Functional aspects of early postnatal developments of small premature infants' lungs.

A. Liashenko[1], A. Karpov [2], V. Dashitchev [3]

[1] Medical Department of the Yaroslavl Refinery, Yaroslavl, Russia
[2] Clinical Hospital №9, Yaroslavl, Russia
[3] Medical Academy, Yaroslavl, Russia

Abstract- **The purpose of the current research is to establish the pattern of the postnatal formation of the external respiration function of small premature infants. Forty-two premature babies of 1, 3 and 7 days of age, were subjected to examination in the center of perinatal development in the city of Yaroslavl. All infants were divided into two groups. The first group comprised 23 small premature infants with the gestation age of 25 - 32 weeks; the second group comprised 19 infants with gestation age of 33 - 36 weeks. In order to determine the lungs electrical conductivity the 16-electrode EIT system, developed in the Research Institute of Radio Engineering and Electronics of the Russian Academy of Sciences. During the first day of life the small premature infants featured hyperventilation, but the blood flow in the vessels of the pulmonary circulation was intensive enough. At the age of three days the small premature infants displayed pronounced increase in the pulmonary blood flow, which might be attributed to the tone decrease of the arterial vessels. In the early neonatal period the small premature infants featured the variant of biomechanics, which is more economic, but less effective from the point of view of ventilating function of lungs. The article is illustrated with electro-impedance tomograms and tables.**

Keywords- ***impedance, lungs, premature infant***

I. INTRODUCTION

The respiratory apparatus pathology is one of the main reasons for postnatal dysadaptation and mortality of premature babies, thus making early detection of structural changes and adequate estimation of the lungs functional state one of the principal problems of neonatology.

According to modern conceptions effective pulmonary surface for gas exchange and the state of surfactant system play significant roles on the process of external respiration of premature infants. Nevertheless, during the early postnatal adaptation period no respiratory impairments are detected in 65% of infants, born on the 26th week of gestation, and thus having pronounced lung immaturity. These facts prove that small premature infants within few days after being born, have other mechanisms for stabilization of lungs functions. Development of methods for study of premature infants pulmonary function is the key problem of neonatology since the survival rate of such newborns is defined in many respects by the status of external respiration. There are few publications devoted to application of the electrical impedance tomography in neonatology aimed at detection of structural changes in lungs. (1, 2, 3, 4).

The purpose of the current research is to establish the pattern of the postnatal formation of the external respiration function of small premature infants.

II. MATERIALS AND METHODS

Forty-two premature babies, within gestation age of 25-26 weeks and weight at birth 800 – 2600 grams with no respiratory abnormalities or severe pathologies of other systems, were subjected to examination. The first group comprised 23 small premature infants with gestation age of 25 - 32 weeks weight at birth 800 – 1500 grams; the second group comprised 19 infants with gestation age of 33 - 36 weeks and weight at birth 1600 – 2600 grams. During daily examinations the infants' general status as well as somatic (with assessment of respiratory system and cardiovascular system) and neurological status was assessed according to the generally accepted method. The infants' gestation age was evaluated according to the Bollard scale.

In addition to the general clinical examination the oxygen tension ($_pO_2$) and carbon dioxide tension ($_pCO_2$) in capillary blood of the infants were determined utilizing the device "Stat Profile pHOx" ("Nova biomedical"). It was supplemented by the electrical impedance lung tomography (EILT) correspondingly at the age of 1, 3 and 7 days. The electrical impedance lung tomography was performed with the help of the electroimpedance tomograph, developed at the Institute of Radio-Engineering of Russian Academy of Science. To create the lung electroimpedance tomogram 16 round contact electrodes (∅6 mm), manufactured from stainless steel, were fixed with an elastic band around the chest at the level of the 4th intercostals area. Electroconductive gel was applied to the inner side of the electrodes before their placement. The examination lasted 20 seconds and was carried out on the 1st, 3^{d} and 7th day of the infants' birth, on average after 1 hour of feeding time, with the infants breathing quietly. The quantitative assessment of the electroimpedance tomogram comprised an electroconductivity index determination in the respiratory zone and in the zone of respiratory tract at the inspiration phase as well as expiration (fig. 1). The obtained data were statistically processed with Statistica 6.0.

