, and alveolar interstitial syndrome.

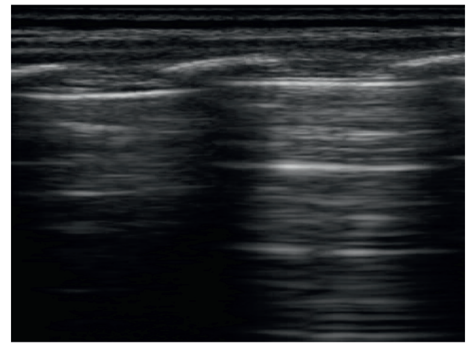

Figure 1: The lung B-ultrasound image of one subject in the control group. Note: the line A was smooth and visible.

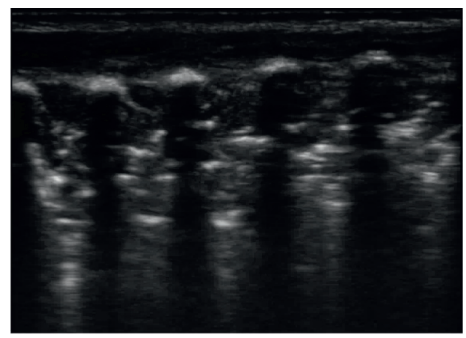

Figure 2: The lung B-ultrasound image of one subject in the experimental group. Note: the line A disappeared and the pleural line was abnormal.

3.3. Analysis of the Therapeutic Effect of Vitamin A on the Subjects with NRDS. After one week, there was significant therapeutic effect on 16 subjects with NRDS (the decreased moaning, improved shortness of breath, no cyanosis in face and limbs, and normal muscle tone in limbs). The moans of 13 subjects with NRDS were slightly reduced, breathing was slowed, and there was slight cyanosis in the mouth and nose. However, there was no obvious therapeutic effect on 1 subject with NRDS. Figure 3 revealed the comparison of blood gas indexes PaO_2 and $PaCO_2$ in subjects from the two groups. PaO_2 and $PaCO_2$ of subjects in the experimental group were very close to those of the control group after treatment, with statistically great differences ($P < 0.05$). Compared with the experimental group before treatment, PaO_2 (87.61 ± 5.79) increased obviously, but $PaCO_2$ (40.07 ± 6.12) decreased steeply after treatment, with statistically marked differences ($P < 0.05$). After treatment in the experimental group, PH of subjects in the experimental group was lower than that of the control group. Besides, PH of subjects in the experimental group after treatment was slightly increased compared to that before treatment, and the difference was statistically substantial ($P < 0.05$) (Figure 4).

3.4. Comparison of Mechanical Ventilation Parameters among the Subjects in the Two Groups before and after Treatment. Compared with the control group, RR and PEEP of subjects in the experimental group increased dramatically after

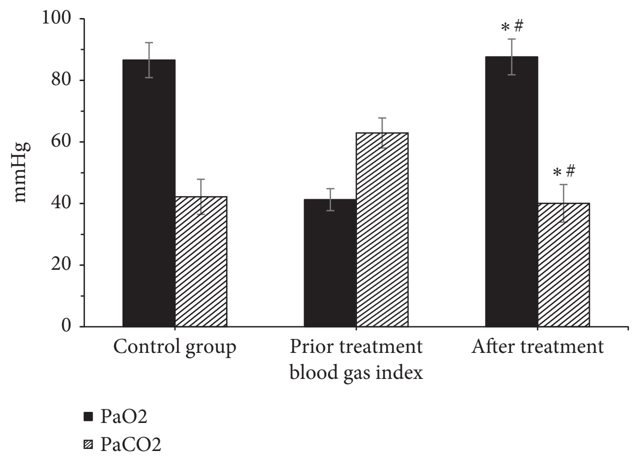

Figure 3: Comparison of blood gas indexes (PaO_2 and $PaCO_2$) in subjects from the two groups (note: * meant that $P < 0.05$ in contrast to the control group; # expressed that $P < 0.05$ compared with the experimental group before treatment).

