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EVOLUTION OF THE FUNCTIONAL STRAIN LINES ALONG CHARACTERISTIC REMODELING PROCESSES OF THE HUMAN LEFT VENTRICLE

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Principal strains at a point of a material body measure the maximum and minimum strains which can be attained at that point, and can be measured through a post–processing analysis of tissue motion, being only dependent on the three–dimensional strain state of the tissue. Recently, it was conjectured that principal strain lines (PSLs) on the endocardial and epicardial surfaces of the left ventricle (LV) can emerge as relevant in specific stages of the cardiac cycle. In [1] it was suggested that, as during the systolic phase strains will mainly be suffered by the highly-contracting muscle fibers, systolic PSLs would identify muscle fibers; hence, PSLs's detection might help to give a look at the muscle fiber architecture within the heart walls. On the contrary, we demonstrated in [2] that endocardial PSLs are almost circumferential at the systolic peak, and we conjectured that it is due to the relevant stiffening effect of the circumferential material lines when high pressures are involved, as it occurs along the systolic phase, and to the capacity of the same material fibers to contrast the dilation of the left ventricle (LV). Our conclusions were supported by a preliminary simulation study aimed to demonstrate the validity of our argumentations. In [3], we applied the same type of analysis to real human left ventricles, whose full–volume images were obtained by 3–dimensional (3D) speckle tracking-based motion–detecting echocardiography (STE) (in short, 3DSTE), applied on a group of volunteers at the General Hospital of Sapienza–University of Rome. Our conclusions agreed with the previous simulation study.

We planned to deeply investigate the relevance of our findings: what is the role of the circumferential material lines along a process starting from a healthy situation and going towards a pathophysiological one? We present a simulation study aimed to answer that question. Our study is based on a nonlinear mechanical model of LV which accounts for both the anisotropic passive and active material response [4]. The initial shape of our LV

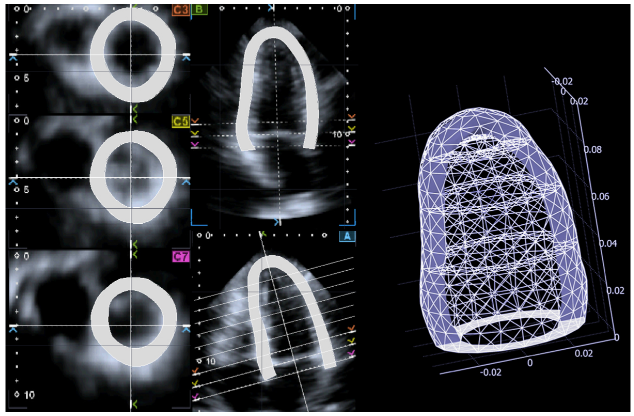

Figure 1: Wall-motion tracking performed by 3DSTE is shown on the left panel. The position of many speckle patterns is tracked along a cardiac cycle. The right panel shows the FEM of our LV whose shape correspond to the end–diastolic shape of the real human LV.

corresponds to the shape of the normal LV of a representative element of our volunteers's group, and was detected through 3DSTE (see figure 1). Distinguished remodeling processes are defined within that model to describe the evolution from a health LV towards a ventricle which presents both shape and thickness largely modified; they are based on two independent parameters describing the change of the shape and the thickening of the LV's walls. At any stage of the remodeling, PSLs are detected through the protocol presented and discussed in [2], with the aim to catch characteristic signals when the stiffening effect of the circumferential lines stops working. The study might suggest a way to detect early cardiac diseases through non–invasive methods, such as 3DSTE.

REFERENCES

[1] G. Pedrizzetti, E. Kraigher-Krainer, A. De Luca, G. Caracciolo, J.O. Mangual, A. Shah, L. Toncelli, F. Domenichini, G. Tonti, G. Galanti, P.P. Sengupta, J. Narula, S. Solomon. Functional Strain-line Pattern in the Human Left Ventricle. *Phys. Rev. Lett.*, Vol. 109, 048103, 2012.

[2] S. Gabriele, P. Nardinocchi and V. Varano. Evaluation of the strain-line patterns in a human left ventricle: a simulation study. *Comput. Methods Biome.*, Published online: 25 Oct 2013. (doi:10.1080/10255842.2013.847094).

[3] A. Evangelista, S. Gabriele, P. Nardinocchi, P. Piras, P.E. Puddu, L. Teresi, C. Torromeo, V. Varano. On the function of the strain-line patterns in the real human left ventricle. *Submitted*, 2013.

[4] A. Evangelista, P. Nardinocchi, P.E. Puddu, L. Teresi, C. Torromeo, V. Varano. Torsion of the human left ventricle: experimental analysis and computational modelling. *Prog. Biophys. Mol. Bio.*, Vol. 107, 112–121, 2011.