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ORIGINAL PAPER

CLINICAL-IMAGING ASPECTS IN PREMATURE INFANTS WITH BRONCHOPULMONARY DYSPLASIA

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Abstract

Introduction. Bronchopulmonary dysplasia (BPD) is a common complication in premature infants, often linked to chronic pulmonary disease. This study aimed to assess the clinical and imaging data in premature infants diagnosed with BPD.
Materials and methods. A cohort of 105 premature infants with a history of respiratory distress syndrome requiring oxygen therapy was analyzed. The study group included 53 infants with BPD, while 52 infants without BPD formed the control group. All infants underwent clinical and paraclinical evaluations, including pulmonary imaging. The diagnosis of BPD was established based on specific criteria at the Pulmonology Clinic of the Institute of Mother and Child in Chisinau, Republic of Moldova. Statistical analysis was performed using SPSS version 20 (a p-value ≤ 0.05 being statistically significant).
Results. Neonatal factors, such as gestational age ($p<0.001$), birth weight ($p<0.0001$), and the need for invasive mechanical ventilation (IMV) ($p<0.0001$), were associated with chronic lung changes. Oxygen saturation (SaO_2) levels ($p<0.0001$) and radiological

Résumé

Aspects d'imagerie clinique chez les nourrissons prématurés atteints de dysplasie bronchopulmonaire

Introduction. La dysplasie bronchopulmonaire (DBP) est une complication fréquente chez les prématurés, souvent liée à une maladie pulmonaire chronique. Cette étude visait à évaluer les données cliniques et d'imagerie chez les prématurés diagnostiqués avec une DBP.
Matériel et méthodes. Une cohorte de 105 prématurés ayant des antécédents de syndrome de détresse respiratoire nécessitant une oxygénothérapie a été analysée. Le groupe d'étude comprenait 53 nourrissons atteints de DBP, tandis que 52 nourrissons sans DBP formaient le groupe témoin. Tous les nourrissons ont subi des évaluations cliniques et paracliniques, y compris une imagerie pulmonaire. Le diagnostic de DBP a été établi sur la base de critères spécifiques à la clinique de pneumologie de l'Institut de la mère et de l'enfant de Chisinau, Republique de Moldova. L'analyse statistique a été réalisée à l'aide de SPSS version 20 (une valeur de $p \leq 0,05$ étant statistiquement significative).

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findings, including discoidal atelectasis (p<0.0001), subsegmental atelectasis (p=0.018), pulmonary emphysema (p<0.0001), fibrosis (p<0.0001), pulmonary hypertransparency (p<0.0001), and microcystic lesions (p<0.0001), were also significant in the development of BPD.

Conclusions. Neonatal predictors, including gestational age, birth weight, FiO_2 during mechanical ventilation, and radiological changes, such as atelectasis, emphysema, fibrosis, and microcystic formations, provided significant data for confirming the diagnosis of BPD.

Keywords: bronchopulmonary dysplasia, neonatal predictors, clinical-imaging aspects.

List of abbreviations:
BPD – bronchopulmonary dysplasia
IMV – invasive mechanical ventilation
SGA – small for gestational age

Résultats. Des facteurs néonatals, tels que l'âge gestationnel (p < 0,001), le poids à la naissance (p < 0,0001) et le besoin de ventilation mécanique invasive (VMI) (p < 0,0001), étaient associés à des modifications pulmonaires chroniques. Les niveaux de saturation en oxygène (SaO_2) (p < 0,0001) et les signes radiologiques, notamment l'atélectasie discoïde (p < 0,0001), l'atélectasie sous-segmentaire (p = 0,018), l'emphysème pulmonaire (p < 0,0001), la fibrose (p < 0,0001), l'hypertransparence pulmonaire (p < 0,0001) et les formations microkystiques (p < 0,0001), étaient également significatifs dans le développement de la DBP.

Conclusions. Les facteurs prédictifs néonatals, notamment l'âge gestationnel, le poids à la naissance, la FiO_2 pendant la ventilation mécanique et les modifications radiologiques, telles que l'atélectasie, l'emphysème, la fibrose et les formations microkystiques, ont fourni des données significatives pour confirmer le diagnostic de DBP.

