MITRAL VALVE DYNAMICS IN A CLOSED-LOOP MODEL OF THE CARDIOVASCULAR SYSTEM

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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. Results are shown for normal and diseased valve.

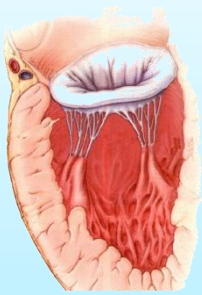
Methods

CVS model

We used a CVS system model with 6 elastic chambers (Fig 1) :

→Left and right ventricles, vena cava, aorta, pulmonary artery and veins

→Accounting for ventricular interaction by means of septum displacement.



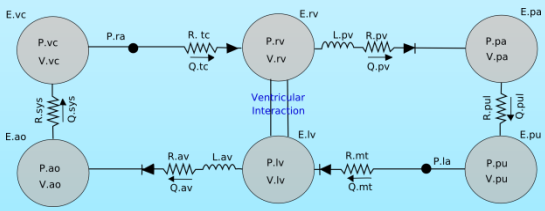


Fig 1

The mitral valve model

The mitral valve aperture (Fig 2) was modelled by considering the pressure forces induced by blood flow during a complete cardiac cycle.

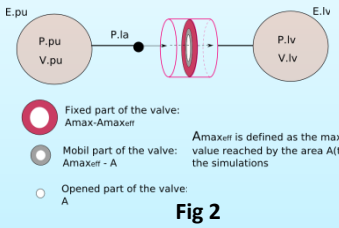


Fig 2

$$\frac{1}{\omega^2}\ddot{A} + \frac{2D}{w}\dot{A} + A = F(t)$$

$$F(t) = (A_{max} - A)\left[K_s(P_a - P_v) + K_d signe(v)\,v^2 + K_a\frac{dv}{dt}\right]$$

Coupling both models

→ Simulate cardiac hemodynamic (ventricular pressure-volume loops) with healthy and diseased regurgitating valves.

Results

Comparaison between initial and new models

In both models :

Hemodynamics variables trends show a **good correlation** for both ventricles.

The new model:

Describes **accurately** the **opening** and **closing** of the valve as expected physiologically (Fig 3).

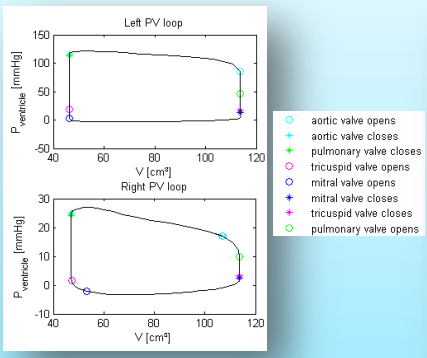


Fig 3

Simulation of mitral regurgitation (MR)

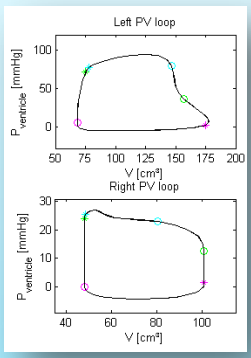


Fig 4

MR is a common valvulopathy where the valve can not close completely. To simulate MR, we do not allow a perfect closure of the valve during systole. Despite the large number of parameters to optimise, our model gives realistic pressure-volume loops (Fig 4) comparable to those observed clinically.

Conclusions

This work describes a new CVS model 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.**

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