Mitral valve dynamics in a closed-loop model of the cardiovascular system

By: Paeme, S, Chase, JG, Hann, CE, Lambermont, B, Kolh, P, Moonen, M, Lancellotti, P, Dauby, P.C., Barnett, A, Desaive, T

Abstract:

Introduction: A cardiovascular and circulatory system (CVS) model has been validated *in silico*, and in several animal model studies. It accounts for valve dynamics by means of Heaviside function to simulate “open on pressure, close on flow” law. Thus, it does not consider the real time scale of the valve aperture and thus doesn’t fully capture valve dysfunction. This research couples the CVS model with a model describing the progressive aperture of the mitral valve.

Method: We used a CVS system model with 6 elastic chambers (left and right ventricles, vena cava, aorta, pulmonary artery and veins) also accounting for ventricular interaction by means of septum displacement. The mitral valve aperture was modelled by considering the pressure forces induced by blood flow during a complete cardiac cycle. This valve equation was coupled with the CVS model to simulate cardiac hemodynamics with healthy and diseased regurgitating valves.

Results: We compared the simulations with the initial CVS model and the Heaviside valve law and with the new model including variable mitral valve aperture. Hemodynamics variables trends in both models show a good correlation and the new model describes accurately the opening and closing of the valve as expected physiologically. Despite the large number of parameters to optimise, we simulated realistically mitral valve regurgitation and found pressure-volume loops comparable to those observed clinically.

Conclusions: This work describes a new coupled model of the cardiovascular system that accounts for progressive mitral valve aperture. Simulations show good correlation with physiologically expected results for healthy or diseased valves. The large number of valve model parameters indicates a need for emerging, lighter and minimal mitral valve models that are readily identifiable to achieve full benefit in real-time use. These results suggest a further use of this model to track, diagnose and control valves pathologies.