SIMULATION OF BLOOD FLOW IN THE CARDIOVASCULAR SYSTEM AND IN MEDICAL DEVICES

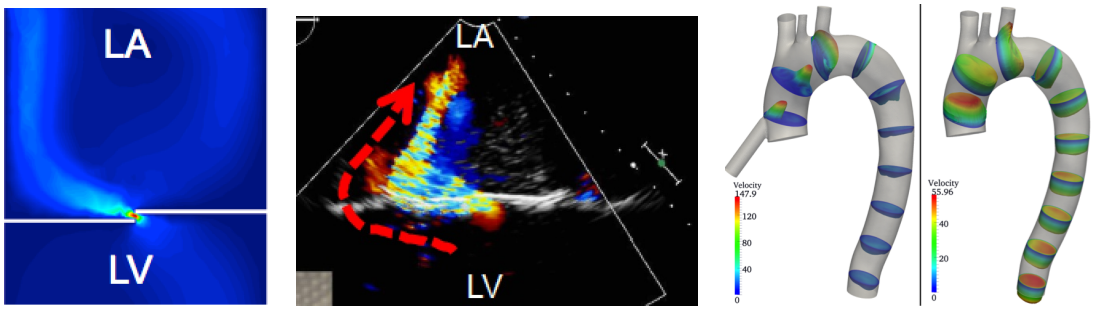
ABSTRACT

Cardiovascular diseases affect the life of millions of people every year. Mathematical models and numerical simulations can help understand physiological and pathological processes, complementing the information provided to medical doctors by medical imaging and other non-invasive means, thereby opening the possibility for a better diagnosis and more in-depth surgical planning.

We will report on how mathematical modeling can be used to advance the diagnosis and quantification of mitral regurgitation. Mitral regurgitation (MR) is a valvular disease in which the mitral valve does not close properly, thereby allowing blood to flow backward from the left ventricle to the left atrium of the heart. MR is among the most prevalent valve problems in the western world. However, due to the various instrumentation limitations, the accurate quantification of MR remains one of the major challenges in modern echocardiography. We are using computational models to show strengths and limitations of echocardiographic methods to assess the severity of mitral regurgitation.

We will also discuss how mathematical modeling can be used to plan surgery for Left Ventricular Assist Device (LVAD) implantation and Transcatheter Aortic Valve Replacement (TAVR). LVADs are implantable mechanical pumps that temporarily aid the function of the left ventricle. Very little is known about the influence of the LVAD on blood flow in the aorta. Computational models are a powerful tool to gain insights on such a matter. TAVR is an emerging therapy for the treatment of aortic valve stenosis. TAVR entails implanting a bioprosthetic valve mounted on a stent. An imperfect seal of the aortic annulus can lead to regurgitation of blood around the new valve, and to sub-optimal function of the prosthetic valve leaflets. We are working on predictive computational models of paravalvular regurgitation and deployed TAV geometry.

The presented work is in collaboration with cardiologists from the Methodist Hospital in Houston, and mathematicians and cardiologists from Emory University in Atlanta.



Left and center: computational simulation (left) and in-vitro reproduction (center) of a mitral regurgitant jet from the left ventricle (LV) into the left atrium (LA). Right: computed blood velocity in a human aorta when blood is pumped from the LVAD (left) and it is pumped from the heart (right).