The cardiac torsion as metrics of cardiac performance

E. Cutrì¹, M. Serrani², R. Fumero¹, and M. L. Costantino¹

¹Laboratory of Biological Structure Mechanics, Chemistry, Materials and Chemical Engineering Department "Giulio Natta", Politecnico di Milano, Milan, Italy.
²Department of Chemical Engineering and Biotechnology, University of Cambridge, Cambridge, UK.

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.

Materials & Methods

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.

Results & discussion

The multi-scale model coupling a 3D finite element (FE) model of the two ventricles to lumped parameter model (LPM) of circulation was used to investigate cardiac torsion alterations under pathological conditions.

Multi-scale closed loop model

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)

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

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.