Mots-clés: dysplasie bronchopulmonaire, facteurs prédictifs néonatals, aspects cliniques et d'imagerie.

Introduction

A premature newborn is defined as a baby born before 37 weeks of gestation, with a birth weight below the limit specified for gestational age[1]. One of the most common complications in neonatal intensive care in premature infants is the development of chronic lung diseases, especially bronchopulmonary dysplasia (BPD)[2].

BPD is a major problem in premature infants with a birth weight below 750 g, approximately 50% of them can be oxygen-dependent from 36 weeks of pregnancy, and half of them can even be discharged home with oxygen therapy[3]. BPD is a chronic pulmonary disease, polyetiological, developed in premature infants with morphofunctional immaturity of the lungs, undergoing oxygen therapy, with development of emphysema, fibrosis, bronchoobstructive syndrome and various radiological changes in the first months of life[4]. In the etiopathogenesis of BPD, a significant role is played by the negative impact of pulmonary artificial ventilation on immature lung tissue.

Recently, a "new" form of BPD has been observed, which occurs in profoundly premature babies, because surfactant therapy and artificial pulmonary ventilation (APV) with less aggressive parameters, are necessary in the management of respiratory distress syndrome of the newborn[3]. According to retrospective research, it has been concluded that the presence of risk factors for BPD does not always correlate with an increased likelihood of its occurrence. At the same time, BPD is considered a causal factor for the development of idiopathic chronic lung diseases, especially chronic obstructive pulmonary pathologies in adults[5]. It is essential to identify newborns at major risk of developing BPD from the first days of life and to implement appropriate prophylactic measures.

While advances in neonatal care have led to improved survival rates in premature infants, there has been somewhat limited progress in reducing BPD rates. About 65% of premature infants with birth weight less than 1500 grams are supported by invasive mechanical ventilation (IMV)[6]. Although IMV improves the respiratory status, serious complications with long-lasting consequences can also result. IMV is associated with an increased risk of developing respiratory distress syndrome, and it is considered an important risk factor for the development of BPD.

These approaches, along with optimal nutrition and medical therapy, decrease the risk of developing BPD; however, the impact on long-term outcomes is poorly defined. Characterization of late outcomes remains a challenge, as rapid advances in medical management result in adult survivors of BPD, but who have received outdated neonatal care.

Chest X-ray is useful in determining the severity of BPD, the imaging findings range from pulmonary hyperinflation with thickening of the bronchi and atelectasis to the presence of radiopaque images of fibrosis, large cysts, and interstitial emphysema. The pulmonary artery trunk may be enlarged because of

Table 1. Distribution of children from the group of study by gestational age at birth (weeks)

The groups	*Children with BPD (n=53)*		*Children without DBP (n=52)*		*p-value*
Prematurity group I (32-37 gestational age)	0	0	12	23.1%	p<0.001
Prematurity group II (29-31 gestational age)	16	30.2%	23	44.2%	
Prematurity group III (26-28 gestational age)	25	47.2%	12	23.1%	
Prematurity group IV (23-25 gestational age)	12	22.6%	5	9.6%	

Gestational age is a prognostic criterion for the viability of premature newborns. In our study, the mean gestation age in premature infants from the group of study was 27.28±2.24 weeks (95% CI [26.67-27.90]), and in the control group, it was 29.52±2.71 weeks (95% CI [28.76-30.27]). There was a statistically significant difference between the groups, p<0.0001 (Table 2).

Table 2. The mean gestational age at birth of children included in the study (weeks)

The study groups	*m*	*Standard deviation*	*Minimum*	*Median*	*Maximum*	*p-value*
Children with DBP (n=53)	27.28	2.24	2.3	27	31	p<0.0001
Children without DBP (n=52)	29.52	2.71	24	30	35	

the associated pulmonary hypertension and, in severe cases, cardiomegaly may be observed[6]. Chest imaging in BPD identifies major radiological criteria, such as significant basal chest distention, opacities with blurred contour, poorly delimited in the middle and upper regions of the lungs, subsegmental atelectasis, fibrotic opaque areas, emphysema areas, linear or round opacities[7]. In BPD, radiological manifestations include hypertransparency of the lungs, linear interstitial opacities, pulmonary cysts, and emphysema[8]. In most cases of BPD, chest X-rays are performed, as it is necessary to determine the presence and severity of dysplasia and to differentiate it from atelectasis, pneumonia, pulmonary edema, and interstitial emphysema.

