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RESEARCH ARTICLE

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Ultrasound Assessment of Changes on the Lungs during Respiratory Distress Syndrome in Newborns with Low Body Weight

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ABSTRACT

Introduction: Respiratory distress syndrome (RDS) is a common pathology of premature newborns and one of the most common causes of hospitalization in intensive care units, as well as mortality among them.

Aims of Study: To study the possibilities of ultrasound imaging for respiratory distress syndrome of varying severity in premature newborns.

Patients and Methods: Lung Ultrasound was performed in 72 premature infants in whom an X-ray diagnosis of RDS was established.

Results: In accordance with the radiological data of RDS I degree diagnosed in 13 (18,1±4,5%) patients, RDS II degree – in 31 (43,0±5,8%), RDS III degree – in 19 (26,4±5,2%) and RDS IV degree – in 9 (12,5±3,9%) premature infants. The results of lung ultrasound and chest x-ray in the diagnosis of stage I and IV RDS coincided in all cases. Moreover, the correlation coefficient between them had a high degree (0.924 and 0.950, respectively). Ultrasound revealed stage II RDS in 21 out of 31 preterm infants diagnosed by radiography. By ultrasound of the lungs, stage III RDS was diagnosed in 4 more premature infants than by X-ray (23 and 19).

Conclusions:

1. The integrated use of lung ultrasound and chest X-ray significantly improves the quality of diagnosis and monitoring of lung lesions in premature infants with RDS with a significant reduction in radiation exposure to the patient.
2. Ultrasound is particularly useful for monitoring established radiographic lung pathology (eg, RDS, pneumonia) to reduce radiation exposure.

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Introduction

Respiratory distress syndrome (RDS) is a common pathology of premature newborns and one of the most frequent cause causes of mortality in them. According to the American Academy of Pediatrics, 15% of full-term and 29% of preterm newborns are hospitalized in intensive care units due to the development of RDS [1]. According to other authors, among low birth weight newborns, RDS is the cause of frequent hospitalization in neonatal intensive care units, approximately 25.0% - 63.0% [2,3]. According to the results of studies by Bulimba M et al. mortality in the perinatal period due to RDS reaches 31.3% [4]. The prevalence of RDS is particularly high in low- and middle-income countries, particularly in Southeast Asia and Africa, and these are also the countries where the most severe consequences of the disease are reported [5].

The pathogenesis of the disease is based on immaturity of lung development, in which there is no pulmonary surfactant. As the gestational age and body weight of the newborn increases, the risk of developing RDS decreases. In newborns at a gestational age of less than 28 weeks, the incidence of RDS reaches 80%, at a period of 32-34 weeks it is 15-30%, and at a period of 35-36 weeks it is less than 5% [6]. The success of treatment for RDS depends on the timeliness and accuracy of determining the nature of lung damage and the severity of this pathological process [7-10].

Respiratory distress syndrome is characterized by closure of the air sacs in their lungs of newborns due to the absence or deficiency of surfactant. Newborns with RDS have severe difficulty breathing and may appear cyanosis of the skin because of oxygen in the blood. The diagnosis of RDS is based on breathing trouble, oxygen levels in the blood, and chest x-ray results [11].

In the diagnosis of RDS, a special role is given to imaging methods, which include conventional chest radiography, computed tomography, magnetic resonance imaging and ultrasound.

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Conventional radiography is the most commonly used method among them. However, the method is accompanied by ionizing radiation and has a high rate of false positive results [12,13]. Chest CT is not a suitable method for bedside examination because it is expensive and ionizing radiation is another limitation for use in neonates. In recent years, ultrasound has become an important component of lung imaging in newborns [14,15].

Objective

To study the possibilities of ultrasound imaging for respiratory distress syndrome of varying severity in premature newborns.

Materials and Methods

A retrospective analysis of the results of lung ultrasonography was carried out in 72 preterm infants who were diagnosed with respiratory distress syndrome (RDS). Among them were 43 boys, 29 girls, with a gestational age of 25-34 weeks. The diagnosis was established based on clinical, laboratory and chest X-ray examination. The comparative group consisted of 24 preterm infants with a gestational age of up to 32 weeks with mild respiratory disorders of central origin.

