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Original Article

Cardiac MR-assessed hemodynamic changes in pulmonary arterial hypertension and their relation to pulmonary artery pressure

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ABSTRACT

Purpose: To demonstrate the hemodynamic changes of pulmonary arterial hypertension using cardiac MRI and to determine which parameters are best representative of the pulmonary artery pressure.
Patient and methods: We examined 44 patients with pulmonary arterial hypertension using cine cardiac imaging and phase-contrast velocity encoding sequence to obtain data regarding ventricular morphology, function and pulmonary artery flow. The resulting parameters were correlated to echocardiography-derived mean pulmonary artery pressure.
Results: We found increased right ventricular end diastolic, end systolic volumes and mass with decreased stroke volume and ejection fraction. The left ventricular end diastolic volume and stroke volume decreased and the end systolic volume increased while the ventricular mass index has increased compared to normal populations. The mean pulmonary artery pressure had significant positive correlation with the ventricular mass index ($r = 0.61$; $p = 0.02$) and right ventricular mass ($r = 0.40$; $p = 0.02$) with significant negative correlation with right ventricular ejection fraction ($r = -0.48$; $p = 0009$).
Conclusion: MR-derived ventricular mass index, right ventricular mass, and right ventricular ejection fraction had the strongest relation with the pulmonary artery pressure, and hence they could be reliable parameters on monitoring patients with pulmonary arterial hypertension.

1. Introduction

Pulmonary hypertension (PH) is clinically defined as the presence of mean pulmonary artery pressure (mPAP) $\geqslant$ 25 mm Hg at rest measured at right heart catheterization [1]. Being an invasive technique, right heart catherterization has a limited role in confirming the diagnosis, whereas echocardiography has proven to be a reliable non invasive method to assess the pulmonary artery pressure with high sensitivity and specificity [2]. PH has been classified into five groups based on sharing similar clinical presentation, pathological findings, hemodynamic characteristics and treatment strategy. Group 1: pulmonary arterial hypertension either idiopathic or associated with other conditions such as connective tissue disease and congenital heart disease. Group 2: PH due to left heart disease. Group 3: PH due to lung diseases and/or hypoxia. Group 4: chronic thromboembolic PH. Group 5: PH due to unclear and/or multifactorial mechanisms [3]. Independently from the origin, PH has an important effect on patient's clinical status and life expectancy. In addition to reaching an exact diagnosis and classification, understanding the associated hemodynamics provides the basis for often challenging therapy decisions [4]. The right ventricle (RV) is the major determinant of functional state and prognosis in PH. RV hypertrophy triggered by pressure overload is initially compensatory but often leads to RV failure [5]. Although echocardiography is the most frequently used diagnostic tool to assess RV size and function, it has limitations regarding assessment of the complex geometry of the RV as previously discussed in several studies [6–8]. Cardiac magnetic resonance imaging (CMRI) has become accepted as the gold standard tool to assess the RV (its morphology and function) as well

Abbreviations: AT, acceleration time; CMRI,, cardiac magnetic resonance imaging; EDV, end diastolic volume; EDVI, end diastolic volume index; ESV, end systolic volume; ESVI, end systolic volume index; EF, ejection fraction; ET, ejection time; LV, left ventricle; mPAP,, mean pulmonary artery pressure; PH, pulmonary hypertension; RV, right ventricle; sPAP, systolic pulmonary artery pressure; SV, stroke volume; SVI, stroke volume index.

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as the proximal pulmonary circulation. This is attributed to its advanced technology that offers a valuable non-invasive multiplanar method that provides a more complete assessment of the RV in PH patients [9,10]. This study is focused on group 1 pulmonary hypertension to demonstrate the hemodynamic changes using CMRI and their relation to PAP measured by echocardiography to pick up the MRI parameters representative to pulmonary artery pressure.

2. Patient and methods

2.1. Study population

Forty-four patients diagnosed to have PH in Kasr AlAini Hospital over 2 years from June 2014 to June 2016 were enrolled in this study. The diagnosis of pH was established based on clinical data and echocardiography. Following estimation of the systolic PAP (s PAP) by echocardiography performed by an experienced sonographer, mean PAP (mPAP) was calculated according to the formula (mPAP = 0.61 × sPAP + 2 mmHg) [11]. Exclusion criteria were the hemodynamic instability, sever dyspnea, atrial fibrillation, contraindications for MR imaging; claustrophobia, patients with pacemaker and metal implants. No certain medication needs to be stopped or avoided before the examination. All participants gave informed written consent. The study was approved by the Institutional Ethics Committee.

