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## RESEARCH ARTICLE



# Evaluation of pulmonary imaging data by radiography in children with bronchopulmonary dysplasia

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## ABSTRACT

**Introduction.** According to specialized literature, X-rays are also used in the diagnosis and suspicion of chronic bronchopulmonary disease (bronchopulmonary dysplasia (BPD), in premature children.

**Material and methods.** The study included 105 premature babies who were divided into the study group – premature babies with bronchopulmonary dysplasia (BPD) and the control group – premature babies without BPD. Data were statistically analyzed using Microsoft Excel, MedCalc, SPSS and Contingency Table Analysis as a method of evaluating the performance of a diagnostic test.

**Results.** Radiological changes of discoidal atelectasis type in subjects with BPD were detected in 49.1% in the basic group versus 13.5% in the control group ( $\chi^2 = 15.431$ ;  $p < 0.0001$ ), subsegmental ones 47.2% vs 25.0% ( $\chi^2 = 5.586$ ;  $p = 0.018$ ); pulmonary emphysema areas 62.3% vs 5.8% ( $\chi^2 = 37.182$ ;  $p < 0.0001$ ), opaque fibrosis sectors 50.9% vs 11.5% ( $\chi^2 = 18.911$ ;  $p < 0.0001$ ); signs of pulmonary hypertransparency 47.2% vs 1.9% ( $\chi^2 = 28.843$ ;  $p < 0.0001$ ); microcystic formations 41.5% vs 5.8% ( $\chi^2 = 18.482$ ;  $p < 0.0001$ ). Depending on the severity degrees of BPD, changes such as discoidal atelectasis were noted, in those with mild grade – 50% medium grade – 38.5%, severe grade – 56.3% ( $\chi^2 = 16.502$ ;  $p < 0.001$ ), subsegmental atelectasis 41.7%, vs 38.5% ( $\chi^2 = 7.956$ ;  $p = 0.047$ ), pulmonary emphysema areas 58.3%, vs 38.5%, vs 87.5% ( $\chi^2 = 45.138$ ;  $p < 0.0001$ ); microcystic formations, 33.3%, vs 53.8%, vs 43.8% ( $\chi^2 = 20.502$ ;  $p < 0.0001$ ).

**Conclusions.** The changes recorded on radiological examination in mild, moderate, and severe cases of BPD in premature babies are of the type discoidal atelectasis, areas of emphysema, opaque sectors of fibrosis, pulmonary hypertransparency, microcystic formations.

**Keywords:** bronchopulmonary dysplasia, prematurity, radiography.

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## Key messages

### What is not yet known about the issue addressed in the submitted manuscript

Bronchopulmonary dysplasia is a multifactorial pathology with multiple associated comorbidities, responsible for the majority of chronic lung disease cases in childhood. The use of imaging examinations, in this particular case - bronchopulmonary radiography, is essential for the objective evaluation of the patients' clinical evolution, the identification of pediatric subjects that require closer follow-up, as well as for the improving communication with the family.

### The research hypothesis

Premature infants may develop bronchopulmonary dysplasia with radiological changes, which can affect their health.

**The novelty added by the manuscript to the already published scientific literature**

Evaluation of imaging data has established a significant increase in premature infants with bronchopulmonary dysplasia.

**Introduction**

Prematurity remains one of the most important health problems worldwide, which is associated with high morbidity and mortality, high costs of medical care and increased risk of disability. Bronchopulmonary dysplasia (BPD) is considered to be one of the forms of chronic lung damage in newborns, with predilection of preterm infants, which frequently develops as a complication of artificial pulmonary ventilation (APV) [1-3]. It evolves primarily with the primary involvement of the bronchioles and lung parenchyma, with onset of emphysema, fibrosis and/or impairment of alveolar replication and characterized by specificity of radiological changes in the first months of life and regression of clinical and imaging manifestations as the child grows [4-6].

Data on BPD frequency vary considerably worldwide, and the incidence rate is influenced by the used diagnostic criteria ("28 days" or "36 weeks, oxygen dependence"), the mortality of premature newborns, the studied population, the level of technical equipment in neonatal, pulmonology, intensive care units, etc. On average, according to literature data, BPD develops in 30% of newborns who require mechanical ventilation, and about 40% of infants with extremely low birth weight (birth weight of <1000 g) develop DBP [7]. Unlike other causes of morbidity that complicate severe prematurity, the incidence of DBP has not decreased over the past few years [8, 9].

