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TOWARDS FULLY AUTOMATED 3D RECONSTRUCTION OF HEART - SEGMENTATION AND PARAMETRIC HEART MODEL OF PATIENTS WITH CARDIOMYOPATHY

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Summary: Automatic diagnosis of dilated cardiomyopathy using cardiac ultrasound images is a complex process, as the primary challenges in developing an accurate and fast algorithm for automated left ventricle (LV) segmentation lie in the poor signal-to-noise ratio, weak echoes as well as the fact that pixel intensity levels in the images are not related to the physical properties of the tissue. This work focuses on the creation of an automated diagnostic tool based on (1) machine learning algorithms to segment region of interest, (2) geometrical algorithms to reconstruct 3-dimensional model of the heart and (3) finite element method to analyze the mechanical response of the left ventricle to different loading conditions. Dataset included 1809 images with an apical view and 53 images with an M-mode view from cardiomyopathy patients collected at three clinical facilities in the United Kingdom and Serbia. Methodology for apical view analysis included implementation of U-net convolutional neural network for LV segmentation which is followed by rectangle bounding box creation and extraction of longer side, which has a meaning of left ventricular length (LVL). The methodology was applied parallelly for both systole and diastole to extract LVLs and LVLd, respectively. For the M-mode view, due to smaller number of images, traditional algorithms such as adaptive histogram equalization, template matching, Canny edge detection and thresholding are applied in order to extract internal dimension (LVID), posterior wall thickness (LVPW) and interventricular septum thickness (IVS), both in systole and diastole at the same time in one image. When manually annotated LV and calculated related parameters are compared to the proposed methodology results, a dice coefficient of 92.091% for segmentation and an average root mean square error (RMSE) of 0.3052cm for parameter extraction in apical view images and an average RMSE of 1.3548cm for parameter extraction in M-mode view images are obtained. Based on calculated left ventricle length, radiuses, wall thicknesses, and user-supplied divisions, we build a 3D model of the left ventricle and we can use this model to simulate full cardiac cycle. The approach is now available on a user-friendly platform. Fully automated cardiomyopathy detection, 3D reconstruction and cardiac cycle simulation of the left ventricle using ultrasound images can help clinicians make faster decisions and establish reliable treatments.