Time-Resolved MR Angiography for Assessment of Pulmonary Hypertension in Patients with Congenital Heart Disease

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Introduction:

Congenital heart disease is a common congenital malformation at birth with an incidence of 8/1,000 live births. Pulmonary hypertension remains a major complicating factor of many types of congenital heart disease and is usually the result of an increase in pulmonary blood flow through a large left to right shunt. MRI has the advantage of not only assessing cardiac morphology and function but also flow dynamics using time-resolved MRA (TR-MRA). Calculation of pulmonary circulation parameters using TR-MRA has previously been demonstrated in patients with heart failure[1] and a similar approach could be applied for assessment of pulmonary hypertension. The purpose of our study was to retrospectively determine cardiopulmonary transit times, as measured by TR-MRA, in patients with congenital heart disease and concomitant pulmonary artery hypertension and correlate with volumetric indices of heart failure.

Materials and Methods:

Eleven patients (3 male, 8 female, mean age 38±17, age range 19-69) diagnosed with Congenital Heart Disease (ASD, VSD, PDA, TOF and dTGA) and eleven control patients (7 male, 4 female, mean age 40±13, age range 24-67) were retrospectively evaluated using MRI. Images were acquired on a 1.5T scanner (Avanto, Siemens Medical Systems, Erlangen, Germany) using a phased array body coil. The imaging protocol consisted of multiplanar cine steady state free precession (SSFP), time resolved contrast enhanced MR angiography, phase contrast MRI and delayed enhanced inversion recovery turboFLASH. Time resolved CE-MRA was obtained in left anterior oblique (LAO) and coronal orientations using a 3D gradient echo FLASH pulse sequence with following parameters: TR/TE: 2.2/1.1 msec, flip angle: 25^0; voxel size: 1.5x2.5x2.5 mm. Parallel imaging with iPAT acceleration x2 and echo sharing with TWIST were utilized to further accelerate the acquisition.

All patients with Congenital Heart Disease had previously received a diagnosis of Pulmonary Hypertension, defined as Right Ventricular Systolic Pressure (RVSP) of more than 40 mm-Hg at Echocardiography. Right and Left Ventricular volumetric parameters including Ejection Fraction (EF), End-Diastolic Volume (EDV), End-Systolic Volume (ESV) and Stroke Volume (SV) were measured using Argus (Siemens Post-processing software). Additionally, Cardiopulmonary transit times and dispersions (full widths at half maximum [FWHM]) were determined from maximum intensity projection (MIP) MR angiographic images. (Fig. 2, 3) Pulmonary blood volume was calculated by multiplying the average blood flow through the pulmonary valve (measured from phase-contrast images) by the cardiopulmonary transit time. Transit times and FWHM values for the congenital heart patients were compared with those for the control subjects by using two-tailed t tests. Pearson correlation coefficients were used to assess the relationship between transit times and Pulmonary Blood Volume and right and left heart volumetric parameters (EF, EDV, ESV,and SV).

Results:

Cardiopulmonary transit times, pulmonary and aortic FWHM values were significantly prolonged in patients with congenital heart disease compared with those in the control patients ($p<0.001$) (Fig.4) There was a statistically significant correlation between cardiopulmonary transit time, pulmonary and aortic FWHM and right ventricular ejection fraction (RVEF) ($R>0.60$, $P<0.05$). (Fig.3) Also we found a strong correlation between pulmonary FWHM and all of volumetric parameters of left and right ventricles, except for right ventricular EDV (Fig.3). There was no statistically significant correlation between left ventricular EF, ESV, EDV, transit times and pulmonary blood volume ($P>0.05$). (Fig.3)

Conclusion:

Cardiopulmonary transit time and dispersion are significantly prolonged in congenital heart disease complicated with pulmonary artery hypertension and correlate well with ventricular volumetric indices of right heart failure. The results of our study suggest that transit times and curves measured by TR-MRA may provide a useful adjunct tool for assessing and following pulmonary hypertension and early right-sided heart failure in congenital heart disease patients.

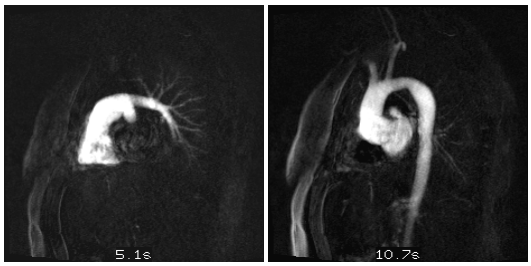

Fig.1 Time-resolved oblique sagittal projection MR Angiogram

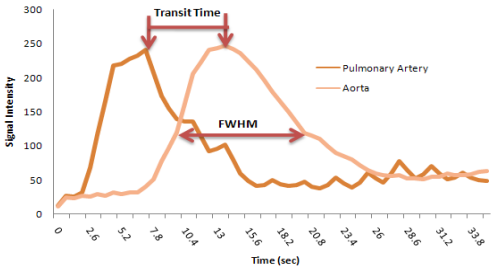

Fig. 2 Generation of Cardiopulmonary Transit Curves, Calculation of Transit Time and FWHM

Correlation	Transit Time	Pulmonary FWHM	Aortic FWHM	Pulmonary Blood Volume
LVEF	-0.34 (p=0.31)	***-0.75 (p=0.00)***	-0.38 (p=0.24)	-0.06 (p=0.92)
LVEDV	0.19 (p=0.31)	***0.59 (p=0.05)***	0.17 (p=0.61)	0.42 (p=0.39)
LVESV	0.29 (p=0.38)	***0.70 (p=0.01)***	0.28 (p=0.40)	0.30 (p=0.57)
RVEF	***-0.69 (p=0.01)***	***-0.69 (p=0.01)***	***-0.66 (p=0.02)***	-0.53 (p=0.13)
RVEDV	0.13 (p=0.71)	0.44 (p=0.17)	0.47 (p=0.14)	0.26 (p=0.77)
RVESV	0.37 (p=0.16)	***0.57 (p=0.04)***	***0.59 (p=0.02)***	0.30 (p=0.62)

Fig.3 Correlation between Transit and Volumetric parameters
(Numbers in Bold: Statistically significant)

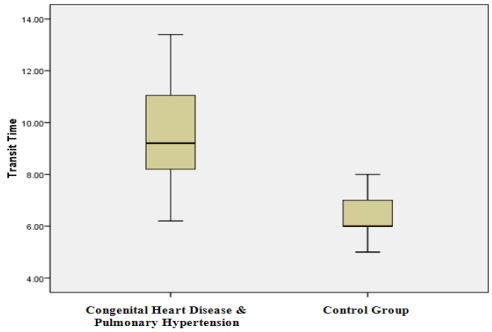

Fig.4 Box plot depicting the difference in transit time between Congenital heart disease patients and controls

References:

1. Shors SM, Finn JP, et al. Heart Failure: Evaluation of Cardiopulmonary Transit Times with Time-resolved MR Angiography, Radiology 2003; 229: 743-748.