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ORIGINAL ARTICLE

The Association of Functional Capacity With Right Atrial Deformation in Patients With Pulmonary Arterial Hypertension: A Study With Two-Dimensional Speckle Tracking

Liu Weiwei, Wang Yueheng*, Zhou Jinling, Bai Hui, Wang Feng, Wang Ju

Department of Cardiac Ultrasound, The Second Hospital of Hebei Medical University, China

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Background The purpose of this study was to assess right atrial (RA) myocardial mechanics in pulmonary hypertension (PH) patients using two-dimensional speckle tracking (2D-STE), and define the relationship between RA function and exercise capacity in PH patients.

Methods Thirty-eight consecutive PH patients were studied and compared with a control group of 25 healthy volunteers. Peak atrial longitudinal strain (PALS), RA strain rate were measured in all subjects. Peak atrial longitudinal strain values were obtained by averaging all segments (global PALS), and by averaging segments measured in the four-chamber view.

Results Right atrial PALS was significantly lower in PH patients than in controls, and gradually reduced with the development of cardiac insufficiency. A significantly positive correlation between global PALS and 6-minute walk distance (6MWD) was found ($p = 0.003$). Furthermore, global PALS demonstrated the highest diagnostic accuracy (AUC of 0.979) and excellent sensitivity and specificity of 86.8% and 84%, respectively, to predict functional status using a cutoff value less than 38.08%.

Conclusions Right atrial deformation is significantly damaged in PH patients. Right atrial reservoir function can be estimated using 2D-STE, which gradually decreases in PH patients with different World Health Organization-functional class (WHO-FC). Right atrial PALS is a valuable factor for predicting the functional status and exercise capacity in PH patients.

Keywords Right atrium • Pulmonary hypertension • Speckle-tracking Echocardiography • Longitudinal strain

Introduction

Pulmonary arterial hypertension (PAH) is a chronic, progressive, fatal disease. The main reason is increased pulmonary vascular resistance caused by pulmonary arteriole primary lesions or other related diseases. Pulmonary arterial hypertension, which is characterised by increased pulmonary artery pressure and normal pulmonary vein pressure and pulmonary capillary wedge pressure, ultimately leads to right heart failure and premature death.

As does the left atrium, right atrial (RA) function contributes to right ventricular filling by means of its three

*Corresponding author at: Department of Cardiac Ultrasound, Second Hospital of Hebei Medical University, Shijiazhuang 050000, China.,
Email: wyhucg@sina.com

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components: acting as a reservoir for the systemic venous return when the tricuspid valve is closed, as a passive conduit when the tricuspid opens and, lastly, acting as an active conduit when it contracts [1]. The right atrium plays an integral role in cardiac performance by modulating right ventricular function with its reservoir, conduit, and contractile functions [2]. So, RA function is closely related to right heart function throughout the whole cardiac cycle.

Right atrial dilatation and increased RA pressure are associated with adverse outcomes in patients with PH [3–5]. And a recent study [6] has shown that clinical deterioration is better associated with RA rather than right ventricular (RV) remodelling. Therefore, evaluation of RA structure and function has very important significance in patients with pulmonary hypertension (PH). But, few people focus on right atrial function in patients with PH, maybe partly because right atrial function is difficult to assess. Speckle tracking echocardiography (STE) is a novel technique of two-dimensional echocardiography image analysis, which allows the study of atrial myocardial deformation, and has been shown to be feasible to estimate RA myocardial mechanics [7].

Previous studies of RA myocardial mechanics have been conducted mostly in healthy subjects [7,8]. Thus, details regarding the impact of PH on RA myocardial mechanics remain incompletely investigated.

Accordingly, the purpose of this study was to assess RA myocardial mechanics in PH patients using 2D-STE, and define the relationship between RA function and exercise capacity in PH patients.

Methods

Thirty-eight consecutive patients with PH and 25 age-matched normal volunteers who were admitted to the Second Hospital of Hebei Medical University, were enrolled in this study between March 2013 and August 2014. According to the diagnosis criteria of PAH [9], all patients had a mean pulmonary arterial pressure (mPAP) $\geq$25 mmHg and a normal pulmonary artery wedge pressure (PCWP) <15 mmHg. All patients underwent echocardiography and right heart catheterisation (RHC). Right heart catheterisation measurements included mPAP, mRAP (mean right atrial pressure), cardiac output and pulmonary vascular resistance (PVR).

Exclusion criteria consisted of any myocardial, organic valvular, or congenital heart disease that might affect right heart structure and function. Additionally, patients with arrhythmias, such as atrial fibrillation/flutter, were excluded from the study.

We selected 25 healthy subjects who were matched in age and gender with the pulmonary arterial hypertension patients to serve as controls. The patient's functional class was determined by the study investigator using the WHO classification [10]. All patients underwent the 6-minute-walk-test (6MWT) to assess function capacity. Written informed consent was obtained from all recruited subjects.

Echocardiography

Standard complete transthoracic echocardiographic studies were performed with all subjects in the left lateral decubitus position with a commercially available Vivid E9 ultrasound machine (GE Healthcare, Shijiazhuang, China) equipped with M5S probe. Bidimensional and Doppler measurements were performed in accordance with current recommendations of the American Society of Echocardiography (ASE) [1,11]. Pulmonary artery systolic pressure (PASP) was calculated from the maximal velocity of TR and RAP using Bernoulli's equation ($PASP = 4(V_{TR})^2 + RAP$). RAP was estimated by the respiratory motion and the size of the inferior vena cava from the subcostal view [1].

Two-dimensional measurements were also included: tricuspid annular plane systolic exertion, RV myocardial performance index, isovolumic relaxation time, systolic S-wave from tissue Doppler imaging, and presence of pericardial effusion.

Speckle Tracking Echocardiography

Apical four chamber view images were obtained using conventional two dimensional grey scale echocardiography. Three consecutive heart cycles were stored during breath-hold with stable ECG recording, in order to achieve a better image for 2D-STE analysis. Care was taken to obtain true apical images and not foreshorten the RA. The frame rate was set between 60 and 80 frames/s.

Two-dimensional echocardiography images were analysed using EchoPAC v110 (GE Healthcare, Shijiazhuang, China). The STE analysis was performed offline by a single experienced and independent echocardiographer, who did not attend the image acquisition, to avoid inter-observer variability.

Right atrial endocardial border was manually traced in four-chamber view when the RA was at its minimum volume after contraction [8]. The software automatically generated a region of interest (ROI), composed by six segments. If tracking of the RA endocardium was unsuccessful, manual adjustments of the shape and width of ROI were performed to ensure optimal tracking. As previously described [7], RA peak atrial longitudinal strain (PALS), measured at the end of the reservoir phase, was calculated by averaging values observed in all RA segments (global RA PALS). Right atrial strain rate (SR) was measured by quantifying RA endocardial velocities of contraction and relaxation and local deformation. Strain rate was measured from the QRS onset and three different waves were analysed.

Statistical Analysis

Continuous variables were summarised as mean $\pm$ SD if normally distributed. Categorical variables were expressed as percentages. Pearson correlation was used to analyse the

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