Novel formula to measure mean pulmonary artery pressure

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Abstract
Mean Pulmonary Arterial Pressure (MPAP) is an important parameter in evaluation of patients with pulmonary hypertension. The aim of this study is to correlate a new formula using non-invasive blood pressure and Bernoulli’s right ventricle systolic pressure (RVSP) with invasive method. To archive the objectives, we enrolled 143 patients with suspected pulmonary hypertension from January 2015 till January 2016; all patients underwent right heart catheter evaluation and simultaneously RVSP by transthoracic echocardiography and non-invasive blood pressure to calculate MPAP by the formula MPAP = Pulse Pressure / (Mean Arterial Pressure/RVSP); and the results were compared using the Pearson’s simple-linear correlation method. We found a significant association between invasive and equation results with a Pearson’s correlation of 0,872 with a confidence interval from 0,795 to 0,921; sensitivity was 1,538% with a 95% confidence interval (CI) from 0,038% to 8,276%, and Specificity was 100% with 95% CI from 94,48% to 100%. Our results suggest that the new formula have a good correlation estimating MPAP compared with invasive right heart catheterization method.

Keywords
Mean pulmonary artery pressure, Pulmonary hypertension, Echocardiography, Non-invasive hemodynamic assessment

Introduction
The pulmonary circulation is a circuit with a high flow and low pressure, and this favors the pulmonary gas exchange by preventing fluid moving out of the pulmonary vessels into the interstitial space so that the right ventricle operates with a low energy cost. The right ventricle is a thin-walled structure, and for this reason, it is poorly prepared to rapid changes in loading condition. Pulmonary arterial pressure (PAP) is the blood pressure in the pulmonary artery; it is generated by the right ventricle ejecting blood into the pulmonary circulation, which acts as a resistance to the output from the right ventricle. With each ejection of blood during the ventricular systole, the pulmonary arterial blood volume increases that stretches the wall of the artery. As the heart relaxes (ventricular diastole), blood continues to flow from the pulmonary artery into the pulmonary circulation [1].

In hemodynamic terms, the mean pulmonary arterial pressure (MPAP) can be described by the following equation: MPAP = (Cardiac output $\times$ Pulmonary vascular resistance) + Pulmonary venous pressure, or in clinical terms $\text{MPAP} = \text{Pulmonary arterial systolic pressure } + (2 \times \text{Pulmonary arterial diastolic pressure}) / 3$. Therefore, increases in cardiac output, pulmonary vascular resistance or pulmonary venous pressure will lead to increases in PAP. The normal mean pulmonary artery pressure is 11-17 mmHg, however there is some variation with age, weight and physiologic states [2].

By consensus, pulmonary hypertension (PH) refers to the presence of a MPAP $\geq$ 25 mmHg at rest measured by right heart catheterization (RHC). The RHC is technically demanding and has been associated with serious, sometimes fatal complications, thus,
this invasive diagnostic procedure should be performed in expert centers. The zero level of the pressure transducer varies among centers and should be standardized for future research because the level of the transducer has an important impact on the hemodynamic results, especially on the right atrium pressure and pulmonary artery wedge pressure [3,4].

Echocardiography is performed to estimate the pulmonary artery systolic pressure through Doppler ultrasound and to assess right ventricular size, thickness, function, right atrial size, left ventricular systolic and diastolic function, and valve function, while detecting pericardial effusions and intracardiac shunts; they can be causes of PH. Overestimation and underestimation of pulmonary arterial pressure occurred with similar frequency when used Doppler echocardiography, especially when an inadequate tricuspid regurgitant jet is over-interpreted. There is also variability for the operator and the equipment [5,6].

Both echocardiography and RHC are subject to disagreement when performed at different times and under different medical conditions, which is a major limitation of the studies that compare their accuracy in the diagnosis of PH. Nonetheless, while echocardiography detects PH with a greater accuracy than clinical history and examination, its greatest value is the detection of underlying left-sided heart disease as well as assessing RV function [7].

The aim of this study is to assess a formula for MPAP and right ventricular systolic pressure measurement from non-invasive variables.