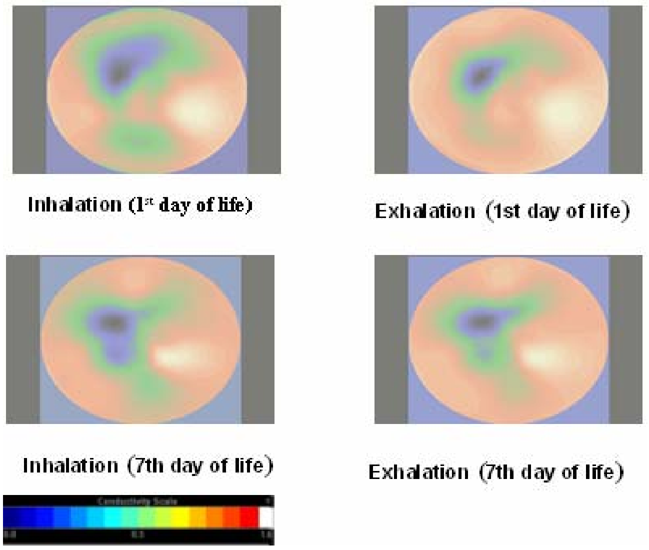

Fig.1 Electroimpedance lungs tomograms of small premature infants during various phases of breathing cycle.

III. RESULTS

The study of the internal respiration function brought the following results. The newborns displayed similar correlation between respiratory rate and lungs conductivity as the adults do: increase of respiratory rate was accompanied by increase of the lungs electrical conductivity, with the correlation coefficient between them being 0,6. At the age of 3 days the respiratory function of the premature infants featured the following particularity: increase of respiratory rate was accompanied by a significant increase of electroconductivity index during the inspiration and expiration phases. By the end of 7th day the electroconductivity index went significantly below the levels of the 1st day of life at expence of the inspiration phase. ($t=3,57$; $p<0,001$) The infants from the 2nd group at the age of 3 days simultaneously with the breathing rate decrease featured a significant reduction of electroconductivity in the inspiration and expiration phases. By the end of 7th day the electroconductivity index significantly exceeded the levels of the 1st day of life due to the expiration phase ($t=4,11$; $p<0,001$) (Table. 1). On the basis of the experiments as well various scientific sources a correlation dependence was established between the air content in the pulmonary tissue and the total electrical resistance (impedance) (5). On the basis of this data we consider it relevant to characterize the respiratory volume (RVeit) as difference between the electroconductivity index in the respiratory zone during expiration phase (EC exp) and inspiration phase (EC insp): = EC insp - EC exp. The premature infants from the both groups demonstrated the electrical conductivity index increase, which corresponded to respiratory volume, but the mechanism of these changes was different (figure 2). If in case of premature infants of the first group the change of the electroconductivity index, which corresponded to the respiratory volume, took place

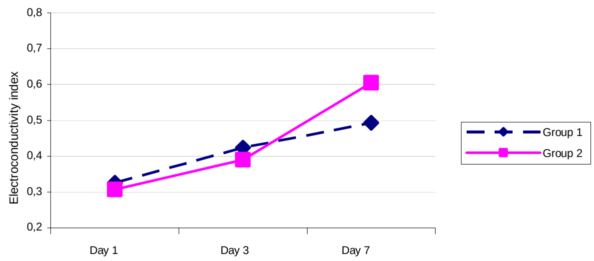

Fig 2 Dynamics of lung electrical conductivity index, corresponding to respiratory volume of the premature infants lungs in two clinical groups (on the 1st, 3^{d} and 7th day).

due to electroconductivity changes of lungs during the inspiration phase (table 1), in respect of the infants, comprising the second group, - due to electroconductivity changes in the expiration phase. In addition a significant increase of electrical conductivity index, which corresponded to the respiratory volume of the 2nd group premature infants, was discovered. When gas homeostasis was subjected to examination, it was established that mean values of oxygen tension ($_{p}O_2$) in capillary blood of the infants from the 1st group were below those of the infants' from the 2nd group.

