Evaluation of Right Ventricular Function and Pulmonary Perfusion in Ross Procedure Patients using Magnetic Resonance Imaging

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Introduction

The Ross procedure is an aortic valve replacement surgery performed to manage progressive disease of the aortic valve or left ventricular outflow tract. The operation entails the replacement of the aortic valve with a pulmonary autograft and reconstruction of the right ventricular outflow tract with a pulmonary homograft conduit (1). Complications of the Ross procedure include dilatation of the aortic root and aortic regurgitation, as well as pulmonary stenosis and pulmonary insufficiency (2). Pulmonary stenosis can be caused by autoimmune response and by the fact that the homograft does not have a potential for growth (2, 3). Hence, right-sided cardiac dysfunction is a major problem due to the increased pressure gradient across the right ventricular outflow tract in many patients (3). Conventionally-used echocardiography is poor at visualizing the right ventricular outflow tract. Digital subtraction angiography (DSA) and catheterization are primary diagnostic tools used for right heart evaluation, but they are invasive, expose the patient to radiation and require nephrotoxic contrast agents. MRI, however, provides global depiction of the left heart, right heart and pulmonary perfusion in a noninvasive manner. The purpose of this retrospective study was to evaluate whether valve dynamics and pulmonary perfusion parameters as measured by MRI can predict right heart dysfunction in patients post Ross procedure.

Materials and Methods

Institutional review board approval was obtained.

Patient Population Sixteen patients post-Ross procedure and 16 age-sex matched control patients with Cardiac MRIs between 2003 to 2007 were retrospectively selected and evaluated.

Imaging Technique Imaging was performed using a Siemens 1.5T Avanto (Malvern, PA) with a 12-channel body array coil. The imaging protocol included multiplanar cine TrueFISP, phase contrast MRI (PC-MRI), dynamic time-resolved MR angiography (TR-MRA) and delayed enhanced imaging.

Quantitative Analysis All images were de-identified and transferred to a three dimensional post-processing workstation. Right ventricular (RV) and left ventricular (LV) volumetric parameters, including ejection fraction (EF), end systolic volume (ESV) and end diastolic volume (EDV), were calculated from the cine TrueFISP images using the Argus post-processing software. Pulmonary and aortic valve velocity and flow were calculated from the PC-MRI images using the Argus post-processing software. Valve areas at maximal leaflet opening were measured from the PC-MRI using the Viewing post-processing software. Cardiopulmonary transit time and time-intensity curves of pulmonary artery and aorta with full width at half maximum (FWHM) calculations were measured from dynamic TR-MRA using the Mean Curve post-processing software (see Fig 1). Pulmonary blood volume was calculated by multiplying the average flow through the pulmonary valve from PC-MRI by the cardiopulmonary transit time from the TR-MRA.

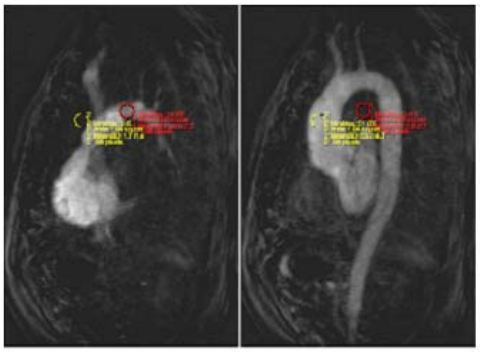

Fig 1. Select dynamic time-resolved MR Angiography (TR-MRA) images depicting maximum intensity in regions of interest on the Pulmonary Trunk and Ascending Aorta respectively.

Statistical Analysis All parameters were compared between the patients post-Ross procedure group and the age-sex matched control group. The valve velocity, flow, area, regurgitation, pulmonary perfusion parameters and pulmonary blood volume were correlated with volumetric data. The results were statistically analyzed with SPSS for Windows (version 14.0). The Mann-Whitney U test, Paired-Samples T test, Pearson Correlation and Linear Regression were performed. Statistical significance was indicated by a p-value of less than 0.05.

Results:

Patients post Ross procedure had lower EF, EDV, and higher ESV than control patients. The differences in RVEF and RVESV values between groups were statistically significant ($p < 0.05$). There was a statistically significant difference in all pulmonary circulation parameters between both groups. Patients post Ross procedure had a longer cardiopulmonary transit time, longer pulmonary artery FWHM, and longer aorta FWHM than control patients ($p < 0.01$). Volumetric parameters correlated with pulmonary perfusion parameters (see Table 1). RV parameters correlated with cardiopulmonary transit time, pulmonary artery FWHM and aorta FWHM better than LV parameters. Moreover, pulmonary blood volume correlated with RVEF, RVESV, and LVESV in patients post Ross procedure. Higher pulmonary blood volume predicts lower EF and higher ESV, especially for the right ventricle.

TABLE 1

Correlations (R Value, P Value) between Volumetric Parameters and Pulmonary Circulation Parameters

Volumetric Parameters	Transit Time (s)	Pulmonary A. FWHM (s)	Aorta FWHM (s)	Pulmonary Volume (mL)
LVEF (%)	-0.44, 0.012	-0.30, 0.132	-0.30, 0.124	-0.41, 0.129
LVEDV (mL)	0.37, 0.035	0.31, 0.126	0.49, 0.008	0.48, 0.067
LVESV (mL)	0.45, 0.009	0.34, 0.092	0.43, 0.023	0.54, 0.036
RVEF (%)	-0.66, <0.001	-0.53, 0.006	-0.35, 0.065	-0.58, 0.023
RVEDV (mL)	0.31, 0.089	0.39, 0.048	0.58, 0.001	0.33, 0.232
RVESV (mL)	0.59, <0.001	0.62, 0.001	0.64, <0.001	0.57, 0.026

Conclusion:

In this retrospective study of Cardiac MRIs of patients post Ross procedure and normal controls, we have determined that pulmonary perfusion parameters best predict right heart dysfunction in patients post-Ross-procedure.

Neither degree of stenosis, as measured by valvular areas and peak velocity, nor regurgitation, as measured by regurgitant volume and fraction, can predict ventricular function. This finding is in contrast with that found by Grotenhuis et al, who have shown that aortic root dilation and aortic regurgitant fraction correlate with impaired LV systolic function (4).

The most discriminative parameters between patients post Ross procedure and controls are the pulmonary perfusion parameters. The cardiopulmonary transit time, pulmonary artery FWHM and aorta FWHM were prolonged in patients post Ross procedure ($p < 0.01$). All pulmonary perfusion parameters correlate with RV parameters better than they do with LV parameters. Strong correlations exist between pulmonary circulation parameters and right ventricular function, especially cardiopulmonary transit time and right ventricular ejection fraction ($R > 0.60$, $p < 0.001$). Hence, cardiopulmonary transit time and its related parameters are useful tools for predicting RVEF, RVEDV and RVESV, all of which are difficult to measure on echocardiography.

Estimating RV volumetric data might be especially important for patients post Ross procedure, for whom right sided pulmonary homograft dysfunction is a major concern. Therefore, the MRI-derived pulmonary perfusion parameters might be useful for monitoring or predicting the progression of cardiac disease in Ross Procedure patients. Further physiological understanding of pulmonary perfusion parameters is essential and more studies are needed to delineate their use in the clinical setting.

Literature Cited:

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