Patient-Specific Simulation of Degenerative Mitral Valve Apparatus

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Key Words: Mitral valve, Informed tissue modeling, Patient-specific FE model

Background: The mitral valve ensures unidirectional blood flow from the left atrium to the left ventricle. Degenerative mitral valve (DMV) disease is one of the main causes of mitral regurgitation [1]. DMV is associated with disrupted collagen fibers, the main mechanical load carriers in the mitral valve leaflets [2]. The material behaviour is therefore very different from that of healthy tissues. Outcome of different surgical techniques can be evaluated using numerical simulations. However, inter-patient variability requires the use of appropriate material modeling, geometry, and boundary condition. This study characterizes the material of the DMV leaflet combined with a patient-specific finite element (FE) model.
Method: Tissue samples are taken peroperatively from patients diagnosed with DMV disease. Upon explantation, it is snap frozen, stored in a biobank, and transported to the testing facility in liquid nitrogen. After thawing, the mechanical behavior is investigated with planar mechanical tensile tests. The tissue is then chemically fixed, cleared and imaged over its entire thickness using second harmonic generation (SHG) microscopy. The distribution of the collagen fibers as the main load carrier is quantified by image analysis. The quantified structural and mechanical testing are used for informed tissue modeling. The tissue model is implemented in a commercial FE software. The geometry and boundary conditions of the patient are extracted from echocardiography images that were recorded before surgery, as in [3].
Conclusion: FE modeling of DMV apparatus has the potential to assist in preoperative diagnostics and surgical planning for which appropriate tissue models, geometry, and boundary conditions may improve the accuracy. This study examines the material parameters of the DMV leaflets with an informed tissue model and implements it in a patient-specific geometry and boundary condition FE model of DMV apparatus.

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