BPD remains a primary cause of chronic respiratory pathology despite advances in neonatal medicine. It is also recognized as a distinct nosological entity among surviving preterm infants, with a frequency among living preemies of 20-40%. Worldwide, it has been estimated that more than 15 million babies are born prematurely. Newborns with severe degrees of prematurity, especially those with BPD, frequently develop respiratory symptoms (usually coughing and wheezing) as well as frequent hospitalizations in the first years of life. Moreover, this clinical entity is associated with increased respiratory morbidity and mortality [9], in particular, during the first two years of life, due to the persistence of respiratory symptoms and the higher number of hospitalizations compared to preterm infants without BPD [10].

In recent years progress has been made in pediatric thoracic imaging, enhancing the diagnostic potential of BPD, facilitating treatment guidance for respiratory distress syndrome (RDS), reducing the likelihood of further progress of BPD and long-term follow-up of chronic pulmonary pathology [1].

First-line radiological examinations, such as pulmonary radiography, are useful in determining the severity of BPD, differentiating it from atelectasis, pneumonia, and air loss syndrome, with changes such as decreased lung volumes,

areas of atelectasis and hyperinflation, pulmonary edema and pulmonary interstitial emphysema being noted. The findings on radiological examination range from signs of pulmonary hyperinflation with thickening of the bronchi and atelectasis, to the presence of radiopaque images of pulmonary fibrosis, large airborne cysts, and interstitial emphysema. The trunk of the pulmonary artery may be highlighted due to associated pulmonary hypertension, and in extremely severe cases, cardiomegaly may also be noted [11].

Nevertheless, the recognized major radiological criteria include significant thoracic distension predominantly in the basal areas, opacities with blurred contour, poorly delineated in the middle and upper regions of the lungs, subsegmental atelectasis, fibrotic opaque sectors, areas of emphysema, linear or round opacities [12, 13].

The aim of the research was to evaluate chest x-rays in children with bronchopulmonary dysplasia.

**Material and methods**

This study represents an analysis of a cohort of 105 premature babies admitted to the Clinic of Pulmonology of the Institute of Mother and Child with a positive history of premature birth and with RDS supported during the neonatal period. Two groups were created: the study group of 53 children (33 boys and 20 girls) with the diagnosis of bronchopulmonary dysplasia and the control group 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, history, clinical, laboratory and instrumental data, especially pulmonary imaging, based on international criteria [14]. Radiological examination was performed on all children included in the study. The study complied with the international standards of medical ethics, developed by the Declaration of Helsinki, regarding confidentiality and personal data protection of the participants. The research was approved by the Research Ethics Committee of *Nicolae Testemițanu* State University of Medicine and Pharmacy (minutes № 73 from 31.05.2017). The resulting data were disclosed only to the concerned participant; the personal data of each subject were not used and will not be used for any other purpose. The data collected from the primary sources were introduced in the electronic database, whereas the statistical processing was performed using the SPSS (Statistical Package for the Social Sciences) version 20.

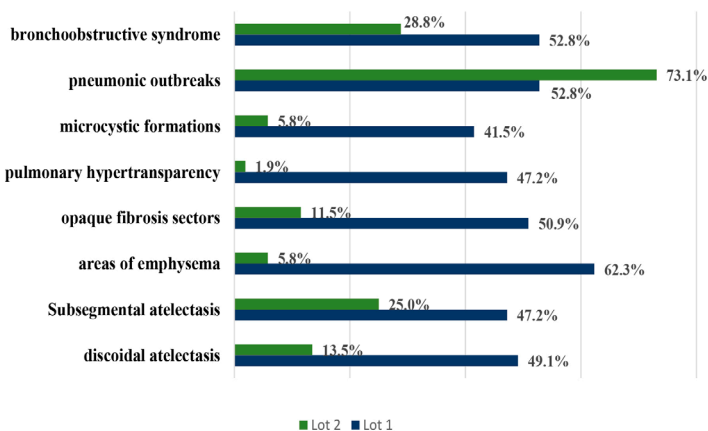
**Results**

Pulmonary radiography was performed on all children included in the research. Thus, the children in the study (Fig. 1) had predominantly radiological changes of atelectasis type, with discoidal changes detected radiologically in 49.1% (n=26) of children with BPD and in 13.5% (n=7) of

