A Multi-Scale Computer Model of the Cardiovascular System Can Account for the Three Roles of the Left Atrium

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Introduction : During a cardiac cycle, the left atrium exerts three different roles. It behaves as a reservoir when the mitral valve is closed. Then, when the valve opens, the atrium behaves as a conduit, passively emptying into the left ventricle. Finally, at the end of ventricular diastole, the atrium contracts as a pump, ejecting a supplementary amount of blood in the ventricle.

The left atrial behavior is difficult to reproduce *in silico* with the time-varying elastance concept since the shape of the elastance curve is complex and it is not sure whether the elastance curve is load-independent.

Methods : A simple model of sarcomere contraction is used to describe the behavior of the left ventricle and atrium, which are considered as hemispherical assemblies of sarcomere units. Modeled left ventricle and atrium are inserted into a closed-loop hydraulic model of the cardiovascular system.

Then, model parameters are adjusted to reproduce the hemodynamics of a normal dog. The set of adjusted parameters includes vascular resistances, vessel compliances and geometrical features of the left ventricle and atrium.

Results : The model correctly accounts for the three roles of the atrium. During one cardiac cycle, the following succession of events occur: the atrium fills (reservoir) until mitral valve opens, then it passively empties into the left ventricle (conduit) before actively contracting (pump) to further fill the left ventricle, before mitral valve closes.

The simulated left atrial pressure-volume loop consists of two lobes, namely the “v” loop and the “a” loop. The “v” loop is the result of passive atrial properties (reservoir and conduit), whereas the “a” loop reflects atrial contraction.

Conclusion : We implemented a multi-scale model of the cardiovascular system, in which left ventricular and atrial contraction are described by a detailed sarcomere model. Using this model, we successfully reproduced the physiological behavior of the atrium.