PATENT DUCTUS ARTERIOSUS IN TERM NEWBORNS: APPLICATION OF ELECTRONIC HEART AUSCULTATION

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Annotation. *This study presents the results of the use of computerized heart auscultation of full-term infants with echocardiographic signs of patent ductus arteriosus detected during the first days of life. Infants who maintained these symptoms during the first 3 months of life had significant differences in the data of the phonocardiogram recorded on the second day of life.*
Key words: *patent ductus arteriosus, computer-assisted auscultation, term newborn.*

Introduction. The ductus arteriosus (DA) is the vascular connection between the pulmonary artery and the fetal aorta that closes shortly after birth. DA usually closes functionally in 12-18 hours and anatomically in 2-3 weeks after birth. If it persists after 6 weeks in infants over 36 weeks of gestation (except in the case of shunting during complex congenital heart disease), it is a sign of a patent ductus arteriosus (PDA) due to the impossibility of complete postnatal closure. The frequency of spontaneous DA closure after this age is very low. Usually, the ability to predict the closure of DA in full-term infants who do not have clinical symptoms at the time of discharge from the hospital (at the end of the third day of life) is limited [1, 6].

PDA in full-term infants is diagnosed with a frequency of 3-8 per 10 000 live births, and accounts for 5-10% of all congenital heart defects [2, 7].

Children with small isolated PDA are usually asymptomatic, the degree of pulmonary over-circulation and left ventricular overload in a small PDA is minimal. In children with moderate to severe PDA, symptoms can range from shortness of breath during exercise to heart failure. Clinicians recognize that timely identification of PDA and its hemodynamic significance is extremely important. In patients with small PDA, noise is usually the only finding, but its characteristics vary in newborns [1, 6]. Auscultation of the heart with heart murmurs is a traditional screening tool for clinical diagnosis. However, the accuracy of this method of auscultation is subjective and dependent on skills [9].

The availability of innovative methods of sound recording using phono- and spectrograms provides important assistance in diagnosis. Computerized auscultation of the heart (computer/automatic phonocardiogram analysis) includes recording of heart sounds using an electronic stethoscope, visualization, storage, analysis of digital recordings. Standardized auscultation and phonocardiogram (PCG) evaluation systems can help implement cost-effective screening programs [4, 5].

With the rapid development of signal processing techniques, computer auscultation can increase the accuracy of a specific cardiac diagnosis and reduce the number of unnecessary referrals for repeated echocardiographic examinations. A pilot study has been published to test the ability of e-auscultation followed by a computerized phonocardiogram evaluation algorithm to accurately differentiate physiological and pathological noises in children. Compared with echocardiography, the computer algorithm had a sensitivity of 87% and a specificity of 100%, a positive prognostic value of 100%, a negative prognostic value of 90% and an accuracy of 94% [4]. It is proved that the method of computerized auscultation can reach a high sensitivity of 100% and a specificity of 91.67% for the detection of PDA.

The aim of the study was to examine the data of computer analysis of phonocardiogram in full-term infants with different terms of ductus arteriosus closure.

Research methodology. A screening of 253 full-term infants was performed. Prenatal ultrasound examination of the fetus showed no signs of any structural abnormalities of the heart and large vessels. In the group of examined children were not identified any pathological changes during traditional auscultation, differentiated pulse oximetry. There were no signs of hemodynamic or respiratory disorders. The children had no signs of asphyxia at birth. They were staying with this mothers.

Electronic auscultation and Doppler echocardiography were performed during the first 4 days of life.

Newborns with signs of hemodynamically insignificant PDA at the time of examination (PDA with minor shunting) were selected to the observation group: duct diameter up to 1.4 mm/kg body weight; PDA to left branch of pulmonary artery (LPA) ratio <0.5; maximum blood flow velocity PDA >2 m/s; final diastolic blood flow velocity in the pulmonary artery and/or its left branch <0.2 m/s; diastolic flow in the postductal descending part of the aorta is unidirectional; the ratio of left atrium to aorta <1.5; antegrade diastolic blood flow in the anterior cerebral and superior mesenteric arteries [8]. Exclusion criteria - the presence of any other diagnosed congenital disease of heart or large blood vessels.

Electronic auscultation was performed with a Thinklabs (USA) ds32a+ digital stethoscope in the mode of maximum sound amplification and narrowed listening spectrum. The sound was recorded on a Sony-ICD-UX71 (Japan) digital voice recorder. The procedure was performed during sleep or in the absence of screaming or increased child movement. Auscultation was performed at 5 standard points. The duration of recording at each point was about 10-15 seconds to obtain 20-30 heart cycles. The analysis of the obtained phonocardiograms was performed using the developed computer program "Hearttone-D" and included the selection of stable fragments at recording points, filtering (separation from other sounds, such as respiratory sounds), automatic detection of heart sounds in fragments, calculation and evaluation of heart parameters cycles after identification of heart tones [8]. Doppler echocardiographic examination was performed immediately after auscultation on the device MyLab25Gold by Esaote (Italy) and Z.ONE.Ultra by ZONARE (USA).