children in the control group ( $\chi^2=15.431$ ;  $p<0.0001$ ). Subsegmental changes were reported in 47.2% of children with BPD ( $n=25$ ) and in 25.0% of children without BPD ( $n=13$ ) ( $\chi^2=5.586$ ;  $p=0.018$ ). Areas of pulmonary emphysema in the study group were noted in 62.3% ( $n=33$ ), while in the control group, they were observed in only 5.8% ( $n=3$ ) ( $\chi^2=37.182$ ;  $p<0.0001$ ). Opaque fibrosis sectors in children with BPD were identified in 50.9% ( $n=27$  cases), and in children without BPD in 11.5% ( $n=6$ ) ( $\chi^2=18.911$ ;  $p<0.0001$ ). Signs of pulmonary hypertransparency were observed in 47.2% of children with BPD ( $n=25$ ) compared to single cases (1.9%) in control subjects ( $\chi^2=28.843$ ;  $p<0.0001$ ). Microcystic formations were recorded with a higher share in 41.5% of children with BPD (control group – 5.8% cases) ( $\chi^2=18.482$ ;  $p<0.0001$ ).

The periods of hospitalization resulted in radiological changes with pneumonic foci character (Fig. 1) in 52.8% ( $n=28$ ) among those in the first group, and in those without BPD in 73.1% ( $n=38$ ) ( $\chi^2=4.609$ ;  $p=0.032$ ), and bronchoobstructive syndrome was noted in children with BPD in 58.5% ( $n=31$ ), vs 28.8% ( $n=15$ ) in the control group ( $\chi^2=9.370$ ;  $p=0.002$ ).

The analysis of radiology results in relation to the severity degrees of BPD (Table 1) noted changes such as dis-



**Fig. 1** Imaging changes on pulmonary radiography in children with bronchopulmonary dysplasia

coidal atelectasis (Fig. 2f), present in 50% of those with mild grade (present in every second child,  $n=12$ ), 38.5% with medium grade ( $n=5$ ), and 56.3% with severe grade ( $n=9$ ) ( $\chi^2=16.502$ ;  $p<0.001$ ). Subsegmental atelectasis (Fig. 2b), among those with mild BPD, was recorded in 41.7% ( $n=10$ ) and in 38.5% with medium grade ( $n=5$ ) ( $\chi^2=7.956$ ;  $p=0.047$ ). Areas of pulmonary emphysema in children with mild BPD were detected in every second case – 58.3% ( $n=14$ ), in every third child with average severity (38.5%,  $n=5$ ), and in most of those with severe grade (87.5%,  $n=14$ ) ( $\chi^2=45.138$ ;  $p<0.0001$ ).

Microcystic formations (Fig. 2d, e), which are often characteristic of pulmonary diseases with obstructive genesis, were present in children with mild BPD degree in 33.3% ( $n=8$ ), in medium severity – 53.8% ( $n=7$ ), and in severe grade – 43.8% ( $n=7$ ) ( $\chi^2=20.502$ ;  $p<0.0001$ ).

Pneumonic foci were also visualized (Fig. 2. a, c, f): in children with mild BPD in 41.7% cases ( $n=10$ ), in those with medium grade – in 76.9% cases ( $n=10$ ), and in every second child with severe BPD ( $n=8$ ) ( $\chi^2=9.177$ ;  $p=0.027$ ).

At the same time, in pediatric subjects with BPD in pulmonary imaging evaluation, bronchoobstructive syndrome was also present (Fig. 2 c, e, f), noted in 62.5% ( $n=15$ ) in those with mild degree, 5% ( $n=5$ ) in medium grade, and 68.8% ( $n=15$ ) in severe grade ( $\chi^2=12.329$ ;  $p=0.006$ ). The imaging expression of broncho-obstructive disorders is also relevant through signs of pulmonary hypertransparency, which in children with mild BPD was found in 45.8% ( $n=11$ ), in the middle degree – 38.5% ( $n=5$ ), and in severe degree – 56.3% ( $n=9$ ), ( $\chi^2=30.103$ ;  $p<0.0001$ ).

