

SURGICAL VENTRICULAR RESTORATION IMPROVES THE INTRA-VENTRICULAR FLOW: MRI/CFD SIMULATION

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Introduction: The surgical ventricular restoration (SVR) by Dor procedure consists of surgically creating a smaller ventricle with a more normal shape via an endoventricular circulo-plasty technique used to treat ventricular aneurysms. The effect of this surgery on left ventricle (LV) 3D flow has not been fully studied. We have recently published a new method for determining LV flow via the combination of magnetic resonance imaging and computational fluid dynamics (CFD) [1-2]. Patients after myocardial infarction had significantly differences on vortex formation and number of vortex compared to normal hearts [2].

Purposes: To examine LV 3D flow before and after SVR in a patient-specific model.

Methods: The SVR procedure was performed by means of endoventricular circular patch plasty by Dor procedure in an end-stage heart failure. The cine MR images were acquired on a 1.5T Siemens scanner with conventional ECG gating. The TR/TE/flip angle is typically 65ms/1ms/70°. The voxel size is 1.46x1.46x8mm. The LV localization algorithm was coded using MATLAB (The Mathworks, Natick, USA). The MRI acquisition was performed both before and 4-month after surgery. Short-axis and long-axis MRI were used to reconstruct LV three-dimensional geometry during cardiac cycle, as previous published [3-4]. Intermediate geometries are generated to provide fine enough time steps for CFD modeling and discontinuous time step fashion is used. In each geometry, a separate unstructured grids consisting of tetrahedral cells are generated. A semi-automatic method in commercial software ANSYS ICEM CFD12 was used for grid generation. The final model contained 168752 tetrahedral cells. The criterion for grid quality was that the maximum value of face skew angle must be lower than 40 degree. To solve the Navier-Stokes equations and to visualize the data, FLUENT 14.0 software was used.

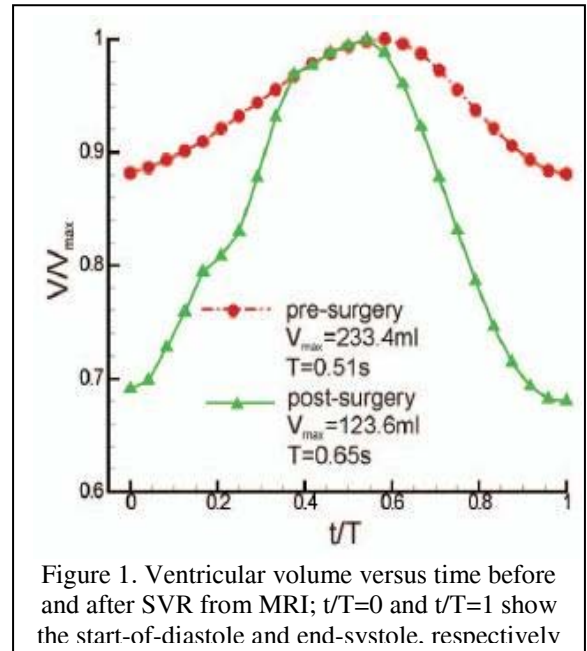


Figure 1. Ventricular volume versus time before and after SVR from MRI; $t/T=0$ and $t/T=1$ show the start-of-diastole and end-systole, respectively

Results and discussion: Figure 1(a) shows the change of volume versus time before and after SVR. Before surgery, the LV end-systolic volume (ESV) and end-diastolic volume (EDV) are 205.6 ml and 233.4 ml, respectively, which give the SV of 27.8 ml and LVEF as 12%. The ESV and EDV after surgery are 84.1ml and 123.6 ml, respectively, which give the SV of 39.5 ml and LVEF as 32%. Ventricular flow patterns in the patient were significantly altered by SVR during diastole and systole phases (Figures 2 & 3). Further, LV vortices are more powerful post-surgery than pre-surgery and this helps to an efficient ejection and minimize the energy dissipation.

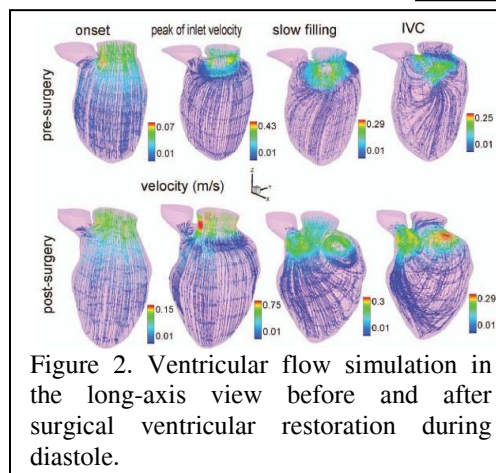


Figure 2. Ventricular flow simulation in the long-axis view before and after surgical ventricular restoration during diastole.

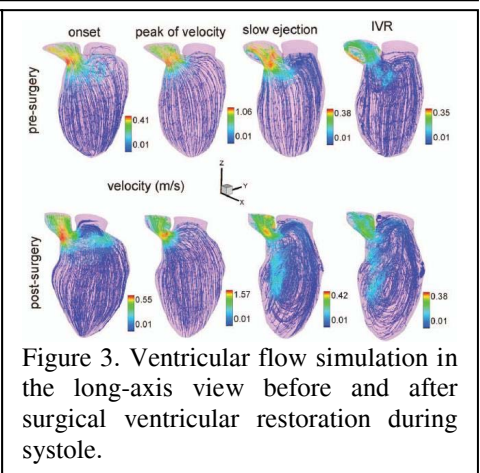


Figure 3. Ventricular flow simulation in the long-axis view before and after surgical ventricular restoration during systole.

Conclusion: The combined MRI/CFD simulation of flow enables quantitative assessment of SVR procedure. Future work should focus on flow optimization in preoperative modeled ventricle undergoing SVR.

Acknowledgement: Grant support by the National Medical Research Council (NMRC), Grant #EDG/1037/2011

References:

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