The cardiac torsion as metrics of cardiac performance

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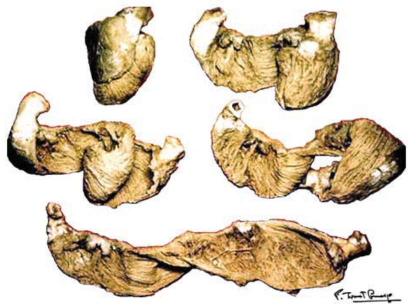
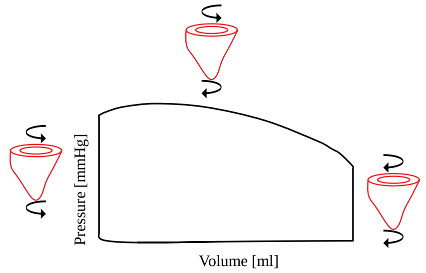
Motivations

The organization of the myocardium at a macroscopic level in a unique ventricular muscle band is responsible for the mutual coupling of anatomy and function in the ventricular myocardium in terms of electrical, mechanical and **kinematical** behavior. The peculiar arrangement of the myocardial fibers determines the **cardiac torsion**.



The **cardiac torsion** is conventionally defined as the difference between the **cardiac apical** and **basal cross-sections rotation.** A counter-clockwise rotation when viewed from the apex is conventionally assumed as positive. During isovolumic contraction, the apex and the base both rotate in a counter-clockwise direction. During the systole the base rotates in a clockwise direction, while the apex continues to rotate counterclockwise, causing the torsional peak. The apex returns to its initial position during diastole.

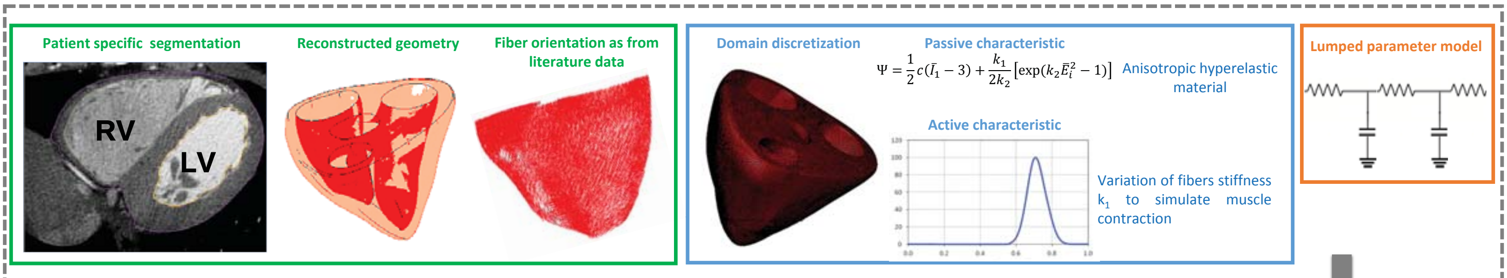


The torsional behavior of the heart was proved to be sensitive to the alteration of some cardiovascular parameters, i.e. preload, afterload and contractility.

Multi-scale model coupling a 3D finite element (FE) model of the two ventricles to lumped parameter model (LPM) of circulation.

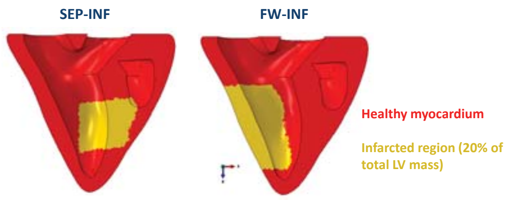
Investigate cardiac torsion alterations under pathological conditions

