Echocardiographic Assessment of Pulmonary Hypertension in Patients with Heart Diseases Compared with Cardiac Catheterization

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SUMMARY

Background: Pulmonary hypertension (PH) is a haemodynamic and pathophysiological condition defined as increase in mean Pulmonary Artery Pressure (PAP) ≥ 25mmHg at rest as assessed by right heart catheterization (RHC). Objective and purpose: The objective of this study is to determine, by investigating haemodynamic parameters of the pulmonary hypertension in congenital and left heart diseases, the linkage and diagnostic value of echocardiography in detecting the pulmonary hypertension in heart diseases and assessing its degree, as well as to warrant a wider application of this non-invasive diagnostic method. Patients and methods: The research covered 56 adult subjects of both genders, who were subjected to echocardiography as part of the clinical cardiological examination. The patients were examined on an ultrasound machine ATL HDI-3000 and 5000, equipped with a cardiologic probe for adults 2.25 MHz and a multi-plan transoesophageal probe ATL MPT7-4 TEE. The patients, for whom invasive cardiologic diagnostic methods were indicated following evaluation by echocardiography, were subjected to cardiac catheterization. RHC was performed in all patients and diagnosis of pulmonary hypertension was established by measuring mean PAP ≥ 25mmHg at rest, also left heart catheterization was performed in order to define the underlying heart disease. The haemodynamic parameters, obtained for each method applied, have been statistically processed. Results: By the statistical processing of the echocardiographic parameters a correlation ratio has been found, which shows significant correlation between the non-invasive variables (AcT, AcT/RVET, PEP/AcT, PEP/RVET and RVSP according to modified Bernoulli equation, MPAP according to Mahan’s equation, SPAP according to Berger’s equation) and the variables obtained by right heart catheterization (RHC): (RVSP, MPAP, SPAP):

a) In AcT and AcT/RVET variables, a negative correlation was found AcT r = -0.936, Standard Estimation Error (SEE) = 5.53, p < 0.001, AcT/RVET r = -0.896, SEE = 6.96, p < 0.001;
b) while positive correlation was found in variables PEP/AcT r = 0.915, SEE = 6.36, p < 0.001 and PEP/RVET r = 0.917, SEE = 6.26, p < 0.001;
c) MPAP obtained by echocardiography (calculated by applying Mahan’s equation) V.S. MPAP obtained by right heart catheterization r = 0.936, SEE = 5.53 mmHg;
d) SPAP obtained by echocardiography (calculated by applying Berger’s equation) V.S. MPAP obtained by right heart catheterization r = 0.971, SEE = 5.72 mmHg;
e) RVSP obtained by echocardiography (calculated by applying a modified Bernoulli’s equation) V.S. RVSP obtained by right heart catheterization r = 0.882, SEE = 9.39 mmHg;
f) RVSP obtained by echocardiography (calculated by applying a modified Bernoulli’s equation) V.S. RVSP obtained by RHC r = 0.972, SEE = 5.60 mmHg.

Conclusion: Significant correlation has been found between the haemodynamic parameters obtained by noninvasive echocardiographic examination and those obtained by right heart catheterization.

Key words: pulmonary hypertension, echocardiography, cardiac catheterization.

1. INTRODUCTION

According to the ESC guidelines for diagnosis and treatment PH published in 2009 (Dana pointe 2008) the pulmonary hypertension (PH) is a haemodynamic and pathophysiological condition defined as increase in mean Pulmonary Artery Pressure (PAP) ≥ 25mmHg at rest as assessed by right heart catheterization (RHC). According to the ESC guidelines for diagnosis and treatment PH (2009) the clinical classification of pulmonary hypertension (Dana pointe 2008) includes PH associated with congenital heart disease and pulmonary hypertension due to left heart disease is classified as Post-Capillary PH and defined by a mean PAP ≥ 25mmHg, PWP > 15mmHg, cardiac output (CO) is normal or reduced and passive TPG ≤ 12mmHg, active TPG > 12mmHg APAH. The signs and symptoms of the pulmonary hypertension are often unpecific and inconspicuous; therefore it is hard to distinguish whether they pertain to an underlying cardiac or extra cardiac disease. An exact evaluation of whether the pulmonary hypertension exists can be achieved by echocardiography, as a non-invasive examination method, and by right heart catheterization as an invasive diagnostic method (1, 2, 3).
In the majority of patients with various cardiac diseases, either as part of the basic characteristics of the illness or as a complication of untreated heart disease can lead to the pulmonary hypertension, which signs or symptoms are often subtle and nonspecific. Regardless of the etiology of untreated pulmonary hypertension it can lead to right heart failure. The diagnosis of pulmonary hypertension is quite difficult because it requires a precise evaluation, registration and determination of hemodynamic parameters to be defined. Exact evaluation of the existence of pulmonary hypertension and its level can be achieved by echocardiography as a noninvasive method of examination and right heart catheterization and pulmonary artery as invasive diagnostic method (4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18).

