COMPARISON OF HEMODYNAMIC END POINTS BETWEEN NORMAL SUBJECT AND TETRALOGY PATIENT USING WOMERSLEY VELOCITY PROFILES AND MR BASED FLOW MEASUREMENTS

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Background: Adults who have undergone Tetralogy of Fallot (rTOF) repair in infancy are known to develop age-related, progressive right ventricular (RV) dilatation. Failure to recognize the degree of RV dilatation, and subsequent failure to intervene, can lead to RV failure and sudden death. Despite the lifelong need for cardiac surveillance in this population, there is a paucity of numerical data characterizing blood flows in the branch pulmonary arteries (PA) of rTOF patients. The objective of this study was to apply computational fluid dynamics (CFD) to understand the blood flow mechanics in both an rTOF and a normal subject using Womersley type velocity profiles computed from anatomic and cine phase contrast MRI (PCMRI) based flow measurements.

Methods : Patient specific 3D geometry for the branch pulmonary arteries (PA) was reconstructed from anatomic MRI scans of the individual subjects (rTOF and normal; Fig. 1). Pressure was measured using catheterization data, and PA flow rates were measured using PCMRI. CFD analysis was performed by using pulsatile pressure and Womersley type velocity boundary conditions at appropriate inlet and outlets of the branch PA computed from the PCMRI measurements. The equation for velocity profile is given by

$$u(r,t) = \frac{2Q_0}{\pi R^2}\left(1 - \frac{r^2}{R^2}\right) + \sum_{n=1}^{N} \mathrm{Real}\left\{ \frac{2Q_n}{\pi R^2} \left[\frac{1 - \dfrac{J_0(\alpha_n \frac{r}{R} i^{3/2})}{J_0(\alpha_n i^{3/2})}}{1 - \dfrac{2J_1(i^{3/2}\alpha_n)}{i^{3/2}\alpha J_0(i^{3/2}\alpha_n)}} \right] e^{in\omega t} \right\}$$

where, J_0 and J_1 are the Bessel function of first kind of order 0 and 1 respectively, and α_n is the Womersley number, R is the inlet/outlet radius and Q_n's are complex Fourier series coefficients of the respective flow rate pulse.

Results: Numerically calculated data for MPA and RPA pressures and LPA flow rate were validated with experimental measurements. For the normal subject, the time averaged RPA pressure from computational (13.8 mmHg) and experimental measurements (14.6 mmHg) differed by 6%. The time-averaged pressure for the MPA differed from computational (16.5 mmHg) to experimental measurement (16.3 mmHg) by 1%. The LPA regurgitant fraction based on the computational LPA flow was 89% compared to measured 77.5%, while the same for the rTOF was 43% (computational), compared to 39.6% (measured).

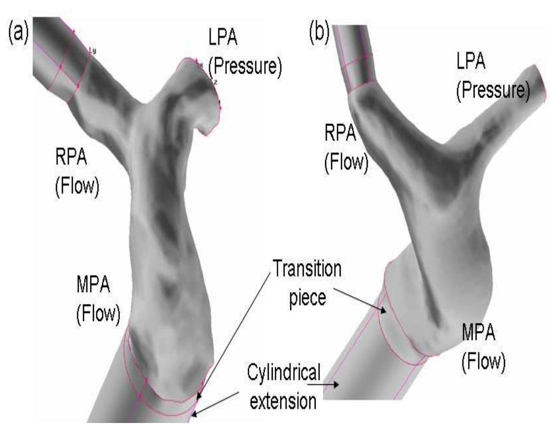

Fig. 1: Patient specific geometry of (a) normal and (b) rTOF subjects along with locations of flow/pressure measurements.

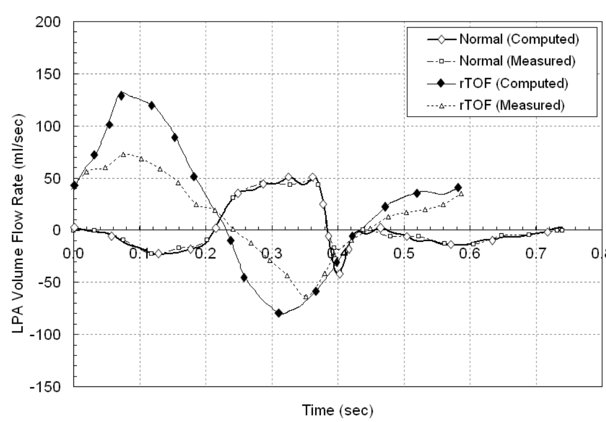

Fig. 2: Validation of numerical flow rates at LPA with measured flow rate for normal and rTOF subject.