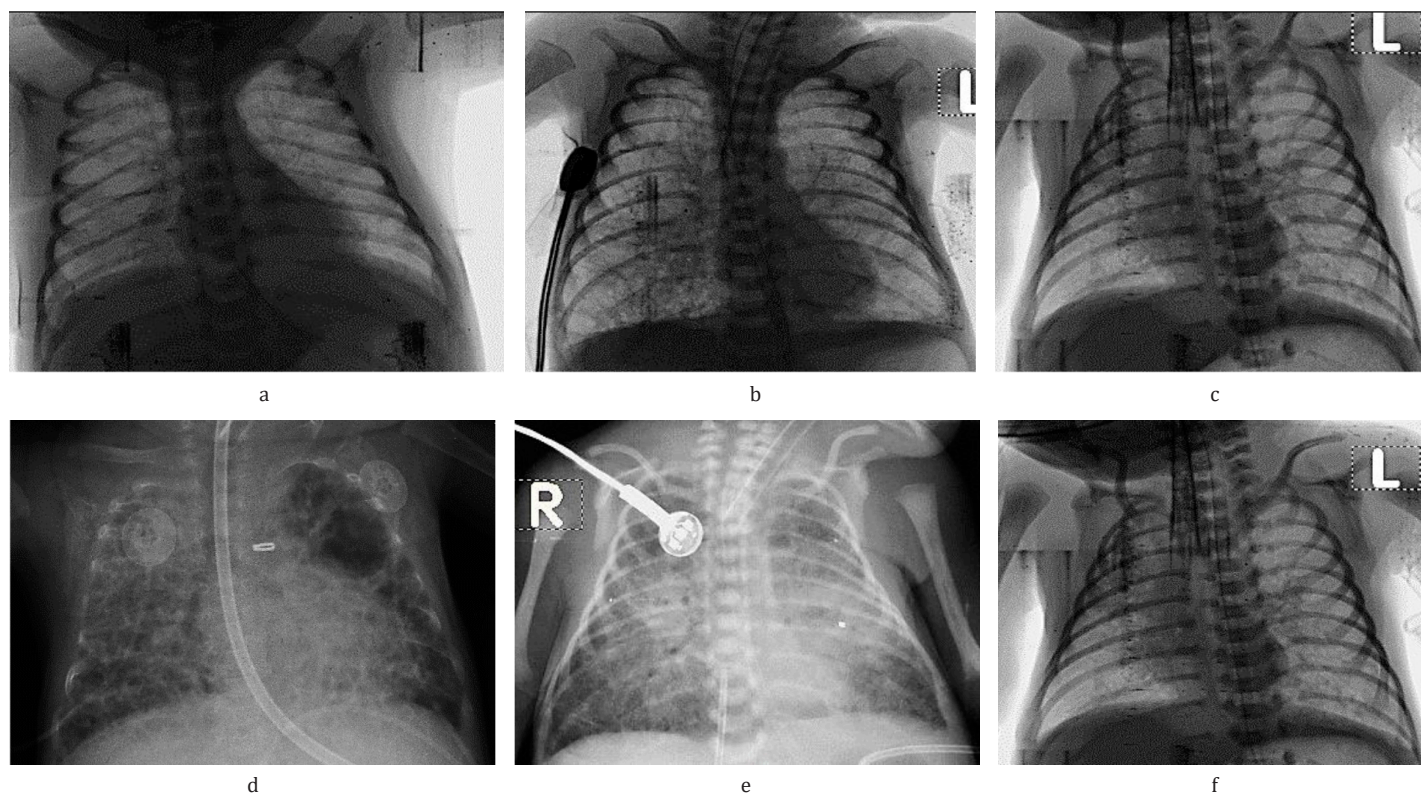
Foci of pulmonary fibrosis are mentioned in the literature as imaging signs suggestive of BPD and were recorded in the research performed. Opaque fibrosis sectors (Fig. 5, 6, 7) were identified in 54.2% ( $n=13$ ) of subjects with a mild degree of BPD, in 46.2 ( $n=6$ ) of those with medium severity, and in 50.0% ( $n=8$ ) of those with severe degree ( $\chi^2=19.172$ ;  $p<0.0001$ ).

For the objectification of imaging data characteristic of the evolutionary development of BPD, radiographic images with various modifications are presented (Fig. 2 a-f).

**Table 1.** Lung imaging changes in varying degrees of severity of BPD

Lung imaging signs	BPD light grade (n=24)		BPD medium grade (n=13)		BPD severe grade (n=16)		p
	Abs	%	Abs	%	Abs	%	
Discoidal atelectasis	12	50,0	5	38,5	9	56,3	0,001
Subsegmental atelectasis	10	41,7	5	38,5	10	62,5	0,047
Areas of emphysema	14	58,3	5	38,5	14	87,5	<0,0001
Microcystic formations	8	33,3	7	53,8	7	43,7	<0,0001
Pneumonic outbreaks	10	41,7	10	76,9	8	50,0	0,027
Broncho-obstructive syndrome	15	62,5	5	38,5	11	68,8	0,006
Opaque fibrosis sectors	13	54,2	6	46,2	8	50,0	<0,0001
Pulmonary hypertransparency	11	48,5	5	38,5	9	56,3	<0,0001

