Magnetic Resonance Imaging Provides Non-Invasive Assessment of Pulmonary Hypertension Severity by Reduced Relative Area Change of the Pulmonary Artery

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INTRODUCTION

Pulmonary arterial hypertension (PAH) is a disease of the distal pulmonary arteries that results in an elevation in pulmonary arterial resistance and pressure [1]. Currently, right heart catheterization is the gold standard for assesment of PAH. The relative cross sectional area change (RAC) of the main pulmonary artery may be a useful non-invasive measure of PAH severity [2]. Here, we use magnetic resonance (MR) imaging to measure the cross sectional area of the main pulmonary artery (MPA) at different times during the cardiac cycle. Preliminary results on the utility of this metric are presented based on five PAH patients and four healthy controls.

MATERIALS AND METHODS

Time resolved MPA area and flow measurements were performed in a 3.0T scanner (Signa HDx, GE Healthcare, Waukesha, WI) using an 8-channel cardiac coil and ECG gated CINE 2D phase contrast (PC) images. True cross-sectional images of the MPA were obtained from double oblique planes through the MPA in five patients with documented PAH and four healthy controls (Figure 1). The study was approved by our IRB and the patients and controls were consented for it. Image analysis was performed on the magnitude PC images using ReportCard™ (GE Healthcare, Waukesha, WI) to semi-automatically segment the area of the pulmonary arteries and subsequently quantify flow and cross sectional area from the phase velocity images [3]. Right ventricular functional parameters were calculated from axial ECG-gated CINE balanced SSFP images using ReportCard™ [4]. Using the area measurements, RAC was calculated using:

$$RAC = \frac{A_{max} - A_{min}}{A_{max}} \qquad (1)$$

where A_{max} and A_{min} are the MPA cross sectional areas measured at peak systole and end diastole, respectively [2].

In the PAH patients, right heart catheterization was performed to clinically evaluate disease progression. The mean pulmonary artery pressure values were used to confirm the diagnosis of pulmonary arterial hypertension.

RESULTS

The relative area change in the main pulmonary artery was lower in the PAH patients (9.6±4.5%; range = 4.6-16%) compared to healthy controls (47.1±19.8%; range = 30-76%) ($p<0.005$), as shown in figure 2. Average RV stroke volume was also lower in the PAH group (63.4±16.8 ml/beat; range = 44-85 ml/beat) compared to healthy, controls (92±11.5 ml/beat; range = 77-105 ml/beat) ($p<0.05$). There was no significant difference in cardiac output (5.8±1.4 L/min vs. 6.9±1.9 L/min for PAH vs. healthy controls; $p=0.33$).

Average mean pulmonary artery pressure in the patient population was 52±7.2 mmHg (range 42-59 mmHg), which is higher than the normal range (12-20 mmHg). Pulmonary capillary wedge pressure was 11±6 mmHg (range 4-17 mmHg), which confirms pulmonary arterial hypertension in this group of patients.

DISCUSSION AND CONCLUSIONS

These preliminary data show that patients with pulmonary arterial hypertension have a significantly lower relative cross sectional area change in the main pulmonary artery compared to healthy controls. The area measurements in this analysis depend on the quality of the image as well as the position in which the image was taken. Improper positioning of the cross sectional imaging plane can be problematic because the calculation assumes a circular artery cross-sectional area perpendicular to the axis of the main pulmonary trunk. 3D gated sequences could avoid this potential pitfall. These data suggest that heart rate (HR) may affect RAC. In particular, the lowest RAC value obtained in the healthy controls corresponded to the subject with the highest HR (96 bpm), which shortened diastole and increased A_{min} (i.e., decreased RAC). Nevertheless, the resulting RAC from this control subject was nearly twice the highest RAC in the PAH group. In future work, the sensitivity of RAC to image plane positioning and HR will be investigated. In conclusion, the relative area change may provide a useful non-invasive metric for detection and quantitative assessment of pulmonary arterial hypertension.

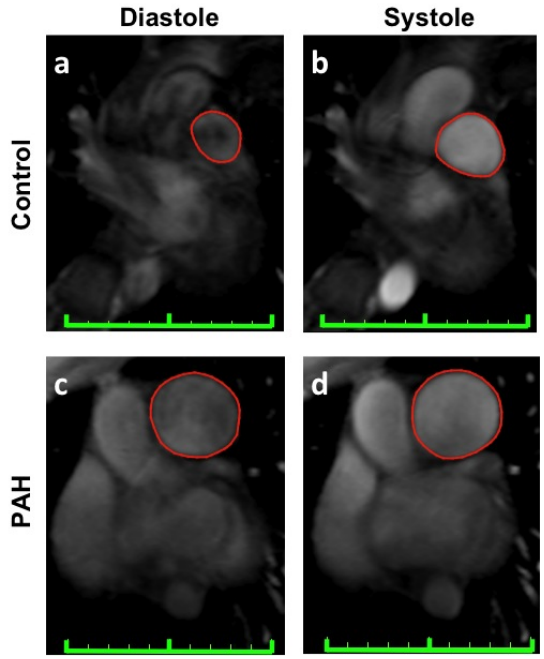

Figure 1. Cross sectional images of the main pulmonary artery from one healthy control in (a) diastole and (b) systole, and one PAH patient in (c) diastole and (d) systole. In each panel, the main pulmonary artery boundary is highlighted (red) and the scale shows 10 cm (green). Note the enlarged heart in the PAH patient relative to the healthy control.

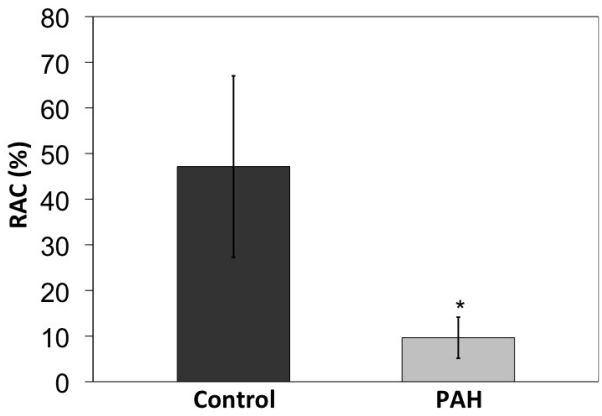

Figure 2. Relative area change in the main pulmonary artery in healthy controls (n=4) and PAH patients (n=5). Mean ± standard deviation shown; *$p<0.005$.

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Acknowledgements: This work was supported in part by GE Healthcare and by NIH R01HL086939.