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The impact of myocardial fiber orientation on the left ventricle diastolic compliance: an in-silico study

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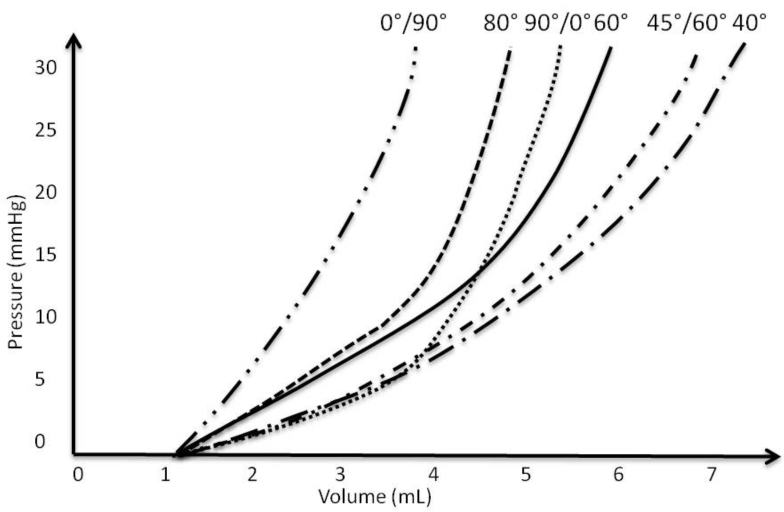
Background. Left ventricular myocardium is arranged in a complex three-dimensional network of fibers, which form a counterclockwise helix in the endocardial layer and a clockwise helix in the epicardial layer. This architecture may change in congenital and acquired heart disease. However, few studies evaluated the myocardial development as well as the mechanism promoting these changes.

Purpose of the study. Based on morphometric and functional observations on histological sections of fetal human heart and on newborns, we developed an in-silico model in order to test the influence of different myocardial fibers arrangements on diastolic performance.

Methods. In vivo data were obtained by the echocardiographic evaluation in 72 fetuses and 39 premature babies without cardiac pathologies. For the histological section, we studied 20 hearts without cardiac pathologies from autopsy investigation (range 12-40 weeks of gestation). Based on functional and histological data, three finite element models of the left ventricular myocardium were developed, corresponding to 20, 30 and 40 weeks' fetuses. For the 40 GW model alternative models of fiber orientation were tested.

Results. In silico model showed a mild decrease in diastolic compliance since 20 to 40 weeks of gestation. The multi-layer model warrantees the shape of the left ventricle as known. The early development of the endocardial longitudinal layer since 12 WoG gives a pressure-volume plot similar to the adult type plot, while a paradoxical early development of the epicardial longitudinal layer gives higher stiffness of the left ventricle. Finally, a less longitudinal arrangement of the myocardial fibers determinates higher diastolic compliance (see figure).



Conclusions. In silico models showed that a less longitudinal arrangement of the myocardial fibers gives the highest diastolic compliance. The endocardial longitudinal fibers are the main contributors to the preservation of the shape of the left ventricle. Based on these data, the reduction of the fibers' angle in the endocardial longitudinal layer can be a compensatory effect to prevent the increase of left ventricular stiffness. Based on these data, the assessment of the longitudinal strain may be used to improve the diagnostic abilities in left ventricular outflow tract obstruction in fetal life.