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Evaluation of Systolic and Mean Pressure in Pulmonary Artery by using Impedance Cardiography Method

S. Sadauskas, A. Naudžiūnas
Clinic of Internal Diseases, Kaunas University of Medicine, Josvainių str. 2, LT-47144 Kaunas, Lithuania
L. Gargasas, R. Ruseckas, R. Jurkonienė
Institute of Cardiology, Kaunas University of Medicine,
Sukilėlių av. 17, LT-50009 Kaunas, Lithuania, tel. +370 37 302881, e-mail: liugar@kmu.lt

Introduction

The pulmonary artery hypertension (PAH) is pathology, which more and more often is met in practice of cardiologist, internist or family doctor, and for this reason in last decade many the world over investigations and clinical studies in field of PAH pathogenesis, diagnostics and treatment have been made. Conventionally the diagnosis of PAH is stated, when mean pressure in pulmonary artery (MPPA) exceeds 25 mmHg at rest and 30 mmHg – during physical load. PAH is also determined by systolic pressure in pulmonary artery (SPPA), which in normal state is equal to 28±5 mmHg, and in light form of PAH the SPPA exceeds 30-40 mmHg and in heavy form – more than 70 mmHg. In clinical practice for measurement of SPPA two main methods – heart catheterization and two-dimentional transtoracal cardioechoscopy (2DECHO) are commonly used, and a high degree of correlation between these methods (r=0,57-0,93) have been evaluated during clinical trials [1]. It must be stressed, that heart catheterization is invasive and expensive method, and only in exclusive cases is used for SPPA measurement. More wide using of 2DECHO is obstructed by lack of echoscopic devices and specialists of cardioechoscopy. The said circumstances force to search for less expensive, easy to perform, noninvasive method, which performs the measurement of SPPA and MPPA with the same accuracy as 2DECHO method. One of such methods could be impedance cardiography (ICG), which is based on assessment of thorax impedance changes during systole and diastole of the heart. From synchronously recorded ICG and ECG the various hemodynamic parameters could be estimated: systolic volume, cardiac volume, index of peripheral resistence, index of contractility and others [2,3,4,5]. The history of ICG employment started in 1966 when W. G. Kubicek and co-workers developed first impedance cardiograph and proposed method for assessment of systolic volume from thoracic impedance [6]. Later the various methods of ICG recording (Kubicek 4 belts, Penney 4 electrodes, Bernstein 8 electrodes, Woljer 9 electrodes) and equations for calculation of hemodynamic parameters have been developed [7,8].

The aim of the study was to develop the method for measurement of mean and systolic pressure in pulmonary artery and compare its testing data with such obtained by using two-dimentional transtoracal cardioechoscopy.

Methods and study population

In this study the method of tetra-polar ICG recording (according to Kubicek [6]) was used. Two pairs of conductive belts are applied: one pair is set on the neck and another – on the bottom of the thorax. One belt from each pair is used for passing low voltage and high frequency (50kHz) current and last one – for voltage recording. The three lead ECG system (system deploys five electrodes: 1 – upper part of mid-line sternum, 2 – bottom part of id-line sternum, 3 – left mid axillary line, 4 – right mid axillary line, and 5 – ground) was also synchronously recorded and analysed by using ECG computer analysis system "Kaunas". The software for ICG recognition, measurement and interpretation of parameters was developed and inserted into analysis system "Kaunas" [9]. For assessment the systolic (SPPA), diastolic (DPPA) and mean (MPPA) pressure in pulmonary artery the pre-ejection period (PEP) was measured in ICG (Fig. 1).