Table 1. Changes electroconductivity index in the respiratory zone

Respiratory phases	1st group, age			2nd group, age		
	Day 1	Day 3	Day 7	Day 1	Day 3	Day 7
Inspiration	1,110±0,18	1,234±0,13*	0,929±0,15**	0,990±0,15	0,700±0,08**	1,020±0,20**
Expiration	1,436±0,214	1,650±0,20**	1,422±0,24**	1,297±0,22	1,090±0,13**	1,625±0,27**
Breathing rate per minute	47	51	50	46	44	44

* - reliability of discrepancy between this data and the data of the previous column $p<0,01$; ** - reliability of discrepancy between this data and the data of the previous column $p< 0,001$

Table 2. Tension of oxygen ($_pO_2$) and carbon dioxide ($_pCO_2$) in capillary blood of premature infants

Indices		1st group, age			2nd group, age		
		Day 1	Day 3	Day 7	Day 1	Day 3	Day 7
pO_2 mmHg	M±σ	50,3±1,6	51,8±1,6*	54,3±2,3**	54,8±1,6	54,9±1,5	59,9±1,6**
pCO_2 mmHg	M±σ	33,0±1,2	35,2±1,6**	39,7±1,8**	31,1±0,9	33,5±1,04**	35,7±1,4**

* - reliability of discrepancy between this data and the data of the previous column p<0,002; ** - reliability of discrepancy between this data and the data of the previous column p< 0,001

Growth of oxygen tension ($_pO_2$) in capillary blood in the dynamics of the early neonatal period of the infants, comprising the 1st group was not significant. The infants from the 2nd group displayed significant increase of oxygen tension in capillary blood on the seventh day. (Table 2).

Carbon dioxide ($_pCO_2$) tension in capillary blood of premature infants increased in the subjects from both groups during the whole span of the early neonatal period with no significant difference between them till the third day of life. But by the end of this period the index under consideration displayed a trend to higher values in the infants from the 1st group (Table 2). Low values of carbon dioxide ($_pCO_2$) tension in the infants of both groups during the first days after delivery are indicators of the lungs hyperventilation. This mechanism of the postnatal adaptation of external respiration has probably a universal character, since all newborns display it.

The results of our research enable us to suggest that the type of the respiration biomechanics, meaning the ratio of rate and depth, developed by the premature infants, facilitates the process of inhalation and, with the lungs tissue being still quite rigid, requires less energy from respiratory musculature, but is less effective from the gaseous metabolism point of view. Hence, by the end of the early neonatal period carbon dioxide ($_pCO_2$) tension in the blood of the premature infants features higher values. These data allow to speak about lack of coordination between various links of external respiration of premature infants in the early neonatal period.

The results of the present work prove that the EILT considerably expands possibilities for evaluation of external respiration functions of premature infants under clinical conditions. High sensitivity of the method to the changes in the lungs functional status, good resolution of the obtained images, high speed of evaluation procedure make the EILT method a useful tool for examination of respiration organs of premature infants. Since the method is safe for the patient as well as for the medical staff, the infant can be subjected to examination many times, and what is especially important, the examination can be done in a monitoring mode.

IV. CONCLUSIONS

1. The method of electrical impedance lung tomography makes it possible to determine the indices, which characterize respiratory volume of premature infants, on the basis of the values of electroconductivity index of the lungs respiratory zones.
2. The dynamics of the lung electrical conductivity index values in the respiratory zone of premature infants prove that the most active adaptive reactions take place during the first three days after delivery.
3. Functional status of external respiration of premature infants in the early neonatal period as compared with the status of more mature infants can be characterized as insufficient, latent respiratory embarrassment being its equivalent.

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Address of the corresponding author:

Author: A. Liashenko
Institute: Medical Department of the Yaroslavl Refinery
Street Gagarin
City Yaroslavl
Country Russia
Email Sim-tech@Net76.ru