https://www.sworldjournal.com/index.php/swj/article/view/swj06-02-052
DOI: 10.30888/2663-5712.2020-06-02-052

УДК 616.12 008.28 073:612.22 073.763.5 053.31

COMPUTER-AIDED AUSCULTATION OF HEMODYNAMIC DISORDERS IN PRETERM NEONATES

КОМП'ЮТЕРНА АУСКУЛЬТАЦІЯ ПРИ ГЕМОДИНАМІЧНИХ РОЗЛАДАХ У НЕДОНОШЕНИХ НОВОНАРОДЖЕНИХ

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Abstract. *The aim of this paper was to study the computer auscultation data of hemodynamic disorders in premature infants. 45 premature infants treated in the intensive care unit were examined. 30 children had hemodynamic disorders. A study of 5 key indicators of computer auscultation (characteristics of the tones and intervals between the first and the second tones). While comparing the data of computer auscultation in groups with hemodynamic disorders and without them, significant differences were found in the listening point in the corresponding characteristics of the first and second tone.*

Key words: *computer auscultation, hemodynamic disorders, premature infants*

Introduction.

Despite the use of modern imaging techniques, the clinical use of cardiac auscultation does not lose its diagnostic potential. The availability of innovative methods of sound recording using phono- and spectrograms provides important assistance in diagnosis. Computer heart auscultation (computer/automatic analysis of the phonocardiogram) includes recording of heart sounds using an electronic stethoscope, and visualization, storage, detection of auscultatory symptoms based on the analysis of digitally recorded heart sounds. Compared to traditional auscultation, automatic phonocardiogram analysis can give more accurate and objective results. Standardized auscultation and phonocardiogram evaluation systems can help implement cost-effective screening programs [1-3, 6, 7].

A prospective pilot observational study of newborns with gestational age of 36 ± 3 weeks analyzed the sensitivity and specificity of traditional heart murmur auscultation and computer phonocardiogram analysis. The sensitivity and specificity of the pediatric auscultation were 17% and 100%, respectively. Compared to the traditional auscultation, the sensitivity and specificity of the computer analysis of the phonocardiogram were 70% and 83%, respectively [5].

The results of the spectral analysis of the frequency of the heart sounds recorded with a digital stethoscope are different in children with and without pulmonary hypertension [4]. The connection between the amplitude of the first heart tone (S1) and myocardial contractility is proved. The use of indicators of the ratio of the amplitude of the first heart tone S1 to the amplitude of the second tone S2 (S1/S2) and the ratio of the duration of the periods of the cardiac cycle is proposed. It is proved that these indicators can be used to display the relationship between cardiac contractility and peripheral resistance, to assess the relative load of the left and right ventricles [11-13]. Studies by X. Yang and W. Zeng (2010, 2011) show that the ratios of electronic phonocardiogram parameters differ in children of different gestational ages and can be used to measure and assess cardiac reserve in newborns (normal range limits can be used for screening newborns who need additional counseling) [14,15].

The aim of the study was to investigate the data of computer analysis of the phonocardiogram in hemodynamic disorders in premature infants.

Materials and methods of research.

An examination of 45 premature infants (44.4% of boys and 55.6% of girls) who were in the neonatal intensive care unit was conducted.

At the time of the initial examination, 40 (89%) newborns had echocardiographic signs of an open ductus arteriosus that did not exceed the criteria for hemodynamic insignificance (patent ductus arteriosus (PDA) with minor shunting). 5 infants (11%) had signs of hemodynamically significant arterial duct with moderate shunting [9, 10]. The children were transferred to the intensive care unit due to the need for respiratory support.

Exclusion criteria - the presence of any other diagnosed congenital heart disease and large vessels other than the open ductus arteriosus.

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

1081 PCG indicators were obtained at five auscultaion points as a result of 65 PCG recordings (10 children were screened twice, 4 children screened three times, and 1 child screened four times). The first recordings were made at the age of 7.44 ± 1.32 days (median - 5.0 days). The ratios of the average values of all maxima of the first and second tones (s1_a_max/s2_a_max), the energy of the first and second tones (s1_energy/s2_energy), the ratio of the width of the first and second tones (s1_width/s2_width), the ratio of energy to the ratio of energy first and second tones (s1_energy / m1 energy), the ratio of the energy of the second tone and the total weighted energy in the interval between the second and first tones (s2_energy / m2_energy) were analyzed.

