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Leaflet contact modelling and fluid-structure interaction within the left ventricle of the human heart

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A common treatment method for regurgitation in the mitral valve (MV) in the human heart is by inserting a mitral valve clip. This procedure is minimally invasive, and prevents backflow from the left ventricle to the atrium by permanently sealing part of the MV. However, its effects on the intraventricular blood flow are poorly understood. In a recent study, we found that blood cells are subjected to increased shear levels after this treatment[1], which could imply an elevated risk of thrombosis formation.

Now we significantly improve the model with an FSI approach. Instead of simulating the MV as an opening projected onto the ventricle wall with pre-determined opening patterns, we model the MV leaflets as elastic solids whose displacements are determined by the interaction with the blood flow. These 3D leaflets affect flow patterns in the blood, leading to differences in mechanical stimuli on blood cells. This increases reliability of the results, which opens up for improving the clinical significance of future studies.

To carry out the simulations, we use an arbitrary Lagrangian-Eulerian (ALE) FEM approach that we have previously successfully applied to simulate the aortic valve[2]. The more complex geometry of the MV, with chordae tendinae connecting the leaflets to the papillary muscles, adds new challenges to this endeavour. The model uses a monolithic mesh, with solid and fluid subdomains. Contact between the valve leaflets is modeled using part of the fluid subdomain as a contact medium, letting fluid elements temporarily become solid to close off the MV opening, without any cells collapsing completely between the leaflets as they close. This is done without having to apply any remeshing.

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