The objective of the study was to evaluate clinical and imaging data in premature infants with BPD.

Materials and methods

This study is an analysis of a cohort of 105 premature infants admitted to the Pulmonology Clinic of the Institute of Mother and Child, Chisinau, Republic of Moldova, with a history of premature birth and sustained respiratory distress syndrome (RDS) in the neonatal period. Two groups were created: the core group, consisting of 53 children (33 boys and 20 girls) diagnosed with BPD, and the control group, consisting of 52 children (27 boys and 25 girls) who did not develop BPD. The diagnosis of BPD was established based on the analysis of perinatal anamnestic, clinical, laboratory, and instrumental data, especially lung imaging, according to international criteria[7].

The radiological examination was performed in all children included in the study. The study complied with international standards of medical ethics, developed by the Declaration of Helsinki, on the privacy and protection of participants' data. The research was approved by the Research Ethics Committee of the "Nicolae Testemitanu" University of Medicine and Pharmacy, Chisinau, Republic of Moldova (approval no. 73 of 31.05.2017). The study applied the following research methods: historical, comparative, and biostatistical[4]. The data collected were entered into the electronic database, and the statistical processing was carried out using SPSS (Statistical Package for the Social Sciences) version 20 (a p-value ≤ 0.05 being statistically significant).

Results and discussion

The distribution of children from the study groups into distinct groups according to gestational age (Table 1) revealed the following mean values for the children in the group with BPD: prematurity in group I, with a gestational age of 32-37 weeks – not detected; prematurity in group II, eg. 31-29 weeks, 30.2% cases, prematurity in group III, eg. 28-26 weeks, 47.2% cases; prematurity in group IV, eg. 23-25 weeks, 22.6% 12 cases.

In the group of children without BPD, this distribution was as follows: prematurity in group I – 23.1% (12 cases), prematurity in group II – 44.2% cases, prematurity in group III – 23.1% cases, prematurity in group IV – 9.6% cases, with statistically significant values, p<0.001 (Table 1).

An important factor for the respiratory system status in later stages of premature babies is the average birth weight, which indicates the evolution and poor management of pregnancy. Birth weight, as well as gestational age, is an important indicator in choosing the tactics of caring for premature babies.

Table 3. Birth weight of children included in the study

	Children with BPD (n=53)	*Children without DBP (n=52)*	*p-value*
Average (grams)	1006.49	1424.50	p<0.0001
Standard deviation	239.51	401.42	
Minimum	457	640	
Maximum	1650	2100	

Table 4. Average birth weight of children included in the study

The formed groups	*Children with DBP (n=53)*		*Children without DBP (n=52)*	
	n	%	*n*	%
group I (2000-2500 grams)	1	1.9	4	7.7
group II (1500-1999 grams)	1	1.9	21	40.4
group III (1000-1499 grams)	27	50.9	18	34.6
group IV (≤ 999 grams)	24	45.3	9	17.3
		p<0.0001		

Table 5. The mean oxygen concentration (FiO2) during IVM in the neonatal period, (%)

	Children with DBP (n=53)	*Children without DBP (n=52)*	*p-value*
Mean	42.37	40.08	p=0.572
SD	12.92	18.50	
Median	45.00	40.00	
25th percentile	30	21	
75th percentile	60	60	

According to the literature, the small for gestational age (SGA) child has a weight less than the 10th percentile for gestation and sex. In our study, the mean birth weight in the group of children with BPD was 1006.46±239.51 g (95% CI [940.47-1072.51]) g, the minimum value being 457 g, and the maximum value was 1650 g (Table 3). In the group of children without DBP, the mean weight was 1424±401.42 g (CI 95% [1312.74-1536.26]), the minimum value being 640 g, and the maximum 2100 g. A statistically significant difference can be observed between the groups (p<0.0001), the mean birth weight being higher in the control group than in the study group (Table 3).