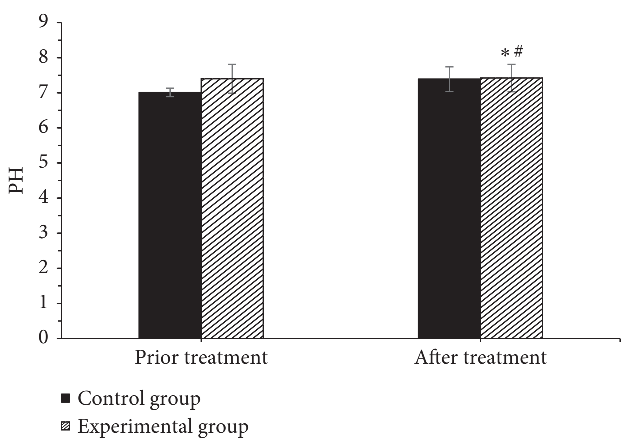

Figure 4: Comparison on PH among the subjects in the two groups (note: * revealed that $P < 0.05$ in contrast to the control group; # indicated that $P < 0.05$ compared to the experimental group before treatment).

treatment, and the difference was statistically considerable ($P < 0.05$). RR and PEEP were sharply lower than those before treatment ($P < 0.05$) (Table 1).

3.5. Comparison of Oxidative Stress Indexes before and after Treatment among the Subjects in Both Groups. Compared with the control group, MDA of subjects in the experimental group increased hugely after treatment, but SOD and GSH-PX reduced sharply, and the differences were statistically obviously ($P < 0.05$). By comparing with before treatment, MDA of subjects in the experimental group decreased obviously, while SOD and GSH-PX increased significantly after treatment, with statistically great differences ($P < 0.05$) (Figures 5–7).

4. Discussion

NRDS is one of the serious diseases that seriously endangers the life of newborn baby and is also one of the main causes of premature death. Based on previous studies, lung ultrasound has been extensively applied in the treatment of pneumonia, pulmonary edema, lung injury, and other diseases because of its advantages such as simple operation, no radiation, and bedside detection. Thus, lung ultrasound has an advantage of diagnosing NRDS over other diagnostic methods [10, 11]. PDE image enhancement algorithm was adopted in this study to amplify the correlation length of lung ultrasound images, so as to make the enhanced lung ultrasound images with high contrast (the effect is ideal) and improve the original image contrast, information entropy, and signal-to-noise ratio to a certain extent. Furthermore, it is combined with visual sense of human eye and image information entropy approach so that the effect of the enhanced image will have a good quality [12].

Recent studies have found that changes of water content in the alveolar and interstitial lung of newborn babies with NRDS can affect normal lung ultrasound imaging to form artifacts that can reflect lung lesions [13]. The normal lung ultrasound images of healthy newborn babies showed smooth and equidistant distribution of pleural line and line A in this study, and there was no line B. There was an increase on the water content in the interstitial lung and alveolar tissue, the disappearance of line A, the thickening and irregular pleural line, and the emerging of line B that was perpendicular to the pleural line and extended radially to the deep lung field in the images of newborn babies with NRDS. In addition, some severe babies suffered from lung consolidation. PS is a compound protein that exists in the junction of gas and liquid in the lungs. The supplement of PS by human is a therapeutic method for clinical treatment of NRDS, which can reduce alveolar surface tension and increase pulmonary pressure to prevent alveolar atrophy. Previous studies have shown that the main cause of NRDS is the lack of PS, leading to alveolar atrophy and hypoxia in newborn babies [14].