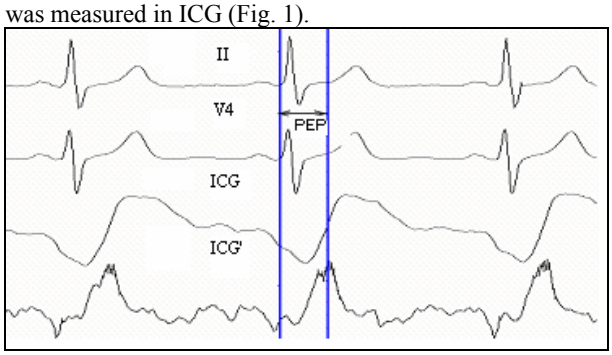

Fig. 1. Sample of ECG and ICG records: II and V_4 – ECG leads; ICG – impedance cardiogram; ICG^I – derivative of ICG; PEP - pre-ejection period

Assessment of SPPA, DPPA and MPPA was performed by using modified Burstin's equations [10,11]: *SPPA = 702 x PEP – 52,8; DPPA= 345,4 x PEP – 26,7; MPPA= (SPPA - DPPA) / 3 + DPPA,* where *SPPA* – systolic, *DPPA* – diastolic, *MPPA* – mean pressure in pulmonary artery, *PEP* – pre-ejection period in milliseconds.

The study population consisted of 109 investigated patients, witch were distributed to four groups:

1 group - 41 patient with clinically and 2DECHO confirmed hypertension of pulmonary artery (PAH), conditioned by cardiac pathology (pathology of mitral valve, chronic disfunction of left ventricle, occlusion of pulmonary veins, congenital and congestive defects of the heart);

2 group (control I)- 33 patients with diseases the same as in first group, but without PAH (excluded clinically and 2DECHO);

3 group - 20 patients with clinically and 2DECHO confirmed PAH, conditioned by pulmonary pathology (lung tumours, chronic obstructive pulmonary disease, bronchial asthma), thrombosis of leg veins;

4 group (control II) - 15 patients with diseases the same as in third group, but without PAH (excluded clinically and 2DECHO).

Data of the study were processed by using STATISTICA-5 and SPSS-12(Statistical Package of Social Science) software. Kolmogorov-Smirnov goodness-of-fit test was performed in order to assess the normality of distribution. As tested groups were small and not all variables in four groups were distributed normally nonparametric tests were used. Mann-Whitney test for independent samples was used to detect the true differences between SPPA and MPPA, measured for investigated patients with and without PAH. In aim to compare the variables SPPA and MPPA, twice measured by two different methods - 2DECHO (labeled as SPPA2DECHO and MPPA2DECHO) and ICG (labeled as SPPAICG and MPPAICG) the Wilcoxon test was used. Correlation analysis was performed by using Spearman coefficient of rank correlation in aim to assess the match between two methods - ICG and 2DECHO.

Results and discussion

The main results of study are presented in Table 1.

Table 1. Detection of hypertension in pulmonary artery (HPA) by measuring systolic (SPPA) and mean (MPPA) blood pressure in pulmonary artery by two methods – impedance cardiogram (ICG) and cardioechoscopy (2DECHO)

Patients' group (n)	Applied method	Wilcoxon's criterion	Mann-Whitney's criterion	Spearman's coefficient
1 group (41) Cardiac diseases with HPA	SPPA by 2DECHO MPPA by 2DECHO	p=0.83 SPPA p=0.505 MPPA	SPPA by 2DECHO p=0,0001 MPPA by 2DECHO p=0,0001 SPPA by ICG p=0,0001 MPPA by ICG p=0,0001	SPPA r=0.6, p=0.0001 MPPA r=0.351, p=0.025
	SPPA by ICG MPPA by ICG			
2 group (control I) (33) Cardiac diseases without HPA	SPPA by 2DECHO MPPA by 2DECHO	p=0.0001 SPPA p=0.986 MPPA		SPPA r=0.61, p=0.0001 MPPA r=-0.89, p=0.622
	SPPA by ICG MPPA by ICG			
3 group (20) Pulmonary diseases with HPA	SPPA by 2DECHO MPPA by 2DECHO	p=0.02 SPPA p=0.008 MPPA		SPPA r=0.432, p=0.057 MPPA r=0.482, p=0.031
	SPPA by ICG MPPA by ICG			
4 group (control II) (15) Pulmonary diseases without HPA	SPPA by 2DECHO MPPA by 2DECHO	p=0.191 SPPA p=0.074 MPPA		SPPA r=0.414, p=0.125 MPPA r=-0.093, p=0.742
	SPPA by ICG MPPA by ICG			
All four groups (109)	SPPA by 2DECHO MPPA by 2DECHO	p=0.915 SPPA p=0.017 MPPA		SPPA r=0.836, p=0.0001 MPPA r=0.585, p=0.0001
	SPPA by ICG MPPA by ICG			

