Fully Automatic Segmentation and Scar Quantification of the Left Ventricle in 3-D Late Gadolinium Enhanced MRI

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Background: Worldwide about 26 million people are suffering from heart failure (HF) (1). The cause of HF is most often a myocardial infarction (MI) (2). The assessment of the myocardium after a MI is very important for diagnosis, therapy planning and success prediction of the therapy and patient prognosis. Particularly, the location and quantification of a patient's scar burden promises to increase the success rate of different therapies such as ablation of ventricular tachycardia or cardiac resynchronization therapy (3).
2-D Late-Gadolinium-Enhanced (LGE) MRI is the current gold-standard to visualize regions of fibrosis in the left ventricle's myocardium. However, these images have a large slice thickness in the range of 5 to 10 mm, which does not allow for an accurate quantification to the extent of the MI.

Purpose: Recently, high-resolution isotropic 3-D LGE-MRI was proposed to allow for a more precise quantification of the myocardium and the MI (4). The major challenge arises in the analysis of the resulting images, as the accurate segmentation of the myocardium is a requirement for accurate scar tissue quantification. A first semi-automatic solution for 3-D LGE MRI myocardial segmentation was proposed in (5). We propose a novel approach for fully automatic left ventricle (LV) segmentation in 3-D LGE-MRI and quantification of the MI.

Materials and Methods: The segmentation algorithm comprises five steps: First, a two-stage registration is performed for an initialization of the LV. Second, the principal axis of the LV is computed and a pseudo short axis (SA) view is estimated. Third, the endocardium is refined in polar space using edge information. A path search is used to find the optimal contour. Fourth, the epicardium is computed starting from the endocardium and considering the edge information. Prior knowledge such as shape and inter-slice smoothness constraints is used during the refinement step. A standard threshold based approach is applied scar quantification. Finally, all the segmented contours can be extracted as 3-D surface meshes using the marching cubes algorithm. These meshes could then be used for guidance during the procedure.

Results: The automatic segmentation of the LV endocardium, epicardium, and scar tissue was compared to a manual annotation of a clinical expert, using 9 clinical 3-D LGE-MRI data sets. Two different measures were used to evaluate the segmentation, the dice coefficient and the average surface distance. The automatic segmentation resulted in an overlap to the gold-standard for the endocardium of 0.85 ± 0.08 and for the epicardium of 0.84 ± 0.06 using the dice coefficient. Evaluating the average surface distance, the endocard had a mean distance of 2.56

± 1.44 voxels and the epicard a mean distance of 2.93 ± 0.92 voxels. Figure 1 presents the dice coefficient of all the cases for the endo and epicard.

Six out of ten MRI scans contained scar tissue. For scar segmentation, we yielded a dice coefficient of 0.59 ± 0.2. Figure 2 (a) depicts the final segmentation result within the 3-D volume, (b) shows the 3-D surface mesh and (c) presents the segmentation result for one slice in the short axis orientation.

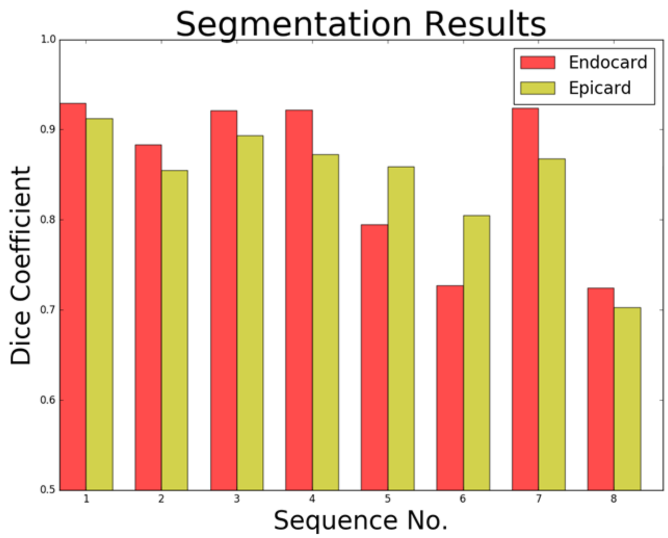

Figure 1: Dice coefficient for the endo and epicard for all 6 clinical data sets. For the endocard an average dice coefficient of 0.85 ± 0.08 was achieved. The best segmentation result yielded an overlap of 0.93 and the worst had a dice coefficient of 0.72. For the epicard a overall dice coefficient of 0.84 ± 0.06 was achieved. The best segmentation achieved a dice coefficient of 0.91 and the worst a dice coefficient of 0.70.

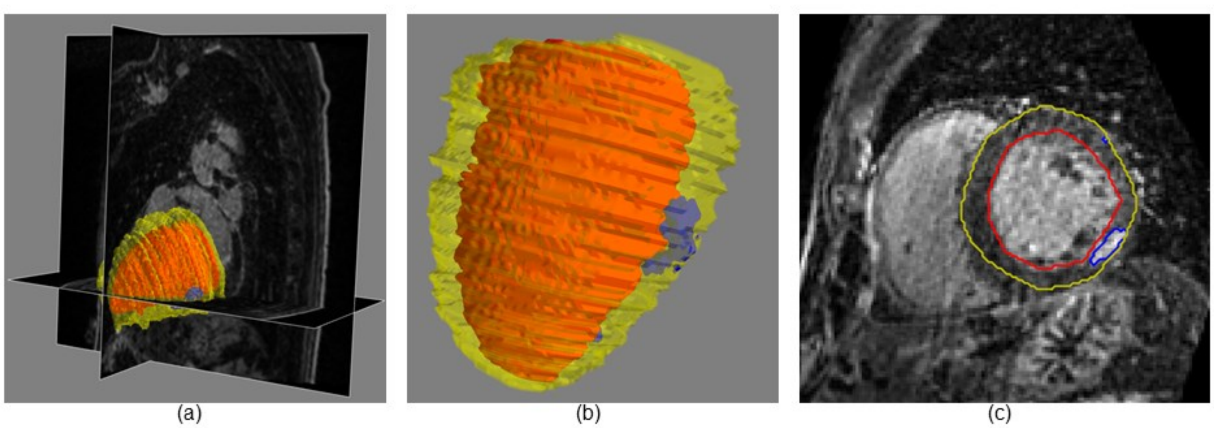

Figure 2: (a) 3-D segmentation result with an sagittal, coronal and axial image plane of the 3-D volume, endocardium in red, epicardium in yellow and scar in visualized in blue. (b) Segmentation result in 3-D. (c) Final contours in the short axis view, endocardium in red, epicardium in yellow and scar is visualized in blue.

Conclusions: The aim of this study was to provide an automatic, accurate and consistent left ventricle myocardial segmentation using 3-D LGE-MRI. The results indicate that our proposed fully automatic approach is accurate and robust for segmenting the LV anatomy from 3-D LGE-MRI. However, the scar quantification depends on the threshold applied and on the preferences of the physician. The gain of the presented algorithm is the independence of user interaction and from an anatomical scan.

Disclaimer: The methods and information presented in this paper are based on research and are not commercially available.

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