The distribution of children according to birth weight by groups was as follows: in the group with BPD, group I (2000-2500g), 1.9%, group II (1500-1999g), 1.9%, group III (1000-1499g), 50.9%, group IV (≤999g), 45.3%. In the group of children without BPD, group I had 4 7.7%, group II 40.4%, group III 34.6%, group IV 17.3%, the data presenting statistically significant differences, p<0.0001 (Table 4).

Analyzing the data in the literature, we concluded that the lower the body mass and gestational age at birth, the greater the probability of developing BPD. According to statistical data, all newborns weighing less than 1000 grams at birth develop BPD[9].

The postnatal need in premature infants for IMV or oxygen therapy with the use of continuous positive airway pressure (CPAP) favors the deterioration of the alveolar-capillary barrier resulting in an inflammatory response with subsequent chronic lung damage[1]. The fraction of inspired oxygen (FiO_2) is the concentration of oxygen in the gas mixture. The assessment of the FiO2 level is a very informative current standard of care and continuous monitoring in severe lung impairment. FiO_2 values determine the choice of the type of respiratory support in respiratory impairment.

The FiO_2 value was evaluated in the children in the study at the neonatal period when they required oxygen therapy in respiratory failure. FiO_2 values during IVM were equal to 42.37±12.92% in children who later developed BPD and 40.08±18.50% in the group of children who were on IMV but who did not develop BPD. The difference between these groups was not statistically significant (p=0.572) (Table 5).

Neonatal factors such as gestational age, birth weight, oxygen therapy by invasive mechanical ventilation were analyzed. For the clinical assessment of pulmonary impairment in the study children, examinations were performed after 3 months of age from birth. At this age, the children had already achieved

Table 6. SaO_2 level assessed by pulse oximetry in the groups of study (%)

Study group	*N*	*Median*	*Standard deviation*	*95% CI*	*Minimum*	*Maximum*
Children with BPD	53	93.02	1.45	92.62-93.42	90	96
Children without DBP	52	97.40	0.83	97.17-97.63	95	99
Total	105	94.81	2.83	94.25-95.37	90	99
	p<0.0001					

Table 7. SaO_2 level in children according to gestational age (%)

Study group		*N*	*Standard deviation*	*Mean*	*Minimum*	*Maximum*	*p-value*
Children with BPD (n=53)	3-6 months	19	1.13	93.00	90.00	94.00	p<0.0001
	6-12 months	19	1.49	93.00	90.00	95.00	
	12-36 months	15	1.76	94.00	90.00	96.00	
Children without DBP (n=52)	3-6 months 5 1.44 97.80 97.00					98.00	
	6-12 months	11	1.35	96.25	95.00	97.00	
	12-36 months	36	1.35	97.98	96.00	98.00	
Total	3-6 months	24	1.29	94.58	90.00	98.00	
	6-12 months	30	1.46	95.12	90.00	97.00	
	12-36 months	51	1.61	95.36	90.00	98.00	

lung changes that fit the diagnosis of BPD or not. Pulse oximetry is considered an informative indicator of breathing efficiency. Thus, statistical analysis of O_2 saturation values, determined by pulse oximetry, was performed (Table 6). To identify respiratory failure, oxygen saturation (SaO_2) was assessed in all children in the study. Preterm infants in the study with BPD assessed 3 months after birth had significantly lower SaO_2 (92.62–93.42%), compared to infants who did not develop BPD (97.17–97.63%), with a statistically significant difference between groups (p<0.0001).

Also, the SaO_2 in preterm infants with BPD was evaluated according to gestational age (Table 7). Depending on age, the mean SaO_2 in the group of children with BPD at the age of 3-6 months was 93.00±1.13%, for the age of 6-12 months it was 93.00±1.49%, and at 12-36 months it was 94.00±1.76%, compared to the group of children without BPD in whom, at the age of 3-6 months, the mean SaO_2 was 97.80±1.44%, at the age of 6-12 months 96.25±1.35%, and in the age group 12-36 months it was 97.98±1.35%. Statistically significant differences in SaO_2 levels were identified between study groups (p<0.0001).