VA is a fat-soluble vitamin, which has various physiological functions in the human body such as maintaining bones, participating in the development of lung organs, promoting vision, and normal secretion of mucosal epithelium. Retinoic acid is derived from VA and mainly binds to receptors in the nucleus. Studies have pointed out that the binding process of retinoic acid, and its receptor plays a key role in the development of lung tissue [15]. Yadav et al. [16] pointed out that VA promoted lung development by facilitating alveolar maturation. In recent years, vitamin can be used as a fat-soluble carrier to participate in the synthesis of lung surfactant proteins, thus being used to treat NRDS. Clinical studies have suggested that the therapeutic effect of VA can reduce the mortality of premature infants and the emerging of NRDS. The recent studies showed that VA deficiency was a disease of micronutrition deficiency, and pregnant women in China suffered from the disease commonly. VA of any newborn baby is directly related to that of the mother. If preterm birth occurs, the incidence of VA deficiency is higher in the newborn babies. Therefore, VA deficiency is a high-frequency factor of NRDS [17]. The timely application of VA for treatment can effectively reduce the incidence of the disease if the disease risk of newborn babies is

Table 1: Comparison of mechanical ventilation parameters among the subjects in the control and experimental group ($\overline{x} \pm s$).

Group	n	Observation time	RR (times/min)	PEEP (cmH_2O)
Control group	30	Before treatment	46.41 ± 7.63	2.95 ± 0.65
Control group	30	After treatment	45.56 ± 6.97	2.89 ± 0.57
Experimental group	30	Before treatment	55.21 ± 7.67	4.81 ± 0.47
Experimental group	30	After treatment	47.51 ± 8.54$^{*\#}$	3.78 ± 0.72$^{*\#}$

Note. Compared with the control group, * expressed $P < 0.05$ and $^\#$ meant $P < 0.05$ in contrast to the experimental group after treatment.

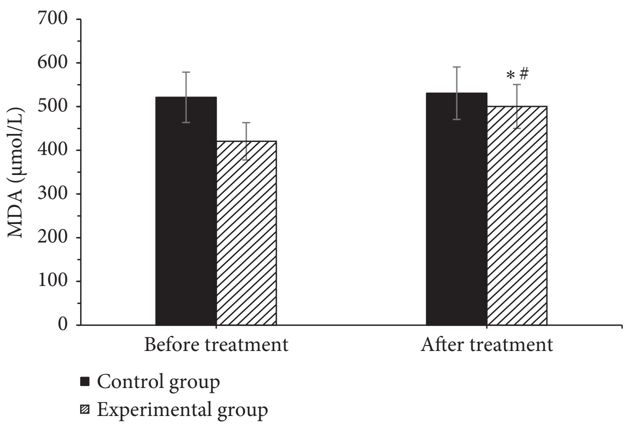

Figure 5: Comparison of MDA among the subjects from both groups (note: $^\#$ and * showed $P < 0.05$ by comparing with the experimental group before treatment and the control group, respectively).

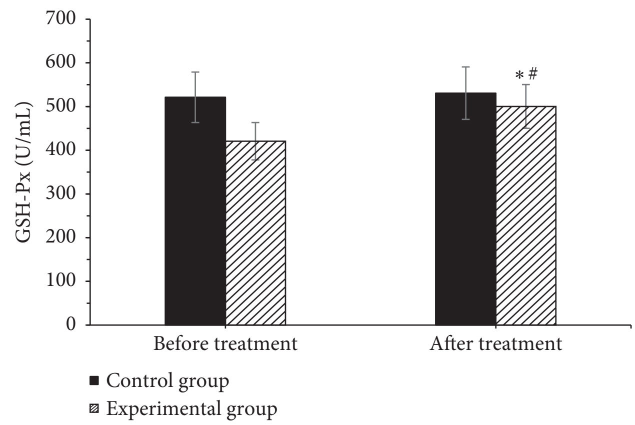

Figure 7: Comparison of GSH-Px among the subjects in the control and experimental group (note: $^\#$ and * revealed $P < 0.05$ in contrast to the experimental group after treatment and the control group, respectively).