Newborns were examined during the first day after birth and were subsequently observed over time [16]. Chest X-ray was performed in the intensive care unit (ICU) according to clinical indications using a Siemens Polymobil-10 X-ray machine. The radiation dose is 0.002 mZV. All patients with ultrasound examination of the lungs were performed on the same day as the X-ray examination. An ultrasound study was carried out at the patient's bed using a Logiq apparatus, GE Medical Systems, with a linear transducer with a frequency of 5-12 MHz.

The examination began with the left half of the chest, then the right half was examined. The sensor was installed strictly perpendicular to the rib spaces. In the position of the child on the back along the front wall of the chest, a scan was performed in the transverse direction from the 2nd to 5th intercostal space, and then in the longitudinal direction along the parasternal, midclavicular, anterior and middle axillary lines. In the position of the child on the side, scanning was performed in the transverse direction below the angle of the scapula and in the longitudinal direction along the para-vertebral, scapular and posterior axillary lines [17]. The gel for examination and the sensor were necessarily heated to body temperature, in order to avoid hypothermia of the child. Statistical processing was carried out using the software package Microsoft Excel and Statistica 7.0.

Results

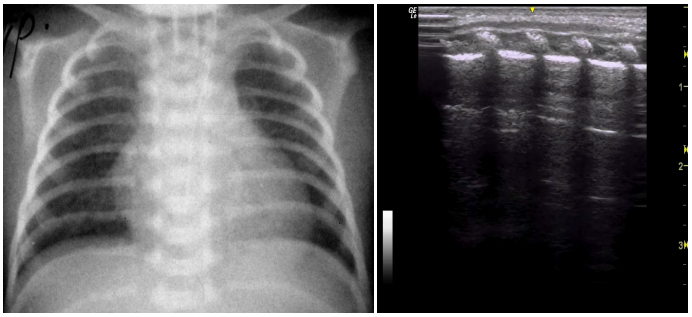
In accordance with the radiological data of RDS I degree diagnosed in 13 (18,1±4,5%) patients, RDS II degree – in 31 (43,0±5,8%), RDS III degree – in 19 (26,4±5,2%) and RDS IV degree – in 9 (12,5±3,9%) premature infants (table 1). As can be seen from Table, II degree of RDS was observed statistically significantly more often than the I (P<0.01), III (P<0.05) and IV (P<0.001) degrees, respectively. The difference between the incidence of grades III and IV RDS was also statistically significant (P<0.05).

Table 1: Distribution of premature infants with RDS, depending on the severity in accordance with x-ray data.

Number	Severity of RDS by X-ray			
	I degree	II degree	III degree	IV degree
n	13	31	19	9
%	18,1±4,5	43,0±5,8	26,4±5,2	12,5±3,9
P value		II-I <0,01 II-III<0,05 II-IV<0,001	III-IV <0,05	

We have identified several sonographic patterns of lung changes in premature newborns with respiratory distress syndrome.

1. A-lines - are horizontal lines, artifacts of the reverberation of the reflected ultrasound from the pleura during normal filling of the lung tissue with air (Figure 1);
2. B-lines - vertical linear artifacts of the "comet tail", not more than 2 in the intercostal space, when combined with gliding of the lung, can occur in a normal lung (especially a newborn baby). Multiple B-lines are a sign of interstitial syndrome (Figures 2-4).
3. "White lung" - is the appearance of a homogeneous signal from the lung tissue along the ultrasound wave, caused by homogenization of the lung tissue as a result of infiltrative changes. In fact, it represents a large number of B-lines between which normal lung tissue is not visualized (Figure 5).
4. Consolidation of lung tissue - occurs when the lung alveoli are filled with pathological elements, such as fluid, cell fragments, fibrous tissue, or another substrate (Figure 6).
5. Free fluid in the pleural cavity - is an anechogenic area delimited by the dome of the diaphragm and pleura.



A B

Figure 1: *Newborn with a gestational age of 31 weeks. A. The X-ray shows a moderate enrichment of the pulmonary pattern. B. Ultrasonographically is demonstrated a normal picture in the form of the presence of A-lines (arrows).*

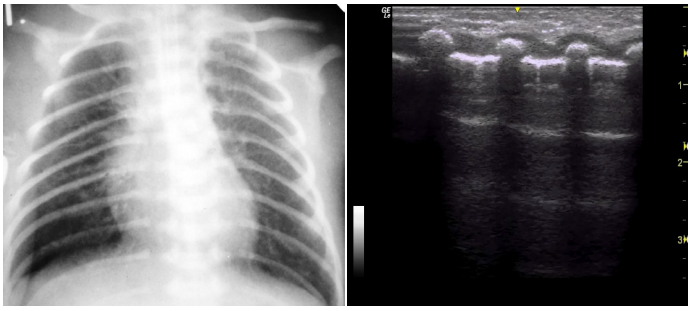


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Figure 2: Newborn, gestational age 33 weeks. Respiratory distress syndrome of I degree. A. X-ray reveals the deformation of the pulmonary pattern according to the reticular-granular type. B. An ultrasound reveals single B-lines (arrows).