The following parameters were analyzed: the ratio of the average values of all maxima of the first and second tones (s1_a_max / s2_a_max), the ratio of the maximum modulo values of the first and second tones (s1_ max_a / s2_max_a), the ratio of the width of the first and second tones (s1_width / s2_width ratio), the modulus of the amplitude of the interval between the first and second tone (s1_ a_max / m1_ mean), the maximum modulus of the first tone and the modulus of the amplitude of the interval between the first and second tone (s1_ max_a / m1_ mean), the ratio of the average value of the maxima of the second tone the second and first tone (s2_ a_max / m2_ mean), the maximum modulus of the second tone and the modulus of the amplitude of the interval between the second and first tone (s2_ max_a / m2_ mean).

The study was approved by the Commission on Biomedical Ethics of the State Institution "Dnipropetrovsk Medical Academy of the Ministry of Health of Ukraine".

Statistical data processing was performed using standard packages of applied statistical analysis Statistica for Windows v. 6.1. The Mann-Whitney statistical criteria for samples that does not correspond to normal distribution were used. The critical value of the significance level (p) <0.05 was selected for all types of analysis.

Results and discussion. Echocardiographic signs of hemodynamically insignificant DA were detected in 97 full-term newborns (47 boys and 50 girls; gestational age - 38.74 ± 0.04 weeks; birth weight 3357 ± 12 g).

Successive echocardiographic examination after at the age of three months revealed the preservation of PDA symptoms in 2 children, which was 2.1% among children with PDA in the first days of life and 0.79% among the general group of examined children.

Phonocardiogram parameters of the newborns received on the second day of life were analyzed (10 records of children with the PDA detected at the age of three months, and 140 records of children in whom PDA was not detected at the age of three months). The results are presented in the table 1.

Significant differences in auscultatory characteristics were found for the third (s1_ max_a/s2_max_a), the fourth (s1_a_max/s2_a_max, s1_a_max/m1_mean, s1_max_a/ s2_max_a) and the fifth standard auscultation points (s1_a_max/m1_mean, s1_max_a/ m1_mean, s1_max_a/s2_max_a).

The most significant differences were found in auscultatory features characterized by the ratios s1_a_max/s2_a_max, s1_a_max/m1_mean, s1_max_a/s2_max_a in fourth and s1_a_max/s1_mean, s1_max_a/m1_mean, s1_max_a/s2_max_a in the fifth standard auscultation points.

Therefore, the presented differences concerned the ratios of the average values of the maxima of the tones and the maxima modulo values of the first and second tones, and the ratios of the amplitudes of the tones and the modulo of the amplitudes of the intervals between the tones.

The most significant were the ratios of the average value of all maxima of the I tone to the average value of all maxima of the II tone s1_a_max/s2_a_max (p=0,0003) and the ratio of the maximum modulus value of the I tone to the maximum modulus value of the II tone s1_max_a/s2_max_a (p=0,0011) in the fourth auscultation point. This may be due to various acoustic phenomena of hemodynamics in the small circulation correlating with the future closure or non-closure of the ductus arteriosus.

Table 1

Indicators of electronic recordings of heart tones in full-term newborns with patent ductus arteriosus

Indicators	Groups of newborns with PDA						Significance according to Mann-Whitney U Test, p
	PDA closed (140 records)			PDA persisted after three months of age (10 records)			
	Average	Median	Standard deviation	Average	Median	Standard deviation	
The first point of auscultation							
s1_a_max/ s2_a_max	1.37	1.123	0.94	1.72	1.42	1.13	0.3553
s1_ a_max / m1_ mean	30.51	28.45	17.83	31.67	22.37	18.79	0.8734
s1_ max_a / m1_ mean	34.77	30.92	20.01	31.85	22.37	18.65	0.7021
s1_ max_a/ s2_max_a	1.39	1.28	0.88	1.67	1.42	1.10	0.4684
s2__a_max / m2_ mean	30.69	26.34	19.31	40.40	9.01	40.49	0.5501
S2_ max_a / m2_ mean	33.35	30.13	19.20	40.68	10.46	40.24	0.5395
s1_width/ s2_width	0.750	0.68	0.32	0.75	0.81	0.14	0.3003
The second point of auscultation							
s1_a_max/ s2_a_max	1.22	1.02	0.77	1.07	1.08	0.19	0.9675
s1_ a_max / m1_ mean	16.62	14.87	8.76	16.44	15.97	4.31	0.6252
s1_ max_a / m1_ mean	19.70	17.28	11.12	20.97	21.55	7.16	0.4063
s1_ max_a/ s2_max_a	1.22	1.02	0.80	1.13	1.12	0.22	0.7020
s2__a_max / m2_ mean	17.56	14.40	10.92	18.29	15.67	7.05	0.4017
S2_ max_a / m2_ mean	20.15	17.90	11.17	22.21	20.09	10.21	0.4249
s1_width/ s2_width	0.68	0.64	0.26	1.05	0.62	0.68	0.1792
The third point of auscultation							
s1_a_max/ s2_a_max	1.30	1.05	1.12	1.81	2.09	1.21	0.2301
s1_ a_max / m1_ mean	17.86	15.03	10.70	15.10	14.47	4.83	0.7417

