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Comparison of Non-invasive Methods – Impedance Cardiography and 2-dimentional Transthoracic Echocardiography Applied for Diagnostics of Pulmonary Artery Hypertension

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Introduction

Pulmonary arterial hypertension (PAH) is defined as increase of blood pressure in the pulmonary blood vessels, which leads to progress the pulmonary vascular resistance for various reasons, accompanied by right heart failure, ending lethal resort. For example, in the case of primary pulmonary hypertension without treatment the median survival time is about 2.8 years [1]. PAH is not rare pathology, met the doctor at his clinical practice. Over the past ten years in the world a lot of research and clinical studies in field analysis of pathogenesis of PAH, the diagnostic and treatment issues are performed. In clinical practice most frequently the pulmonary arterial blood pressure is measured by using 2-dimensional cardioechoscopy (2DECHO) and heart catheterization methods. It is necessary to emphasize that heart catheterization is invasive, costly investigation, and for detection of PAH is used only in exceptional cases. Wider use of 2DECHO in the investigation is hampered by gap of cardioechoscopes and specialists of cardioechoscopy, especially in smaller Lithuanian medical institutions. These circumstances promote the search for cheaper, easily carried out, non-invasive, and none worse than cardio-echoscopy test method for evaluation of pulmonary hypertension. One of such methods could be impedance cardiography (ICG). ICG is a safe, noninvasive, cheap, usually performed without special preparation of personnel diagnostic method, based on determination of chest impedance changes during cardiac systole and diastole. From simultaneous registered ICG and electrocardiogram (ECG) the various indicators of heart hemodynamics, such as systolic volume, cardiac output, systemic resistance, cardiac index, mean arterial pressure, etc. are calculated [2,3]. Comparison of central hemodynamics parameters, evaluated by ICG and other methods used in clinical practice revealed the high degree of correlation, r = 0.64–0.96 [3,4]. However, the programs for measurement of pressure in pulmonary blood vessels and diagnose of PAH are not included into software of contemporary ICG computer analysis systems.

This work aimed to evaluate the diagnostic effectiveness of impedance cardiogram method for finding of pulmonary hypertension, search the additional ICG parameters and touch points of those parameters with 2-dimentional transthoracic echocardiography used in medical practice for patients with cardiovascular and pulmonary diseases.

Methods and study population

On purpose to compare impedance cardiography and cardioechoscopy methods, it was decided to include into study all such patients for those pulmonary hypertension is usually diagnosed, i.e. patients with lung diseases or patients with such cardiologic pathology which may lead to pulmonary hypertension. In order to form more similar testing and control groups, for example, with regard to age, the healthy persons were not included into control set of investigation. After clinical and instrumental examination, the patients were divided into following groups of subjects:

1 Group PP – 19 patients with clinically and cardioechoscopicaly diagnosed pulmonary artery hypertension, conditioned by pulmonary pathology, for example, diseases of lung parenchyma, chronic obstructive pulmonary disease (ChOPD), bronchial asthma, interstitial pulmonary diseases and/or thromboembolism of pulmonary artery.

2 Group KK – 80 patients with clinically and cardioechoscopicaly diagnosed pulmonary artery hypertension, conditioned by cardiovascular pathology, for

example, pathology of mitral and aorta valves, chronic dysfunction of left ventricle, arterial hypertension.

3 Group P – 13 control group, patients with pulmonary pathology, for example, diseases of lung parenchyma, chronic obstructive pulmonary disease (ChOPD), bronchial asthma, interstitial pulmonary diseases and/or thromboembolism of pulmonary artery and clinically and cardioechoscopicaly excluded diagnosis of pulmonary artery hypertension.

4 Group K – 69 control group, patients with cardiovascular pathology, for example, pathology of mitral and aorta valves, chronic dysfunction of left ventricle, arterial hypertension and clinically and cardioechoscopicaly excluded diagnosis of pulmonary artery hypertension.

In this study the tetra-polar impedance cardiogram (ICG) recording (according to Kubicek) was used [5]. Two pairs of conductive belts are applied: one pair is set on the neck and another – on the bottom of the thorax. Recording and analysis of ICG was realized by using computer analysis system of polycardiosignals, developed in the Institute of Cardiology of Kaunas University of Medicine (Fig. 1).