Materials and methods

Patients

The patients evaluated for the present study were hundred forty-three (143); thirty (32) patients were women and thirty-five (111) were men, between 35-56 years old, with clinical suspected pulmonary hypertension, without neoplastic, congenital or psychiatric disease, non-pregnant, and without heart failure admitted to diagnostic right heart cardiac catheterization; non-patients were enrolled with dilated cardiomyopathy, using inotropes or intravenous vasoactive medications. The patients were taken from the hemodynamics unit of the Amosov National Institute of Cardiovascular Surgery in Ukraine, and the study was approved by the Ethics Committee of the same institution. All patients had accepted the informed consent before they entered the study.

Design

All patients submitted to diagnostic coronary cardiac catheterization, after the procedure, were submitted to pulmonary artery catheterization measuring right ventricle systolic pressure and pulmonary mean arterial pressure. Simultaneously, the right ventricle systolic pressure was measured by echocardiography using the Bernoulli's equation, and non-invasive blood pressure was measured by noninvasive method according guidelines [8] to use with the experimental formula as follows.

Formula:

\[
\text{MPAP} = \frac{\text{Pulse Pressure}}{\text{Mean Arterial Pressure} / \text{Right Ventricular Systolic Pressure}}
\]

\[
\text{Pulse pressure} = \text{Systolic blood pressure} - \text{Diastolic blood pressure}
\]

\[
\text{Mean Arterial Pressure} = \frac{\text{Systolic blood pressure} + (2 \times \text{Diastolic blood pressure})}{3}
\]

Statistical Analysis

The information collected was downloaded to GraphPad Prism for Windows 5.1, and a linear correlation was performed by calculating the \( r \) Pearson study.

Results

143 patients were enrolled to the study; mean values of MPAP were 42mmHg with a standard deviation of 18.22 mmHg. The Pearson's correlation was 0.872 with a confidence interval from 0.795 to 0.921 when compared MPAP between invasive and formula results. Sensitivity was 1.538% with a 95% confidence of interval (CI) from 0.038% to 8.276%,
and Specificity was 100% with 95% CI from 94.48% to 100% (Figure 1 and Table 1).

Conclusions

Patients with suspected PH must be evaluated using a multimodality approach to ensure a precise diagnosis, from clinical evaluation, non-invasive imaging techniques like echocardiogram until RHC, which is considered to be the “gold standard”. Echocardiography should be performed always in patients with HP suspected, and it can be used to infer the diagnosis of HP in multiple patients whose results of echocardiographic measurements are consistent with this diagnosis; echocardiographic changes in PH are several: right ventricular enlargement, right ventricular hypertrophy, right atrial enlargement, functional tricuspid regurgitation with a high velocity regurgitant jet by Doppler and a mid-systolic notch on the pulmonary artery Doppler flow tracing; however echocardiography alone is not enough to make a decision about treatment, and RHC is necessary [8,9].

Several authors have attempted to create novel formulas to calculate different hemodynamic variables, for example, pulmonary artery occlusion pressure [10], and PAP is often estimated from echocardiographic estimations [5,11]. The Bernoulli equation was the best way to measure MPAP using echocardiography with a correlation of r=0.451 compared with invasive measurements, in 2011; Pyxaras Stylianos and his working team published a new formula to estimate the MPAP; they compared their new formula against the invasive way in 60 patients, obtaining a correlation of r = 0.692 [12]. In this study we compared the new formula against invasive method in 143 patients obtaining a correlation of r=0.872.

The non-invasive methods to calculate different hemodynamic variables have great advantages over the invasive methods, due to the patient is not subjected to risks inherent to the procedure, and for this reason, this study shows a novel method to calculate the MPAP using vital signs, which is cheap, easy and have good accuracy.

Statement on ethical issues

Research involving people and/or animals is in full compliance with current national and international ethical standards.

Conflict of interest

None declared.

Author contributions

All authors have full access to all data in the study and the final responsibility for the decision to submit for publication. All authors seen and approved the submitted version. There was not any medical writer or editor involved in the generation of this publication. The study was founded by the authors, and there’s no conflict of interest. The author read the ICMJE criteria for authorship and approved the final manuscript.

References


Table 1. Pearson correlation coefficient comparison, specificity and sensitivity predicted values between right heart catheterization MPAP and equation

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<tr>
<th></th>
<th>Pearson r</th>
<th>95% confidence of interval</th>
<th>P Value</th>
<th>Sensitivity %</th>
<th>95% confidence of interval</th>
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<td>Pearson r</td>
<td>0.8720</td>
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<td>&lt;0.0001</td>
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<td>0.038% to 8.276%</td>
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<td>94.48% to 100%</td>
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