Effects of detailed ventricular anatomy on the blood flow

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Abstract-*The presented study is a preliminary test and analysis of the role of trabeculae and papillary muscles in the hemodynamics of the left ventricle (LV).*

I. INTRODUCTION

The aim of the present study is to examine the role of trabeculae and papillary muscles in cardiac functionality. Trabeculae and papillary muscles are two tissue structures that project from the inner surface of the ventricular endocardium. The utility of papillary muscles has been related to valve function by pulling the chordae tendinae. However, little has been done to simulate the role of both papillaries and trabeculae in the overall cardiac electro-mechanics and hemodynamics [1, 2]. Most blood flow simulations consider a smooth ventricular surface [2, 3, 4, 5, 6], however are we sure that trabecular and papillary structures don't modify the blood flow pattern?

II. METHODS

A. LV Models

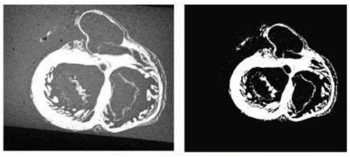
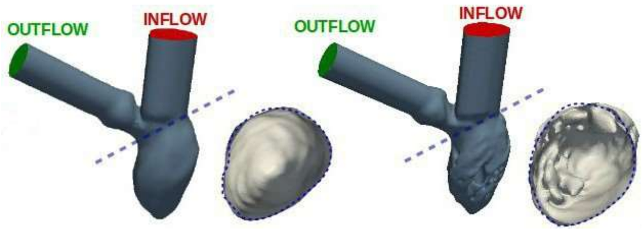


Fig.1: Segmentation of high resolution MRI of ex-vivo human hearts

From MR images of an ex-vivo human heart (Fig. 1) two LV models were created: a smooth-edocardium (Fig. 2, left) and a detailed-endocardium (Fig. 2, right)ventricle *Fig.2:*



Smooth LV and detailed LV models with boundary conditions

comprising trabeculae and papillary muscles. Tubes were attached at mitral and aortic valve levels to extend the inflow and outflow tracts.

B. *Meshes and simulations*

Iris, an in-house mesh generator was used to generate the two meshes and steady flow simulations were carried out with Alya (code developed at BSC) [7]. For the detailed geometry, a mesh of 1.886 million elements was created. For the smooth geometry two mesh resolutions were tested: a 362.740 and a 19.933 elements mesh. Peak physiological velocity was imposed at the inlet [8], zero pressure at outlet and rigid wall boundary conditions were considered with an approximate Reynolds number of 120.

III. RESULTS

For the smooth geometry case, CFD was solved at two resolutions to verify convergence and identify if the blood flow pattern could be influenced by the mesh resolution. The two smooth models showed that results were visually similar.
By analysing the fluid dynamics in the the smooth and detailed geometries, it can be seen that blood flow has a completely different pattern between them. The trabeculae and papillary muscles disturb the flow creating vortices at the apex (Fig. 3), and mitral valve level (Fig. 4) that are not present in the smooth case.

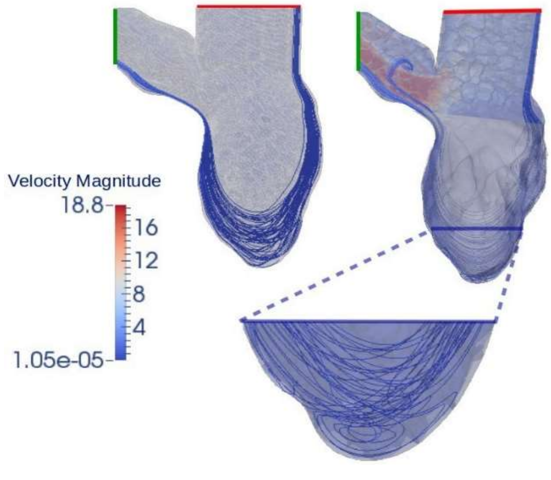


Fig.3: The smooth geometry (left) is characterized by complete laminar flow while in the detailed one (right) vortices can be seen at apex level

IV. LIMITATIONS

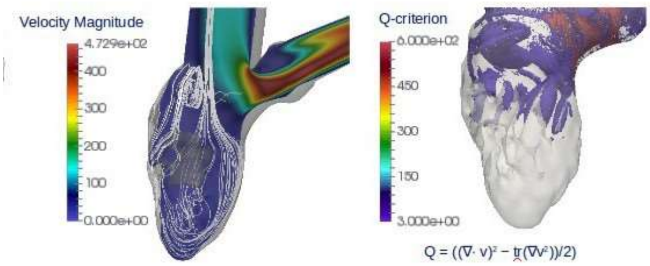


Fig.4: The detailed geometry is also characterized by vortices at the mitral valve level

In this preliminary work, rigid wall boundaries and steady flow conditions were considered, not taking into account physiological pulsatile flow and ventricular contraction during the cardiac cycle. Moreover, the simulations were done without taking into account the mitral and aortic valve.

V. FUTURE DEVELOPMENTS

Ventricular wall motion will be added as boundary conditions and pulsatile flow will be applied at inflow in order to simulate at best the physiological conditions in cardiac contraction. Valves will be attached and simulations will be carried considering valve motion.

ACKNOWLEDGMENT

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