2. RESEARCH OBJECTIVES

The objective of this study is to determine, by investigating haemodynamic parameters of the pulmonary hypertension in congenital and left heart diseases, the linkage and diagnostic value of echocardiography in detecting the pulmonary hypertension in heart diseases and assessing its degree. To evaluate whether the haemodynamic parameters of pulmonary hypertension in heart disease obtained by echocardiography (TTE and TEE) as a noninvasive method of examination and right heart catheterization and pulmonary artery as invasive diagnostic method (4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18).

3. PATIENTS AND METHODS

The research covered 56 adult subjects of both genders, who were subjected to echocardiography as part of the clinical cardiological examination. The patients were examined on an ultrasound machine ATL HDI-5000, equipped with a cardiologic probe for adults 2.25 MHz and a multi-plan transoesophageal probe ATL MPT7-4 TEE. Using Doppler echocardiography can evaluate the following hemodynamic parameters that are relevant in the diagnosis of pulmonary hypertension: a) systolic pressure in the pulmonary artery (SPAP), b) systolic pressure in right ventricle (RVSP), c) the mean pulmonary artery pressure (MPAP), d) diastolic pulmonary artery pressure (DPAP), e) Index pulmonary flow velocity Act, RVET, PEP, Act/RVET, PEP/Act PEP/RVET.

The patients, for whom invasive cardiologic diagnostic methods were indicated following evaluation by echocardiography, were subjected to heart cardiac catheterization.

The patients for whom invasive cardiac diagnostics was indicated following the Echocardiographic evaluation and estimation of pulmonary hypertension were subjected to right heart catheterization. RHC was performed in all patients and diagnosis of pulmonary hypertension was established by measuring mean PAP ≥ 25mmHg at rest, also left heart catheterization was performed in order to define the underlying heart disease.

The echocardiographic Doppler and haemodynamic parameters, obtained for each method applied, have been statistically processed.

4. RESULTS

Among all the cardiac patients referred for echocardiographic evaluation for pulmonary hypertension 56 patients entered the study. Baseline characteristics of the population are depicted in Table 1. Hemodynamic behavior of our pa-

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Men</th>
<th>20 (36%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Women</td>
<td>36  (64%)</td>
<td></td>
</tr>
<tr>
<td>Age, yrs (SD)</td>
<td>51,6 ± 14</td>
<td></td>
</tr>
<tr>
<td>Type of heart disease</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attrial Septal Defect (ASD)</td>
<td>11 (20%)</td>
<td></td>
</tr>
<tr>
<td>Ventricular Septal Defect (VSD)</td>
<td>8 (14%)</td>
<td></td>
</tr>
<tr>
<td>Complex Congential Heart Disease</td>
<td>7 (13%)</td>
<td></td>
</tr>
<tr>
<td>Mitral Stenosis and Regurgitation</td>
<td>16 (29%)</td>
<td></td>
</tr>
<tr>
<td>Ischaemic Cardiomiopathy</td>
<td>9 (16%)</td>
<td></td>
</tr>
<tr>
<td>PAH after Corrective Cardiac Surgery</td>
<td>5 (9%)</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Study population and clinical data
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Patients is shown in Table 2. Right heart catheterization confirmed normal or borderline finding in 10 patients (18%), moderate pulmonary hypertension in 31 patients (55%) and severe PH in 15 patients (27%).

5. DISCUSSION

Pulmonary hypertension (PH) is an important hemodynamic parameter that monitors a wide range of cardiac and extra cardiac diseases, which is crucial in determining the symptomatology, clinical features and treatment of these diseases. Early identification of patients with pulmonary hypertension is a very significant and important impact on morbidity and mortality (19, 20, 21, 22, 23, 24, 25).

The study results indicate significant correlation between the haemodynamic parameters obtained by Doppler echocardiographic methods for PAP estimation as values obtained by right heart catheterization. The results of both authors point to a statistically insignificant difference (r=0.97, SEE=4.9 mmHg) (r=0.96 SEE=6.9 mmHg). In their own study SPAP values was echocardiography obtained using the Berger equation. SPAP=(1.23 x PGTR)-0.09 and the values obtained by echocardiography were compared with SPAP SPAP values obtained by right heart catheterization. Presented results of linear regression showed