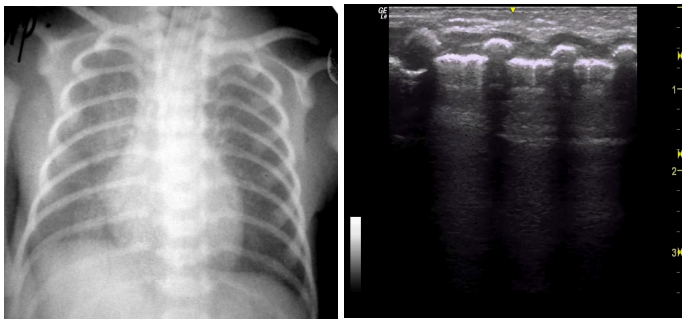

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Figure 3: Newborn, gestational age 34 weeks. Respiratory distress syndrome of II degree. A. X-ray reveals a blurred pulmonary pattern with the presence of isolated small focal shadows. B. An ultrasound reveals 2 B-lines (arrows).

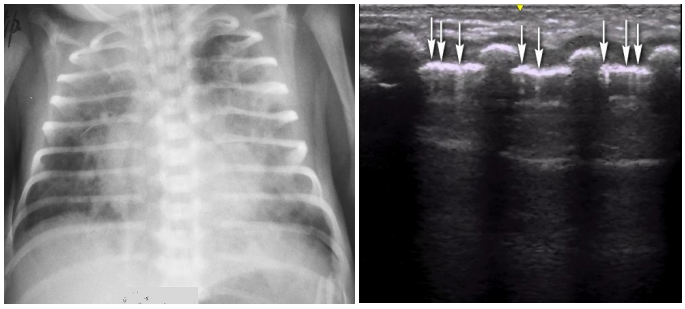

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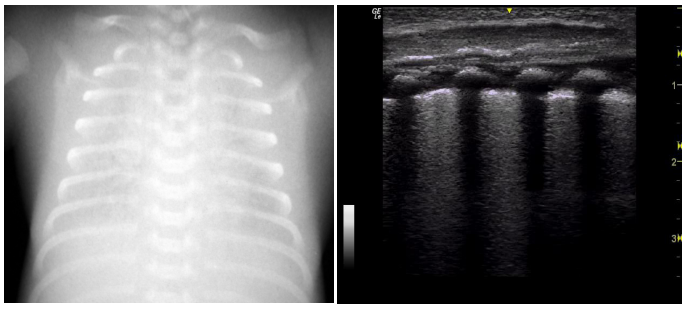
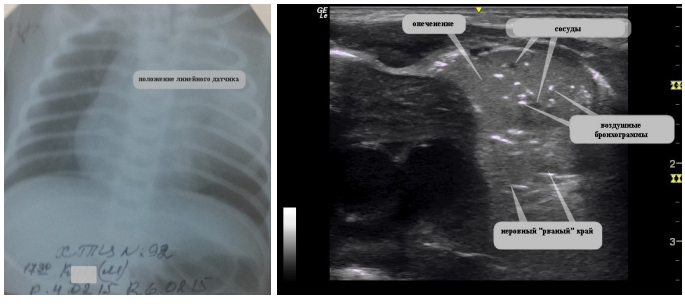
Figure 4: Newborn, gestational age 29 weeks. Respiratory distress syndrome of III degree. A. X-ray reveals an inhomogeneous decrease in the transparency of the pulmonary fields with the presence of an "air bronchogram". B. An ultrasound reveals 3 B-lines in one intercostal space.



A B

Figure 5: Newborn, gestational age 26 weeks. Respiratory distress syndrome of IV degree. A. X-ray reveals a "white lung". B. Ultrasound shows an almost complete absence of pneumatization of the lung.



A B

Figure 6: Newborn, 2nd day of life. A. The X-ray shows a homogeneous darkening of the upper lobe of the left lung. B. An ultrasound (the position of the transducer is indicated on the x-ray) is visualized consolidation of the tissue in the upper lobe of the left lung with an uneven "ragged" edge (arrow), the air bronchos and vessels are determined.

