STRUCTURAL MODEL OF THE MITRAL VALVE
INCLUDED IN A CARDIOVASCULAR CLOSED LOOP MODEL

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Abstract
This research describes the integration of a structural model of the mitral valve in an existing closed-loop cardiovascular system (CVS) model. Keyword(s): modeling of physiological systems

1 Introduction
A minimal cardiovascular system (CVS) model including mitral valve dynamics has been previously validated in silico [1]. However, valvular parameters of this model are difficult to link with structural and anatomical components of the valve.

2 Models and methods
This research uses a simple dynamic model of the stiffness of the valve leaflets to characterize their fundamental effects on flow and pressure. The valve is described as a non-linear rotational spring or a ‘hinge’ with the angle change under pressure driven flow being related to the stiffness and the damping of the valve:

\[ c \dot{\theta} + F_d(\theta) = a\Delta P \]

where \( c \) is the damping coefficient, \( \theta \) is the valvular leaflet opening angle, the \( F_d(\theta) \) is the non-linear restoring force, \( \Delta P \) is the transmural pressure, and \( a \) is a torque constant converting differential pressure into an input torque on the valve.

This model is included in a CVS model consisting of 7 elastic chambers [1].

3 Results
Figure 1 shows the evolution of mitral valve area during one cardiac cycle. The maximum mitral valve values reached during the E-wave and A-wave as well as timing of these two periods correspond to the physiological data [2,3]. Figure 2 shows the evolution of transmural blood flow during one cardiac cycle with the E-wave amplitude nearly 10 times bigger than the A-wave amplitude as expected physiologically [3].

Fig. 1: Mitral valve area evolution during one cardiac cycle
Fig. 2: Transmural flow evolution during one cardiac cycle

4 Conclusions
This study shows that this valvular model included in a CVS closed loop model gives physiological results.

This proof-of-concept study demonstrates that this generic structural valve model could be used to investigate the hemodynamic repercussions of several pathological conditions, such as mitral regurgitation or stenosis.

References