Table 2. Echocardiographic and RH Catheterization Haemodynamic data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>P</th>
<th>R</th>
<th>SEE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceleration Time (AcT) v.s. Mean PAP cath</td>
<td>&lt; 0.001</td>
<td>-0.94</td>
<td>5.35 mmHg</td>
</tr>
<tr>
<td>Mean PAP echo v.s. Mean PAP cath</td>
<td>0.937</td>
<td>0.94</td>
<td>5.53 mmHg</td>
</tr>
<tr>
<td>RVSP echo v.s. RVSP cath</td>
<td>0.934</td>
<td>0.97</td>
<td>5.72 mmHg</td>
</tr>
<tr>
<td>SPAP echo v.s. SPAP cath</td>
<td>0.936</td>
<td>0.97</td>
<td>5.60 mmHg</td>
</tr>
<tr>
<td>RVSP echo v.s. SPAP cath</td>
<td>0.936</td>
<td>0.97</td>
<td>5.60 mmHg</td>
</tr>
<tr>
<td>Act/RVET echo v.s. Mean PAP cath</td>
<td>&lt; 0.001</td>
<td>0.90</td>
<td>6.96 mmHg</td>
</tr>
<tr>
<td>PEP/Act echo v.s. Mean PAP cath</td>
<td>&lt; 0.001</td>
<td>0.91</td>
<td>6.34 mmHg</td>
</tr>
<tr>
<td>PEP/RVET echo v.s. Mean PAP cath</td>
<td>&lt; 0.001</td>
<td>0.92</td>
<td>6.26 mmHg</td>
</tr>
<tr>
<td>RAD v.s. Mean PAP cath</td>
<td>&lt; 0.001</td>
<td>0.83</td>
<td>8.27 mmHg</td>
</tr>
<tr>
<td>RVEDD Vs Mean PAP cath</td>
<td>&lt; 0.001</td>
<td>0.86</td>
<td></td>
</tr>
</tbody>
</table>

Figure 3. Significant negative correlation of Acceleration Time (AcT) v.s. Mean Pulmonary Artery Pressure (MPAP) obtained by RHC in all patients.

Figure 4. Correlation between RVSP (mmHg) obtained using Bernoulli Equation and SPAP (mmHg) obtained by RHC in all patients.

Figure 5. Correlation between MPAP (mmHg) obtained using Mahan’s Equations and MPAP (mmHg) obtained by RHC in all patients.

Figure 6. Correlation between SPAP (mmHg) obtained using Berger’s Equations and SPAP (mmHg) obtained invasively – RHC in all patients.
no statistically significant differences between the parameters $r=0.971$, $\text{SEE}=5.72 \text{ mmHg}$. (Figure 6),

- RVSP: Paul G. Yock, and Richard L. Pop (1984) (15) in 54/62 (87%) patients with tricuspid regurgitation within the cardiac disease found a statistically insignificant difference between the two parameters (RVSP echo vs. RVSP Cath. $r=0.93$, $\text{SEE}=8 \text{ mm Hg}$). Philip J. Currie et al. (17) (1985) in 111/127 (87%) patients with a wide spectrum of cardiac lesions also found statistically insignificant differences between the two parameters ($r=0.96$, $\text{SEE}=7 \text{ mm Hg}$). The results of our study were similar ($r=0.882$, $\text{SEE}=9.39 \text{ mmHg}$).

- (RVSP echo vs SPAP Cath.): Berger et al. (19) (1985) in 41/69 (59%) patients with Doppler detected tricuspid regurgitation by linear regression found a statistically insignificant difference between the two parameters ($r=0.97$, $\text{SEE}=4.9 \text{ mmHg}$). Similar results in their studies were given by Stevenson et al. (14) (1989 in 50 patients) ($r=0.96$, $\text{SEE}=6.9 \text{ mm Hg}$), and Currie et al. (17) (1985.) ($r=0.96$, $\text{SEE}=7 \text{ mm Hg}$). The results of our study were similar ($r=0.972$, $\text{SEE}=5.6 \text{ mm Hg}$). (Figure 5).

- MPAP echo vs. MPAP Cath.: In our study, MPAP values were obtained using echocardiography by Mahan equation in which the accelerating time (ACT) is the main parameter in determining mean pulmonary pressure (MPAP). MPAP echo values obtained by Mahan equation $\text{MPAP}=79\pm(0.45 \times \text{ACT})$, Mahan et al. (1983) (11) compared with the values of MPAP obtained by pulmonary artery catheterization. Results of linear regression showed no statistically significant differences between the two parameters ($r=0.936$, $\text{SEE}=5.53 \text{ mmHg}$). (Figure 5).

- ACT vs. MPAP: Kitabatake et al. (1983), Kosturakis et al. (1984), Žutić H. (1994), Tramarin et al. (1988), Jiang L. et al. (1984), Laaban et al. found a negative correlation between ACT echo vs. MPAP Cath. Our findings also indicate a negative correlation ($r=0.936$, $\text{SEE}=5.53 \text{ mmHg}$, $p<0.001$) for all patients. (Figure 3) (7, 9, 10, 12, 13).

### 6. CONCLUSION

Significant correlation has been found between the hemodynamic parameters obtained by Doppler noninvasive echocardiographic estimation of pulmonary hypertension and those obtained by invasive diagnostic methods i.e. right heart catheterization.

The results of our own study show a high degree of precision in applications of the Mahan equation in assessment of MPAP, Berger equation for the assessment of SPAP and modified Bernoulli equation to evaluation of RVSP.

Based on the study results it can be noted that echocardiography with all its modalities can be considered a reliable diagnostic tool in detecting and assessing the degree of pulmonary hypertension in heart disease.

### REFERENCES


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