Validation of 4D Flow shunt fractions (Qp/Qs) with 2D-PC in patients with Partial Anomalous Pulmonary Venous Return

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Target Audience: Cardiovascular imagers and Surgeons

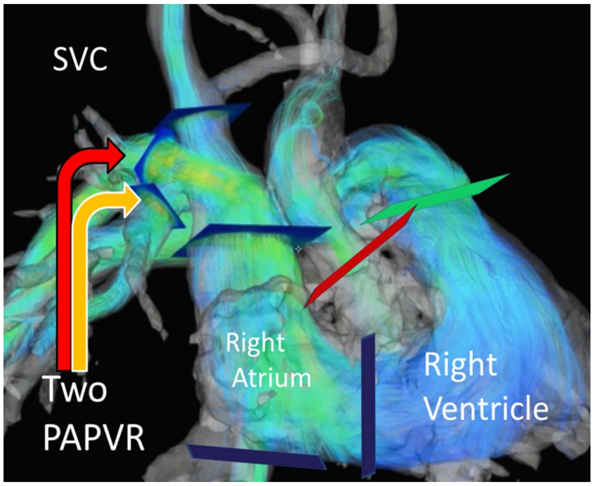

Figure 1: 4D flow of PAPVR patient showing cutplanes at two anomalous pulmonary viens (red and yellow arrows)

Purpose: To compare 4D phase contrast (4D flow) flow imaging with conventional 2D phase contrast (2D-PC) MRA for the quantification of Qp/Qs (shunt fraction) in patients prior to surgical repair for partial anomalous pulmonary venous return (PAPVR).[1] There is a high association of atrial septal defects and PAPVR.[1, 2] Surgery is typically only performed when the left to right shunt fraction (Qp/Qs) is ≥ 1.5.

Methods: This was a HIPAA-compliant, IRB-approved prospective study for validation of 4D flow quantification of shunt fraction in patients with known congenital heart disease. A total of six patients with PAPVR and 10 normal volunteers were studied All patients and volunteers were scanned on clinical 1.5T or 3T systems (HDxt, MR750, GE Healthcare, Waukesha, WI). 2D-PC MRA was performed on patients as part of the routine clinical MRI. Volumetric 4D flow was acquired with dual-echo radial 4D flow MRI (PC-VIPR[3]) including respiratory and retrospective cardiac gating, 1.25mm^3 isotropic spatial resolution, BW=±125 kHz, TR=6.2ms, FOV=32cm x 32 cm x 20 cm, 12,000 dual echoes, scan time= ~13 min, V_{enc} = 160cm/s, reconstructed with 15-20 time frames per R-R interval. All patients and volunteers successfully completed the exam. Post processing and flow analysis of their PC-VIPR and 2D-PC MRA was performed using Encyte ™ (Figure 1). Pulmonary flow (Qp) was divided by the aortic flow (Qs) to yield the shunt fraction (Qp/Qs).

Results: Figure 2 shows a calibration plot for the Qp/Qs ratio obtained from the two methods. Correlation coefficient (R^2) between 4D flow measurements and 2D-PC was 0.79 for normals and 0.98 for the patients with p-values of 0.0006 and 0.0001, respectively. A Bland Altman analysis showed good agreement for normals (0.0504-0.204; 95% C.I.) and PAPVR patients (0.0595-0.287; 95% C.I.). Figure 1 shows 4D flow streamlines from a patient with PAPVR from the right upper lobe into the superior vena cava (SVC). One of the PC-VIPR flow measurements had phase aliasing and was removed from this analysis. 4D flow slightly underestimated Qp and Qs when compared with 2D-PC.

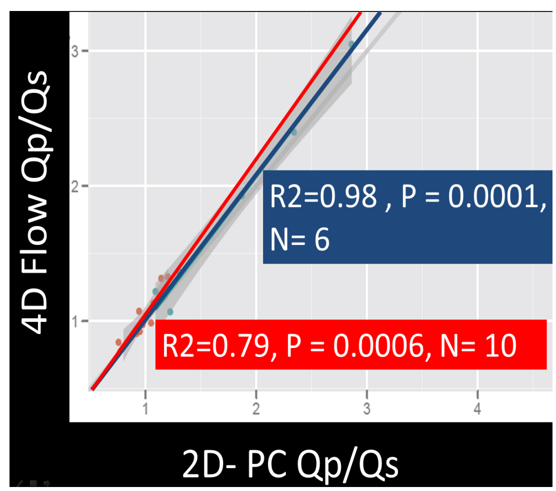

Figure 2: Plot of 4D flow Qp/Qs vs 2D PC Qp/Qs in PAPVR (Blue) and normals (Red).

Discussion: This preliminary study shows no significant difference in the Qp/Qs measurements between PC-VIPR 4D flow and 2D-PC for patients with PAPVR. The main advantage of using 4D flow MRI rather than 2D-PC for patients with PAPVR is the ability to supplant the acquisition of multiple prosepectively acquired double oblique planes with retrospective analysis after a comprehensive data acquisition. This leads to considerable time savings of the patient in the magnet, particularly if there are multiple shunts that are commonly present in congenital heart disease. Additional benefits of 4D flow imaging include advanced visualization of complex flow patterns and the derivation of hemodyanmic parameters from the dynamic velocity vector field such as pressure gradients, pulse wave velocity, wall shear stress, and others.

Conclusion: The use 4D flow MRA allows for accurate retrospective interrogation of Qp/Qs (shunts) in patients with complex congenital heart disease.

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References: 1. Broy C, Bennett S. Military medicine. 2008;173(6):523-4, 2. Healey JE, Jr. The Journal of Thoracic surgery. 1952;23(5):433-44.,3. Nett EJ et al J Magn Reson Imaging. 2012 Jun; 35(6):1462-71.