For all 109 patients the SPPA and MPPA was measured by two methods - ICG and 2DECHO. In this study two relationships, expressed via equations (Fig. 2 and 3) for predicting typical values of SPPA (detected by 2DECHO) for given value of SPPA (detected by ICG) and for predicting typical values of MPPA (detected by 2DECHO) for given value of MPPA (detected by ICG) have been established. To assess the variables SPPA which were measured by two methods - 2DECHO and ICG for the same patients Wilcoxon test was used. Derived results: in 1 group there was no significant difference (p=0,83); in 2 group the difference was especially significant (p=0,0001);

in 3 group the difference was significant (p=0,02); in 4 group there was no significant difference (p=0,191); in all groups there was no significant difference (p=0,915). Mann-Whitney's test was used to compare the data of cardiologic patients (1 and 2 groups) and pulmonary patients (3 and 4 groups) inside the groups. Derived results: there were especially significant differences for SPPA (assessed by 2DECHO, p=0,0001) and SPPA (assessed by ICG, p=0,0001) of cardiologic patients; for SPPA (assessed by 2DECHO, p=0,0001) and SPPA (assessed by ICG, p=0,0001) of pulmonary patients.

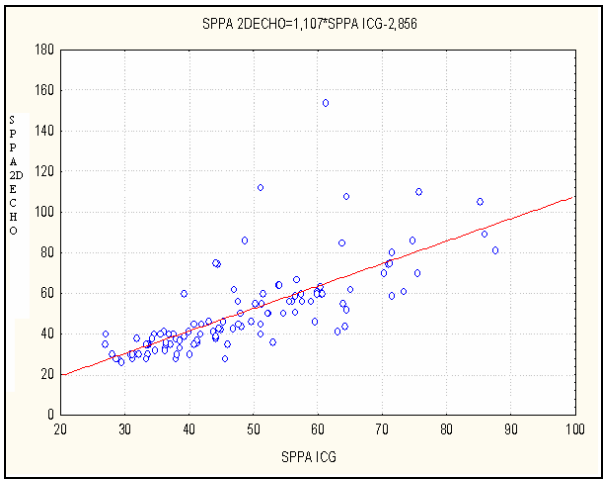

Fig. 2. A line of best fit for SPPAICG expectancy versus SPPA2DECHO, where SPPAICG – systolic pressure in pulmonary artery measured by impedance cardiogram and SPPA2DECHO - systolic pressure in pulmonary artery measured by two-dimentional transtoracal cardioechoscopy

Fig. 3. A line of best fit for MPPAICG expectancy versus MPPA2DECHO, where MPPAICG – mean pressure in pulmonary artery measured by impedance cardiogram and MPPA2DECHO - mean pressure in pulmonary artery measured by two-dimentional transtoracal cardioechoscopy

Correlation analysis was performed using Spearman's coefficient of rank correlation in aim to assess the match between methods ICG and 2DECHO for SPPA. Derived results: in 1 group the correlation coefficient r=0,6 was especially significant at the level of p=0,0001; in 2 group the correlation coefficient r=0,61 was especially significant at the level of p=0,0001; in 3 group the correlation coefficient r=0,432 was significant at the level of p=0,0057; in 4 group there was no significant coefficient of correlation (r=0,414, p=0,125); in all groups there was especially significant coefficient of correlation (r=0,836, p=0,0001).

In aim to assess the variables MPPA, which were measured by two methods - 2DECHO and ICG for the same patients the Wilcoxon's test was used. Derived results: in 1 group there was no significant difference between methods (p=0,505); in 2 group there was no significant difference (p=0,986); in 3 group the difference was significant (p=0,008); in 4 group there was no significant difference (p=0,074); in all groups there was significant difference (p=0,017).

Mann-Whitney test was used to compare the data of cardiologic patients (1 and 2 groups) and pulmonary patients (3 and 4 groups) inside the groups. Derived results: there were especially significant differences for MPPA (assessed by 2DECHO, p=0,0001) and MPPA (assessed by ICG, p=0,0001) for cardiologic patients, as well as for MPPA (assessed by 2DECHO, p=0,0001) and MPPA (assessed by ICG, p=0,0001) for pulmonary patients.