Materials & Methods

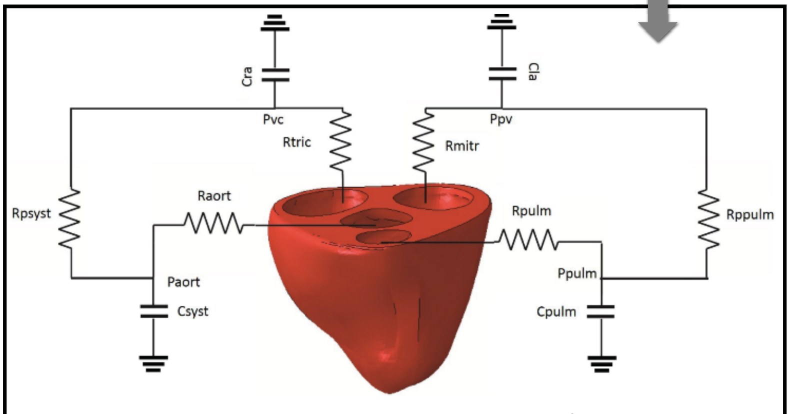


Simulated conditions*:

- ✓ physiological condition (PHYS)
- ✓ systemic hypertension (HYP)
- ✓ mitral valve regurgitation (MVR)
- ✓ myocardial infarction at the interventricular septum (SEP-INF)
- ✓ myocardial infarction at the LV free wall (FW-INF)



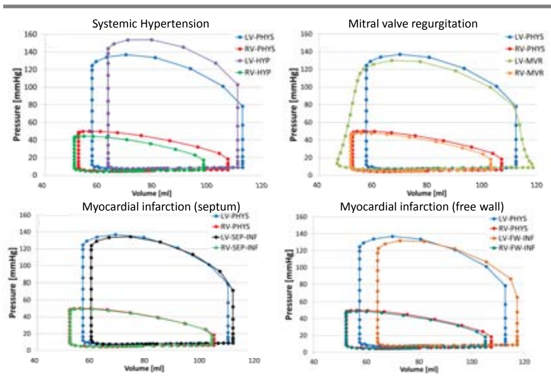
* Abaqus 6.13 ® (SIMULIA, Dessault Systèmes, France)



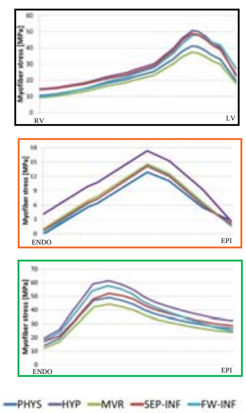
Multi-scale closed loop model*

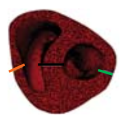
Cutrì E., Serrani M. et al. The cardiac torsion as a sensitive index of heart pathology: A model study, J. of the Mechanical Behavior of Biomedical Materials, 2015, 55; 104-119.

Results & discussion



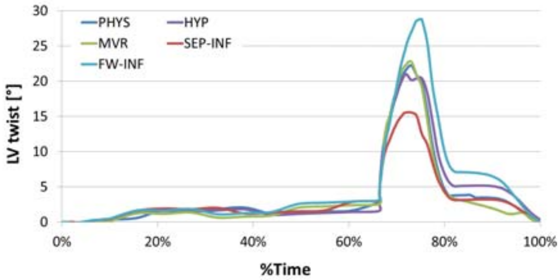
No remarkable change of hemodynamic indices in case of pathology





Good agreement of local mechanics with literature data

Accuracy of the methodology



Pathologies characterized by small changes in the ventricular hemodynamics (namely, the myocardial infarctions conditions) are the pathologies which affects most the ventricular torsion

Cardiac torsion as a sensitive index of heart pathologies even in moderate conditions

Conclusions

The proposed multi-scale model allowed the investigation of cardiac torsion under widespread pathological conditions. The comparison between the pathological and the physiological torsional behaviour highlighted an alteration in the cardiac torsion pattern in case of disease. This finding is particularly interesting in case of the two myocardial infarction conditions. To conclude, our study assessed the ability of the cardiac torsion to reveal even moderate pathological conditions not detected by classical hemodynamic indices, thus suggesting its prognostic relevance.