Lung X-rays were performed on all children included in the study. Analyzing the results of radiological changes, we observed the following: 49.1% with BPD had discoidal atelectasis, compared to 13.5% in the group without BPD, statistically significant (p<0.0001); 47.2% from the BPD group had subsegmental atelectasis, compared to 25.0% in the group without BPD, with no statistical difference (p=0.018). Areas of emphysema were recorded in premature infants with BPD in a proportion of 62.3% cases, and in premature infants without BPD 5.8% cases, with a statistically significant difference (p<0.0001). The opaque fibrosis areas in the group with BPD accounted for 50.9%, in the group without BPD 11.5%, also with statistically significant value (p<0.0001).

Signs of pulmonary hypertransparency were found in 47.2% cases of children with BPD, and only 1.9% in the control subjects. Microcystic changes were observed in 41.5% of children with BPD, and in 5.8% of the control group (p<0.0001). The hospitalization periods resulted in radiological changes of pneumonic foci in 52.8% cases in the group with BPD, and in the group without BPD in 73.1% cases (p=0.032); bronchoobstructive syndrome was attested in children with BPD in 58.5% cases versus 28.8% in the control group (p=0.002) (Figure 1).

Through our study, we presented the results of the clinical imaging evaluation of children with BPD.

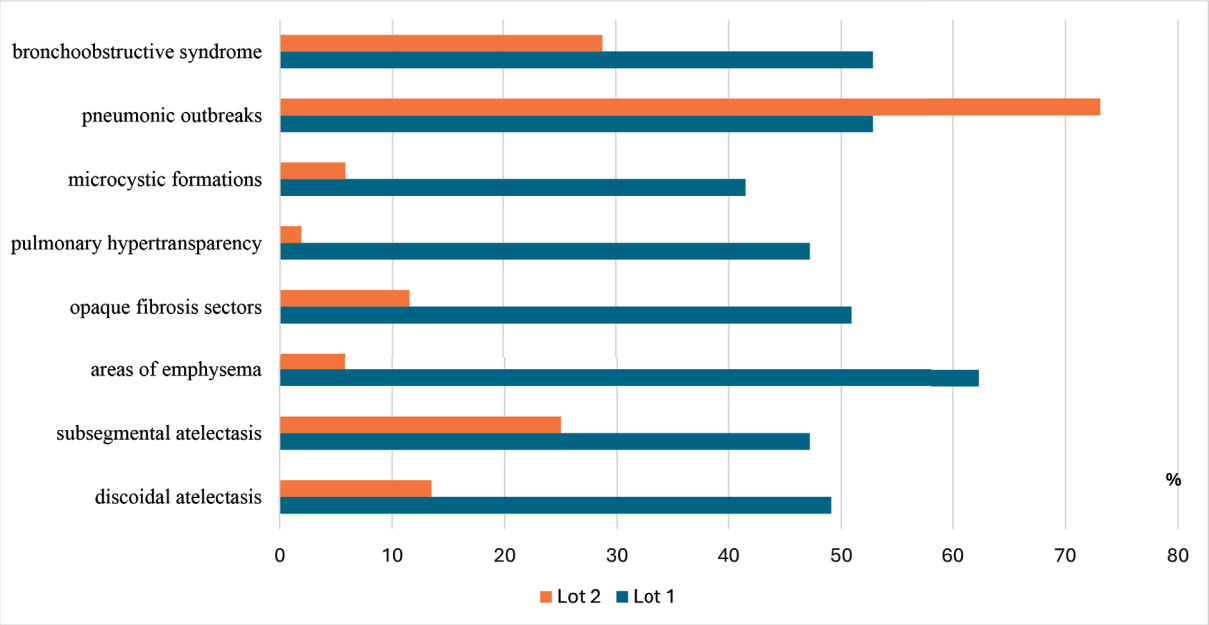


Figure 1. Imaging changes on pulmonary radiography in children with BPD.

From the morbid history of these children, we highlight in the DBP group a prematurity after a lower gestational age, lower birth weight and the need during the neonatal period for oxygen therapy with higher O_2 concentrations. Hypoxia monitored by pulse oximetry determines lower values in the group of children with more severe radiological changes.