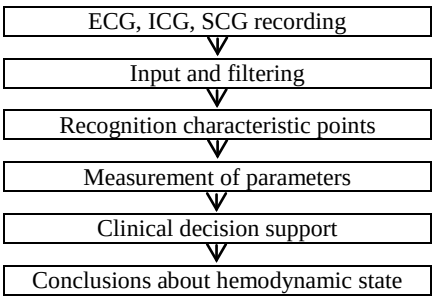

Fig. 1. Architecture of policardiosignal analysis system

The system consists of hardware and software, containing the package of algorithms and programs for analysis of cardiosignals [6–8]. System's software permits to analyse cardiac signals by using linear methods [9, 10], as well as non-linear methods based on complex system theory [11–13]. System's hardware contains portable computer, 15 channels microprocessor recorder of signals and sensors, designed for recording 12 lead ECG, ICG and seismocardiogram (SCG) (Fig. 2). SCG is recorded by using piezoelectric sensor, reflects the mechanical activity of the heart, such as opening and closing valves, filling and ejection blood in ventricles. The synchronous recording and analysis ICG and SCG create possibilities for more accurate recognition the characteristic points on ICG and precise measurement of time intervals, important for diagnostics of pulmonary artery hypertension – such as pre-ejection period and left ventricular ejection time. The software of system contains the programs for recognition characteristic points, measurement of parameters – amplitudes and intervals of ICG, as well as programs for evaluation from ICG the hemodynamic characteristics.

Assessment of systolic blood pressure in pulmonary artery (SPPAICG), diastolic (DPPAICG) and mean blood pressure in pulmonary artery (MPPAICG) was performed by using modified Burstin's equations (1-3):

$$SPPAICG = 702 \times PEP - 52{,}8, \quad (1)$$

$$DPPAICG = 345 \times PEP - 26{,}7, \quad (2)$$

$$MPPAICG = (SPPAICG - DPPAICG)/3 + DPPAICG, \quad (3)$$

where *SPPAICG* – systolic; *DPPAICG* – diastolic; *MPPAICG* – mean pressure in pulmonary artery, evaluated by ICG method; *PEP* – pre-ejection period in milliseconds.

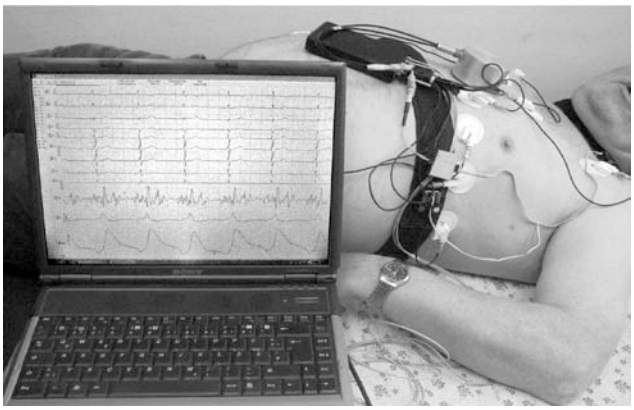

Fig. 2. Common view of system for recording ECG, ICG and SCG

Statistical analysis was performed by using SSPS (Statistical Package for the Social Science 15.0 for Windows) and MS Excel 2007. The descriptive statistics used mean, standard deviation, confidence interval for mean. Kolmogorov-Smirnov and Shapiro-Wilk tests were performed in order to assess the normality of distribution. The differences between two independent variables were analyzed by using Mann-Whitney U test. The relation between investigated variables was estimated by using the Spearman correlation coefficient, Contingency coefficient or linear regression analysis. The suitability of the linear regression model was evaluated with coefficient of determination R^2 that shows which part of dependent variable dispersion is influenced by linear combination of influencing factor. Specificity and sensitivity of impedance cardiography for detection of pulmonary artery hypertension have been calculated.