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

Informed parental consent was obtained prior to the study.

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 with a distribution that does not correspond to normal were used . For all types of analysis, the critical value of the significance level (p) was assumed to be <0.05.

Results and discussion.

Gestational age at birth of the examined children was 29.46 ± 0.31 weeks (median - 29.0 weeks, mode - 29.0 weeks, min-max 26.0-36.0 weeks). Birth weight 1274±60 g (median - 1230 g, mode - 1100 g, min-max 470-2600 g). 21 children (46.7%) were born by cesarean section. The score on the Apgar scale was 3.43 ± 0.18 in the first minute (median - 4, mode - 4, min-max 1-6) and in the fifth minute 4.43 ± 0.16 (median - 5, mode) - 5, min-max 2-7).

27 (60%) newborns required mechanical lung ventilation, 10 (22.2%), 8 (17.8%) infants received short-term oxygen therapy: CPAP or non-invasive mechanical ventilation.

During the examination in 35 cases of electronic auscultation of the heart, the children were hemodynamically stable (at the time of the examination and for the next 24 hours). In the other 30 cases, children showed signs of hemodynamic instability (any of the following: appointment of inotropes at the time of examination or the need for their appointment or increase their dose in the next 24 hours of observation, clinical or Doppler echocardiographic signs of increased hemodynamic significance of the PDA within 24 hours observation). At the time of the examination, the indicators of myocardial contractile function, cardiac output, mean and systolic pressure in the pulmonary arteries were within the age norm.

The indicators of electronic recordings of heart sounds in these groups are compared in the table below.

Significant differences in the measured indicators were registered in all auscultation points, except for the first one. The maximum number of differences was observed in the fourth point.

When comparing groups of preterm infants with hemodynamic disorders and without them, significant differences are primarily observed in the parameters that characterize the ratio of the characteristics of the first and second tones.

Most often, the differences were related to such an indicator as the ratio of the width of the first and second tones (in the second, fourth and fifth point). In the second point (aortic point) there was a relative predominance of the width of the first tone in children with hemodynamic disorders, and in the fourth (tricuspid valve point) and fifth point - there was a relative predominance of the width of the second tone.

Significant differences in the ratio of the mean values of all maxima of the first and second tones in children with hemodynamically stable and hemodynamic disorders were for the second and third (pulmonary artery point) auscultation points. This could be described as the relative predominance of first-tone maxima in children with hemodynamic disorders. The ratio of the energy of the first and second tones at the fourth listening point also indicated a relative predominance of the energy of the first tone.