Discussion

BPD, first described by Northway in 1967 as a chronic lung disease related to respiratory distress syndrome (RDS), is diagnosed when a neonate requires oxygen supplementation 28 days post-birth and presents specific radiographic features at a corrected gestational age of 36 weeks. The condition is classified into four stages based on radiographic findings: stage I (1–3 days) resembles RDS, stage II (4–10 days) shows bilateral opacification, stage III (11–30 days) exhibits uneven pulmonary densities with irregular bands or shadows, and stage IV (≥30 days) presents with bilateral opacities, hyperinflation, and atelectasis.

Advances in neonatal care, including the use of lung surfactant and protective ventilation techniques, have significantly improved survival rates among extremely premature and very low birth weight infants. Approximately 42% of infants weighing less than 750 grams and 4% of those weighing between 1251 and 1500 grams develop BPD[9]. A Chinese study reported an overall BPD incidence of 1.28% in preterm infants, increasing to 19.3% in those born before 28 weeks of gestation[9]. The severity of BPD correlates with birth weight and gestational age, with lower birth weights (<1000 grams) and gestational ages (<28 weeks) being linked to higher incidence and severity[10].

The incidence rates observed in our study are comparable to those reported in the literature. For instance, the finding that approximately 42% of infants weighing less than 750 grams and 4% of those weighing between 1251 and 1500 grams develop DBP aligns with previous research. Our study also reports the increased incidence of DBP in infants born before 28 weeks of gestation, reflecting a similar trend observed in a Chinese study where the incidence of DBP rose to 19.3% for preterm infants born before 28 weeks[11].

Gestational age, birth weight, oxygen therapy with invasive mechanical ventilation are important pathological antecedents in evaluating the diagnosis of bronchopulmonary dysplasia. While technical-scientific changes in neonatology have improved the clinical course and outcomes for infants with BPD, over the past decade the overall incidence of BPD has not changed. All observations on prenatal and postnatal factors involved in the pathogenesis of BPD are welcome.

According to the European consensus and the American Academy of Pediatrics, a goal of maintaining an oxygenation after SpO_2 equal to 90-95% is recommended[12]. According to the specialized literature, pulse oximetry can be informative in the assessment of hypoxia developed in acute and chronic lung disease. These data highlight the importance of monitoring SaO_2 in premature babies, especially those with BPD, to promptly detect hypoxemia and

intervene appropriately with oxygen administration to maintain adequate oxygenation and prevent complications. Pulse oximetry appears to be a suitable alternative for continuous monitoring of arterial oxygen saturation (SaO_2). A newer form of BPD, characterized by obstructive ventilatory impairment and pulmonary emphysema, differs clinically and pathologically from the typical form, rendering the conventional four-stage radiographic classification inapplicable. In clinical studies, chest X-ray images of mild, moderate, and severe BPD have shown changes such as discoid atelectasis, emphysematous areas, opaque fibrotic areas, pulmonary hypertransparency, and microcystic formations, though with varying degrees of severity. Despite its low diagnostic specificity, chest radiography maintains its predictive value, as the earlier appearance of characteristic changes correlates with more severe BPD. Consequently, chest X-ray is used as an adjunctive tool for diagnosing and staging BPD in pediatric patients.

Specifically, the emergence of a new form of DBP, characterized by obstructive ventilatory impairment and pulmonary emphysema, introduces complexities not fully captured by the traditional four-stage classification. This observation is in line with recent literature that identifies clinically and pathologically distinct forms of DBP, rendering the conventional classification less applicable in some cases.

In our findings, chest X-rays showed a variety of changes—discoid atelectasis, emphysematous areas, opaque fibrotic regions, and microcystic formations—that correspond with the results reported in other studies. While chest X-ray remains a useful tool for diagnosing and staging DBP, its diagnostic specificity is limited, as demonstrated in our study. However, we confirm that earlier appearance of characteristic changes on chest X-ray correlates with more severe forms of DBP, thus supporting its predictive value despite the lack of specificity[13].