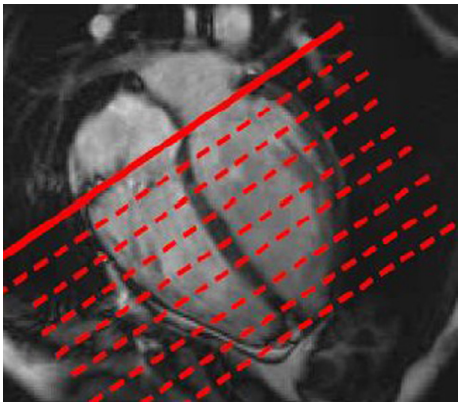

Fig. 1. Planning of the short axis images from the 4 chamber image. They are planned perpendicular to the interventricular septum extending from the ventricular base to the apex.

2.2. Image acquisition

All patients were imaged by a 1.5 T super conducting magnet (Achieva, Philips Medical Systems, Best, The Netherlands) using 5 channel phased-array cardiac coil. The MRI protocol included cine imaging in two, four chamber and short axis views using an ECG-gated, breath-hold balanced turbo field echo sequence (b-TFE) with the short axis images extended from the base to the apex of the ventricles (Fig. 1) using the following parameters: repetition time (TR)/echo time (TE), 3/2; 25 cardiac phases; matrix 128 × 128; FOV 320 mm, NSA 1, flip angle 60; slice thickness 8 mm and scan time of 7–12 s.

Pulmonary artery flow was assessed via through plane phase contrast images perpendicular to the main pulmonary artery in the sagittal and axial images with the following parameters: repetition time (TR)/echo time (TE), 5/3; matrix 128 × 126; FOV 320 mm, flip angle 12; slice thickness 8 mm, velocity encoding 200 cm/s.

2.3. Image analysis

All images were transferred to Philips extended work station (EWS) View Forum 2.6 for analysis.

2.3.1. Analysis of ventricular function and mass

The endocardial and epicardial contours of the RV (Fig. 2) and left ventricle (LV) were manually traced at end diastole and end systole on the short axis cine images (the septum was included in the LV). The workstation automatically calculated end diastolic volume (EDV), end diastolic volume index (EDVI), end systolic volume (ESV), end systolic volume index (ESVI), stroke volume (SV), stroke volume index (SVI), ejection fraction (EF), and ventricular mass (The ventricular mass index was calculated by dividing the right ventricular mass by the left ventricular mass). Also the position of the interventricular septum was assessed.

2.3.2. Analysis of pulmonary artery flow

Using the phase contrast images, a region of interest was drawn manually around the vessel lumen in each phase in the gradient echo images, contours were then correlated with the corresponding phase contrast images. The workstation calculated flow vol-

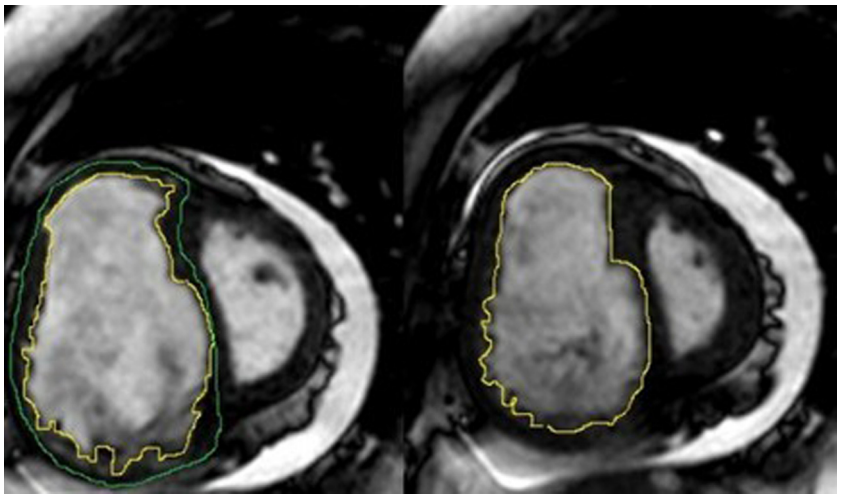

Fig. 2. Right ventricular tracing for analysis. Tracing of the epicardial "green" and endocardial "yellow" contours of the right ventricle in end diastole (left) and end systole (right).

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