Table

Indicators of electronic recording of heart tones in premature infants

Indicators	Groups of premature newborns						Reliability of differences according to Mann-Whitney U Test, p
	Without hemodynamic disorders (131 dimensions)			With hemodynamic disorders (118 measurements)			
	Average	Median	The standard deviation	Average	Median	The standard deviation	
The first auscultation point							
s1_a_max/s2_a_max	2,362	2,081	1,80	2,269	2,161	1,464	0,8629
s1_energy/s2_energy	8,041	4,154	11,29	7,969	5,445	8,264	0,7458
s1_width/s2_width	2,056	1,933	0,80	2,192	2,057	0,954	0,3152
s1_energy/m1_energy	0,093	0,049	0,11	0,072	0,059	0,065	0,6418
s2_energy/m2_energy	0,011	0,007	0,01	0,010	0,006	0,012	0,5861
The second auscultation point							
s1_a_max/s2_a_max	1,423	1,327	0,940	1,931	1,481	1,248	**0,0086**
s1_energy/s2_energy	4,863	3,061	6,477	6,494	3,494	7,524	0,1071
s1_width/s2_width	1,851	1,850	0,848	2,148	2,128	0,919	**0,0136**
s1_energy/m1_energy	0,034	0,019	0,042	0,031	0,019	0,037	0,5339
s2_energy/m2_energy	0,013	0,004	0,020	0,007	0,004	0,008	0,4824
The third auscultation point							
s1_a_max/s2_a_max	1,555	1,209	1,199	1,827	1,399	1,203	**0,0238**
s1_energy/s2_energy	4,736	1,918	6,350	4,369	2,422	5,076	0,3457
s1_width/s2_width	1,993	1,933	0,896	1,930	1,713	0,885	0,3754
s1_energy/m1_energy	0,040	0,018	0,053	0,029	0,019	0,032	0,6259
s2_energy/m2_energy	0,012	0,006	0,013	0,009	0,006	0,010	0,3916
The forth auscultation point							
s1_a_max/s2_a_max	2,031	1,996	1,115	1,903	1,653	1,745	0,0531
s1_energy/s2_energy	5,135	3,114	4,770	5,497	2,109	11,672	**0,0140**
s1_width/s2_width	2,062	2,091	0,817	1,861	1,815	0,768	**0,0370**
s1_energy/m1_energy	0,103	0,050	0,158	0,088	0,058	0,112	0,5539
s2_energy/m2_energy	0,015	0,008	0,020	0,031	0,018	0,038	**0,0000**
The fifth auscultation point							
s1_a_max/s2_a_max	2,434	1,910	2,06	1,874	1,801	1,102	0,1127
s1_energy/s2_energy	8,516	4,393	14,01	5,271	2,965	6,579	0,0843
s1_width/s2_width	2,177	2,143	1,01	1,906	1,795	0,885	**0,0081**
s1_energy/m1_energy	0,113	0,073	0,16	0,099	0,028	0,224	**0,0026**
s2_energy/m2_energy	0,015	0,008	0,02	0,022	0,012	0,026	0,0871

The fourth auscultation point was characterized by the greatest significance of the difference between the ratio of the energy of the second tone and the total weighted energy in the interval between the second and first tones, namely the relative predominance of second tone energy in children with hemodynamic disorders.

The fifth auscultation point was characterized by differences in the ratio of the energy of the first tone and the total weighted energy in the interval between the first and second tones, namely the relative predominance of the energy of the first tone in children without hemodynamic disorders.

Thus, when comparing groups of preterm infants with and without hemodynamic disorders, significant differences primarily concerned those parameters that could characterize changes in hemodynamics in the small circulation.

Conclusions.

The indicators of computer-assisted heart auscultation in premature infants were compared between the groups that were considered hemodynamically stable or which had hemodynamic disturbances at the time of examination (the ratio of the mean values of all maxima of the first and second tones, energy of the first and second tones, the ratio of the width of the first and second tones and the total weighted energy between the first and second tones, the ratio of the energy of the second tone and the total weighted energy between the second and first tones). Significant differences were primerely noted in the parameters that characterize the ratio of the characteristics of the first and second tones. Significant differences in the measured indicators were registered at all auscultation points, except for the first one. The maximum quantity of differences was related to the fourth point.

Significant differences were found in the ratio of parameters that could characterize changes in hemodynamics in the small circle of blood circulation.

Prospects for further research are the need to develop an algorithm for using the parameters of computer analysis of the phonocardiogram, which will greatly simplify the screening diagnosis of hemodynamic disorders in premature infants.

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Анотація. *Метою роботи було вивчення даних комп'ютерної аускультації при порушеннях гемодинаміки у недоношених дітей. Обстежено 45 недоношених немовлят, які проходили лікування у відділенні інтенсивної терапії. 30 дітей мали гемодинамічні розлади. Проведено вивчення 5 ключових показників комп'ютерної аускультації (характеристики тонів та інтервалів між першим та другим тонами). Порівнюючи дані комп'ютерної аускультації в групах із порушеннями гемодинаміки та без них, були виявлені значні відмінності у точках прослуховування у співвідношенні характеристик першого і другого тонів*

Ключові слова: *комп'ютерна аускультація, гемодинамічні розлади, недоношені новонароджені*

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Статья отправлена: 01.01.2021 г.