Chest imaging findings can detect various changes in lung tissue; however, there is a lack of robust studies correlating chest radiographic changes with lung function and clinical symptoms in infants with BPD[7]. A better definition of these laws may facilitate the development of innovative strategies that will follow in experimental models and clinical trials.

Conclusions

Our study revealed that mean gestational age, birth weight, barotrauma caused by oxygen therapy with pulmonary artificial ventilation in premature infants are significant risk factors for the development of BPD. Clinical assessment of hypoxia by pulse oximetry SaO_2 levels and chest X-ray are effective diagnostic methods for BPD in premature infants, allowing the identification of discoidal atelectasis, areas of emphysema, opaque areas of fibrosis, pulmonary hypertransparency, and microcystic formations.

Author Contributions:

Conceptualization, S.R. and M.S.; methodology, S.R.; software, V.M.; validation, S.R.; formal analysis, S.R.; investigation, V.M.; resources, S.R. and M.S.; writing–original draft preparation, S.R.; writing–review and editing, S.R., M.S., V.M.; visualization, S.R. and M.S.; supervision, V.M.; project administration. All the authors have read and agreed with the final version of the article.

Compliance with Ethics Requirements:

"The authors declare no conflict of interest regarding this article"

"The authors declare that all the procedures and experiments of this study respect the ethical standards in the Helsinki Declaration of 1975, as revised in 2008(5), as well as the national law."

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References

1. Gien J, Kinsella JP. Pathogenesis and treatment of bronchopulmonary dysplasia. *Curr Opin Pediatr.* 2011;23(3):305-13.
2. Jensen EA, Schmidt B. Epidemiology of bronchopulmonary dysplasia. *Birth Defects Res A Clin Mol Teratol.* 2014;100(3):145-57.
3. Jobe AH, Bancalari E. Bronchopulmonary dysplasia. *Am J Breathing and Critical Medical Care* 2001;163:1723-1729.
4. Sciuca S, Curteanu A, Selevestru R, Cotoman A, Ceahlau M. PCN dysplasia bronchopulmonary disease in children: national clinical protocol PCN-393. 2021. Available at https://repository.usmf.md/handle/20.500.12710/20265.
5. Czarnecki ŁM. Assessment of chest X-ray images in newborns with respiratory disorders. *Cardiothoracic Thoracic Surgery Pol.* 2015; 112(1):836.
6. Cotoman A, Ceahlau M, Sciuca S. Diagnostic features by radiological examination in children with bronchopulmonary dysplasia. In: Collection of papers of the conference with international participation "News in child pneumology", "Nicolae Testemitanu" State University of Medicine and Pharmacy, Chisinau, 2023, pp. 62-67. ISBN 978-9975-82-328-9
7. Semple T, Akhtar MR, Owens CM. Imaging bronchopulmonary dysplasia – a multimodality update. *Front Med (Lausanne).* 2017; 4:88.

8. Miller JD, Carlo WA. Pulmonary complications of mechanical ventilation in neonates. *Clin Perinatol.* 2008; 35(1):273–281.
9. Muehlbacher T, Bassler D, Bryant MB. Evidence for the management of bronchopulmonary dysplasia in very preterm infants. *Children (Basel).* 2021;8(4): 298.
10. Huang L-Y, Lin T-I, Lin C-H, et al. Comprehensive analysis of risk factors for bronchopulmonary dysplasia in preterm infants in Taiwan: a four-year study. *Children (Basel).* 2023;10(11):1822.
11. Colaborative Study Group for Bronchopulmonary Dysplasia of Prematurity in China. Incidence and risk factors of bronchopulmonary dysplasia in premature infants in 10 hospitals in China. *Zhonghua Er Ke Za Zhi.* 2011;49(9):655-62.
12. Sweet DG, Carnielli VP, Greisen G, et al. European Consensus Guidelines on the Management of Respiratory Distress Syndrome: 2022 Update. *Neonatology.* 2023;120(1):3-23.
13. Li R, Zhang J. Diagnostic value of chest CT combined with x-ray for premature infants with bronchopulmonary dysplasia. *Medicine (Baltimore).* 2018;97(9): e9723.