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A 2D patient-specific FSI assessment of the impact of left atrium boundary conditions on left ventricle vorticity and mitral valve movement

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ABSTRACT

The dynamics of the mitral leaflets and their influence on the transmitral and intraventricular flow is a controversial topic. In this paper we report results from work in progress on patient-specific fluid-structure simulations on the mitral leaflets during left ventricular filling. The aim of our study was twofold: To introduce patient-specific measurements in a rational way, to both achieve a higher degree of physiological realism in the simulations and to reduce the computational cost. Secondly, we aimed at an assessment of the impact of the mitral leaflet dynamics on vortex formation in the left ventricle. The two mitral valve leaflets have significantly different geometries and was therefore separately modeled to capture their individual influence on the flow.

The inflow conditions are in most simulations applied directly on the mitral opening. This is often unavoidable because the atrium is neglected. By incorporating the left atrium, the inflow boundaries will be moved away from the ventricular cavity. The blood flow within the ventricle will then become less sensitive to the imposed boundary conditions and their inaccuracies. There are at present no unity among researchers of which is the most appropriate boundary condition for mitral flow. Different inflow conditions will be analysed in this study. The effect of a moving atrium compared to a fixed atrium will be investigated. By using a moving atrium the inflow condition will be the volume flow from the pulmonary vein into the atrium and the velocity and pressure distribution will follow thereafter.

An implicitly coupled fluid structure interaction scheme was utilized for the numerical simulations of the mitral leaflets. A two-dimensional transient representation of a patient-specific left ventricular wall movement was imposed as boundary conditions for the simulations. For the simulation where a fixed atrium was utilised, a typical pressure distribution was implemented along the LA periphery as an inlet condition. The left ventricular and left atrial wall were rendered by ultrasound recordings of a young healthy heart, and speckle tracking was used for transient tracking of the wall movement during diastole. The region of interest (ROI) for the ventricular and atrial wall are shown in figure 1a and 1b respectively.

The ultrasound measurements were used both for validation/comparison with the simulated mitral valve dynamics as well as for imposition of the left ventricular and left atrial wall movements. Our simulations

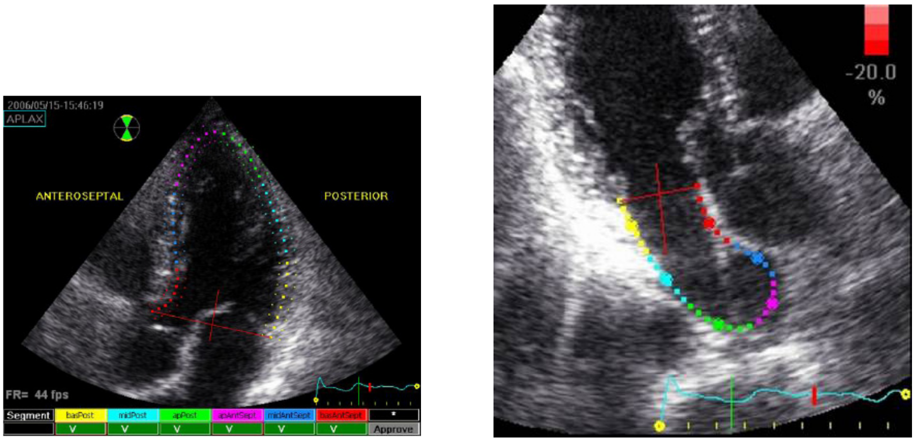

Figure 1: Region of interest for the LV and LA respectively. ECG in the lower right corner

indicate that the mitral valve flutter has important bearings on the vortex formation in the vicinity of the mitral valve. The two leaflets' influence on the flow field were also found to be significantly different from one another, demonstrating that both leaflets should be included to be able to capture a realistic flow field.

A crucial simplification in this study is the 2D approach. By excluding the potential for three dimensional vortex instability, the vortex wake will get more persistent and sustain for a longer time. Simulations in 3D are required to capture the evolution of a wake after the formation phase. However, a 2D approach may still give a qualitative description of the vortex formation.