The nature of the pleural line movement during the act of breathing was necessarily assessed. In the act of breathing, the number of B - lines in the intercostal spaces varied within 1 line. In newborns with RDS among the ultrasonic patterns, B-lines and consolidation zones were significantly more often ($p<0.01$). The frequency of occurrence of B-lines in combination with consolidation zones is presented in table 2.

Table 2: The frequency of B-lines in combination with areas of consolidation at the survey level, as a sign of RDS.

Sonographic B-line patterns of RDS	Main group (n=72)	Comporative group (n=24)
0-1 B-line	13 (18,1±4,5%)	3 (12,5±6,8%)
1-2 B- lines	23 (31,9±5,5%) p<0.01	2 (8,3±5,6%)
2-3 B- lines	25 (34,7±5,6%)	0
3-4 B- lines with areas of consolidation	9 (12,5±3,9%)	0

Comparative characteristics of the distribution of premature severity of RDS syndrome according to the results of pulmonary ultrasound and conventional chest radiography are presented in table 3.

Table 3: Severity of RDS according to ultrasound of the lungs and conventional chest radiography.

Severity of RDS	Ultrasound		X-ray		Correlation (k)
	n	%	n	%	
I degree	13	18,1±4,5	13	18,1±4,5	0,924
II degree	21	29,2±5,4	31	43,0±5,8	0,612
III degree	23	31,9±5,5	19	26,4±5,2	0,634
IV degree	9	12,5±3,9	9	12,5±3,9	0,950

As can be seen from the table, the results of lung ultrasound and chest x-ray in the diagnosis of stage I and IV RDS coincided in all cases. Moreover, the correlation coefficient between them had a high degree (0.924 and 0.950, respectively). Ultrasound revealed stage II RDS in 21 out of 31 preterm infants diagnosed by radiography. By ultrasound of the lungs, stage III RDS was diagnosed in 4 more premature infants than by X-ray (23 and 19).

Discussion

Literature data indicate that pulmonary ultrasonography is non-invasive, inexpensive and can be performed repeatedly at the patient's bedside. The accuracy of the method in diagnosing respiratory distress syndrome approaches the results of radiography. This allows the use of ultrasonography as an alternative method, thereby replacing conventional chest radiography in newborns [18,19].

The normal image is relatively unchanged over all ages and is characterized by the mobility of the pleural line, the presence of A-lines and single B-lines (the "comet tail" phenomenon), which characterize the liquid-air transition. The number of B-lines in the lungs of newborns is greater than in adults [17]. Homogeneous "white" (hyperechoic) lungs with

deformation of the pleural line are an accurate diagnostic criterion for respiratory distress syndrome. The pattern of bilateral merging B-lines in the lower parts of the lung (the "white lung") and normal image in the upper parts has high sensitivity and specificity for transient tachypnea of newborns [20]. Pneumonia in the early neonatal period can be also diagnosed using ultrasound [7,9]. However, algorithms for ultrasound monitoring of RDS in premature infants are not well developed, while frequent CXR is impossible due to high radiation exposure [21].

The analysis of the results revealed good correlation results between the lung ultrasound and conventional X-ray of the thorax. It should be noted that in our study, 4 newborns with grade III and 2 newborns with grade IV RDS were subsequently diagnosed with pneumonia on days 3-5, radiologically. Characteristic ultrasonic signs of pneumonia were an increase in areas of lung consolidation.

In our studies with ultrasound examination of the lungs in newborns with RDS, the main pattern was B-lines, with severe degrees turning into a "white lung", as well as the presence of zones of consolidation in the lung. A good correlation between the results of our X-ray and ultrasound examinations of the lungs allows us to recommend ultrasound of the lungs of newborns as a method of visual monitoring of the condition of the lungs in premature infants with RDS. With an increase in severity, according to ultrasound, an chest X-ray should be performed, with a decrease, one should focus on the clinical manifestations of respiratory failure.

Conclusions

1. The integrated use of lung ultrasound and chest X-ray significantly improves the quality of diagnosis and monitoring of lung lesions in premature infants with RDS with a significant reduction in radiation exposure to the patient.
2. Ultrasound is particularly useful for monitoring established radiographic lung pathology (eg, RDS, pneumonia) to reduce radiation exposure.

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