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Fluid-Structure Interaction Model of Calcific Aortic Valve Disease

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Objective Calcific aortic valve disease (CAVD) has become the most common heart valve disease in the Western countries, affecting approximately 25% of adults over 65. Both mild and severe CAVD are associated with adverse outcomes. Possible pathological triggers for CAVD include elevated hemodynamic shear stress and solid tissue stresses leading to calcification growth mainly in the cusps. The aim of this research is to determine the effect CAVD on the hemodynamics and tissue mechanics. Specifically, the stroke volume, flow shear stresses that acts on the tissue and the mechanical stresses in the tissues are evaluated for different stages of developing calcification of the aortic valves (AVs). Method A three dimensional calcified AV was numerically modeled. The structural model included compliant cusps with anisotropic material properties to depict those of physiologic values. The fluid dynamics model includes blood hemodynamic under physiologic pressures of the left ventricle and ascending aorta. Calcification was modeled based on patient specific computed tomography (CT) scans of patients candidates for Transcatheter Aortic Valve Implantation (TAVI). The mechanical properties of the calcification were also studied using micro-CT scans of excised calcified cusps. Results The collagen fibers of the cusp experience high stress magnitudes due to CAVD. The calcified zone experience about an order of magnitude higher stress values. Asymmetric calcification drives asymmetric flow which introduces high flow shear stresses on the aortic wall. High shear stresses were also found on the calcification. Conclusions The CAVD has significant impact on AV mechanics prior to stenosis. Both hemodynamics and the tissues are affected even by mild calcification. The elevated spatial stresses in the cusps may affect the calcification growth and pattern.