s1_ max_a / m1_ mean	20.51	16.82	12.82	17.55	17.22	3.42	0.8356
s1_ max_a/ s2_max_a	1.19	0.92	0.96	1.62	1.79	0.84	**0.0494**
s2__a_max / m2_ mean	20.20	18.46	11.23	16.31	9.45	11.99	0.2430
s2_ max_a / m2_ mean	25.74	22.34	15.18	17.50	10.91	10.90	0.1099
s1_width/ s2_width	0.72	0.67	0.29	0.72	0.67	0.14	0.5969
The forth point of auscultation							
s1_a_max/ s2_a_max	1.09	0.96	0.72	1.87	1.80	0.67	**0.0003**
s1_ a_max / m1_ mean	33.91	28.28	23.91	49.80	45.59	22.39	**0.0233**
s1_ max_a / m1_ mean	35.91	30.37	23.91	49.80	45.59	22.39	0.0510
s1_ max_a/ s2_max_a	0.89	0.76	0.47	1.43	1.33	0.50	**0.0011**
s2__a_max / s2_ mean	38.22	36.80	20.19	26.98	24.90	6.54	0.0779
s2_ max_a / m2_ mean	49.41	43.90	26.81	35.69	31.70	10.16	0.1703
s1_width/ s2_width	0.66	0.64	0.16	0.65	0.66	0.11	0.8300
The fifth point of auscultation							
s1_a_max/ s2_a_max	1.32	1.06	0.82	1.69	1.95	0.64	0.0629
s1_ a_max / m1_ mean	32.51	28.10	21.66	45.25	47.75	8.26	**0.0111**
s1_ max_a / m1_ mean	36.19	34.54	22.32	45.39	47.75	8.48	**0.0389**
s1_ max_a/ s2_max_a	1.17	1.03	0.75	1.64	1.95	0.69	**0.0492**
s2__a_max / m2_ mean	29.25	24.06	19.09	32.11	24.53	12.12	0.2190
s2_ max_a / m2_ mean	37.33	30.64	24.83	34.64	24.53	15.46	0.9608
s1_width/ s2_width	0.80	0.69	0.50	0.63	0.63	0.07	0.2704

Conclusions. The study found that ductus arteriosus continued to function at three months of age in 2.1% of children with patent ductus arteriosus in the first days of life

(97 newborns) and 0.79% among the total group of examined children (253 newborns).

All patent ductus arteriosus in 97 neonates were hemodynamically insignificant and were not accompanied by any clinical signs, including not having any auscultatory features during traditional auscultation.

The use of computer heart auscultation with subsequent phonocardiogram analysis revealed differences in the ratio of indicators that characterize different acoustic phenomena of hemodynamics in newborns with patent ductus arteriosus in the first days after birth, depending on the prognosis of its closure.

The most significant were the ratios of the average value of all maxima of the I tone to the average value of all maxima of the II tone s1_a_max/s2_a_max (p=0,0003) and the ratio of the maximum modulus value of the I tone to the maximum modulus value of the II tone s1_max_a/s2_max_a (p=0,0011) in the fourth auscultation point. Most likely this is related to various acoustic phenomena of hemodynamics in the small circulation correlating with the future closure or non-closure of the ductus arteriosus.

The results show the benefits of use of the computer heart auscultation for screening and subsequent prognosis of patent ductus arteriosus, to limit the necessity of costly examination methods including Doppler echocardiography.

The use of the computer heart auscultation allows planing the individual management of a patient with patent ductus arteriosus immediately after discharge from the hospital.

The study protocol was approved by the Local Ethics Committee of an participating institution. The informed consent of the patient was obtained for conducting the studies.

No conflict of interest was declared by the authors.

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