**Note:** BPD- bronchopulmonary dysplasia, ABS- absent, n - number, % - percent



**Fig. 2** Various radiographic images with different changes in premature infants with bronchopulmonary dysplasia

- a: Segmental pneumonia (S-4,5) on the right, bronchoobstructive syndrome  
 b: Subsegmental atelectasis, discoidal  
 c: Pneumonic infiltration, bronchoobstructive syndrome  
 d: Intensified, fibrotized, deformed lung drawing. Bilateral diffuse microcystic formations (signs of BPD)  
 e: Hyperaerated lungs, obstructive syndrome. Deformed, fibrotized lung drawing. Bilaterally diffuse microcystic formations. On the right in S2 discoidal atelectasis.  
 f: Deformed drawing, discoid atelectasis S2, bronchoobstructive syndrome, hyperinflation, pneumonia S7.

## Discussion

BPD is a chronic lung disease involving damage to the alveoli and pulmonary vessels due to neonatal lung underdevelopment, oxygen therapy used in the postnatal period, and associated infections [15], which causes delayed lung development, further contributing to insufficient development of the alveoli and pulmonary capillaries. BPD was first described as a chronic lung disease associated with RDS by Northway in 1967.

Clinically, BPD is established as a diagnosis if the newborn requires supplemental oxygen at 28 days after birth and has specific features on chest radiograph at 36 weeks' corrected gestational age. Depending on the characteristics of the lung x-ray images, it is divided into 4 stages, respectively: 1st stage – similar findings in chest x-ray with RDS (1–3 days), 2nd stage – bilateral opacification (4–10 days), 3rd stage – density uneven bilateral lung fields, with bands or irregular shadows (11–30 days), 4th stage – bilateral opacities with lung hyperinflation, atelectasis (30 days).

The survival of extremely premature infants and very low birth weight preterm infants has steadily improved thanks to the use of lung surfactant and various protective

ventilation techniques [16]. Approximately 42% of newborns weighing less than 750 g and only 4% of newborns weighing between 1251 and 1500 g develop BPD.

According to a study conducted in China, the incidence of BPD was about 1.28% among preterm infants compared to 19.3% among extremely premature babies (<28 weeks gestation, in 2011) [17, 18]. Factors influencing the severity of BPD among premature babies were also analyzed, demonstrating that birth weight and gestational age correlated with both the incidence and the severity of BPD. Additionally, low birth weight (<1000 g) and low gestational age (<28 weeks) were associated with a higher incidence and severity of BPD [6, 14].

BPD associated with obstructive ventilation impairment and pulmonary emphysema as an end result is recognized as a new type of BPD, which is significantly different from the typical form in terms of clinical and pathological characteristics and outcomes. Consequently, the conventional 4-step radiographic classification for the typical form cannot be applied to the new type.

In the study, chest X-ray images were compared between mild, moderate, and severe forms of BPD, revealing

changes such as discoidal atelectasis, areas of emphysema, opaque fibrosis sectors, pulmonary hypertransparency, and microcystic formations, albeit with varying degrees of prominence. Although chest X-ray is not a definitive tool for assessing the severity of BPD, it still holds a certain predictive value; specifically, the more severe the BPD, the sooner characteristic changes in chest X-ray will manifest. However, it should be noted that chest radiography has somewhat low diagnostic specificity for BPD in children. Therefore, it is used as an auxiliary tool for the diagnosis and staging of this pathology, considering its limitations.

### Conclusions

Pulmonary radiography is one of the diagnostic methods for BPD in premature infants and can record discoidal atelectasis, areas of emphysema, opaque sectors of fibrosis, pulmonary hypertransparency, and microcystic formations. The research confirms the importance of evaluating the type and extent of radiological changes in premature infants based on the severity of BPD. It has been demonstrated that this method is effective both in practical clinical settings and scientific work.

### Competing interests

None declared.

### Patient consent

Obtained.

### Ethics approval

The research was approved by the Research Ethics Committee of *Nicolae Testemitanu* State University of Medicine and Pharmacy (report no. 73 of 31.05.2017).

### Authors' contribution

The authors contributed equally to the research of the scientific literature, the selection of the bibliography, the reading and analysis of biographical references, the writing of the manuscript and its peer review. All authors have read and approved the final version of the article.

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Nothing to declare.

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