Results

For all 181 investigated patients a cardioechoscopy (2DECHO) was performed, and systolic blood pressure in pulmonary artery (SPPA), mean blood pressure in pulmonary artery (MPPA) have been measured. As a result of impedance cardiogram (ICG) analysis were measurements of systolic blood pressure in pulmonary artery (SPPAICG) and mean blood pressure in pulmonary artery (MPPAICG). Evaluation of presented data in investigated groups permits to state, that measured mean values of systolic and mean blood pressure in pulmonary artery by 2DECHO and ICG methods correspond to pulmonary hypertension diagnosis which is fixed when MPPA, MPPAICG > 25 mmHg or SPPA, SPPAICG > 30mmHg. The confidence intervals of means of investigated parameters did not exceed ± 2–3 mmHg, and really this value has no any influence to diagnostics of pulmonary artery hypertension in medicine practice. The statistically significant differences ($p<0.001$) between data

of coupled patients groups with pulmonary hypertension (PP and KK) and without pulmonary hypertension (P and K) have been obtained. The same statistically significant differences ($p<0.001$) obtained when values of MPPA (determined by 2DECHO method) between KK and K groups, between PP and P groups, as well as MPPAICG values (determined by ICG method) between KK and K groups, between PP and P groups have been compared. Analogical results obtained for SPPA and SPPAICG (Table 1). After assessment of obtained results it could be possible to state that values of systolic or mean blood pressure in pulmonary artery evaluated by cardioechoscopy – SPPA, MPPA and by impedance cardiogram – SPPAICG, MPPAICG have strong and statistically significant correlation – Spearman coefficient of correlation between MPPA and MPPAICG was $r = 0.755$, $p<0.001$ and Spearman coefficient of correlation between SPPA and SPPAICG was $r = 0.893$, $p<0.001$. In Figures 3, 4 the regression equations as a summarized result of correlation and regression analysis are presented.

Table 1. Results of evaluation of pulmonary pressure differences between study groups by using Mann-Whitney U test

Variable	Groups	Method	Mann-Whitney U test
MPPA	KK and K	2DECHO	$p < 0.001$
	PP and P	2DECHO	$p < 0.001$
MPPAICG	KK and K	ICG	$p < 0.001$
	PP and P	ICG	$p < 0.001$
SPPA	KK and K	2DECHO	$p < 0.001$
	PP and P	2DECHO	$p < 0.001$
SPPAICG	KK and K	ICG	$p < 0.001$
	PP and P	ICG	$p < 0.001$

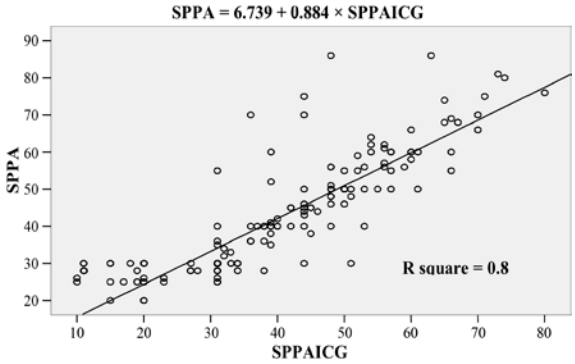

Fig. 3. Correlation of SPPA and SPPAICG data and unvaried regression equation

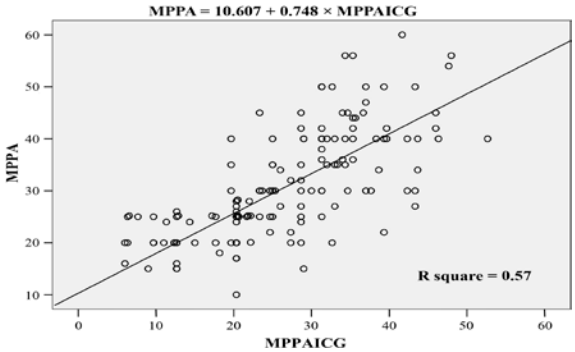

Fig. 4. Correlation of MPPA and MPPAICG data and unvaried regression equation

Specificity and sensitivity of impedance cardiogram for detection of pulmonary artery hypertension were assessed, and such values were obtained: the mean blood pressure in pulmonary artery measured with sensitivity of 72 % and specificity – 90 %; the systolic blood pressure in pulmonary artery measured with sensitivity of 96 % and specificity – 90 %.