Correlation analysis was performed using Spearman coefficient of rank correlation in aim to assess the match between methods ICG and 2DECHO for MPPA. Derived results: in 1 group the correlation coefficient r=0,351 was significant at the level of p=0,025; in 2 group the correlation coefficient r=-0,89 was not significant at the level of p=0,622; in 3 group the correlation coefficient r=0,482 was significant at the level of p=0,031; in 4 group there was not significant correlation coefficient r=-0,093 (p=0,742); in all groups there was especially significant coefficient of correlation (r=0,585, p=0,0001). Finally, the received results permit to state, that impedance cardiography is valuable method when is used to measure the pressure in pulmonary artery for patients with hypertension in pulmonary artery.

Conclusions

The systolic (SPPA) and mean (MPPA) pressure in pulmonary artery assessed by using two methods – two-dimentional transtoracal cardioechoscopy (2DECHO) and impedance cardiography (ICG), and especially significant Spearman's coefficient of correlation (r=0,836, p=0,0001) between performance of these methods have been received. There was revealed, that distribution of values of SPPA measurement, performed by ICG method well coincided with such, obtained by 2DECHO method (p=0,915). 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 could be used in detecting patients with pulmonary hypertension.

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The method based on impedance cardiography for evaluation of blood pressure in pulmonary artery is presented. This method was tested by using data of 109 patients with various cardiac and pulmonary diseases, and for all of them two-dimentional transtoracal cardioechoscopy was performed in aim to confirm or exclude pulmonary artery hypertension. Comparison of results received by applying both methods for measurement the blood pressure in pulmonary artery showed the especially significant correlation of data - Spearman's coefficient of correlation r=0,836, p=0,0001. 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. 3, bibl. 11 (in English; summaries in English, Russian and Lithuanian).

С. Садаускас, А. Науджюнас, Л. Гаргасас, Р. Русяцкас, Р. Юрконене. Разработка компьютерных систем для мониторирования физиологических процессов и диагностики сердечной недостаточности // Электроника и электротехника. – Каунас: Технология, 2006. – № 4(68). – С. 87–90.

Представлен метод для определения кровяного давления в легочной артерии, основан на импеданскардиографии. Метод был тестирован используя данные 109 больных с различной патологией сердца и легких и которым при двухмерной трансторакальной кардиоэхоскопии была определена или исключена гипертензия легочной артерии. Сопоставление результатов определения кровяного давления в легочной артерии обоими методами показали особозначимую корреляцию данных – коэффициент корреляции по Спирману r=0,836, p=0,0001, что позволяет метод импеданскардиографии использовать для выявления больных легочной гипертензией. Ил. 3, библ. 11 (на английском языке; рефераты на ангийском, русском и литовском языках).

S. Sadauskas, A. Naudžiūnas, L. Gargasas, R. Ruseckas, R. Jurkonienė. Sistolinio ir vidutinio kraujo spaudimo plaučių arterijoje nustatymas taikant impedanso kardiografijos metodą // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2006. – Nr.4(68). – P. 87–90.

Pateiktas impedanso kardiografija paremtas metodas kraujo spaudimui plaučių arterijoje nustatyti. Jis testuotas analizuojant 109 įvairiomis plaučių ir širdies ligomis sergančių pacientų duomenis. Jiems dvimatės transtorakalinės echoskopijos metodu buvo aptikta ar atmesta plaučių arterijos hipertenzija. Spaudimo plaučių arterijoje matavimo abiem metodais rezultatų palyginimas parodė gana didelę ir patikimą duomenų koreliaciją – Spirmano koreliacijos koeficientas r=0,836 (p=0,0001). Tai leidžia daryti prielaidą, jog impedanso kardiografija, kaip neinvazinis, nebrangus ir paprastas metodas, gali būti taikoma kraujo spaudimui vertinti diagnozuojant plaučių arterijos hipertenziją. Il. 3, bibl. 11 (anglų kalba; santraukos anglų, rusų ir lietuvių kalbomis).

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