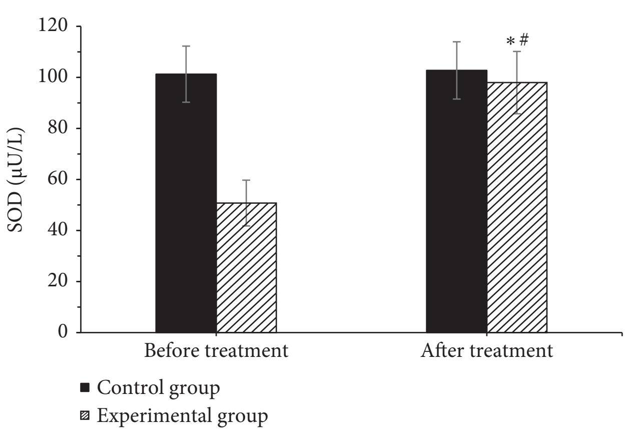

Figure 6: Comparison of SOD among the subjects from the two groups (note: $^\#$ and * showed $P < 0.05$ in contrast to the experimental group after treatment and the control group, respectively).

early detected. In this study, VA was applied to treat the NSDS, which was confirmed to have a good clinical effect.

After treatment, PaO_2 and PH of subjects increased but $PaCO_2$ decreased in the experimental group ($P < 0.05$), and RR and PEEP decreased extremely ($P < 0.05$), indicating that the low dose of VA treatment for NRDS could increase VA in blood and improve lung function. Studies have shown that VA can promote the development and maturation of alveolar tissues and reduce alveolar tension [18]. Mechanical ventilation parameters are often used as reference indexes in the clinical treatment of NRDS. MDA can reflect the degree of free radical damage in lung tissue, SOD can reduce free radical damage, and GSH-Px has a wide distribution range in the human body and can protect the cell membrane of alveolar cells to inhibit the formation of free radicals. MDA of subjects in the experimental group decreased after treatment, while SOD and GSH-Px increased markedly ($P < 0.05$), which was similar to the research results of Wimalawansa [19]. It suggested that VA treatment could reduce the oxidative stress response of NRDS, thus improving the antioxidant capacity of the lung.

It was found that VA was maintained at the normal level in healthy newborn babies, and the lung B-ultrasound images showed smooth line A and pleural line with equidistant distribution. The manifestations of newborn babies with NRDS in the images could be expressed as follows. Line A disappeared and the distribution of line B was dense or discontinuous. Pleural line was abnormal, irregular, and not smooth. There were signs of lung consolidation. In severe cases, alveolar edema emerged, which was characterized by alveolar interstitial syndrome. Newborn babies with NRDS were treated with VA and observed for a constant week. It was found that the images of newborn babies with NRDS had a lot of changes. Some with pleural line abnormal lasted for more than a week, the pleural line of some would be gradually recovered within one week. After clinical treatment, shortness of breath could be improved, their hands and feet were warm, cyanosis was alleviated, and the limbs were healthy with tension [20].

5. Conclusion

PDE image enhancement algorithm was employed to enhance the lung B-ultrasound images of subjects with NRDS so that the enhanced images had good quality. Lung B-ultrasound images were investigated to find that line A and the pleural line were distributed in parallel in the normal neonatal lungs of the control group (without line B). However, the imaging characteristics of newborn babies with NRDS were the disappearance of line A, the abnormal pleural line, and the emerging of line B extended from the pleural line. 30 healthy newborn babies were selected as the control group, and VA treatment was given to newborn babies with NRDS in the experimental group. The results showed that clinical shortness of breath and facial cyanosis of subjects in the experimental group were improved considerably after treatment, indicating that VA could improve the NSDS effectively. However, the samples from only one hospital were selected in this study and the sample size was small, which was likely to cause data deviation. Lung B-ultrasound diagnosis was mainly dependent on subjective operation, which was prone to bias in the analysis of imaging characteristics. Researchers should have extensive clinical experience to avoid the influence of irrelevant factors. To sum up, lung B-ultrasound under image enhancement algorithm had an obvious diagnostic advantage in the application of NRDS, and there was a good clinical effect of VA in the treatment of NRDS, providing reference for the diagnosis and treatment of other lung diseases.

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 no conflicts of interest.

Authors' Contributions

Weina Liu and Jing Ma contributed equally to this work.

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