Conclusions

Assessed by computerized impedance cardiogram the mean and systolic blood pressure in pulmonary artery is diagnostically valuable parameters. Impedance cardiography is sensitive and specific method in diagnostics of pulmonary artery hypertension: the pulmonary artery hypertension was diagnosed by computed mean blood pressure in pulmonary with sensitivity of 72 %, specificity – 90 %, and by systolic blood pressure in pulmonary artery – with sensitivity of 96 %, specificity – 90%. The impedance cardiography is statistically trusted method and it strongly and significantly correlates with cardioechoscopy method when separating patients with or without pulmonary artery hypertension: the values of mean blood pressure obtained by impedance cardiography and cardioechoscopy correlate in level of $r = 0.755$, $p<0.001$, and values of systolic blood pressure – in level of $r = 0.893$, $p<0.001$. For diagnostics of pulmonary artery hypertension by impedance cardiography method preferable using of systolic pressure. Assessment of received results permits to suppose that ICG method performs the measurement of SPPA and MPPA with ample efficacy, as compared with such of basic 2DECHO method, and ICG method could be used in detecting patients with pulmonary hypertension.

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By using an original policardiosignal analysis system developed in the Kaunas Institute of Cardiology, the method based on impedance cardiography for evaluation of blood pressure in pulmonary artery is presented. This method was tested by using data of 181 patients with various cardiac and pulmonary diseases, and for all of them two-dimentional transtoracic cardioechoscopy was performed in aim to confirm or exclude pulmonary artery hypertension Impedance cardiography is sensitive and specific method in diagnostics of pulmonary artery hypertension: the pulmonary artery hypertension was diagnosed by computed mean blood pressure in pulmonary with sensitivity of 72%, specificity – 90 %, and by systolic blood pressure in pulmonary artery – with sensitivity of 96 %, specificity – 90 %. The impedance cardiography is statistically trusted method and it strongly and significantly correlates with cardioechoscopy method when separating patients with or without pulmonary artery hypertension: the values of mean blood pressure obtained by impedance cardiogram and cardioechoscopy correlate in level of $r = 0.755$, $p<0.001$, and values of systolic blood pressure – in level of $r = 0.893$, $p<0.001$. These results permit to assume, that impedance cardiography, as non-invasive, inexpensive and user-friendliness method could be used for blood pressure evaluation in aim to detect the hypertension of pulmonary artery. Ill. 4, bibl. 13, tabl. 1 (in English; abstracts in English and Lithuanian).

S. Sadauskas, A. Naudžiūnas, A. Unikauskas, L. Gargasas, R. Ruseckas, V. Jurkonis, R. Jurkonienė. Plaučių arterijos hipertenzijos neinvazinių dvimatės echokardiografijos ir impedanskardiografijos diagnostinių metodų palyginimas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 9(105). – P. 105–108.

Naudojant originalią Kauno kardiologijos institute sukurtą polikardiosignalų analizės sistemą, sukurtas impedanso kardiografija besiremiantis metodas kraujo spaudimui plaučių arterijoje nustatyti. Testuota analizuojant 181 įvairiomis plaučių ir širdies ligomis sergančio paciento, kuriems dvimatės transtorakalinės echoskopijos metodu buvo patvirtinta ar atmesta plaučių arterijos hipertenzija, duomenis. Tyrimo metu nustatyta, kad impedanskardiografijos metodu išmatuoti vidutinio ir sistolinio kraujo spaudimo plaučių arterijoje parametrai padeda diagnozuoti plaučių arterijos hipertenziją: nustatant hipertenziją pagal vidutinį kraujo spaudimą plaučių arterijoje jautrumas buvo 72 proc., specifiškumas – 90 proc., pagal sistolinį kraujo spaudimą plaučių arterijoje jautrumas buvo 96 proc., specifiškumas – 90 proc. Impedanskardiografijos metodas gerai koreliuoja su kardioechoskopijos metodu atskiriant plaučių arterijos hipertenzija sergančius ir ja nesergančius asmenis – pagal vidutinį spaudimą plaučių arterijoje ($r= 0,755$, $p<0,001$) ir sistolinį spaudimą plaučių arterijoje ($r = 0,893$, $p<0,001$). Tai leidžia daryti prielaidą, jog impedanso kardiografija, kaip neinvazinis, nebrangus ir paprastas naudoti metodas, gali būti taikomas kraujo spaudimo vertinti diagnozuojant plaučių arterijos hipertenziją. Il. 4, bibl. 13, lent. 1 (anglų kalba; santraukos anglų ir lietuvių k.).