TRANSCATHETER MITRAL VALVE REPLACEMENT: ASSESSMENT OF LEFT VENTRICULAR OUTFLOW TRACT OBSTRUCTION

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Introduction

A majority of patients with severe mitral regurgitation (MR) is not eligible fur surgical repair or replacement of the affected heart valve due to high surgical risk. Thus, interventional therapies such as transcatheter edge-to-edge replacement (TEER) or transcatheter mitral valve replacement (TMVR) are promising approaches to provide treatment for this patient group. However, the wide success of catheter-based replacement of the aortic valve could not net been facilitated with TMVR, and this technique is still associated with high mortality [1]. Reasons for this are strong differences in treatment strategies, etiologies, as well as the anatomical challenges in aortic stenosis and MR. In this study we investigate whether in-silico modelling can be used to assess the patient-specific risk of left ventricular outflow tract obstruction (LVOTO) after TMVR, a condition that is associated with intra- and post-procedural mortality [2]. LVOTO can occur due to the TMVR device protruding into the left ventricle, already narrowing the LVOT. Furthermore, the device displaces the anterior mitral valve leaflet into the LVOT to which it can be entrained, worsening the obstruction.

Methods

The patient-specific anatomy of the left ventricle, the mitral valve, and the aorta was reconstructed from time-resolved computed tomography data in the systolic state. Subsequently, a virtual device is implanted using a finite element approach in which both device and anatomy are modelled as shell-elements. The tissue is modelled as linear elastic material, whereas the device is modeled as growing rigid body reaching its full deployment independent of the tissue properties. This device implantation is performed using the same device (model, size) as chosen in the real treatment. However, several positions varying in depth of the device into the ventricle, as well as tilting between the mitral valve and device axis are simulated. For each device configuration, a steady-state hemodynamic simulation is performed using a finite volume approach (STAR-CCM+, Siemens PLM). The steady state uses a peak-systolic volume flow rate measured from the pre-interventional stroke volume (SV) of the patient and accounting for the reduction of the SV due to treatment of the MR. Similar to the device position, the volume flow rate is varied, resulting in multiple simulations per patient. The following parameters are evaluated for each simulation: resulting minimal cross-sectional area in the neo-LVOT, the maximum velocity in the LVOT, the pressure gradient, and the force resulting from the pressure-distribution on the anterior mitral leaflet.

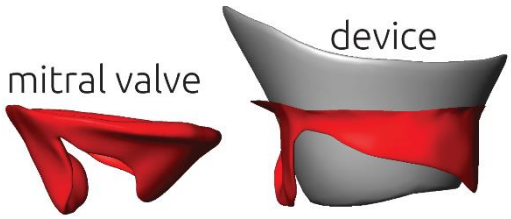

Figure 1: Configuration of the mitral valve before (left) and after (right) device implantation.

Results and Discussion

Computational modelling was shown to be a promising approach for identification of LVOTO risk assessment, as it provides not only detailed understanding of the anatomical configuration of the heart and the device but also provides functional information [3]. However, modelling of the anterior leaflet is usually omitted. This study includes the anterior mitral valve leaflet but opts for a strongly simplified numerical model at first. However, this model is evaluated on large variation of device positions as well as hemodynamic boundary conditions. The reason for this approach is, that necessary information for patient-specific modelling, such as information on the patient-specific tissue properties or the post-interventional SV will not be available from clinical routine data used for planning. Additionally, the implantation procedure itself is also affected by uncertainties, making it impossible to identify the exact configuration a-priori. Thus, we decided to simulate a set of different configurations to assess the entire physiological envelope of possible configurations of device position and hemodynamic boundary conditions. As this study is currently ongoing, only preliminary results are yet available. The methods will be applied to ten patients and results will be compared against post-interventional follow up data, to assess viability of individual LVOTO risk assessment.

References

1. E 10.21037/acs.2018.10.06
2. 10.1016/j.jcin.2018.12.001
3. Hill et al.; 10.3389/fcvm.2022.934305